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3rd International Conference
"SMART MATERIALS, STRUCTURES AND SYSTEMS"

General Chair CIMTEC Conferences

Pietro Vincenzini, *Italy*

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SYMPOSIUM B - Smart Optics: Materials - Devices - Applications

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SYMPOSIUM C - Emboding Intelligence in Structures and Integrated Systems

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SYMPOSIUM D - Biomedical Applications of Smart Materials, Nanotechnology and Micro/Nano Engineering

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SYMPOSIUM E - Mining Smartness from Nature

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FOCUSED SESSION A-10 - State-of-the-art Research and Application of SMAs Technologies

Session Coordinator: Stefano BESSEGHINI, *Italy* *Members:* Ferdinando AURICCHIO, *Italy* Kaushik BHATTACHARYA, *USA* Fabio CASCIATI, *Italy* Eduard CESARI, *Spain* Volodymyr A. CHERNENKO, *Ukraine* Alexander B. FREIDIN, *Russia* Simo-Pekka V. HANNULA, *Finland* Tomoyuki KAKESHITA, *Japan* Ibrahim KARAMAN, *USA* Yoichi KISHI, *Japan* Yuji MATSUZAKI, *Japan* Shuichi MIYAZAKI, *Japan* Peter MÜLLNER, *USA* Patrick OCHIN, *France* Bogdan RANIECKI, *Poland* Xiaobing REN, *Japan* Avadh B. SAXENA, *USA* Huseyin SEHITOGLU, *USA* Petr SITTNER, *Czech Republic* Jan VAN HUMBEECK, *Belgium* Shyi-Kaan WU, *Taiwan* L'Hocine YAHIA, *Canada* Yufeng ZHENG, *China*

FOCUSED SESSION A-11 - Smart Textiles

Session Coordinator: PARADISO Rita, *Italy* *Members:* Ray H. BAUGHMAN, *USA* Annalisa BONFIGLIO, *Italy* Tushar K. GHOSH, *USA* Augustin GRILLET, *Belgium* Juan HINESTROZA, *USA* Sundaresan JAYARAMAN, *USA* Nigel JOHNSON, *Australia* Masatsugu KIDODE, *Japan* Joonseok KOH, *South Korea* Vladan KONCAR, *France* Paul LUKOWICZ, *Germany* Heikki MATTILA, *Finland* Eric McADAMS, *UK* Andreas NEUDECK, *Germany* Ning PAN, *USA* Markus RÜEDI, *Switzerland* George K. STYLIOS, *UK* Xiaoming TAO, *Hong Kong* Gerhard TRÖSTER, *Switzerland* Lieva VAN LANGENHOVE, *Belgium* Xungai WANG, *Australia*

FOCUSED SESSION A-12 - Artificial Muscle Actuators using Electroactive Polymers

Session Coordinators: Yoseph BAR-COHEN, *USA* and Federico CARPI, *Italy* *Members:* Patrick A. ANQUETIL, *USA* Kinji ASAKA, *Japan* Vaclav BOUDA, *Czekia* Paul CALVERT, *USA* Piero CHIARELLI, *Italy* Hyouk Ryeol CHOI, *Korea* Liming DAI, *USA* Toshihiro HIRAI, *Japan* Edwin W.H. JAGER, *Sweden* Keiichi KANETO, *Japan* Jaehwan KIM, *Korea* Guggi KOFOD, *Germany* Gabor M. KOVACS, *Switzerland* Marc MADOU, *USA* Yoshihiro NAKABO, *Japan* Jae-Do NAM, Korea Hoon Cheol PARK, Korea Qibing PEI, USA Ronald PELRINE, USA Steen SKAARUP, Denmark Peter SOMMER-LARSEN, Denmark Satoshi TADOKORO, Japan Minoru TAYA, WA, USA Yaowen YANG, Singapore

ABSTRACTS

3rd International Conference
SMART MATERIALS, STRUCTURES AND SYSTEMS

OPENING SESSION

Plenary Lectures

PL-01 **Development of a Practical Monitoring System of Urban Infrastructure toward Mitigation of Disaster and Accidents**
Y. FUJINO, The University of Tokyo, Tokyo, Japan

In recent years, natural disasters and accidents associated with urban infrastructures such as transportation systems and civil structures have been increased and their reduction is considered to be one of the societal important issues in Japan. Monitoring/sensing is believed to be a key modern technology toward safety and security of urban infrastructure. Japan Science and Technology Agency started a new focused research proposal-based program entitled by Integrated Advanced Sensing (Director: Kiyoshi ITAO) as a part of Core Research for Evolutionary Science and Technology (CREST) in 2005.This paper describes the outline of a new project (Principal Investigator Yozo FUJINO 2006-2012) that started in 2006. The project consists of four subprojects; 1) development of a measurement system of 6-degree displacements for multiple points using free optical laser, 2) high resolution optical fiber sensing system, 3) new hazard (rain and wind) line sensing system using leaky coaxial (LCX) cable, 4) semi-active sensing system of civil structures such as buildings and bridges, 5) development of sensing network and data processing system for infrastructure monitoring. The system developed will be installed in the buildings of the main campus of the University of Tokyo and in the high speed train viaducts.

PL-02 **EAP Actuators for Biomimetic Technologies with Humanlike Robots as one of the Ultimate Challenges**
Y. BAR-COHEN, Jet Propulsion Lab., California Institute of Technology, Pasadena, CA, USA

Since the Stone Age, people have tried to reproduce the human appearance, functions, and intelligence using art and technology. Any aspect that represents our physical and intellectual being has been a subject of copying, mimicking and inspiration. Recent surges in technology advances led to the emergence of increasingly more realistic humanlike robots and simulations. Making such robots is part of the field of biologically inspired technologies - also known as biomimetics [Bar-Cohen 2005] - and it involves developing engineered systems that exhibit the appearance and behavior of biological systems. Robots with selectable characteristics and personality that are customized to our needs and with self-learning capability may become our household appliance or even companion and they may be used to perform hard to do and complex tasks. In enabling this technology such elements as artificial intelligence, muscles, vision, skin and others are increasingly improved. In this paper, making humanlike robots will be described with focus on the use of artificial muscles as the enabling technology and the related challenges.

SYMPOSIUM A

Smart Materials and Micro/ Nanosystems

Session A-1

Ferroelectric, Piezoelectric, Electrostrictive and Magnetostrictive Single Crystal and Polycrystalline Ceramics and Metal Alloys

A-1: IL02 **Piezoelectric Composites: Properties and Applications**
C. BOWEN, University of Bath, Bath, UK

Since the pioneering work of R.E. Newnham *et al* [1], the concept of piezocomposites has continued to attract interest in academia and industry. This paper will present an overview of the design, manufacture, properties and applications of piezoelectric composites. Examples include 3-3 piezocomposites for SONAR applications[2] and the possibility of using piezoelectric composites for structural morphing[3].

[1]R.E. Newnham, D.P. Skinner, L.E. Cross, Mater. Res. Bull. 13 (1978) 525; [2]H. Kara, R. Ramesh, R. Stevens, and C. R. Bowen, IEEE Ultrasonics, Ferroelectrics and Frequency Control, 50 (2003) 189; [3]C.R. Bowen, R. Butler, R. Jervis, H. A. Kim, and A. I. T. Salo, Journal of Intelligent Material Systems and Structures 18 (2007) 89

A-1: IL03 **Lead-free Piezoelectrics for Transducer Applications**
A. SAFARI, Rutgers University, Piscataway, NJ, USA

Recent, advances in materials science of ferroelectrics and ceramic processing led to the discovery of strong piezoelectric activity in the (K0.5Na0.5)NbO3-LiTaO3-LiSbO3 (KNN-LT-LS) system (Saito et al. Science; 2004). KNN-LT-LS system also exhibits a morphotropic phase boundary as the PZT —the backbone of modern transducer. This discovery is timely as new environmental legislations banning lead-based materials are being implemented worldwide. However, the use of such ceramics in ultrasonic technology still remains to be demonstrated. In this study, we demonstrate that such lead-free ceramics indeed comprise an alternative to PZT in transducer technology. We demonstrate processing pathways for obtaining KNN-LT-LS with outstanding electromechanical properties in bulk and thin film form. We also provide results on proof-of-concept transducers, and show that such transducers can be as good as PZT-based ones. The methods used are processing under controlled humidity, oxygen sintering, chemical doping, and pulsed laser deposition with composite targets. KNN-LT-LS processed under controlled humidity and sintered oxygen exhibit k33~61%, RT 1 kHz K33~1740 and tanδ~2.1%, Qm~53, d33~350 pC/N, Nt~2970, and Ec~ 8.4 kV/cm. Ba+2 and Cu+2 doping up to 1 mol% enhance electromechanical properties and sinterability. 5.6-5.7 MHz transducers fabricated from 1% Ba2+ doped ceramic using epoxy-glass matching layers exhibit a -6 dB fractional bandwidth of 50.4% which compared extremely favorable with 53.5% of PZT-4. 24 MHz transducer were also fabricated using 90 µm thick disks, whose -6 dB fractional bandwidth is as high as 57% (with matching layer). Strong dependence of properties on processing routes and conditions were observed and will be discussed in the context of donor doping and H+ interstitial defects. We also show the integration of such lead-free ceramics as thin films on a variety of substrates for ultrahigh frequency transducers. Critical factors in obtaining single phase films via stringent stoichiometric control using composite targets in PLD, by which the thermalization problem was surmounted, will be discussed. Pending challenges as dc-conductivity and dielectric loss phenomena will be reviewed as well.

A-1: IL04 **Phase Transition Behavior of Anti-ferroelectric Ceramics and its Applications**
ZHUO XU, YUJUN FENG, XI YAO, Xi'an Jiaotong Univ., Xi'an, China

This talk presents our recent investigations on the fundamentals of the phase transition behavior in and the novel applications of, anti-ferroelectrics (AFE) ceramics. In the research, La and Sn doped PZT ceramics, which exhibit a reversible AFE-FE phase transition, were used. For the phase transition behavior study, three independent variables - hydrostatic pressure, temperature, and dc biases - were used. Additionally, the hydrostatic pressure, which ranges from 1 atm up to 2 GPa, was combined with dc bias in the experiments for the ceramics at temperature from room temperature to 250 °C. First of all, the pressure induced FE-AFE transition was observed at different temperature and the relationship between the phase transition behavior and composite was established. Then, the pressure dependence of the dielectric properties was determined for the ceramics at different temperatures under different dc biases. It is found that the FE-AFE transition pressure increases with temperature and is strongly dependent on the polarity of the dc bias. The phenomenological theory was utilized to analyze the results. The FE-AFE phase transition behavior provides some unique characteristics, which may be used to develop high performance devices, such as energy storage and electric discharge. The materials features related to these applications were characterized in our recent experiments. The results will be presented.

A-1: L05 **High-performance Lead-free Barium Titanate Piezoelectric Ceramics**
T. KARAKI, K. YAN, M. ADACHI, Toyama Prefectural University, Imizu, Toyama, Japan

Barium titanate (BaTiO3) ceramics with a high-density were fabricated by two-step sintering method from hydrothermally synthesized BaTiO3 nano-particles of 100 nm. The dielectric constant was 4500 and electromechanical coupling factor kp was 45%. Large piezoelectric constants d33 and d31 were observed in the specimens. A large Poisson's ratio, about 0.38, was determined from the ratio of overtone frequency and resonant frequency in the planar mode. The high Poisson's ratio and the large dielectric constants are most likely the origin of the high-performance in the ceramics.

A-1: L09 **An Enhancement of Magnetic Properties of Cobalt Ferrite by Magnetic Annealing**
N.B. EKREEM, S.A. MAZLAN, T. PRESCOTT, A.G. OLABI, A. RAFFERTY, Dublin City University, Dublin, Ireland

The family of Cobalt ferrites is known to respond to heat treatment in the presence of strong magnetic fields. During the annealing operation, cobalt ions gain sufficient energy to change sites and orientations, and as a result, not only the domains on a temporary basis, but also the easy axis of magnetization on a more permanent basis, have a preferred direction which is parallel to the magnetic field. Also taking place is the more common annealing effect, in which creep at these temperatures relieves stresses, set up between non-aligned crystals. Magnetic annealing is effective at temperatures as low as 150?C. A sample, which has been magnetically annealed, showed almost zero magnetostriction when placed in a magnetic field which was aligned along its easy axis of magnetization. It also showed almost no magnetostriction when the magnetic field was in the opposite direction. However when placed in a magnetic field whose direction was not aligned with either of these directions, its magnetostriction properties were significantly greater than a sample which had received no annealing treatment. Results indicate that annealing a cobalt ferrite sample can enhance the magnitude of its magnetostriction coefficient, which in turn improves its sensitivity in high frequency applications.

A-1: L10 **Difference in Ferroelectric Aging Between A-site and B-site Acceptor Doped $BaTiO_3$ Crystals**
LIXUE ZHANG, Xi'an Jiaotong University, Xi'an, China; XIAOBING REN, National Institute for Materials Science, Tsukuba, Ibaraki, Japan

Aging, the time-dependent changing of material properties, has been widely found in acceptor-doped ABO3 ferroelectrics. The origin is usually ascribed to gradual domain stabilization by acceptor-dopant-generated oxygen vacancies. As both A-site and B-site acceptor doping can induce oxygen vacancies in ABO3 systems, they are expected to cause similar aging effect. However, here we report that there exists a significant difference in aging effect between A-site (K-doped) and B-site (Mn-doped) acceptor-doped BaTiO3 crystals. The B-site acceptor doping has much stronger aging effect. This new phenomenon can be fully explained by a semi-quantitative model based on the defect symmetry principle[1-5]. According to this model, the "strength" of aging is determined by a symmetry-conforming force of the defect symmetry to crystal symmetry. This model may also have potential applications in predicting and understanding the strength of the aging effect in other systems.

[1] X. Ren, Nat. Mater., 3: 91, 2004; [2] L.X. Zhang, W. Chen and X. Ren, Appl. Phys. Lett., 85: 5658, 2004; [3-4] L.X. Zhang and X. Ren, Phys. Rev. B, 71: 174108, 2005; Phys. Rev. B, 73: 094121, 2006; [5] H. X. Bao, L. X. Zhang, etc. Appl. Phys. Lett., 91:142903, 2007.

A-1: IL11 **Constitutive Modeling for Design and Control of Magnetostrictive Galfenol Devices**
M. DAPINO, The Ohio State University, Columbus, OH, USA

Galfenol, Fe(1-x)Ga(x), is a new class of magnetostrictive alloys which have structural grade mechanical properties. These alloys could enable active load-bearing devices and structures in innovative 3-D geometries manufactured by welding, extrusion, rolling, machining, or deposition. Further, the control of anisotropies through manufacturing and postprocessing methods made possible with Galfenol could lead to innovative devices with fully-coupled 3-D functionality. In this presentation we discuss the modeling of strain and magnetization as a function of applied magnetic fields and stresses. We develop a thermodynamic framework incorporating magnetocrystalline, magnetoelastic, and elastic energies. The total Gibbs energy is constructed through Legendre transformation of the Helmholtz energy. Dynamic effects are quantified by considering magnetic field diffusion and structural dynamics coupled with the magnetic domain. Thermal relaxation is included through Boltzmann statistics. Spatial discretization yields an efficient, low-order model suitable for design, parametric analysis, and real-time control of dynamic devices subjected to combined dynamic magnetic fields and stresses.

A-1: IL12 **New Multifunctional Materials Based on $BiFeO_3$**
A.J. BELL, University of Leeds, Leeds, UK

BiFeO3 has become one of the key materials in studies of multiferroic materials. Whilst intriguing of itself, solid solutions with other perovskites, notably PbTiO3, probably offer the greatest potential for exploitation. Whist in some aspects the material is similar to PZT, a crucial difference is the exceptionally large spontaneous strain (18%) on the tetragonal side of the morphotropic phase boundary, which promises exceptional ferroelectric properties. Here we report on the microstructure-property relationships in ceramics, single crystals and thin films of BiFeO3-PbTiO3 materials. In thin films, the promise appears to be borne out, with the switchable polarization peaking at 80 micro C cm-2. In ceramics, such large anisotropy would be expected to result in extensive micro-cracking and poor strength (cf. PbTiO3). However, in fine-grained ceramics, micro-cracking is avoided by a reduction in the tetragonal strain and by partial transformation to the rhombohedral phase. Hence there is a wide region of phase coexistence. A similar phenomenon is observed in single crystals, suggesting that the transformation may be associated with stress relief at domain walls, rather than with inter-grain stresses.

A-1: IL13 **Novel Magnetostrictive Nanobars for High Performance Biological Detection**
Z.-Y. CHENG, SUIQIONG LI, KEWEI ZHANG, LILING FU, BYRAN CHIN, Auburn University, Auburn, AL, USA

Nanowires attract a great attention in the development of biological and chemical sensors. These nanosensors exhibit a ultra-high sensitivity, which is highly needed for real applications due to the facts that the sample to be detected is usually small amount with a low concentration. However, their small size makes these nanosensors face a great challenge in the real detection. For example, a long time is required for the tinysensors sample to react with the target species. We introduced a novel type of nanosensor, which is based on magnetostrictive particles, which provide a way to bring the nanosensors to target species. The magnetostrictive particles are utilized as an acoustic resonator in the design of the sensors. In order to fabricate the sensors, amorphous magnetostrictive alloy was selected. The fabrication of the nanowire made of amorphous magnetostrictive alloys, such as FeB and CoFeB, are reported. The properties of these nanowires were determined. The microstructure and the morphology of the nanowires were characterized. The results ware analyzed and the size effect on the microstructure and properties is discussed.

A-1: IL14 **Multilayered Magnetic Films and Fibers for Electromagnetic Sensor Technology**
L.V. PANINA[1, 2], A. ZHUKOV[1], J. GONZALEZ[1], D.P. MAKHNOVSKIY[2], [1]Universidad del Pais Vasco, San Sebastian, Spain; [2]University of Plymouth, Plymouth, UK

The discovery of the magnetoimpedance (MI) effect in 1994 had a strong impact on the development of magnetic sensors, offering miniature, highly sensitive, and quick response elements. Along with traditional areas of sensing applications (data storage, bio-medical electronics, robotics and security), the MI elements have a high potential for non-destructive testing (as eddy current probes) and smart sensory systems (self-sensing composites). In certain soft magnetic materials, such as composites of amorphous thin wires, the impedance change (MI ratio) is in the range of 50-100% in the MHz and GHz frequency bands subjected to small magnetic fields or stress. Furthermore, special thin-film structures have been proposed to improve the MI performance in miniature elements. This paper discusses physical concepts of MI in multilayered structures including MI ratio enhancement and effect of anisotropy, experimental results proving high sensitivity to the external stimuli for excitation frequencies up to few GHz, and practical sensor designs. Special attention is given to the use of MI fibers for tagging the composites to build-in sensing functionality.

A-1: L15 **Numerical Advances on a Hyperbolic-parabolic Problem Arising in Magnetoelasticity**
V. VALENTE, F. PISTELLA, IAC-CNR, Rome, Italy

We propose a simplified model for the mathematical study of the dynamics of a magnetoelastic material, that is a material which is capable of deformation and magnetization. Our starting point is the evolution equation of spin fields in ferromagnets introduced by Gilbert-Landau-Lifschitz. The magnetization distribution is well described by a free energy functional which we assume composed of three terms, namely the exchange energy, the elastic energy and the elastic-magnetic interaction energy usually adopted for cubic crystals, neglecting the contributions due to the anisotropy and the demagnetisation effects. The derived nonlinear hyperbolic-parabolic system can be simplified replacing the saturation constraint (constant magnitude magnetization) with the addition of a penalty energy term . In the one-dimensional case we provide a stable numerical scheme for the approximation of the unique solution to the corresponding initial boundary value problem.

A-1: IL16 **Piezoelectric Properties of Sputtered AlN Thin Films and their Application**
U. SCHMID, Saarland University, Saarbruecken, Saarland, Germany

In MEMS-based, devices sputter-deposited aluminium nitride (AlN) is a well-established material for the realization of actuator and sensor elements. Outstanding advantage is the CMOS compatible synthetization process requiring only a low thermal budget. In the paper I will give a detailed overview on the influence of sputter-deposition parameters on the degree of c-axis orientation of AlN thin films being a necessary pre-request for high piezoelectric coefficients. To reduce the effort for a qualitative evaluation of this important property, a novel approach is presented applying a wet chemical etching procedure. Due to a lower etch rate associated with the (002) plane, AlN films with a poor quality exhibit a high surface roughness which can be measured with a surface profilometer. Furthermore, the impact of different substrate materials (i.e. crystalline silicon and sputter-deposited metallic films) on the c-axis orientation will be demonstrated. In the more application oriented part of the paper, I will mainly focus on the implementation of AlN thin films for the excitation of resonantly-driven, Coriolis-based gyroscopes fabricated in bulk micromachining technology. The influence of the actuator performance on the device characteristics will be discussed.

A-1: IL17 **Piezoelectric Ceramic Films for MEMS Applications**
JING-FENG LI, ZHI-XIANG ZHU, YING XU, FENG-PING LAI, Tsinghua University, Beijing, P.R. China

Piezoelectric ceramic films are basic structural and functional components for MEMS devices such as micro sensors and actuators. In this presentation, we introduce our recent work related to processing of textured and epitaxial piezoceramic films. Single-phase perovskite-structured textured and epitaxial PZT thin films with various Zr/Ti ratios were deposited on different substrates by the sol-gel method. It was found that PZT deposited on Pt(111)/Ti/SiO2/Si substrate using an oxide seeding layer (lead oxide or titanium dioxide) resulted in highly textured orientations, while epitaxial PZT films was obtained on the Nb-doped SrTiO3 single-crystal wafers. The relationships between ferroelectric and piezoelectric properties of PZT films and different preferential orientations were evaluated. Higher piezoelectric constants were obtained in <001>-oriented PZT films that are beneficial for MEMS applications. In particular, high d33 value up to 200 pC/N was obtained in the [001]-oriented epitaxial PZT films. Recently, we also successfully fabricated (Na, K)NbO3-based lead-free piezoceramic films on silicon substrates, which show fairly good ferroelectric properties. The fabrication processing and electrical properties of the lead-free piezoelectric ceramic films will also be presented.

A-1: L18 **The Use of Different Fibres Geometry and Sintering Conditions for AFC Structures**
F. CLEMENS, M.R. ISMAEL, J. HEIBER, R. PARADIES, T. GRAULE, EMPA, Duebendorf, Switzerland; M. PIECHOWIAK, L. KOZIELSK, D. CZEKAJ, University of Silesia, Sosnowiec, Poland

Among the wide range of shapes and sizes available for piezoceramic materials, PZT fibres are considered to have a high potential. However, the brittle nature of these materials makes difficult their performing. For this reason, a newly developed configuration, the Active Fibre Composites (AFC), which presents numerous benefits over other sensing and actuating device, is in discussion. However, one of the main technical challenges in the production of high quality PZT material is maintaining the composition close to the morphotropic phase boundary. During sintering, the high partial pressure and the accompanied evaporation of PbO influence the densification process and consequently, the piezoelectric properties. In this work, single fibres with different geometries were sintered using two different enriched atmospheres (PbO and PbZrO3 + ZrO2). They were analysed and compared regarding their microstructure and piezoelectric properties. AFC structures were performed from round and rectangular fibres and characterized. The investigations showed that the electromechanical behaviour of AFC structures is enhanced using round fibres sintered in a PZZ enriched atmosphere. Comparing the two different fibre geometries, the ferroelectric response is improved by using rectangular fibres.

A-1: L19 **Production of 3Y-PSZ Powders by Co-precipitation and Milling**
E. FURLANI, E. ANEGGI, S. MASCHIO, University of Udine, Udine, Italy

The present research compares properties and behaviour of coprecipitated 3Y-PSZ powders submitted, after coprecipitation, to different milling treatments. The characteristics of the different products were evaluated by measurements of particle size distribution, thermogravimetric analysis, X-rays diffraction, specific surface area and scanning electron microscopy. It has been demonstrated that 1 h of attrition milling enables production of powders with micrometric particles: the dispersing liquid used on milling has little influence. Crystallization of the amorphous powder is achieved after 1h of high energetic milling, without any thermal treatment.

Session A-2
Stimuli Responsive Polymers and Gels

A-2: IL01 **Ionic Polymeric Conductor Nano Composites (IPCNC's) as Distributed Nanosensors and Nanoactuators**
M. SHAHINPOOR, University of Maine, Orono, ME, USA

This presentation covers advances made in connection with Ionic Polymeric-Conductor Nano Composites (IPCNC's) as distributed biomimetic nanosensors, nanoactuators, nanorobots and artificial muscles. A review of the fundamental properties and characteristics of IPCNC's will first be presented. This summary will include descriptions of the basic materials' molecular structure and subsequent procedure to manufacture the basic material for chemical plating and electroactivation. Further described are chemical molecular plating technologies to make IPCNC's, nanotechnologies of manufacturing and trapping of nanoparticles, SEM, TEM, SPM and AFM characterization of IPMNC's, biomimetic sensing and actuation characterization techniques, electrical characterization and equivalent circuit modeling of IPCNC's as electronic materials. A phenomenological model of the underlying sensing and actuation mechanisms is also presented based on linear irreversible thermodynamics with two driving forces, an electric field and a solvent pressure gradient and two fluxes, electric current density and the ionic+solvent flux. The presentation concludes with a number of videos and some live demos.

A-2: IL02 **Colloids and Beyond**
J. BIBETTE, ESPCI, Paris, France

Colloids have been for many years a very influential system to elucidate the microscopic mechanisms of a myriad of phenomena in condensed matter physic. Indeed, due to their micron size range, colloidal particles are moved by thermal motion, whilst easy to track. Thus, exploring complex phenomena involved in chemistry or biology with colloids is a very tempting challenge too. Here we review a few attempts made along these lines these last years. We first present an experiment based on colloidal filaments that directly measures the association kinetics between attached ligands and receptors, revealing its extreme diversity related to slight intended changes imposed on the linkers that hold the surface and the molecule together. We then present a strategy to mimic flagella that are able to swim, allowing quantifying the relation between the surrounding viscosity, the actuating frequency, the flexibility and the velocity. Finally we present an attempt to mimic at a colloidal scale the growth of configurationnal isomers. We have indeed designed magnetic colloids that self-assemble with controlled isomery depending on both their shape and their spontaneous direction of magnetization.

A-2: L03 **Design and Optimization of IPMC for Biomedical Applications**
CHOONGHEE JO, H.E. NAGUIB, R.H. KWON, University of Toronto, Toronto, Ontario, Canada

The electroactive behavior of ionic polymer-metal composite (IPMC) actuator was modeled and the optimum parameters for maximizing the load capacity of the material were studied. A suitable equation of motion characterizing the mechanical response of the IPMC actuator that is subjected to a given electrical field was determined considering the electro-chemical parameters such as backbone ionic polymer, morphology of metal electrode, type of cation, saturation level of hydration, action of ions, and time-variation of voltage. To find the optimum conditions maximizing the stiffness and minimizing the response time, multivariable constrained optimization method was used and its nonlinear programming was also studied.

A-2: L05 **Static and Dynamic Electroresponse of Triblock Polymer Gel Actuator**
T.I. VALADAS LEITAO, S.J. PICKEN, E. MENDES, Delft University of Technology, Delft, The Netherlands

Dielectric elastomers, a class of electroactive polymers, are specially promising due to their proven high actuation strain and energy density. Their electromechanical response is described by the Maxwell stress, where the level of strain reached depends mostly on the dielectric constant, elastic modulus and applied electric field. Since a decrease in modulus can enhance the elastomer response, swelling in appropriate

solvents, transforming them into gels may enhance actuation. Tri-block copolymer gels offer a large range of possibilities since the mechanical properties and electroactive behaviour of these physically crosslinked materials can be adjusted by varying the polymer concentration, morphology and molecular weigh between crosslinks. In this work efforts were undertaken in reducing the elastic modulus by selective swelling of the elastomer midblocks with an organic oil. In addition, compatible compliant electrodes were studied and their role in actuator assemblage and response investigated. Strain responses to static and dynamic electrical stimuli were considered and, in particular, the effect of the frequency on the mechanical efficiency was investigated in detail. A simple theoretical model describing the frequency response was formulated.

A-2: IL06 **Shape-memory Polymers for Biomedical Applications**
A. LENDLEIN, GKSS Research Centre Geesthacht, Teltow, Germany

Most polymers used in medical applications today are materials that have been developed originally for application areas other than biomedicine. Considering this, different biomedical applications are demanding different specifications for the properties and the functionalities of the biomaterials. Compared to the intrinsic material properties, we define functionality as a certain combination of the polymer architecture and a specific process. Examples for functionalities that play a prominent role in the development of multifunctional polymers for medical applications are biofunctionality, degradability, or shape-memory functionality. In this sense, multifunctional polymers are tailor-made for specific biomedical applications. This concerns not one single synthetic material, but polymer systems whose macroscopic properties can be tailored over a wide range by variation of molecular parameters. Shape-memory signifies the ability to trigger predefined shape changes by external stimuli. A change in shape initiated by a change in temperature is called thermally-induced shape-memory effect. Thermally-, light-, and magnetically induced shape-memory polymers will be presented, that were developed especially for minimally invasive surgery and other biomedical applications.

A-2: L08 **Photoresponsive Liquid Crystal Elastomers with Large Deformation and Fast Movement**
T.J. WHITE[1, 2], V.P. TONDIGLIA[1, 3], H. KOERNER[1, 4], S. SERAK[5], V. GROZHIK[5], N. TABIRIYAN[5], R.A. VAIA[1], T.J. BUNNING[5], [1]Air Force Research Lab., WPAFB, OH, USA; [2]General Dynamics IT, WPAFB, OH, USA; [3]Science Applications International Corp.; [4]University of Dayton; [5]BEAM Company

A liquid crystalline elastomer containing both main chain and side chain azobenzene mesogens exhibits bidirectional actuation upon illumination of low power polarized laser light. Large angle deformation (+/-70 deg), the direction of which is controlled by the laser polarization, is achieved in less than 300 ms. Additionally, we will present recent work on the development of a high modulus LCE polymer formed from the copolymerization of an LC crosslinker and a monofunctional azobenzene LC monomer. The resulting copolymer is a side-chain LCE that can bend up to 85 deg in nearly 200 ms. Results regarding the systematic evaluation of this material including thickness, azobenzene concentration, polymerization conditions, and also comparison to a main-chain analogue will be reported.

A-2: L09 **Tailor-made Segmented Polymers: Versatile Smart Materials**
S. VERBRUGGHE, F. DU PREZ, Ghent University, Ghent, Belgium

Segmented polymer networks (SPN's) are defined as cross-linked multicomponent polymer structures in which polymer chains of type A are connected to polymer chains of type B. As the polymer chains B are formed, there is a tendency to phase separate but, due to the simultaneous network formation, the mobility of the chains becomes restricted as soon as gelation occurs. The potential technological importance of this class of network architectures has been demonstrated by many researchers. It is generally accepted that the multipurpose character of these materials originates from their unique controllable nano-structure. If thermo- and/or pH-responsive prepolymers are introduced, a new type of hydrogel structure with stimuli-sensitive properties can be designed in which segments with desired philicity can be introduced without breaking the sequences of the stimuli-sensitive polymer chains. The properties of such multicomponent hydrogels can be controlled and varied by means of the composition, crosslinking density, nature and molecular weight of the prepolymer. For example, SPN's based on the thermo-responsive polymer poly(N-isopropylacrylamide) (PNIPAA) and poly(tetrahydrofuran) (PTHF) have been investigated as polymer membranes with thermo-responsive permeability.

A-2: L10 **Smart Reverse Thermoresponse Hydrogel**
M. DOLATKHANI, PolymerExpert SA, Pessac, France

PolymerExpert research laboratories have developed a new range of smart thermoresponse hydrogel. A low concentration in water leads to a low viscosity solution at room temperature and to a high viscosity gel at body temperature. These hyperbranched poly(ethylene oxide-b-propylene oxide-b-ethylene oxide) possess fully reversible thermogelification with LCST values adjustable between 20 to 50°C and with a functional pH range between 1 and 12. Compared to other systems which require elevated concentrations, these polymers require only a very low concentration in order to be effective (1-5%). The viscosity change is between 3 and 5 decades depending on the shear rate. A focus on different applications with this technology in cosmetic and pharmaceutical domain will be done. The interest of this kind of polymer will also be discussed in painting, latex and oil industry. This technology is flexible and presents different benefits as smart excipient in the following applications: - Sprayable products; - Cream and lotions with new texture when applied; - Viscosity controller; - Thickener for solutions containing high salt amount; - Drug delivery systems.

Session A-3
Shape Memory Polymers & Magnetorheological Fluids

A-3: IL01 **Ferrofluids and Magnetorheological Fluids**
L. VEKAS, University Politehnica Timisoara, Timisoara, Romania

Two distinct types of magnetically controllable fluids, ferrofluids (FFs) and magnetorheological (MR) fluids, with nanometer and, respectively micrometer range ferri- or ferromagnetic particles as magnetic component, will be reviewed. Ferrofluids (or magnetic fluids) having subdomain nanoparticles (Fe3O4, γ-Fe2O3, CoFe2O4, Fe, Co, Fe-C etc) with permanent magnetic dipole moment stably dispersed in a liquid carrier, exhibit relatively modest increase of viscosity even under saturating magnetic fields. MR fluids are suspensions of polydomain magnetic particles (usually Fe) with induced dipole moment and show rather strong magnetorheological effect, i.e. an up to 103 times relative increase of effective viscosity. Application orientated synthesis procedures of ferrofluids (e.g. FFs for rotating seals or biomedical uses) are presented, followed by a detailed analysis of their structure (e.g. by TEM, HRTEM, SANS, SANSPOL), colloidal stability (DLS), magnetic (VSM, Mössbauer spectroscopy) and flow (rheo/magnetorheometry) properties. Comparatively, the composition, preparation methods and sedimentation stability, as well as the magnetic and magnetorheological behavior of MR fluids are reviewed, mainly related to their use in semi-active damping devices.

A-3: L02 **Synthesis and Evaluation of a New Class of Shape Memory Materials based on Multi-Block Copolymers**
S. D'HOLLANDER, F.E. DU PREZ, Ghent University, Ghent, Belgium

Thermoplastic polyurethanes (TPU's) are multi-component materials. In case TPU's are used as shape memory polymers, switching and permanent segments are covalently attached together. The permanent segment has the highest transition temperature (Ttrans) and is responsible for the physical cross-linking. Heating up the material above the Ttrans cleaves the physical cross-links in the switching phase. As a result of the entropy elasticity, the material returns to its primary shape. The TPU's synthesized for this project, are based on crystalline poly(caprolactone) (switching segment) and crystalline permanent segments. It is known that the crystallinity of polycaprolactone (PCL) is reduced when it is incorporated in a TPU. This is due to the fact that the permanent segments crystallize at higher temperature and hamper the crystallization of PCL. In this work is an extra flexible spacer introduced between the two segments in order to improve the phase separation between the switching and the permanent segments. For example, with the introduction of flexible PPO segments, better shape memory properties and more narrow switching temperatures are observed. With different techniques (DSC, DMA, WAXS, SAXS, Solid State NMR) the influence of the flexible segment was investigated.

A-3: L03 **Micromechanical Modelling of Shape Memory Polymers**
M. BÖL, S. REESE, Braunschweig University of Technology, Germany

Shape memory polymers (SMPs) belong to the group of smart materials that can be easily formed into complex shapes, retaining memory of their original shape even after undergoing large deformations. The shape memory properties can be quantified by cyclic thermomechnical investigations. In a typical test program the sample is heated up to a temperature above its transition temperature. Then the deformed shape of the specimen is fixed by decreasing the temperature under the glass transition temperature. When the temperature is kept lower than the transition temperature, this deformed shape describes the new temporary shape. After reheating above the transition temperature the sample is contracting itself and the original shape is restored. To describe the aforementioned phenomenon, a three-dimensional thermoviscoelastic model is proposed to represent the thermomechanical behaviour of SMPs. The model is thermodynamically motivated and is formulated in a finite strain framework in order to account for large strain deformations. The main focus of this work is the influence of both, the material constants and heat transfer boundary conditions on the response of SMPs. Therefore we illustrate different general simulations as well as some examples of application.

Session A-5
Smart Multifunctional Materials and Composites

A-5: IL01 **Composite Coatings with Phase Change Materials for Thermal Actuation**
L. STAPPERS, J. FRANSAER, A. MALFLIET, Katholieke Universiteit Leuven, Heverlee, Belgium

Fast responding thermal actuators were made by incorporating finely dispersed phase change material (PCM) particles in a metal matrix by electrodeposition. Paraffin was chosen as a phase change material since it has a volume expansion of 10 % upon melting. The paraffin was encapsulated with a polymer by different techniques, resulting in microcapsules with a diameter of 5 to 10 micron containing 90 vol% of paraffin. These microcapsules were embedded in copper and zinc to make linear and deflection actuators. Thermal properties of the actuators were tested by thermal dilatometry and laser deflection. The linear actuators have a displacement of 0.5 % and the deflection actuators of more than 10 % over a temperature range of 20 degrees. Such an expansion behavior is ideal for thermal actuators, but the effect decreased by thermal cycling due to plastic deformation of the metal matrix. A thermo-elasto-plastic model was developed to describe the thermal actuation of the metal-PCM composites.

A-5: L04 **Self Healing of Mechanical Damage in Metallic Materials**
NORIO SHINYA, National Institute for Materials Science, Tsukuba, Ibaraki, Japan

Creep cavity and fatigue crack, which cause creep and fatigue fractures, respectively, are greatly expected to be self healed. Because they are difficult to be detected by nondestructive tests and repaired at the operating sites. For self healing of mechnical damages in structural materials, (1)embedding of self healing agents in materials, (2)delivery of the agents to damage sites, and (3)healing at the damage sites, are main factors. Actual process proposed recenly for creep cavity and fatigue crack are, (1)addition of solute B or Cu atoms, (2)delivery of the solute atoms to damages through volume or pipe diffusion, and (3)segregation or precipitation of the solute atoms at damage sites. As to the creep cavity, trace elements of B and Ce are added in austenitic stainless steels. Solute B atoms segregate or precipitate as BN on creepcavity surfaces. The B segregation and BN precipitation suppress creep cavity growth rate remarkably, leading to prevention of the creep fracture. The B segregation and BN precipitation are developed autonoumously during the operating service of the steels and provide the steels with improved properties.

A-5: IL06 **A New Design Concept for Multifunctional Structural Material Systems Based on Composites**
HIROSHI ASANUMA, Chiba University, Chiba, Japan

A new designing concept to realize multifunctional structural material systems without using sophisticated functional materials is proposed and demonstrated in this paper. The concept can be explained as follow: There exist a couple of competitive structural materials which normally compete with each other because of their similar and high mechanical properties, and they tend to have another property which is different from each other or opposite among them. So if they are combined together to make a composite, the similar property, normally high mechanical property, can be maintained, and the other dissimilar property conflicts with each other, which will successfully generate a functional property without using any sophisticated functional materials. According to the proposed concept, a titanium fiber/aluminum matrix composite was fabricated, where the fiber is oxidized for electrical insulation and strengthening. This material system is very simple, but it can generate many useful functions such as heating, actuation, temperature sensing, deformation sensing and healing. A carbon fiber reinforced plastics (CFRP)/aluminum laminate was also fabricated and its various actuation capabilities and multifunctionality were successfully demonstrated.

A-5: L07 **Multistable Textured Shell Structures**
A.D. NORMAN, K.A. SEFFEN, S.D. GUEST, University of Cambridge, Cambridge, UK

Multistable structures have tremendous potential as the basis for reconfigurable systems. A multistable structure will remain in one of its stable configurations until actuation forces it to move to another stable configuration. This paper will describe one promising method of forming structures with useful multiple stable states by using prestressed textured shell surfaces. Textured shell structures have features at a scale intermediate between the global structural scale, and the material scale, and can have some remarkable structural properties. This paper will describe a particularly simple example: a globally flat, but corrugated shell. When correctly prestressed, this structure has a second stable state where the structure is tightly coiled, and can move back and forth repeatedly and elastically between the two states: there are obvious applications to systems where a large area has to be tightly coiled for transportation or storage.

A-5: L08 **Friction Coefficients and Wear Rates of MoS_2/Cu, BN/Cu Composites**
TAKASHI HASHIMOTO, H. KOHRI, A. YUMOTO, I. SHIOTA, Kogakuin University, Hachioji, Tokyo, Japan

It is difficult to use an ordinary bearing in a vacuum and/or at a high temperature, because of evaporation or deterioration of the lubricant. A solid lubricant, MoS2 or BN, is promising in such condition. Recently, a thin solid lubricant film is often applied on a hard material by PVD. The thin film is, however, easily removed when the load or friction speed is too high. On the other hand, when the lubricant is dispersed in a matrix, the solid lubricant always exists even the surface of the bearing is worn out. The aim of this experiment is to examine friction properties of the composites. Cu was plated on the lubricant particles by electroless deposition. The lubricant volume fraction was up to 30 vol%. The Cu plated lubricant powder was hot-pressed to form composites at 873 K under 30 MPa in a vacuum. Friction properties of composites were determined by using a ball-on-disk type testing machine. The test was performed either in air or in a vacuum without oil at room temperature. The coefficients of friction of the composites were in the range of 0.061 to 0.066 in air despite of Vf, which was in the range of 1/4 to 1/5 of Cu. The wear rates of the composites were larger than Cu in air. On the contrary, the wear rate of Cu was larger in a vacuum than the composites.

A-5: L09 **Continuous Damage Monitoring and Self Repairing in CFRP/SMA Smart Hybrid Composites**
J. JELLID, M. SALVIA, Ecole Centrale de Lyon, Ecully, France

This paper deals with a smart hybrid Epoxy matrix composite reinforced by carbon fibres (CFRP) with a network of embedded threads of Ni-Ti-Cu shape memory alloys (SMAs). The damage caused by 3 point bending test is followed by in situ optical micrography, acoustic emission (AE) and electrical resistance (ER) measurements. Our aim is to detect damages, partcularely fibre breakages in CFRP specimens then to cancel or at least control the progression of this damage thanks to the local internal stresses associated to the actuation of the SMA network,

the contribution of the embedded SMA is studied through the load sensor in the bending microtest machine and by ER measurement. The second series of experiments is a comparison between mechanical properties of CFRP specimens, with and without integrated SMA through studying the load vs displacement evolution for different temperatures.

A-5: L10 **Development of Stress and Temperature Sensitive Microwires**

A. ZHUKOV[1, 2], V. ZHUKOVA[1, 2], J. GONZALEZ[1], J.M. BLANCO[1], [1]Universidad del Pais Vasco, San Sebastian, Spain; [2]TAMAG Iberica S.L., San Sebastian, Spain

We report on tailoring of magnetic properties and GMI of glass-coated microwires by means of selection of their alloy composition and/or conditions of annealing. Under stress annealing the hysteresis loop of Fe-rich changes its shape transforming into the inclined with well-defined transverse anisotropy. Stress annealing of Co-rich microwires results in opposite tendency: initially inclined hysteresis loop transforms into rectangular one. The induced magnetic anisotropy field depends on temperature and time of annealing and applied stress. Application of the stress drastically changes the shape of the hysteresis loop and the impedance. Glass-coated microwires with compositions Co-Fe-Ni-Si-B and Co-Fe-Cr-Si-B fabricated by the Taylor-Ulitovsky method wilow Curie temperature allows to achieve temperature dependent magnetic properties and GMI effect. Few samples with vanishing magnetostriction constant also present high and temperature dependent GMI effect. Developed microwires are quite useful for stress and temperature sensitive sensors and for creation of the stress and temperature sensitive tuneable composite materials based on thin ferromagnetic wires with the effective microwave permittivity depending on an external dc magnetic field, temperature and stress.

A-5: IL11 **Development of Smart Composite Actuator/Sensor Material and Device using the Multi-ferroic Effect**

YASUBUMI FURUYA, TEIKO OKAZAKI, Hirosaki University, Japan

Technical importance of multi-ferroic approach for designing advanced multi-functional actuator/sensors based on a mutual coupling effect between each ferroic material element is pointed out for intelligent/ smart technology. Two types of multi-ferroic actuator/sensor devices. i.e. (1) magnetically driven composite actuator and (2) multi-functional surface acoustic wave (SAW) sensor by MEMS are presented. First, a large-scale robust composite actuator is the composite structure which is reinforced by the superelastic fiber or lamellar of shape memory alloys (TiNi) in the ferromagnetic metal (Ni) matrix. This multi-ferroic composite can be driven with high speed as well as considerably large strain by applying a wireless magnetic field. Secondarily, multi-functionally designed, multi-ferroic senor device using surface acoustic wave (SAW) is introduced. On the surface part between IDTs, environmentally active material films such as SMA, FSMA, magnetostrictive alloy etc. are formed by magnetron-sputtering. Various environmental sensing parameters i.e. temperature, magnetic field strength, stress, loading hysteresis and internal damage etc. can be evaluated nondestructively from the signal analysis of amplitude and phase change of SAW. Consequently, these results show the promising new types of multi-functional composite actuator and sensor based on multi-ferroic effect.

A-5: L12 **Fabrication of Electrode for Thermoelectric Oxide Materials**

H. KOHRI, I. SHIOTA, Kogakuin University, Hachioji, Tokyo, Japan; M. KATO, I.J. OHSUGI, Salesian Polytechnic, Machida, Tokyo, Japan

Thermoelectric materials can directly convert thermal energy into electrical energy. Research and development of thermoelectric generators have been actively carried out to use waste heat. Electrodes are necessary to take out the electrical power from the thermoelectric couples. However, large portion of the generated electrical power is often lost at the interface between electrode and thermoelectric materials. Though oxide materials are promising materials for a thermoelectric generator at a high temperature, they are not practically used as the joining technique is not established. In the previous works, the n-type material was cracked in operation, when silver paste was applied to join a silver electrode with oxide material. Then not only low contact resistance, but also mechanical strength are important for the joining. In this report, tin alloy solder was attempted for cold side junction to obtain low contact resistance and mechanical strength at the interface. Wettability of the solder to thermoelectric oxide materials (Ca3Co2O6) was improved by adding titanium to tin alloy. Thermoelectric generating properties of thermo-modules with Ca3Co2O6 and tin alloy will be reported in the presentation.

A-5: L13 **Electromechanical Response of Piezoelectric Composite Materials**

T.A. VENKATESH, Stony Brook University, Stony Brook, NY, USA

Piezoelectric materials, by virtue of their unique electromechanical characteristics, have been recognized for their potential utility in many applications as sensors and actuators. However, the sensing or actuating functionality of monolithic piezoelectric materials is generally limited. The composite approach to piezoelectric materials provides a unique opportunity to access a new design space with optimal mechanical and coupled characteristics. An analytical model is developed to predict the complete elastic, dielectric and piezoelectric constitutive properties of a general piezoelectric composite system, where in the constituent phases are elastically anisotropic and piezoelectrically active. Furthermore, through finite-element modeling, a systematic methodology for quantifying the effects of piezoelectric characteristics (such as the poling direction), microstructural aspects (such as the grain-size and phase volume fraction) and geometric features (such as the size, shape, and distribution of the constituent phases), on the electromechanical response of piezoelectric composites is presented. Strategies for designing unique piezoelectric sensors with enhanced functionality in multiple directions are formulated.

A-5: L13B **Interrelated Electrical and Optical Properties of Gold-Decorated Single Wall Carbon Nanotube (SWCNT) Hybrid Composites**

I.N. IVANOV[1], J.D. HUNT[2], M. GARRETT[2], R. GERHARDT[3], KAI XIAO[1], BIN ZHAO[1], A. PURETZKY[1], D. STYERS-BARNETT[1], D.B. GEOHEGAN[1], [1]Center for Nanophase Material Sciences, Oak Ridge National Laboratory; Oak Ridge, TN, USA; [2]University of Tennessee, Knoxville, TN, USA; [3]Georgia Institute of Technology, Atlanta, GA, USA

Carbon nanotubes have unique combinations of electrical, optical[1] and thermal properties[2] which are essential for multifunctional materials of the future. In this presentation we will discuss plasmonic and electrical properties of Au-SWCNT hybrid composites. The composites were prepared from ultra-high purity SWCNTs generated by laser vaporization which were processed into thin conductive membranes decorated with thermally-evaporated Au. The SWCNT bundles act as templates to understand the growth and optical activity of the gold nanoparticles. The low affinity of gold to carbon resulted in the formation and segregation of discrete 3-5 nm gold nanoparticles along the nanotube bundles. The Raman signature of the SWCNTs was enhanced by factor of 25 through the enhancement of the laser's electromagnetic field by the plasmonic nanoparticle assemblies. The hybrid composites also demonstrate tunability of electrical properties in the 100 mHz to 6 MHz frequency range which have been modeled using RLC circuit analysis. The individual contribution of SWCNTs and Au particles to the tunability of the electrical properties of the hybrid composites will be demonstrated. The possibility of using the multifunctionality of these hybrid systems in plasmonic electronics will be discussed.

[1]I. N. Ivanov, F.A. Reboredo, A Technology Roadmap, Foresight Institute, (2007); [2]I.N. Ivanov, A.A. Puretzky, H. Wang, Z. Pan , H. Cui, R. Jin, J. Howe, D. Geohegan, Appl. Phys. Lett. 89, 223110 (2006).

A-5: L14 **Thin-film Multiferroic Nanocomposites in the System $LuMnO_3$-$Pr_{0.7}Sr_{0.3}MnO_3$**

O.Yu. GORBENKO, A.R. AKBASHEV, A.R. KAUL, Lomonosov Moscow State University, Moscow, Russia

Composite multiferroics made of the ferroelectric and ferromagnetic materials are robust and show the high magnetoelectric effect. Here we report new composite multiferroic films in the system Pr1-xSrxMnO3-LuMnO3 on single-crystalline (111) ZrO2(Y2O3) substrate grown by MOCVD. Pr(thd)3, Lu(thd)3, Mn(thd)3, Sr(thd)2 (where thd = 2,2,6,6-tetramethylheptane-3,5-dionate) were used as precursors. Depositions were accomplished at 700-800oC and total pressure 8 mbar. The thin film samples were characterized by XRD, SEM, EDX, SQUID measurements, optical second harmonic generation, magneto-optical transmission and reflection study. In particular, XRD reveals two crystalline phases in the films with strong broadening of the perovskite reflections. It was found, that two-phase composite Pr1-xSrxMnO3 - LuMnO3 was formed in-situ due to the miscibility gap between perovskite and layered hexagonal manganite phases. LuMnO3 formed c-oriented epitaxial matrix of the layered hexagonal phase which demonstrated ferroelectric properties. Pr0.7Sr0.3MnO3 crystallized as random nanometric perovskite inclusions (metallic and ferromagnetic below the room temperature) inside the ferroelectric matrix. No secondary phase inclusions were sticking out of the smooth surface of the films according to SEM.

A-5: IL15 **Tunable and Self-sensing Microwave Composite Materials Incorporating Ferromagnetic Wires**
D.P. MAKHNOVSKIY, University of Plymouth, Devon, UK

A novel class of tunable and self-sensing composite materials has been discussed. The sensory and tunable properties become possible by the embedded short ferromagnetic wire inclusions. These wire inclusions play the role of the elementary dipole scatterers, when the electromagnetic microwave irradiates the composite. Thus the microwave response of the composite as a whole can be characterised by some complex effective permittivity with the resonance frequency dispersion (typical for the wire-filled structures). In turn, the field/stress dependence arises from a high field/stress sensitivity of the ac magnetoimpedance (MI) in ferromagnetic wires with circumferential or helical magnetic anisotropy. A strong temperature dependence of MI is observed near the Curie temperature in the wires with longitudinal anisotropy. In the vicinity of the so-called antenna resonance frequency any variations in MI of wires will result in large changes of the effective permittivity, and hence the reflection/transmission coefficient. Therefore, the proposed composites demonstrate self-sensing properties that can be utilized for the local stress and temperature visualization in the microwave range. The field tunable properties may find some interesting applications to radar technique.

A-5: L16 **Termoelectric Properties of High Density Sintered $Ca_3Co_2O_6$**
T. UESUGI, H. KOHRI, I. SHIOTA, Kogakuin University, Hachioji, Tokyo, Japan; M. KATO, I.J. OHSUGI, Salesio Polytechnic, Machida, Tokyo, Japan

Ca3Co4O9 is a promising material for thermoelectric generation, as it is stable up to 1173 K in air, and shows good thermoelectric properties. Recently, it was found that Ca3Co2O6, which is decomposed phase of Ca3Co4O9, was stable up to 1300 K in air which is higher than the one of Ca3Co4O9. The electrical resistivity of Ca3Co2O6, however, was higher than the one of Ca3Co4O9. It is required not only high power generation performances but also excellent strength for practical use of the thermoelectric oxide materials. Polycrystalline samples of Ca3Co2O6 were prepared by solid-state reaction or hot pressing. Relative density of Ca3Co2O6 by Hot-pressing (HP) was over 98% which is larger than the one of Ca3Co2O6 by solid-state reaction (SSR). Ca3Co2O6 (HP) showed larger strength and lower resistivity than Ca3Co2O6 (SSR). The resistivity of Ca3Co2O6 (HP) in perpendicular direction to the pressurizing axis decreases from 6.4 to $4.0 \times 10\text{-}2$ Ocm at the temperature range between 373 and 1173 K. In addition, the resistivity of this sample was decreased by heat treatment in air. The Seebeck coefficient of Ca3Co2O6 (HP) was positive value and more than 0.16 mV/K at the temperature range between 373 and 1173 K. Fabricating a module of Ca3Co2O6 is now attempting.

A-5: IL18 **Room Temperature Magnetic-semiconductors in Modified Iron Titanates: their Multifunctional Nature and Potential Applications**
R.K. PANDEY, P. PADMINI, P. KALE, J. DOU, R. SCHAD, University of Alabama, Tuscaloosa, AL, USA; R. WILKINS, Prairie View A&M University, Prairie View, TX, USA; W. GEERTS, Texas State University, San Marcos, TX, USA

The phenomenal growths of information technology and related fields have warranted the development of new class of materials. Multifunctional oxides, magnetic-semiconductors, multiferroic and smart materials are just a few examples of such materials. They are needed for the development of novel technologies such as spintronics, magneto-electronics, radhard electronics, and advanced microelectronics. For these technologies, of particular interest are some solid solutions of ilmenite-hematite (IH) represented by (1-x) $FeTiO_3$.xFe_2O_3 where x varies from 0 to 1; Mn-doped ilmenite (Mn-$FeTiO_3$) and pure and Mn-doped pseudobrookite, Fe_2TiO_5 (PsB). These multifunctional oxides are ferromagnetic with the magnetic Curie points well above the room temperature as well as wide bandgap semiconductors with band gap $E_g > 2.5$ eV. In this presentation, we will discuss: (a) processing of device quality samples for structural, electrical and magnetic characterization, (b) the response of the non-linear current-voltage (I-V) characteristics to a magnetic field, (c) their response when irradiated with high energy radiations; and (d) how the introduction of a gate voltage changes the behavior of these curves. Subsequently, we will identify a few applications based on this class of oxides.

Session A-6
Hybrid Active Materials Systems

A-6: L01 **Multiscale Molecular Modeling of Hybrid Organic-inorganic Nanocomposites of Type I and II**
M. FERMEGLIA, P. POSOCCO, S. PRICL, University of Trieste, Trieste, Italy; M. MALY, Academy of Sciences of the Czech Rep., Prague, Czech Republic

A current challenge of physical, chemical and engineering sciences is to develop theoretical tools for predicting structure and physical properties of hybrid organic inorganic nanocomposite (both of type I and II) from the knowledge of a few input parameters. However, despite all efforts, progress in the prediction of macroscopic physical properties from structure has been slow. Major difficulties relate to the fact that (a) the microstructural elements in multiphase material are not shaped or oriented as in the idealizations of computer simulations, and more than one type can coexist; (b) multiple length and time scales are generally involved and must be taken into account, when overall thermodynamic and mechanical properties wish to be determined, and finally (c) the effect of the interphases/interfaces on the physical properties is often not well understood and characterized. As a consequence, their role is often neglected in the development of new theoretical tools or they are treated in a very empirical way. In this work, we focus on issues (b) and (c) in a multiscale molecular simulation framework, with the ultimate goal of developing a computationally-based nanocomposite designing tool. In particular, we developed a hierarchical procedure in which lower scale (i.e., QM, MD and /or MC) simulations are performed to obtain parameters for higher scale (i.e., mesoscopic and/or finite element) calculations, from which the bulk properties of the hybrid nanocomposite material can be ultimately estimated.

A-6: L02 **Structural Design of Smart Organic-inorganic Hybrid Membranes from Quaternized Chitosan and Alkoxysilane**
TADASHI URAGAMI, Kansai University, Suita, Osaka, Japan

Membrane separation techniques with easy operation and high energy savings are greatly appreciated in a variety of applications in medical, food, industrial, energy and environment field. The chemical and physical structures of polymer membranes are engineered to improve membrane performance by several methods. Ethanol is a clean energy source that can be produced by the fermentation of biomass. In general, aqueous bioethanol solutions are concentrated by distillation, but an azeotrope (96.5 wt% ethanol) prevents further separated by distillation. Pervaporation (PV), a membrane separation technique, can be used for separation of these azeotropes. Hybrid materials consisting of organic and inorganic materials have been recognized in various fields as functional materials that have the merits of both organic materials, plus inorganic materials. In this study, novel organic-inorganic hybrid membranes via hybridization between quaternized chitosan (q-Chito) as an organic component and tetraethoxysilane (TEOS) as an inorganic component using the sol-gel reaction were prepared. The relationship between the structure of q-Chito/TEOS hybrid membranes and their permeation and separation characteristics for an azeotrope of ethanol/water during PV will be discussed in detail.

A-6: L03 **Ultrafilm Formation by Gamma-ray Induced Polymerization in Surfactant Template on Solid Surface**
T. PONGPRAYOON, King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand

Ultrafilm of polyisoprene was formed on silica surface in the two dimensional adsorbed surfactant by gamma-ray induced polymerization. The effect of gamma-ray doses on the polymeric film formation was investigated. The modified silica and formed film were characterized. The results show the potential of the surface modification by polymer film-surfactant-silica hybrid.

A-6: L04 **Bistable Buckled Beam: Modelling and Piezo-electric Actuation**

C. MAURINI[1], J. POUGET[1], S. VIDOLI[2], [1]Université Pierre et Marie Curie, Paris, France; [2]University "La Sapienza", Rome, Italy

Bistable structures, such as buckled beams, are characterized by a two-well potential. Their nonlinear properties are currently exploited in actuators design (e.g. MEMS micropumps, switches, tactile surfaces) to produce relatively high displacements and forces with low actuation energies. We investigate the use of distributed multiparameter actuation to control the buckling and postbuckling behaviour of a three-layer piezoelectric beam pinned at either end. A two-parameter bending actuation controls the transversal motion, whilst an axial actuation and beam end-shortening modulate the tangent bending stiffness. The postbuckling behaviour is studied by reducing to a 2 dof system a nonlinear extensible elastica model. When the bending actuation is spatially symmetric, the postbuckling phenomena are analogue to those obtained for a transversal midspan force, being characterized by a snap-though instability. The use of a two-parameter actuation opens new transition scenarios, where it is possible to get quasi-static transitions between the two specular equilibriums of the buckled beam, without any instability phenomenon. The efficiencies of these different transitions paths are discussed in terms of energetic requirements and stability properties. A numerical example shows the technical feasibility of the proposed actuation technique.

A-6: L05 **Design of Smart Material Based Actuators for Bistable Structures**

P. CAZOTTES[1,2], A. FERNANDES[1], J. POUGET[1], M. HAFEZ[2], [1]Université Pierre et Marie Curie, Paris, France; [2]Sensory Interfaces Laboratory, Fontenay-aux-Roses, France

Several Smart materials such as shape memory alloys (SMA) and electroactive polymers (EAP) have good properties in small scales and are often a good choice for tiny surface deflection applications. However they need continuous powering to keep their shape change, leading to a significant loss of energy. An interesting approach is to associate a smart material with a bistable element, which provides two positions without power. This action requires some energy to snap from one position to the other one. This association gives a very power-efficient solution. In this paper, we present a mechanical study on the actuation of a bistable structure, using a distributed torque actuation that is very suitable for smart materials. We will also compare it with a localized actuation. The paper will point out that the design of the actuator can be used to obtain highly different properties, such as stiffness or efficiency, and be used to design more compact systems. Then we will provide an illustrative example for the optimization approach. Finally, the paper will discuss the performances that can be obtained for different smarts materials such as SMA and EAP.

Session A-7

Smart Nanocomposites and Nanomaterials

A-7: IL01 **Designing Soft Nanocarbons by Programmed Assembly**

TAKUZO AIDA, TAKANORI FUKUSHIMA, The University of Tokyo, Tokyo, Japan

Understanding and utilization of pi-electronic conjugation has become of increasing importance in materials sciences, particularly, for targeting molecular electronics, and a variety of molecules and substances, which show interesting optoelectronic properties have recently been reported. We recently found that bucky gels, prepared by grinding single-walled carbon nanotubes in imidazolium ion-based ionic liquids, serve as highly powerful capacitors, and can be applicable to the fabrication of fully plastic actuators by layer-by-layer casting. There are many other potential applications. Graphitic nanotubes, prepared by self-assembly of an amphiphilic hexa-peri-hexabenzocoronene, are also interesting electronically active materials. We also succeeded in obtaining a pseudo-crosslinked version of this graphitic nanotube by ADMET-triggered self-assembly of an allyl group-appended new amphiphilic hexa-peri-hexabenzocoronene. On the other hand, we have developed photo and redox-mediated covalent stabilization of the graphitic nanotubes. Use of a chiral amphiphilic hexa-peri-hexabenzocoronene with stereogenic centers results in the formation of graphitic nanotubes with one-handed helical chirality. Water-dispersible graphitic nanotubes and surface-polymerized graphitic coils have also been fabricated. The most recent achievement includes the successful fabrication of a photoconductive graphitic nanotube with a coaxial architecture.

A-7: L02 **Tailoring the Long Range Order of Block Copolymer Based Nanomasks on Flat Substrates**

R.A. PUGLISI, P. LA FATA, S. LOMBARDO, CNR-IMM, Catania, Italy

We investigate the self-assembling of polystyrene/poly-methylmethacrylate (PS/PMMA) block copolymer films for the formation of nano-templates. PS/PMMA self-assembling provides a simple and low-cost method for creating nanostructures with critical dimensions controlled down to 10 nm, well beyond the standard lithograpic methods. Moreover, PS/PMMA is compatible with standard semiconductor processing techniques, like standard photoresists. One important aspect is that, during phase transformation, PS/PMMA self-assembles in macrodomains of hexagonal arrays, randomly oriented between each other. For technological application, it is desirable to control the macrodomain number and size. We show how to control these structural characteristics by modifying the parameter which plays the major role in the self-assembling, i.e. the annealing process. The experimental observation is performed through an original, simple and quick analysis method, which also offers high resolution and large statistics, and it is based on the elaboration of the electronic micrographs in the reciprocal space. Thanks to it, it is possible to follow the PS/PMMA phase transformation, and for the first time, to demonstrate an onset of secondary grain growth crystallization behavior in this system.

A-7: L03 **High Internal Phase Emulsion Foams (HIPE) Filled with Organo-bentonite: Hybrid Organic-inorganic Porous Clay Heterostructures (HPCH) Versus Organo-modified Bentonite (MOD)**

P. PAKEYANGKOON, R. MAGARAPHAN, P. MALAKUL, M. NITHITANAKUL, Chulalongkorn University, Bangkok, Thailand

Organoclay derived from Na-bentonite can offer an alternative used as an inorganic filler for high internal phase emulsiom foams. Two types of Organoclay, hybrid organic-inorganic porous clay heterostructures (HPCH) derived from organo-bentonite which prepared through surfactant-directed assembly of tetraethoxysilane (TEOS)/ methyltetraethoxysilane (MTS) into galleries of clay mineral and organo-modified bentonite (MOD) treated with quaternary alkyl ammonium cation by ion exchange reaction, were used as a reinforcement for Poly(divinylbenzene; DVB)PolyHIPE foams in this study. Poly(divinylbenzene; DVB)PolyHIPE foams filled with Organoclay (HPCH and MOD) loadings of 0, 1, 3, 5 and 10 wt.% were successfully prepared using high internal phase emulsion technique (HIPE). To study the effects of organoclay on morphology, surface area, thermal and mechanical properties of the prepared Poly(DVB)PolyHIPE foams, a scanning electron microscopy (SEM), a N2 adsorption-desorption (Autosorp 1), a thermalgravimetric analysis (TGA) and a LLoy Universal testing machine were employed respectively. It was demonstrated that the addition of Organoclay (both HPCH and MOD) into PolyHIPE foams resulted in the enhancement of physical properties of the Poly(DVB)PolyHIPE foams. The incorporation of layered silicate in the polymer matrix were supported by SEM micrographs, which showed that the roughness of the wall surface appear to increase due to the presence of Organoclay. It was established that the usage of organo-bentonite as inorganic filler of Poly(DVB)PolyHIPE, has an effect on improving surface area of the obtained materials for both HPCH and MOD. However, higher improvement in surface properties were achieved in HPCH filled Poly(DVB)PolyHIPE foams when compared with PolyHIPE foams filled with MOD. Because of the surface charateristic of HPCH which is a combination of micro- and mesoporosity between each layered of silicates, therefore gas molecules might be able to adsorbed into these porous structures. The degradation temperature (Td) enhancement of the Poly(DVB)PolyHIPE foams due to the inclusion of layered silicate into the PolyHIPE matrix were also observed. Moreover, the mechanical properties of Poly(DVB)PolyHIPE foams were found to improved when compared to that of the neat Poly(DVB)PolyHIPE. Highest Young's modulus and compressive stress were observed at 5 wt.% Organoclay loadings. It was clearly demonstrated in this study that the suitable content of Organoclay (both HPCH and MOD) is 5 wt% in Poly(DVB)PolyHIPE foams.

A-7: L04 **The Effect of Transition Metal on the Thermal Conductivity of Filled Epoxy Resin**

K. WATTANAKUL, H. MANUSPIYA, T. CHAISUWAN, N. YANUMET, H. ISHIDA, Petroleum and Petrochemical College, Chulalongkorn, Bangkok, Thailand

The microelectronics packages are becoming smaller and thinner, while more heat is being generated. High thermally conductive under-fill material can be an effective way to solve the problem by removing heat from the package. In general applications, silica has been widely used as filler mainly because it is low in cost and the relevant application techniques have been well developed but the thermal conductivities of silica is very low (1.3-1.4 W/mK) such that it cannot meet the requirement of high thermal conductive encapsulation. Of the ones available, alumina (Al2O3) has been the most common and cheapest. Studies have shown that addition of either Al2O3 or ZnO fillers into silicone rubber can increase both its thermal stability and thermal conductivity, but reduces its coefficient of thermal expansion (CTE). At a fixed filler loading, ZnO-filled silicone rubber exhibits better thermal performance than Al2O3-filled silicone rubber, due to its higher intrinsic thermal conductivity and lower intrinsic CTE value. Previous studies also show that the introduction of transition metal oxide such as MnO2, Fe2O3 or CuO can increase the thermal conductivity of glass. Following the above consideration, the motivation of this study is to develop a new composite for printed circuit board (PCB) substrates. We expect that Transition metal with different atomic weight and different compounds (oxide and nitride) will show the significantly difference of thermal conductivity because of the bonding strength. The thermal conductivity, CTE, dielectric constant, Tg and mechanical properties of the composites will be examined. In addition, the moisture absorption will also be studied as moisture can damage the circuit board.

A-7: IL06 **Towards Nanoscale Self-healing**

N.R. SOTTOS, B.J. BLAISZIK, P.V. BRAUN, A. JACKSON, S.R. WHITE, University of Illinois, Urbana-Champaign, IL, USA

The development of nanostructured self-healing materials has the potential to significantly impact current research and development of self-healing technologies and opens up several new applications for responsive paints, optical coatings and controlled-release membranes. The extension to the nanoscale also enables precise, localized control over the distribution of self-healing functionality, resulting in a material that has healing capability only where needed. This talk will describe on-going efforts to achieve nanostructured self-healing materials by exploiting innovative strategies for encapsulation of healing chemistries and active delivery of the self-healing functionality into polymers. To date, we have achieved over an order of magnitude size reduction for the preparation of UF capsules filled with DCPD healing agent. Free-flowing capsules with diameters as small as 200 nm are obtained through a combination of sonication techniques and chemical stabilization with a ultrahydrophobe. Functionalization of the capsule surface enables uniform dispersion of high capsule concentrations in an epoxy matrix. Preliminary mechanical test results from the nanocapsule-filled polymer specimens indicate significant toughening even at small capsule concentrations, and examination of the resulting fracture surfaces verifies capsule rupture and release at the nanoscale. Protocols for assessing the healing efficiency are currently under development.

A-7: L09 **Environment Adaptive Friction Reducing Nano-composites with Remaining Life Sensor Capability for Aerospace Applications**

A.A. VOEVODIN, C. MURATORE, J.G. JONES, Wright-Patterson Air Force Base, Dayton, OH, USA

Long service life, friction reduction, and active feed-back of information about contact health and remaining life-before-failure are paramount for aerospace mechanisms operating across multiple environments, including variation of atmospheric gases, vacuum, and temperatures from cryogenic to 800 °C. To meet such multi-functionality new coating materials were designed to re-arrange their structure and chemistry on demand and adapt to variable surface conditions. These materials have been dubbed “chameleon” because of their ability to change surface chemistry and structure depending on the exposed environment. The design involves mixed crystalline (ZrO2, Al2O3, Ag, Au) and amorphous (MoS2, carbon) nanocomposite structure sandwiched between diffusion barrier TiN nano-layers to provide nano reservoirs for contact surface self-reconstruction. The nanocomposites were enhanced by imbedding sensor layers of materials, which have distinctive luminescence spectra under a laser probe interrogation, e.g. Er and Sm doped ZrO2. Examples of smart, multifunctional, environment self-adaptive, and remaining life sensing nanocomposite coatings are discussed together with the preparation technologies.

A-7: IL11 **Polymer-metal Nanocomposites for Functional Applications**

F. FAUPEL, V. ZAPOROJTCHENKO, H. GREVE, U. SCHÜRMANN, H. TAKELE, C. HANISCH, V.S.K. CHAKRAVADHANULA, A. KULKARNI, Christian-Albrechts University at Kiel, Kiel, Germany; A. GERBER, E. QUANDT, Inorganic Functional Materials; R. PODSCHUN, University Hospital Schleswig-Holstein, Kiel, Germany

The present talk is concerned with the preparation of polymer-based nanocomposites by vapor phase deposition and the resulting functional properties. The techniques involve evaporation[1] and sputtering[2], respectively, of metallic and organic components and inter alia allow the preparation of composites which contain alloy clusters of well defined composition. Examples include soft-magnetic high frequency materials with cut-off frequencies well above 1 GHz[3] and high quality factor, optical composites with tuned plasmon resonances suitable for ultra thin color filters, Bragg reflectors, and other devices[4-6], antibacterial coatings[7] and selective sensors for organic vapors. Moreover, a novel approach to produce magnetic nanorods for potential applications in high-density data storage and other fields will be presented[8].

[1]A. Biswas et al, Nano Letters, 3, 1, (2003); [2]U. Schürmann et al, Nanotechnology, 16, 1078, (2005); [3]H. Greve et al, Appl. Phys. Lett. 89, 242501 (2006); [4]A. Biswas et al, Appl. Phys. Lett., 84, 2655, (2004); [5]H. Takele et al, Nanotechnology, 17, 3499, (2006); [6]V. Zaporojtchenko et al, Nanotechnology, 17, 4904, (2006); [7]H. Greve et al, Appl. Phys. Lett., 88, 123103 (2006)

A-7: L12 **Nano/Micro-sized $Ge_2Sb_2Te_5$ Structures Formed (100)/(111) Si Substrate by Electrical Pulse Induced Evaporation Method**

H.J. KIM, S.K. CHOI, Korea Advanced Institute of Science and Technology, Daejeon, Korea

Phase change materials such as chalcogenide Ge2Sb2Te5(GST) are of importance in a future universal memory that combines the best attributes of static RAM, dynamic RAM, and flash RAM. However, it is essential to reduce the size of the phase change memory cell to sub-lithographic length scales for high density, a major bottleneck for achieving the true potential of these materials. Also, the scale-down to nanoscale is critical in reducing the current for amorphizing(reset) GST rapidly, thereby enabling fast data switching with less power consumption. Nanostructures can be a powerful approach to assemble memory devices at small length scales owing to their sub-lithographic size and unique geometry. We present four growth modes of nano/micro-sized GST crystal; fractal-like, rod, dot, and tube structure, which is formed on (100)/(111) Si crystal substrate by the electrical pulse induced evaporation method. We believe that this method has an important merit of arraying GST nanostructure in double-quick time. On the based of both scanning electron microscope and atomic force microscope observation, we propose that the rod and the dot growth is related to 2D clusters of Ge, Sb, and Te element, which are formed after evaporating the heated GST film by applying an electric pulse to it.

A-7: L13 **Functionalized Nanostructures with Noble Metals Shells and Magnetic Cores**

O. PANA, R. TURCU, M.L. SORAN, A. NAN, National Institute R&D for Isotopic and Molecular Technologies, Cluj-Napoca, Romania; O. CHAUVET, C. PAYEN, E. GAUTRON, Institute of Materials Jean Rouxel, Nantes, France

The core-shell nanoparticles with a magnetic core and a shell made on noble metals like Au or Pt, offer both advantages of tailoring the magnetic properties of the core and of the functionalizing of the external shell in view of various applications. In this work we report the synthesis and characterization of novel core-shell nanostructures, consisting in three types of core-shell nanoparticles formed by either Fe, Fe3O4 and La2/3Sr1/3MnO3 (LSMO) perovskite manganite covered by an external Au or Pt shell. Further, the magnetic core-shell nanoparticles were functionalized. The function was realized either by direct attachment of different amino acids to the nanopatricles or by covalent attachment of amino acids and depeptides to the pyrrole monomer. The substitution was realized at position 1 and 3 of the pyrrole ring. Further the substituted and unsubstituted pyrrole monomer was chemically polymerized around the magnetic core-shell particles. Morphological, compositional and magnetic characterization of the core-shell nanoparticles was performed by HRTEM, EDX, AES, XRD and magnetic measurements. The magnetic behavior shows no hysteresis loops indicating that all the studied systems are superparamagnetic. A comparison between properties of different samples is performed.

Session A-8
MEMS / NEMS

A-8: IL01 **CNT Based Sensors**
C. HIEROLD, A. JUNGEN, L. DURRER, T. HELBLING, ETH Zurich, Zurich, Switzerland

Carbon Nanotubes (CNT) are intensively studied as a new functional material for sensors, nanosystems and electronic systems. Single-walled carbon nanotubes (SWNTs) for example show unique mechanical and electromechanical properties and they change electronic properties by interacting with the environment (e.g. for chemical and biochemical sensing). Therefore CNTs are very promising candidates for active elements in future nano scaled transducers. Concepts for carbon nanotube sensors for mechanical and chemical quantities are presented. We focus on single-walled carbon nanotubes as “simple” macro molecular functional structures with an option for low scale integration in MEMS and NEMS and we discuss topics of relevance for future fabrication.

A-8: L02 **Design and Fabrication of a Piezoelectric MEMS AC Current Sensor**
E.S. LELAND, P.K. WRIGHT, R.M. WHITE, University of California, Berkeley, CA, USA

The need for energy efficiency combined with advances in compact sensor network technologies present an opportunity for a new type of sensor to monitor electricity usage in residential and commercial environments. A novel design for a self-powered, proximity based AC electric current sensor has been developed. This sensor device is constructed of a piezoelectric cantilever with a permanent magnet mounted to the cantilever’s free end. When the sensor is placed in proximity to a wire carrying AC electric current, the permanent magnet couples to the wire’s alternating magnetic field, deflecting the piezoelectric cantilever and thus producing a sinusoidal voltage proportional to the current being measured. Meso-scale (2-3 cm ^ 3) devices have been built and tested, with sensitivities of 70 mV/A. MEMS-scale devices are currently under development using a three-mask process and aluminum nitride as the active piezoelectric layer. For the permanent “micromagnet” in the MEMS scale device, a process has been developed to dispenser-print very small (hundreds of microns) composite magnets comprised of magnetic powders in a polymer matrix.

A-8: IL03 **MEMS Fabrication Based on Epitaxial Piezoelectric Thin Films on Silicon**
S. GARIGLIO, N. STUCKI, J.-M. TRISCONE, University of Geneva, Switzerland; D. ISARAKORN, D. BRIAND, N.F. DE ROOIJ, University of Neuchatel, Switzerland; S.H. BAEK, C.-B. EOM, University of Wisconsin, Madison, USA; J.W. Reiner, C.H. AHN, Yale University, USA

This contribution will describe the realization of novel micro-electro-mechanical systems (MEMS) based on epitaxial piezoelectric thin films grown onto (100) silicon substrates. Using $SrTiO_3$-buffered silicon substrates, it is possible to grow epitaxial thin films of $Pb(Zr_{0.2}Ti_{0.8})O_3$ and $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ which have superior piezoelectric coefficients over conventional piezoelectric thin films. This approach allows one to take advantage of their high piezoelectric coefficients as actuating/sensing layers in MEMS.

A-8: L04 **Model and Simulation of Resonant MEMS Based on High-electron Mobility Transistor**
I. KHMYROVA, University of Aizu, Aizu-Wakamatsu City, Japan

Model of resonant MEMS based on high-electron mobility transistor (HEMT) with suspended cantilever serving as a gate is developed and used for characterisation implementing SPICE simulation. Resonant MEMS under consideration has been recently proposed and fabricated. They can be used as a sensor for detection of small forces, masses, etc. Developed model accounts for transduction of mechanical oscillations of the cantilever driven by bias voltage into variation of electric field and electron density in the HEMT channel directly beneath the cantilever which, in turn, results in the variation of source-drain current flowing along the channel. Influence of ungated channel regions and depletion of the channel has been also taken into account. Simulated output characteristics reveal peak at a frequency corresponding to that of cantilever mechanical resonance.

A-8: IL05 **A Review of Test Structures for Characterising Microelectronic and MEMS Technology**
A.J. WALTON, S. SMITH, University of Edinburgh, Edinburgh, UK

Microelectronic and micromachined test structures consist of lithographically formed patterns that are specifically designed to aid the characterisation of microelectronic and microsystem fabrication processes. Typically, electrical, optical or physical measurements are made on these structures for device evaluation or process characterisation and optimisation. Data analysis techniques that are applied to characterise these structures are a key component of all test structure related activities. With test structures being specifically designed to help characterise specific elements of the fabrication process they have played a key part in the success of integrated circuits. For process control/monitoring they can be used in a wide variety of roles. These include transistor parameter extraction, equipment characterisation, reliability evaluation and defect monitoring, as well as process verification and development. During the manufacturing process a small subset of test structures are typically used to confirm that the wafers have been successfully processed and can be therefore be passed over for functional test. The paper will present and review a selection of available microelectronic and MEMS test structures.

A-8: L06 **Friction Drive Simulation of a SAW Motor with Slider Surface Texture Variation**
MINORU KURIBAYASHI KUROSAWA, TAKASHI SHIGEMATSU, Tokyo Institute of Technology, Yokohama, Japan

Potential of a surface acoustic wave (SAW) linear motor had been demonstrated; high speed up to 1.5 m/s, huge output force more than 10 N, quick response and fine stepping motion down to 0.5 nm by using a 60 x 15 x 1 mm3 SAW device at 10 MHz operation frequency and 4x4 mm Si slider by experiments. Mechanical output of the SAW motor was 270 times larger that of the weight and 500 W/kg in power. The conversion efficiency from the traveling wave power to the motor mechanical output was 14 %. Now, transformation mechanism research from high frequency vibration of 10 to 100 MHz frequency range to mechanical linear motion through frictional drive is noteworthy. Contact, friction and other physical matters between a stator and slider are being studied for stable operation and much superior performance. The slider friction surface has a lot of projections to control the contact with the stator. From the experimental results, it was shown that the slider surface projection diameter has huge influence on the motor characteristics. If the total projection contacting surface areas were same, the output force, for example, varied with the projection diameter; smaller projection, for example 20 micron diameter, had superior performance than larger one. In this paper, we could explain, for the first time, the reason why the smaller projection slider has advantage in performance by theoretical analysis using contact mechanics.

A-8: L07 **MEMS Rotational Thermal Actuator for High Force and Large Displacement**
L.J. CURRANO, D. GEE, W. CHURAMAN, M. DUBEY, P. AMIRTHARAJ, U.S. Army Research Lab., Adelphi, MD, USA; M. YU, B. BALACHANDRAN, University of Maryland, College Park, MD, USA

Electrothermal actuators are of interest in MEMS due to the simplicity of the fabrication process and the high force available from thermal actuation. We will present a new type of rotational thermal actuator, an electrothermomechanical model to guide the design, and experimental characterization which validates the model. The rotational actuator is capable of realizing forces which approach those of similar sized bent-beam thermal actuators while also yielding displacements which approach similar sized hot arm/cold arm actuators. The device is constructed on an SOI wafer using the low-resistivity single crystal device silicon layer. It consists of two straight, parallel beams with an offset between the respective axes. One end of each beam is anchored to the substrate, the other ends are connected at the center of the device with a small bridge. Current through the beams causes thermal expansion, which results in a torque about the center of the connecting bridge. Because of symmetry in the device, the output is pure rotation about the center point which can be converted into near-linear translation for relatively small angles. Output forces of up to 1.44mN simultaneous to displacements greater than 20um have been achieved with the test devices.

A-8: IL09 **Anthropod Flow Sensing: when MEMS Design Learns from Physical Ecology**
J. CASAS, Université de Tours, Tours, France; G. KRIJNEN, University of Twente, Enschede, The Netherlands

Crickets, as many other insects, possess some of the most exquisite hairs to sense the air flow produced by approaching predators. In this talk, we first describe the functioning of the real and the bionic hairs. In order to gain some understanding of the flow experienced by hairs, we describe longitudinal and transversal flows around the cerci, two appendages at the rear of the animal and bearing the hairs. We compare the observed flow using Particle Image Velocity (PIV) with existing theories. On the basis of our understanding of the flow, we interpret the the hair positions on cerci. The question of hydrodynamical hair to hair interactions becomes central to the biomimetic design of MEMS arrangements on an artificial cercus. We end up the talk with our latest results on micro-PIV for characterizing flow around single bionic hairs and within hair canopy.

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Steinmann, T., Casas, J., Krijnen, G. & O. Dangles (2006) Air-flow sensitive hairs: boundary layers in oscillatory flows around arthropods appendages. Journal of Experimental Biology, 209:4398-440

A-8: IL10 **Nanofluidic Membranes and Filters for Biosample Preparation**
PAN MAO, MIT, Cambridge, MA, USA; M. STERN, Lehigh University, Bethlehem, PA, USA; C. BATISTA, Roxbury Community College, Roxbury Crossing, MA, USA; JEONGHOON LEE, YONG-AK SONG, JONGYOON HAN, MIT, Cambridge, MA, USA

Recent advances in fabrication techniques allows one to create regular nanofluidic pores and channels down to 10 ~ 20nm in critical dimension, with excellent uniformity and size control. This creates unique opportunities for molecular sieving and other traditional membrane applications, since now one can manufacture molecular filters and membrane structures with regular pore shape and size, which were previously only possible with polymer-based nanoporous materials and gels. This will both enhance our understanding of important membrane phenomena, as well as allowing us to engineer molecular filters with better functionality. In this talk, several fabrication approaches for regular nanofluidic membranes and molecular filters, as well as their application into biomolecule separation and sample preparation, will be shown. Massively parallel nanofilter arrays can be fabricated either by standard MEMS processing or self-assembly of micro/nanobeads, to be integrated into a microfluidic system. Carefully designed integration of nanofilters in microfluidic systems leads to unique continuous-flow fractionation of biomolecule mixtures. Such a nanofilter membrane can be used as a perm-selective membrane, both for biomolecule preconcentration and fuel-cell related applications.

A-8: IL11 **Electronically Controlled Micro- and Nanosystems for Biosensing and Interfacing Biology**
J. VÖRÖS, ETH Zurich, Zurich, Switzerland

The success of medical devices critically depends on the ability to interact with the biological environment. The bioresponse is often determined by the properties of the biointerface which requires the precise control of this interface on the micron- and nanometer scale. Recent advancements in nanotechnology have created a variety of top-down and bottom-up self-assembly based techniques that can reach feature sizes of 100 nm or less, thus approaching a size range very relevant to biology. The combination of these novel top-down and bottom-up approaches enables us to interact with complex biological systems: tissues, cells, proteins and DNA in an unprecedented manner. In addition, new tools, such as arrays of nanoparticles and nanowires can be created on a large scale with promising applications in electronic and optical biosensing. Recently, we have put a lot of efforts into achieving not only spatial but also a dynamic control over the properties of biointerfaces. Surfaces that change upon external stimuli provide us with new research tools for studying complex biological problems and for tissue engineering. Highlights for the use of novel, electronically- or photo-active surfaces for applications in biosensing and local drug delivery will also be presented.

A-8: IL12 **Dynamic Fluidic Microarray for Biological Cell Analysis**
SHOJI TAKEUCHI, The University of Tokyo, Tokyo, Japan

In this talk, I will introduce one of our approaches for high-throughput cell analysis, i.e. a dynamic microarray technology. This technology allows us to transport and immobilize the cells, infuse reagents, observe their reactions, and retrieve selected cells; these functions are necessary for highly parallel screening. We achieve all these functions in a single integrated device through the combination of hydrodynamic and optical approaches. The approaches include: (i) cell encapsulation in alginate hydrogel beads. Encapsulation allows us to work with both adherent and non-adherent cell types, protects cells from direct mechanical stresses and the size uniformity of beads facilitates trapping in the microarray system; (ii) μ-Fluidic traps (hydrodynamic confinement and arraying of particles). Hydrodynamic forces allow simultaneous transportation and immobilization of large number of particles without complicated control; (iii) optical-based microbubbles for retrieval of particles. Optical-based microbubble technique for bead retrieval gives dexterity in handling individual particles without complicated circuitry. We believe that the device is highly amenable to automatic processing, and can be easily scaled up to cater for fast, high-throughput, and highly parallel screening.

A-8: L14 **Design and Fabrication of a Two Hot Arms Thermal Micro-actuator with Integrated Micro Tweezers**
A.B. ALAMIN DOW, University of Bremen, Bremen, Germany; K. IVANOVA, T. IVANOV, I. RANGELOW, Technical University of Ilmenau, Ilmenau, Germany

Micro tweezers are one of the microsystems technology applications and typically used for handling micro parts and manipulate small objects. Microactuators such as thermal microactuator are mainly used to drive the micro tweezers. This paper present the design, simulation, fabrication and characterization of a new developed two hot arms thermal micro actuator with integrated micro tweezers. The advantages of this new micro actuator with integrated tweezers are: the actuator flexure is not more part of the actuation loop and the electric current only passes through the inner and outer thin hot arms of the actuators which have a high electrical resistance. The actuator efficiency will increases dramatically since all applied power will contribute to the tweezers movement. Furthermore, a heat dissipation element which acts as a heat radiator was introduced to decrease the heat transfer to the tweezers which is strongly required in some applications. The device was fabricated out of silicon substrate by inductively coupled plasma etching process. The device showed very good controlling ability during its operation, and a good agreement between experimental and simulation results was achieved.

A-8: L15 **Three-axis MEMS Threshold Accelerometer Switch for Enhanced Power Conservation**
W. CHURAMAN, L.J. CURRANO, D. GEE, U.S. Army Research Laboratory, Adelphi, MD, USA

In many applications such as system health monitoring, where MEMS accelerometers are used, information must be sampled continuously, and sensors must respond to immediate changes. Constant monitoring poses a challenge to system power constraints because the sensor draws current continuously. To address this issue, the U.S. Army Research Laboratory has developed a revolutionary no-power 3-axis bidirectional MEMS threshold accelerometer switch that responds to accelerations at 25g, 50g, and 100g. The design is based on a conductive spring-mass system made of metal layers which close a switch between two metal contacts when the designed threshold is exceeded. No power is consumed before the switch closes, and the switch reopens once the acceleration drops below the threshold level due to the restoring force of the springs. A single, three-threshold, 3mmx3mm die can be integrated with a conventional commercial accelerometer, alleviating the demand for constant power while still ensuring constant monitoring and detailed acceleration time-history. We present the MEMS threshold accelerometer switch fabrication process and provide an analytical and experimental framework for the device performance in terms of its response time capability and reliable contact resistance.

A-8: L16 **Piezoelectric MEMS Actuators for Bio-inspired Micro-robotic Applications**
J. PULSKAMP, K. OLDHAM*, R. POLCAWICH, M. DUBEY, P. AMIRTHARAJ, United States Army Research Laboratory, Adelphi, MD, USA; *University of Michigan, Ann Arbor, MI, USA

Biologically-inspired autonomous micro-robots have a variety of anticipated applications resulting from their unique scale and cooperative potential. To achieve locomotion comparable to biological systems, these micro-robots will require actuators substantially more capable than most existing MEMS actuation technologies. Piezoelectric thin films can meet these specifications while drawing limited power and contributing little mass to micro-robotic systems. Theoretical actuation requirements for micro-robotic applications show that lead zirconate titanate (PZT) thin film actuators can meet these requirements. Using chemical solution deposited PZT with a Zr/Ti ratio of 52/48, lateral actuators have been fabricated using MEMS surface micromachining techniques. These lateral actuators have demonstrated large forces (~8 mN) over strokes of almost 1 µm in a 500 µm by 100 µm footprint. These actuation forces exceed those of other common MEMS actuation techniques acting with similar footprints and voltages, and furthermore can meet actuation specifications for insect-like micro-robotic joints.

A-8: IL17 **Combinatorial Studies and Scaling in Smart Metallic Thin Film Materials**

R. SPOLENAK, ETH Zurich, Zurich, Switzerland

Alloying development in thin films requires different approaches compared to bulk materials. First, alloying elements may easily diffuse to surfaces and interfaces; second, the texture evolution of thin films depends on the film thickness; and third, thin films usually exhibit columnar grain structure unlike the globular ones found in bulk materials. Thus combinatorial approaches have to be used to most efficiently optimize thin film alloys. Here, two case studies on actuator materials will be presented. In the first, the shape memory alloy Ni-Ti-Cu will be presented and thin film effects on texture, phase and the derived mechanical properties will be discussed. The second example focusses on nanoporous gold thin films that may be used as charge driven actuators. In this case the properties depend on grain size, porosity and pore size. The morphology of the thin film may eventually be turned into nanoparticles by applying a heat treatment resulting in dewetting. Scaling as the common denominator of this talk will critically be discussed in terms of positive as well as detremental effects on materials properties.

A-8: L18 **A Novel Fuel Cell Electrode Structure with Porous Pt Layer Formed on a Si Substrate**

MASANORI HAYASE, T. FUJII, J.G.A. BRITO-NETO, Tokyo University of Science, Noda, Chiba, Japan

Miniaturized fuel cells are expected as a dream portable power sources. In this study, a MEMS based novel fuel cell electrode fabrication process is demonstrated. The anodized porous Si is an attractive material, because of its formation easiness and its large surface area. Recently, we found that porous Pt layer is formed by just immersing high porosity porous Si into Pt plating bath containing HF. In the plating bath, Si works as a reducing agent and Pt ion is reduced while Si oxide is formed on the porous Si surface. If HF was not added in the plating bath, because of the insulation nature of the Si oxide, Pt deposition stops after Si oxide covers the porous surface. The Si oxide is removed by HF added to the plating bath and raw Si surface appears. This reaction repeats until almost all Si are replaced by Pt and porous Pt layer can be formed on a Si chip. Electrochemical measurements showed that the porous Pt has catalytic features. After making porous Pt layer, fuel channels are opened from the opposite side of the chip by plasma Si etching. This strategy is possible because the plasma etching rate is much lower at the porous Pt layer. A prototype cell was made by putting a PEM sheet between two Si fuel cell electrodes. Peak output of 54mW/cm2 was observed by hydrogen feed.

A-8: L20 **Electromechanical Behavior of Single and Multiwall Carbon Nanotubes**

A. PANTANO, Università degli Studi di Palermo, Italy; D.M. PARKS, M.C. BOYCE, MIT, USA; M. NARDELLI, North Carolina State University, USA

Carbon nanotubes (CNTs) can be metallic or semiconductors depending simply on geometric characteristics. This peculiar electronic behavior, combined with high mechanical strength, make them potential building blocks of a new nano-electronic technology. High resolution images of CNTs often disclose structural deformations such as bent, twisted, or collapsed tubes. These deformations break the tube symmetry, and a change in their electronic properties should result. A computationally effective mixed finite element-tight-binding approach able to simulate the electromechanical behavior of single and multiwall nanotubes used in nano-electronic devices is presented. The finite element (FE) computes the evolution of atomic coordinates with deformation and provides these coordinates to a tight-binding (TB) code, enabling computation and updating of the electrical conductivity. The TB code is engineered to realize dramatic computational savings in calculating deformation-induced changes in electrical transport properties of the nanotubes. The FE-TB computational approach is successfully validated in a simulation of laboratory experiments which had measured the changes in electrical conductivity of a multiwall carbon nanotube during mechanical deformation.

A-8: L21 **RF MEMS Devices Using PZT Thin Films**

R.G. POLCAWICH, J. PULSKAMP, D. JUDY, M. DUBEY, P. AMIRTHARAJ, US Army Research Laboratory, Adelphi, MD, USA

RF MEMS utilizing piezoelectric thin films has been limited in the past with a majority of efforts emphasizing lower performance materials such as ZnO and AlN because of their ability to be easily integrated with standard microelectronics fabrication. However, incorporating higher performance materials such as lead zirconate titanate (PZT) thin films can facilitate improved characteristics in switches and resonators. Recently, PZT actuators have been successfully integrated to yield RF MEMS switches capable of operating at less than 10 volts. The series switch has been demonstrated from -25 °C to 100 °C with an actuation voltage remaining below 10 V, an isolation better than -30 dB, and an insertion loss less than 0.3 dB from DC to 50 GHz. In addition, a shunt switch based on the same technology has been shown to operate from 0 °C to 100 °C with better than -18 dB isolation and insertion loss less than 0.25 dB from DC to 50 GHz. These same shunt switches have been integrated into a 17 GHz, 2-bit reflection phase shifter with an average insertion loss of 2.96 dB using switches operating at 15 V. Along with switches, PZT based resonators show promise as filters and oscillations in communications capable of achieving sub 3 dB of insertion loss in an extremely small footprint.

A-8: L22 **Superelastic and Shape Memory Micro-nano Devices**

J. SAN JUAN[1, 2], M.L. NO[1], C.A. SCHUH[2], [1]Universidad del Pais Vasco, Bilbao, Spain; [2]MIT, Cambridge, MA, USA

Shape Memory Alloys are good candidate materials for micro-nano sensors and actuators, in spite of some works claiming that the martensiticc transformation would be suppressed at nano-scale. In the present work we have micromachined, by Focused Ion Beam technique, some basic micro and nano devices that exhibit superelasticity and shape memory effect with displacements of some tens or hundreds nanometers with complete reversibility. These basic micro-nano devices demonstrate the feasability of more complex MEMS and NEMS using these outstanding properties.

A-8: IL24 **The Promise and Potential of Nano and Micro Systems for Military Applications**

J.M. PELLEGRINO, Director, Sensors and Electron Devices Directorate, US Army Research Lab., Adelphi, MD, USA

The ever changing challenges faced by the current and future warfighters to control and dominate the battlefield create the need for solutions which can only be met by advances in sensor technology and electronic devices. New nano and micro system approaches offer potential solutions to fulfill warfighter needs in applications such as; chem./bio sensors, high-frequency and low-power electronics, micro autonomous systems, micro power generation, specialized optical sources and detectors etc. This presentation will review some emerging challenges with recent illustrative examples from the field and will follow up with potential solutions that are being developed within the Army Research Laboratory and its partners. These include such items as; carbon nanotubes, other nanostructure based chem./bio sensors, biomimetic approaches to materials development for power storage applications, and nanostructured semiconductors for integrated electronics and energetics.

A-8: L25 **Fully Integrated Bridge-type Anemometer in LTCC-based Microfluidic Systems**

H. BARTSCH DE TORRES, C. RENSCH, T. THELEMANN, M. FISCHER, J. MÜLLER, M. HOFFMANN, TU Ilmenau, Germany

The presented sensor is integrated in a retention module based on Low Temperature Cofired Ceramics (LTCC). This material system allows the cost-effective realisation of fluidic microsystems with integrated electronics. The challenge of this work is to design a highly sensitive

anemometer using thick film technologies only. The sensor principle requires resistive pastes with a high temperature coefficient of the resistance, usually used only on the surface of LTCC systems. If the pastes are used in inner layers, outgassing destroys the stack. The presented solution uses embossed chimney structures to enable the inner use of such pastes. Since maximal heat-insulating of the sensor from the substrate is required, a solution was found for the use of resistive pastes combined with embossed structures on free standing bridges. The anemometer has a linear sensor characteristic for flow rates up to 0,033 m/s. The layout guarantees that the fluid gets only in contact to the basic ceramic material, which is compatible with cell fluids or PCR-reagents (Polymerase Chain Reaction). Therefore this new fully integrated anemometer is suitable for fluid process control in micro reaction systems, biological applications as well as screening applications.

A-8: L26 **Improvement of MEMS Vibrational Energy Scavenging Devices**

L.M. MILLER, N.C. EMLEY, P. SHAFER, P.K. WRIGHT, University of California, Berkeley, CA, USA

We present a study on sol-gel derived lead zirconate titanate (PZT) as the active layer in MEMS vibrational energy scavenging devices. Sol-gel-deposited PZT typically suffers from lower piezoelectric constants than those from other deposition methods (i.e. MOCVD, PLD), but it remains a simple method for depositing PZT films onto arbitrary wafer sizes. The texture of the adhesion and bottom electrode layers affects the formation of the piezoelectric phase in the PZT film thereby impacting its efficacy as an active layer. We attempt to improve the piezoelectric response of the sol-gel PZT by investigating the effects of various adhesion layers (Ti, Zr, Cr, or Ta) between a Pt bottom electrode and an oxidized silicon wafer, exploring their impact on PZT morphology, piezoelectric, and ferroelectric response. The PZT is then used as the active layer in first generation prototypes of cantilever beam scavenger devices. Several alternate geometries are explored in order to improve power output by increasing the fraction of the material strained and reducing the natural frequency to better match input vibrations. Finite element modeling and fabrication results are presented.

A-8: L28 **3C-silicon Carbide Hetero-epitaxial Films for Sensors Fabrication**

R. ANZALONE, G. D'ARRIGO, F. LA VIA, IMM-CNR, Catania, Italy; G. CONDORELLI, M. MAUCERI, Epitaxial Techn. Center, Catania, Italy; G. FOTI, University of Catania, Catania, Italy

Silicon Carbide (SiC) is the most promising material for the fabrication of a new category of sensors and devices, to be used in very hostile environments (high temperature, corrosive ambient, presence of radiation). The fabrication of Silicon Carbide sensors requires new processes able to realize microstructures on bulk material or on the silicon carbide surface. The hetero-epitaxial growth of 3C-SiC on silicon substrate allows to overcome the traditional limitation of SiC micro-fabrication. This new approach put together the standard silicon bulk microfabrication methodologies to the high mechanical properties of 3C-SiC. Using this new approach we are able to fabricate SiC membranes and cantilevers for a new class of pressure sensor. We applied two different transducer principles (piezoresistive effect and optical detection) to characterize the structures. Chemical vapour deposition (CVD) of 3C-SiC on Silicon (100) oriented substrate (on-axis Si wafers) are carried out, using Trichlorosilane as silicon supply, Ethylene as carbon supply and hydrogen as gas carrier. The epitaxial films were grown in a hot-wall CVD reactor built by LPE. The entire deposition process was constituted by four different steps (multi-step process) that allow to produce high quality 3C-SiC film.

A-8: IL29 **RF MEMS Products and Applications**

D. HYMAN, XCOM Wireless Inc., Signal Hill, CA, USA

RF MEMS technologies and manufacturing processes have finally achieved a level of maturity sufficient to release viable products to the marketplace. Products are being sampled to eager customers in military, test, and instrumentation industries who are desperate for these high-performance components. The critical commercialization issues of cost, yield, and system-level insertion and customer management are finally being tackled, now that the industry has finally addressed packaging and reliability in industry-standard ways. After nearly twenty years of development, the RF MEMS industry has released real products, which is a similar time frame for many other types of MEMS technologies past and present. This talk discusses the wide variety of presently available RF MEMS products from XCOM and selected competitors, and discusses the applications where these components are being used. There are upcoming applications in consumer handsets and portable devices that offer even greater opportunities for RF MEMS. Dr. Hyman will discuss the prospects and challenges that remain before any developer can get these potentially lucrative high-volume design wins.

A-8: L30 **Porous Metal Frameworks on Silicon Substrates**

J.G.A. BRITO NETO, TAKU MATSUZAKA, YOSUKE SAITO, MASANORI HAYASE, Tokyo University of Science, Noda, Chiba, Japan

Porous metal frameworks have important applications in catalysis, separations, and sensing because of their high surface-to-volume ratios. Single-crystal Si, on the other hand, is ubiquitous in the microelectronics industry and MEMS. Consequently, the possibility of producing MEMS-compatible porous metallic micro-structures on Si substrates is very interesting. In this work, we describe the use of porous Si as a base material for the production of porous metal layers by a galvanic displacement reaction. We have applied this process for the production of porous Pt, Au, Ru and Pd layers. By adding HF reaction bath, we achieve a virtually complete displacement of Si by the metal. We have worked with porous Si samples of different morphologies, obtained on differently doped Si substrates, and studied the influence of the chemical nature of the metal precursor on the morphology of the porous metal layer produced. The samples were studied by SEM with EDS, BET analysis, and voltammetry. Porous metal layers comprising random agglomerates of spherical particles with diameters between 50 and 100nm are usually obtained, while the original porous Si samples show arrays of straight pores. With Au, using its ethylenediamine complex, the original straight pore morphology could be preserved.

SPECIAL SESSION A-9

Recent Development in Electrical Writable Organic Memory Devices

A-9: IL01 **Organic Memory Devices from C60 and Insulating Polymers**

M. CHHOWALLA, Rutgers University, Piscataway, NJ, USA

We describe an all organic molecular memory device that combines the advantages of molecular and organic electronics. Specifically, we demonstrate memory devices using C60 fullerene molecules dispersed in an insulating poly-vinyl-phenol (PVP) polymer. The devices exhibit high and low conductance states, rapid switching, low power consumption, long term cycling stability and data retention which renders them suitable for membership in the class of non-volatile, high speed and inexpensive memory devices. In addition, we demonstrate that mild thermal annealing enhances the stability of the devices. Specifically, after annealing, the hysteresis in our devices can be preserved up to 85C in 60% humidity. Furthermore, memory retention tests show that it is possible to preserve a state even after annealing at 85C in 60% humidity for 30 minutes. Our devices are fabricated at room temperature using spin coating thus they are easily scalable for mass production.

A-9: IL04 **Nanoparticles for Charge Storage**

D. TSOUKALAS, National Technical University of Athens, Zografou, Greece; M.C. PETTY, Durham University, Durham, UK

Memories represent by far the largest part of electronic systems; these are either non-volatile (for example Flash memories) or volatile (DRAM). An ideal device would combine the speed of DRAM with the retention characteristics of Flash structures. The purpose is to find materials and concepts that lead to devices that are scalable for at least several generations below 32 nm and fast (ns and less). The technology and materials must also be compatible with present-day and future

generations of CMOS. In our presentation we shall describe the use of nanoparticles as charge storage elements and their application in non volatile memory devices. Nanoparticles that can be deposited at room temperature either by chemical self-assembly, Langmuir-Blodget technique or by physical deposition are integrated into the gate stack material of a FET device resulting to a non volatile flash like memory operation. Integration of nanoparticles in such device structures has been shown using either a hybrid silicon-organic technology or purely organic materials. Following that review we shall present a 3-D integration concept of such low temperature fabricated memories that could result into an increased memory density.

A-9: L08 **Floating Charge Storage Centers for Non-volatile Organic Memory Applications Enabled by In-situ Synthesis of Gold Nanoparticles in a Self-assembled Block Copolymer**

W.L. LEONG, P.S. LEE, T.P. CHEN, S.G. MHAISALKAR, Nanyang Technological University of Singapore, Singapore

A system consisting of self-assembled block copolymer of polystyrene-b-poly-4-vinylpyridine (PS-b-P4VP) with in-situ room temperature synthesized gold nanoparticles (AuNPs) is shown to have an electrical writable memory effect, with the AuNPs acting as charge centers. The block copolymer is an excellent model system, which is simple, forms self-assembled ordered nanostructure, single-step processing of nanoparticles and provides optimum control over nanoparticle size formation and isolation. The electrical properties of these fascinating nano-arrays were studied by fabricating a Metal-Insulator-Silicon structure, where a capacitance-voltage hysteresis window ranging from -0.4 to -1.5V was observed within the operating range of 3-5V, indicating a net hole trapping effect. The ability to tune the memory behaviour was illustrated by changing the loading of AuNPs. Organic memory device comprising a Metal-Pentacene-Insulator-Silicon structure has been demonstrated, using the AuNPs in PS-b-P4VP as charge storage components for the holes from pentacene. Writing and erasing operations take place by applying various voltage pulses to gate electrode, displaying a significant memory window. The data retention properties of this novel device under ambient conditions were also characterized.

A-9: L10 **Non-volatile Memory Devices Based on Diphenyl Bithiophenes**

E.V. CANESI, C. BERTARELLI, A. BIANCO, M. CAIRONI, G. DASSA, D. FAZZI, D. NATALI, M. SAMPIETRO, G. ZERBI, Politecnico di Milano, Milano, Italy

Non volatile memory devices have been developed using diphenyl bithiophene derivatives (DPBT) as active layer. A series of DPBTs with both aromatic and quinoid structure at the ground state has been synthesized. These molecules differ for the position of the functional phenyl groups, that are connected in the position α or β of thiophenes, generating structures with the linear or the so call “Z” shape. The electrical features of these molecules have been tested in a two-terminal electrical bistable memory cell based on a spin cast organic layer sandwiched between ITO and aluminium electrodes. All the considered molecules show electrical bistability, with differences in the electrical behaviour depending on the chemical structure. In particular, the Z shaped-molecules, which are characterized by a highly distorted geometry at the ground state, have shown the best electrical performances: 250 consecutive write-and-erase I-V cycles, appreciable ON/OFF current ratios, retention of the ON and OFF states longer than 48 hours[1]. The cell performance has been further increased by mixing the active molecule with an inert polymeric matrix of polystyrene, reaching more than 1000 write-and-erase cycles. A key factor to develop materials with optimized performances is understanding the molecular origin of the electrical bistability. To this aim, a spectroscopy study has been carried out both *in situ* on the device and on the organic material itself. Attention was paid to the species that are supposed to be involved in the molecular switching: neutral and doped species. UV-visible absorption measurements, luminescence, infrared and Raman spectroscopies have been considered. The experimental investigation was supported by first-principles theoretical modeling on the molecules in different conditions: neutral species at the ground state, neutral molecules perturbed by an applied static field and charged species. Finally, DPBT with linear configuration interestingly showed luminescence with high quantum efficience both in solution and in solid state, that can be compared with the best so far reported in literature for thiophene-based oligomers.

[1]*M. Caironi, D. Natali, and M. Sampietro, C. Bertarelli, A. Bianco, A. Dundulachi, E. Canesi, G. Zerbi, Appl. Phys. Lett., 89 Art. No. 243519 DEC 11 2006.*

A-9: L11 **Resistive Electrical Switching of Nonvolatile Memories from Electrodeposited Copper Tetracyanoquino-dimethane (CuTCNQ)**

R. MÜLLER, A. KATZENMEYER, O. ROUAULT, L. GOUX, D.J. WOUTERS, J. GENOE, P. HEREMANS, IMEC v.z.w., Leuven, Belgium

CuTCNQ is a charge transfer complex displaying resistive electrical switching when sandwiched between Cu and Al contacts. Corresponding memory cells switch from a high resistive OFF state (HRS) to a low resistive ON state (LRS) by applying a negative voltage to the Al with respect to the Cu. Inversion of the signal polarity leads to switching from the LRS to the HRS. Typical CuTCNQ preparation occurs by a chemical reaction between the Cu substrate and TCNQ, leading often to corrosion of the Cu electrode. In this contribution we present electrodeposition of CuTCNQ on Au and Pt substrates. Compared to a published CuTCNQ electrodeposition procedure leading to dendritically crystal growth, our method gives rise to relatively smooth, micrometer thick layers. Corresponding large area cross-bar memory arrays (200um by 200um, with Al top contacts) exhibited up to several thousand write/erase cycles with an ON/OFF current ratio above 10. These results of electrical measurements are very promising for further studies, especially since preliminary CuTCNQ electrodeposition experiments in 250 nm diameter vias of CMOS wafers with blanket metal bottom contacts were also successful.

This research was performed within the framework of the EMMA project of the European Commission (FP6-033751).

A-9: L12 **Effect of Various Electrode Materials in Non-volatile Memory Device using Poly(3,4-ethylenedioxythiophene): Poly(styrenesulfonate) (PEDOT:PSS) Thin Films**

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During last decade, non-volatile memory devices are rapidly scaled down transistor size to lower process costs and increase chip density. This has made the non-volatile memory devices more difficult and more expensive. Accordingly, non-volatile polymer memory devices that have the advantage of easy process and cheap process cost are actively being researched. This paper reports on a non-volatile polymer memory device using a Poly(3,4-ethylenedioxythiophene):Poly(styrenesulfonate) (PEDOT:PSS) thin film. The metal/PEDOT:PSS/metal was constructed using various electrode materials, such as Indium Tin Oxide (ITO), Al, Ni, Ti, Pt, Cr, Pd and Au. The current-voltage (*I-V*) characteristics of the devices were measured. The reversible switching behavior and the effect of various electrode materials in non-volatile memory device using PEDOT:PSS thin films is explained.

A-9: L13 **Organic Memory Devices with Negative Differential Resistance and their Physical Interpretation**

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Of all the organic memory devices reported so far the ones having the negative differential resistance (NDR) is the best in terms of yield, reproducibility and repeatability. We have observed two different kinds of NDR in nanoparticle based organic memory devices. One is the memory-NDR which follows the observation in SiO2 devices [Simmons et al, *Proc. R Soc. Lond. Ser. A* 301(1967)77]. Here the I-V characteristics trace different paths based on device history. The second type is the tunneling-NDR, where the I-V curves always trace the same path, irrespective of the history. This behavior is similar to the one observed in resonant tunnel diodes and multiple tunneling is the explanation. We will discuss these two phenomena in light of our experimental results in a polystyrene:fullerene nanocomposite system and present a physical model for the same. We have performed a multitude of optical and electrical experiments and clarified the influences of morphology on the complex and interesting device performance observed in this new class of organic electronic devices.

FOCUSED SESSION A-10

State-of-the-art Research and Application of SMAs Technologies

Session A-10.1
Materials

A-10.1: IL01 **New Ferromagnetic Shape Memory Systems: Research Lines and Unresolved Problems**

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During the last ten years, large research efforts centered on the Ni-Mn-Ga system have led to a good understanding of the mechanism and factors controlling the magnetic field induced strains (MFIS) in these alloys. Other issues as pre- and inter-martensitic effects, the possibility of high transformation temperatures and the use of Ni-Mn-Ga alloys as conventional shape memory alloys (SMA), including pseudoelasticity, have also broadened the interest in these alloys, but at the same time have shown several drawbacks and problems for their practical use. Apart from quaternary additions to the Ni-Mn-Ga system (as Co and Mn), other Ni-based alloys as Ni-Mn-X (i.e. X= Al, In, Sn, Sb) and Ni-Fe-Ga, as well as Co-based alloys (i.e. Co-Ni-Ga and Co-Ni-Al) are being developed in order to improve the properties of Ni-Mn-Ga in view of their use as sensors/actuators based on the MFIS. Recent results on the above mentioned alloy systems will be reviewed, paying attention not only to their capabilities of producing large MFIS, but also considering open problems, as control of second phases precipitation, thermal stability, etc. Very recently, some families of ferromagnetic shape memory alloys have gained new interest, due to the possibility of magnetic-field-induced shape recovery through the reverse martensitic transformation, as in Ni-Mn-In-Co or Ni-Mn-Sn-Co alloys. In this case the shape memory effect can be driven by a magnetic field in the same way as a temperature change induces the martensite-austenite transformation in conventional SMA; therefore, much large recovery stresses than in the conventional MFIS by variant reorientation are available. Even though much less research has been carried out in these new systems, some essential aspects appear as deserving discussion, as the dependence of the transformation temperatures on the magnetic field and its intensity in order to achieve a practical magnetic-field-induced shape memory effect.

A-10.1: IL02 **Recent Developments of Magnetic SMA**

O. SÖDERBERG, I. AALTIO, YANLING GE, XUWEN LIU, S.-P. HANNULA, Helsinki University of Technology, TKK, Finland

In the shape memory alloys (SMAs) the thermal triggering induces reversible dimensional change by the phase transformation - these materials may be also magnetic, such as NiTi-alloys with Fe or Co or Fe-Mn-Cr-Si-based alloys. However, in the magnetic shape memory (MSM) alloys this remarkable dimensional change is activated by the external magnetic field without a change of temperature. The MSM effect is caused either in a single phase by change of the twinned martensite structure or by generation the phase transformation. In addition to the magnetic shape memory effect, magnetic field may also result in the conventional magnetostriction (MS), enhance the superelasticity (magnetic-field-assisted superelasticity MFAS) or induce the giant magnetocaloric effect (GMCE). Certain alloys such as Ni-Mn-Ga may even be multifunctional showing more than one of these. The present paper gives an overview the different types of the MSM alloys, their properties as well as their potentials for applications. Also, the recent research activities are briefly discussed.

A-10.1: IL03 **Combinatorial Search of Shape Memory Alloys and Other Smart Materials**

ICHIRO TAKEUCHI, University of Maryland, College Park, MD, USA

We have developed combinatorial thin film synthesis and characterization techniques in order to perform rapid compositional survey of shape memory alloys and other smart materials. Various thin film deposition schemes including co-sputtering, and electron-beam deposition, and pulsed laser deposition are implemented for fabricating binary and ternary composition spreads as well as discrete libraries of metallic alloy systems and metal oxide systems. A suite of high-throughput characterization tools are employed to track physical properties of the materials as a function of sweeping composition changes. They include micromachined arrays of cantilevers for investigation of martensitic transformation and magnetostriction and scanning SQUID microscopes for quantitative mapping of ferromagnetic properties. High-throughput mapping of phase diagrams allows identification of new compounds as well as rapid delineation of composition-structure-property relationships. This technique was used to search for shape memory alloys with minimal hysteresis widths. Synchrotron microdiffraction was performed on ternary composition spreads of Ni-Ti-Cu in order to track the continuous change in lattice parameters across a region of the phase diagram. A clear relation between the transformation matrix (determined by the lattice parameters) and the thermal hysteresis of the shape memory alloys were observed across a large compositional region which verified the non-linear theory of martensite. Investigations of other multinary shape memory alloy systems will be discussed.

This work was performed in collaboration with Jun Cui, Y. Chu, A. Ludwig, M. Wuttig and Richard D. James.

A-10.1: L06 **Texture Analysis and Magnetic Properties of Ni-Mn-Ga Magnetic Shape Memory Thin Films Deposited using Pulsed Laser Deposition**

YUEPENG ZHANG, G.A. BOTTON, M. NIEWCZAS, R.A. HUGHES, J.S. PRESTON, McMaster University, Hamilton, Ontario, Canada

We report structural and magnetic properties of Ni51Mn22Ga27 magnetic shape memory thin films produced by pulsed laser deposition (PLD) technique. Texture analysis in combination with electron microscopy observations show that films deposited on different oxide substrates are well crystallized and contain uniform microstructure. All films produced have a cubic L21 structure and their texture depends strongly on the substrates used. Magnetic properties measured between 20K and 298 K reveal that the films exhibit soft ferromagnetism at room temperature, but are magnetically harder below 200 K. Films deposited on different substrates show similar value of the in-plane saturation magnetization however they exhibit significant differences in the initial susceptibility. The latter is caused by the differences in the domain structure and the orientation of the magnetization, which is strongly correlated with the texture of these materials. The details of the relationship between the magnetic properties and the films texture will be discussed.

A-10.1: L07 **Development of Cu-Al-Mn Based Shape Memory Alloys: Phase Stability and Microstructural Control**

TOSHIHIRO OMORI, Y. SUTOU, R. KAINUMA, K. ISHIDA, Tohoku University, Sendai, Japan

Cu-based shape memory (SM) alloys are attractive because of their low cost, however, the conventional highly ordered alloys with polycrystalline structure are too brittle to be sufficiently cold-worked. The present authors have found that the cold-workability can be drastically improved by controlling the degree of order in Cu-Al-Mn alloys and they show good SM properties. In this paper, the fundamental including the phase stability and microstructural control in Cu-Al-Mn alloys are presented. The phase equilibria in Cu-Al-Mn system were determined. It was found that the addition of Mn stabilizes the beta phase, which significantly extends to low Al content region. The A2/B2 and B2/L21 transition temperatures decrease with decreasing Al content, and the cold-workability is drastically improved by decreasing the Al content, which is clearly correlated with the degree of order. The SM properties can be enhanced by the application of microstructural control.

In particular, they strongly depend on the grain size relative to the specimen size and the development of texture. The Cu-Al-Mn alloys with Al content of 17at% are ductile SM alloys with a large superelastic strain of 7% developed by the suitable thermomechanical treatments.

A-10.1: IL08 **Metamagnetic Shape Memory in the NiMnIn and NiMnSn Based Heusler-type Alloys**
RYOSUKE KAINUMA, W. ITO, K. OIKAWA, K. ISHIDA, Tohoku University, Sendai, Japan

In 2006, a unique transformation from a ferromagnetic parent (P) to an antiferromagnetic-like martensite (M) phase was found in some Heusler-type alloys in the Ni-Mn-In and Ni-Mn-Sn systems, and a reverse transition from the M to P phase induced by a magnetic field was reported. Furthermore, a shape memory effect due to the magnetic field-induced reverse transformation, namely, metamagnetic shape memory effect, was confirmed at room temperature in the NiCoMnIn and NiCoMnSn alloys. Since this phase transition is accompanied with drastic changes of electric resistance and thermal conductivity besides of magnetism, the NiMnIn and NiMnSn based alloys are potential candidates for new types of devices. In this paper, magnetic and martensitic properties of these alloys will be reviewed and the details of the metamagnetic shape memory effect will be presented.

A-10.1: IL09 **Glassy Martensite**
XIAOBING REN, National Institute for Materials Science, Tsukuba, Japan

Martensitic transformation is a long-range ordering of lattice strain (distortion of the parent lattice) below Ms, with strain being the order parameter. The strain-ordering transition creates a low symmetry martensite phase characterized by a micron-sized hierarchical twin/domain microstructure. The above “normal” martensite has been the research subject of our field to date. Here we show that, when doping point defect into a martensitic system beyond a critical value, there appears a hitherto unrecognized wide composition range in which an “abnormal martensitic state” comes into being, through a “strain glass transition” below a critical temperature Tg. Such a transition is characterized by the formation of nano-sized martensite domains instead of micron-sized hierarchical twins as the case of normal martensite. The strain glass transition is not accompanied by a change in the average structure. It is a freezing of the nano-martensite domains. The seemingly “non-martensitic” strain glass exhibits unexpected properties: it exhibits shape memory effect and superelasticity like a normal martensitic alloy, although there is no sign of a spontaneous martensitic transformation in such a system. The discovery of strain glass may open a new horizon in the field of martensite.

A-10.1: L10 **Co-doping: Tuning Ni-Mn-Ga for Actuator Application?**
K. ROLFS, N. ALLIOUANE, R. SCHNEIDER, Hahn-Meitner-Institut, Berlin, Germany; A. MECKLENBURG, J.-M. GULDBAKKE, TU Braunschweig, Germany; M. CHMIELUS, Boise State University, Boise, USA; J. BROWN, Institut Laue-Langevin, Grenoble, France

During the last decade the research interest for magnetic shape memory effect has been increasing in an enormous way. These materials are standing out due to a magnetic field induced strain which is approximately one magnitude higher than the strain of magnetostrictive materials. Thus they qualify extraordinarily for applications in new types of actuators and sensors. One of the most common magnetic shape memory alloys is the Ni-Mn-Ga due to its relatively high operational temperature (up to 80°C) and the low magnetic fields (less than 0.3T) needed to induce macroscopic strains. Industry claims for operational temperatures of more than 140°C for these materials to be used in car engines. Additionally the twin-boundary mobility and thus the strength of the magnetic fields needed has to be optimized. Therefore a focused alloy design is necessary. Since the Bridgeman-technique for single-crystal growth can’t cope with the high vapour-pressure of manganese a recently developed technique called SLARE was used for a reliable and repeatable growth of homogeneous single crystals of known composition and low porosity. Here we will present the results of doping Ni-Mn-Ga with cobalt. We started to grow single crystals with two different compositions: $Ni_{46,65}Co_{6,14}Mn_{30.9}Ga_{19.05}$ and $Ni_{45}Co_5Mn_{31}Ga_{20}$. Both show a phase-transition-temperature of more than 100°C and a Curie-Point above 120°C. Neutron-diffractometric measurements give insight into the bulk crystallographic structure of macroscopic single crystals. Especially the probability of Co on specific atomic places within the Ni-Mn-Ga lattice is of strong interest. The crystallographic and mechanical characterization of both alloys will be discussed here in detail.

A-10.1: L11 **Work Output Enhancement of Ferromagnetic Shape Memory Micro Actuators**
Y. GANOR, D. SHILO, Technion, Haifa, Israel

Ferromagnetic shape memory (FSM) alloys are a class of materials which are both ferromagnetic and capable of undergoing a structural phase transformation. FSM alloys have significant advantage over conventional shape-memory temperature-based actuators because they can be remotly actuated by fast alternating magnetic fields. Therefore, FSM alloys attract keen attention as promising candidates for a variety of MEMS applications, as they can provide large strokes using small components. The most commonly used FSM alloy is Ni2MnGa and its off-stoichiometric alloys, which are used in commercial cm-scale FSM actuator. However, at the current stage, no experiments of the magneto-mechnical behavior of micro-scale actuators were conducted. Overall, the behavior of FSM alloys involves motion of twin boundaries and is significantly influenced by its microstructure. Based on a theoretical model, we have shown that down-scale specimens have finer twin boundary microstructure that consequently may increase the blocking stress characteristic such that it will enhance the output work for actuation. In light of this, a novel experimental method was realized to establish this conjecture and to provide comprehensive information on the behavior of small actuators.

A-10.1: L12 **High Energy Milling and Hot Extrusion of Equiatomic NiTi Shape Memory Alloy**
L.C. DA SILVA, IPEN, Sao Paulo, Brazil; F. AMBROZIO FILHO, UNIFEI, Sao Bernardo, Brazil; M.C.A. DA SILVA, Universidade de Sao Paulo, Brazil

In this work a 50Ni50Ti at % powder mixture, commercially pure, was prepared by mechanical alloying in a attritor with the following conditions: the milling speed and the ball charge were 1500 rpm and 10:1 respectively. The milling time was 1h under an nitrogen atmosphere at room temperature. After milling it was determined the particle size distribution, the phases by X-ray diffraction (XRD) and the powder morphology by scanning electron microscopy (SEM). The powders after milling were compacted and hot extruded at 800 °C with an extrusion ratio of 3 to 1 and characterized by measuring the final density and microstructural determination by microscopy and X-ray diffractions (XRD). The obtained results are discussed to show that this route could be an alternative route to prepare shape memory alloys.

A-10.1: IL13 **Ni-free Ti-base Shape Memory Alloys**
SHUICHI MIYAZAKI, HEE YOUNG KIM, University of Tsukuba, Tsukuba, Ibaraki, Japan

Biomedical shape memory alloys are required to have superior corrosion resistance, biocompatibility and excellent shape memory property. Recently, b type Ti alloys composed of non-toxic elements have attracted attention as biomedical shape memory and superelastic materials. The b-Ti alloy is one of the most attractive candidates for biomedical shape memory alloys. Ti-Nb-X (X = Zr, Ta, Mo, Au, Pd, Pt, Al, Ga, Ge, O) and Ti-Mo-X (X = Ta, Nb, Zr, Au, Pd, Pt, Al, Ga, Ge) alloys have been developed and their shape memory effect and superelasticity were investigated systematically by the present authors’ group for about six years. Low temperature annealing and aging treatment were effective in improving shape memory and superelastic behavior. Addition of alloying elements such as Zr, Ta, Mo, Au and Pt was also effective in stabilizing the superelasticity. In this paper, the effects of alloying elements and heat treatment condition on shape memory and superelastic properties will be presented. The unique deformation texture and recrystallization texture appearing in the Ti-base alloys are also effective for the shape memory and superelastic properties and also reviewed based on the recent works of the present authors.

A-10.1: IL14 **Elastic Properties of Shape Memory Alloys**
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Resonant ultrasound spectroscopy (RUS) is a well-known technique for investigation of elastic properties of solids based on the inversion of natural frequencies of free elastic vibrations of a small simple shaped specimen. However, low symmetry phases appearing in ferroelastic materials (shape memory alloys) commonly exhibit specific behaviors, particularly i) strong elastic anisotropy, ii) unusual temperature dependence of some elastic constants and iii) natural tendency of

ferroelastics to form twinned microstructures. We summarize recent experimental and theoretical improvements in particular: i) the reliable vibration mode identification exploiting scanning laser interferometry, ii) well-posed resonance inversion based on analytical expression of the gradient and the Hessian of the minimized error function. It is not always possible to obtain an interface free single crystal of some SMA's. Then the measurement must be done on microtwinned crystals. For such case, a homogenization algorithm based on the macroscopic deformation response of the layered structure is applied. Selected results, recently obtained by applying the RUS method to investigate phases in shape memory alloys, will be presented and discussed.

A-10.1: L16 **Development of Cu-Al-Mn Based Shape Memory Alloys: Application to Medical Devices**

Y. SUTOU, T. OMORI, R. KAINUMA, Y. YAMAGUCHI, K. ISHIDA, Tohoku University, Sendai, Japan

Shape memory alloys (SMAs) are attracting attention as materials for medical devices because of their superelasticitiy (SE). The present authors have developed Cu-Al-Mn SMAs with excellent ductility and large SE strain based on phase stability and microstructural control. The Cu-Al-Mn-based SMAs show a SE strain of about 8% by controlling grain size and texture. Moreover, their mechanical properties such as SE, Young's modulus and hardness can be varied by age-hardening. The Cu-Al-Mn SE wire is much softer than the Nitinol SE wire, while the stiffness of the age-hardened Cu-Al-Mn wire is much higher than that of the Nitinol SE wire. Consequently, a new class of medical guidewire with functionally graded properties was developed. Such guidewire exhibits excellent pushability and torquability and shows considerably better handling ability than the conventional guidewires with Nitinol or stainless steel core wires. Furthermore, new class of ingrown nail correcting device made of Cu-Al-Mn SE alloys will be introduced.

Session A-10.2
Phase Transformation and Microstructure

A-10.2: IL01 **In Situ Experimental Methods for Characteriz-ation of Deformation Processes in SMAs**

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Shape memory alloys are used not as much for their structural properties but mainly for their unique thermomechanical responses due to deformation and transformation processes in solid state. We still need to improve our understanding of these processes to be able to better predict the functional responses and further develop engineering applications of SMAs. In-situ experimental methods capable to detect and distinguish the activity of multiple deformation and transformation processes in SMAs exposed to temperature and stress changes are excellent tools for this purpose. In this work, an overview is given on the applications of various recently developed in-situ experimental methods and approaches involving in-situ electrical resistance, neutron and synchrotron diffraction, acoustic wave propagation, infrared camera detection of the transformation heat and acoustic emission to the investigation of functional responses of SMAs, particularly to thin NiTi wires for textile applications. In this work, an overview is given on the applications of various in-situ experimental methods and approaches involving in-situ electrical resistance, neutron and synchrotron diffraction, acoustic wave propagation, infrared camera detection of the transformation heat and acoustic emission.

A-10.2: L02 **Effect of the Loading History on Shape Memory Alloy Transformation Temperatures**

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Due to the complex microstructure and phase transitions taking place in Shape Memory Alloys (SMA), the behaviour and properties of these materials are deeply influenced by their loading history in terms of stress, strain and temperature. Understanding the effects of the loading history on SMA properties is fundamental for modelling and design of SMA applications, in particular in case of complex loading. An example is that of shape memory alloys embedded in composite systems, in which stress, strain and temperature vary simultaneously depending on the properties of the SMA and composite.This work presents the first results of an experimental investigation on the effects of the loading history on SMA transformation temperatures. Nitinol wires of untrained material were considered. Specimens consisting of martensite or R-phase were subjected to different loading histories, keeping in turn stress, strain or temperature at a constant value. Transformation temperatures at zero stress of these as treated samples were measured via Differential Scanning Calorimetry. Contrarily to most constitutive models assumptions, the DSC results highlight a dependence of the transformation temperatures on the loading history, influencing in particular the martensite to austenite phase transition.

A-10.2: L03 **Elemental Interfaces and Displacive Phase Transformations**

V. PAIDAR, Institute of Physics, ASCR v.v.i., Prague, Czech Republic

Conservative diffusionless displacive phase transformations are based on lattice shearing and on shuffling of atomic planes. Generalized planar defects representing different displacements of atomic planes will be examined and their role in structural modifications will be analysed. A suitable model for the structural alternations at the nanoscopic level can utilize semiempirical many-body potentials fitted to the appropriate physical quantities. Ab initio quantum-mechanical modelling of complex structures is not yet entirely feasible. Two main governing parameters control the materials properties: the energy of atomic bonding and the atom size. Their interplay and importance for the material behaviour will be discussed. The effect of additional deformation required to obtain close-packed atomic arrangements will also be treated.

A-10.2: L05 **Monte-Carlo Simulation of the Phase Transform-ation and the Magnetocaloric Properties in Ni-Mn-Ga Shape Memory Alloys**

V.D. BUCHELNIKOV, S.V. TASKAEV, V.V. SOKOLOVSKIY, Chelyabinsk State University, Chelyabinsk, Russia

The magnetocaloric effect (MCE) has a significant importance since the magnetic materials with large MCE values can be employed as a refrigerant in room magnetic refrigerators. Ni-Mn-Ga alloys also seem to be promising materials for investigation and probable application of MCE in household refrigerators. These alloys have approximately the same properties as the best MCE materials. In this work we proposed the theoretical model for description of the MCE in Ni2MnGa alloys. The three-dimensional model included the coupling between the magnetic and structural subsystems. For magnetic and structural subsystems we use Ising model with local interactions, i.e. interactions between the nearest points of a lattice and the degenerate three-state Blume-Emery-Griffiths model for martensitic transformations. The model is solved by statistical Monte-Carlo simulations. The temperature dependences of the normalized magnetization, magnetic heat capacity, total heat capacity, magnetic entropy, total entropy and the isothermal entropy change for magnetic field variation from 0 to 5 T are obtained. For the comparison with Monte-Carlo simulations we calculated magnetic entropy within the molecular field approximation. All quantities are in good agreement with the available experimental data.

A-10.2: IL06 **Rearrangement of Crystallographic Domains Driven by Magnetic Field in Ferromagnetic Shape Memory Alloy and Antiferromagnetic Oxide**

TOMOYUKI KAKESHITA, Osaka University, Suita, Japan

A large magnetic field-induced strain appears in some ferromagnetic shape memory alloys (FMSMAs). This phenomenon is of interest because magnetic field is not the conjugate variable of strain. This strain in FMSMAs is not due to the conventional magnetostriction, but due to the rearrangement of crystallographic domains. In this presentation, we will show such behavior in three ferromagnetic shape memory alloys of Fe-31.2at.% Pd, Fe3Pt (S = 0.8) and Ni2MnGa and an antiferromagnetic oxide of CoO. When a magnetic field is applied in the [001]P direction (P stands for the parent phase) in the low temperature phase state, the Fe-31.2Pd expands while the Fe3Pt and Ni2MnGa contracts in the field direction under the magnetic field. Such difference in strain is due to the difference in magnetization easy axis. Moreover, the rearrangement actually occurs in the antiferromagnetic CoO. We

have proposed a criterion for realizing the rearrangement of crystallographic domain under a magnetic field. That is, the shear stress exerted on the twinning plane under the magnetic field should be larger than the shear stress required for the rearrangement. This criterion is confirmed to be appropriate for both FMSMAs and the antiferromagnetic CoO.

A-10.2: IL07 **Texture Development in Ni-Ti Thin Films**
F.M. BRAZ FERNANDES, R.M.S. MARTINS, N. SCHELL*, K.K. MAHESH, R.J.C. SILVA, CENIMAT, Monte de Caparica, Portugal; *GKSS, Geesthacht, Germany

The Shape Memory Effect on Ni-Ti thin films is strongly dependent on several factors: (i) chemical composition of the matrix, (ii) presence of precipitates and (iii) preferential orientation. Ni-Ti alloys derive their unique nonlinear and anisotropic mechanical behavior from stress-induced martensitic transformations, where the resulting strains are affected by crystallographic orientation. The influence of the texture on the transformation characteristics of Ni-Ti thin films is discussed on the basis of models and experimental results of the literature. A brief review of the texture build-up on thin films obtained by different fabrication techniques (sputtering, melt spinning, diffusion treatment of ultra-fine laminates,..) is presented. Details about in situ techniques allowing the identification of the preferential orientation during the fabrication process are presented. The processing parameters that more strongly influence the preferential orientation of the Ni-Ti thin films are identified. The mechanisms for the different microstructures are summarized and a special emphasis is put on the type of preferential orientation and its evolution along the processing time.

A-10.2: L08 **In-situ Studies of Ferroelastic Domain Textures in NiTi Shape Memory Alloys under Load**
W.W. SCHMAHL, M. HASAN, C. MERKEL, LMU Munich, Germany; M. HÖLZEL, FRM-II, Munich and TU Darmstadt, Germany; J. FRENZEL, S. GOLLERTHAN, M. WAGNER, G. EGGELER, Ruhr-University Bochum, Germany

Shape memory and superelasticity are based on the selective orientation of ferroelastic twin variants under applied stress. We investigated crystallographic strain and orientational distribution of twins in polycrystalline NiTi alloys with diffraction techniques using high-energy synchrotron radiation or neutrons during in-situ tensile loading. In NiTi ferroelastic twinning is related to the phase transition from paraelastic austenite (cubic B2 type) to ferroelastic martensite (monoclinic B19' type). Superelasticity is optimized in cold-rolled Ni-rich NiTi when the load axis is parallel to the rolling direction (RD). Rolling preferentially alligns the austenite (110) in the RD. The long semiaxis of transformation (Bain) strain ellipsoid is near (110). Area detector diffractograms directly show that if the tensile axis coincides with the RD, the martensite inherits the preexisting austenite texture matching the maximum Bain expansion in (110) for many grains in the microstructure. If stress is applied perpendicular to the RD, the texture inheritance places the strongest compressive semiaxis in the RD, and we find increased residual austenite (ca. 15%), increased critical transformation stress, and a reduced superelastic stress-strain plateau.

A-10.2: L10 **A Study on Phase Transformation in NiTi Shape Memory Alloy Films Deposited Using Heated Target**
K.P. MOHANCHANDRA, G.P. CARMAN, University of California, Los Angeles, CA, USA

In this article we discuss the phase transformations in sputter deposited NiTi shape memory alloy thin films. XRD with General Area Detector Diffraction System (GADDS) is used to observe the different phases in different position of the film. NiTi thin films are produced using DC magnetron sputtering technique with varying target temperatures. During the deposition SiO2/Si substrate is translated above the target at 45 degree arc with 80 mm arc length to improve composition and thickness uniformity. Several points on the substrate along the translation direction are chosen for XRD measurements. Film deposited with ramping target temperature shows mixture of austenitic and martensitic phases at selected locations whereas, the film deposited with a heated target temperature of 600 °C and above shows only martensitic phases at selected measured points. This clearly indicates that target temperatures above 600 °C produces fairly uniform compositions. To support this claim, film compositions are measured using EDAX at the same points where the XRD are measured to evaluate the composition uniformity in the film. Transformation temperatures at different part of the films are also measured using DSC.

A-10.2: IL11 **Instability of the B2-type Structure and Second Order-like Incommensurate-commensurate Transform-ation in Iron-doped Ti-Ni Alloys**
TAKASHI FUKUDA, TOMOYUKI KAKESHITA, Osaka University, Suita, Japan

Some of martensitic transformations in SMAs are preceded by anomalies such as diffuse scattering and phonon softening. Ti-Ni SMAs are representatives of such alloys, and diffuse scattering appears at an incommensulate position above the R-phase transformation temperature. Such diffuse scattering is frequently referred to as a precursor phenomenon of the R-phase transformation. However, the relation is not clear because most physical properties show an obvious discontinuity in association with the transformation. To understand the relation, we have examined the transformation behavior of Ti-(50-x)Ni-xFe alloys with x = 2.0, 4.0, 5.0, 5.5, 5.7, 6.0, 7.0, 8.0, 10.0. As a result, we have found that a second order-like incommensurate-commensurate transformation is realized in the Ti-44Ni-6Fe alloy. The commensurate phase (C-phase) inherits the microstructure of the incommensulate phase (IC-phase) unlike the R-phase. That is, the IC-phase and C-phase have nanoscale domain-like microstructure while the R-phase has twinned one. The C-phase is most likely different from the R-phase in nature because iron content dependence of the transformation behavior shows an obvious discontinuity between x = 5.7 and 6.0. These results suggest that the IC-phase is precursor of the C-phase, not the R-phase.

A-10.2: IL12 **Two-way Memory Effect in NiTi Shape Memory Alloys**
YONG LIU, Nanyang Technological University, Singapore

SMAs have fascinated us by large shape restoration through crystal structure change. The origin of *one-way shape memory effect* is now well understood. However, the other memory effect namely, *two-way memory effect*, which is also of technical importance, is not satisfactorily understood. Such effect is manifested as a spontaneous deformation upon cooling under external stress-free condition and has been naturally related to the action of internal stress. The internal stress was proposed originated from formation of dislocations as a result of either constrained thermal cycling or a simple plastic deformation of martensite. The present research is to further understand the mechanism responsible for the TWME and to correlate it to the *stress-assisted two-way memory effect*. Extensive research was conducted to identify the major factors dominating the TWME and the condition for obtaining optimum TWME. NiTi alloys with different processing histories and microstructures and under different deformation procedures were studied and compared. TWME and SATWME developed as a result of various constrained thermal cycling were systematically investigated. Internal stress developed during constrained thermal cycling is estimated and a microstructural model responsible of TWME is proposed.

A-10.2: IL13 **Magneto-microstructural Characterization of Magnetic Shape Memory Alloys**
H.J. MAIER, D. NIKLASCH, University of Paderborn, Paderborn, Germany; I. KARAMAN, Texas A&M University, College Station, TX, USA

Ferromagnetic shape memory alloys (FSMAs) have attracted increasing interest in recent years because of their ability to obtain high reversible magnetic field-induced strain (MFIS)[1-3]. If the magnetic field-induced reorientation of martensite twins is employed, the MFIS in NiMnGa can reach 5-10%,[1, 3, 4]. However, the low actuation stress levels of usually less than 3 MPa[3-5] limits the use of these materials for actual applications. Recently, the magnetic field-induced phase transformation was also reported to result in large MFIS in NiMnGa at stresses exceeding 20 MPa[6]. In this case, however, the low operating temperatures required seriously limit the use of the material for actual applications. Clearly, a detailed understanding of the processing-microstructure-magnetic relationships is needed in order to tailor microstructures for improved magneto-thermo-mechanical response. In the present study we will report on the detailed magneto-microstructural characterization of different FSMAs. Specifically, NiMnGa and CoNiGa single crystals of various crystallographic orientations were analyzed by electron optical techniques (transmission electron microscopy, electron-back scatter diffraction (EBSD)) and magnetic force microscopy. In addition, the macroscopic response of the alloys was closely monitored as a function of compressive stress and applied magnetic field. The data obtained demonstrates that the materials' response can be varied substantially through heat treatment, crystallographic orientation and thermo-mechanical training, and the ramifications of the results obtained with respect to optimization of actuator performance will be addressed.

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Session A-10.3
Engineering

A-10.3: IL01 **Shape-memory Alloys: Effective 3D Modelling, Computational Aspects and Micro-device Design**

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The employment of shape memory alloys (SMA) in a large number of engineering applications, among which biomedical applications, has been the motivation for an increasing interest toward a correct and exhaustive modeling of SMA macroscopic behavior in order to construct reliable simulation tools, which can be successfully used in the design procedures of SMA devices. In this work we review a robust three-dimensional model, giving a good overall description of pseudo-elastic and shape memory behaviors and we use it for the development of a new design procedure of SMA micro-actuators. Starting from a SMA micro-device proposed in the literature, we then adopt such a procedure to design a new effective variant of micro-gripper.

A-10.3: IL02 **Engineering Aspects of Shape Memory Thin Film Actuators and Sensors**

M. KOHL, Forschungszentrum Karlsruhe, Karlsruhe, Germany

Shape memory alloys (SMAs) belong to the category of smart materials as they exhibit multifunctional properties, which can be used simultaneously to generate actuation, sensing and adaptive functions. The high energy density and favourable scaling behaviour of their mechanical properties upon miniaturization make these materials particularly attractive for applications in small dimensions. Here, recent developments in the materials, design, fabrication and performance of selected SMA thin film actuators and sensors are described. First, an overview is given on recent progress on the development of SMA thin films and foils, like ternary TiNi(Pd,Pt,Hf) thin films for high temperature applications or ferromagnetic SMA thin films. Selected examples on design aspects of SMA thin film actuators and sensors will be given, e.g., how shape optimization is used to make an optimum use of the shape memory effect and how an optimum balance of power requirement and heat transfer times can be achieved. For fabrication of such microdevices, novel transfer bonding technologies are described, which offer a means to implement all kinds of SMA materials without affecting their functionality. As an example, the performance of novel SMA microgrippers, microvalves and microscanners will be presented.

A-10.3: L03 **Transformation / Deformation Behavior and its Constitutive Equation for Ti-Ni-Cu Shape Memory Alloy**

Y. TAKEDA, TAKE R&D, Japan; T. YAMAMOTO, T. SAKUMA, Oita University, Oita, Japan

Since the shape memory characteristics depend on stress, strain and temperature, deformation and recovery behavior of the material is very complex. Therefore, it is not so easy to describe the thermomechanical behavior of shape memory alloy using constitutive relations. However, in order to design the articles using shape memory effect and superelasticity, the development of constitutive relations for simulating the recovery strain and stress is indispensable. The modeling of the transformation and deformation behavior of a shape memory alloy has been investigated by many researchers. However, there are few reports that investigate plastic deformation of shape memory alloys. To design an actual product, the modeling in consideration of plastic deformation is indispensable. In this work, plastic deformation after pre-deformation is investigated using the volume fraction of slip-deformed martensite. New kinetics and constitutive equations are proposed for the reverse transformation process. The material constants in the proposed equations are determined from the results of tensile and heating/cooling tests on Ti-Ni-Cu alloy. The calculated results describe well the deformation and transformation behavior affected by pre-strain.

A-10.3: L04 **Effect of Microvoids on Plasticity in NiTi-alloy**

J.S. OLSEN, Z.L. ZHANG, Norwegian University of Science and Technology, Trondheim, Norway; C. VAN DER EIJK, Sintef, Trondheim, Norway

Recent experimental investigation has indicated that commercial NiTi superelastic alloys consist of particles and inclusions which can nucleate microvoids. Almost no study on the effect of microvoids has been carried out in the literature. In this study the effect of microvoids on plasticity and behaviour of a superelastic NiTi-alloy has been investigated. Axisymmetric unit cell models with different microvoid volume fraction have been analyzed with various stress triaxiality states. It is shown that the onset of plasticity is located at the void edge as the maximum stress initially occurs at this position. The finite element results indicate that the existence of microvoids can reduce the re-centring capabilities in NiTi-alloys and that this effect should be taken into consideration of constitutive equations.

A-10.3: IL07 **Experimental Characterization of NiTi SMAs Thermomechanical Behaviour Using Temperature and Strain Full-field Measurements**

P. SCHLOSSER[1, 2], D. FAVIER[1], H. LOUCHE[2], L. ORGEAS[1], [1]Universities Grenoble, France; [2]SYMME, Polytech' Savoie, France

The tension behavior of an initially austenitic NiTi thin wall tube was investigated using measurements of temperature and strain fields. The main conclusions of the study are: - The first apparently linear elastic stage is a homogeneous deformation stage which involves elastic distortion of the crystal lattice but also a mixture of partial A-R and A-M transformations occurring as soon as the deformation starts; - The first stage is followed by a strongly localized deformation stage, characterized by high strain helical bands that propagate and widen around the sample until the deformation becomes again homogeneous; - Localization occurs although tensile stress-strain curve doesn't exhibit clear peak and plateau. The positive slope is due to thermal effect; - When a localized deformation band (LDB) boundary passes a certain point, there is a sudden increase of the local strain rate associated to phase transformation. This transformation is not complete once the boundary has passed and the local strain continues to increase inside the LDB; - During unloading, the apparent linear elastic stage is a homogeneous deformation stage, involving de-twinning of martensite variants and reverse transformations.

A-10.3: L08 **Thermomechanical Behavior of Tubular NiTi Textile Structures**

L. HELLER, D. VOKOUN, P. SITTNER, Academy of Sciences of the Czech Republic, Prague, Czech Republic

Thin NiTi wires have been considered for producing knitted and woven smart textiles with unique thermomechanical properties promising a wide range of new industrial applications. This work deals with a new concept of tubular NiTi textile structures with enhanced functional properties in comparison to that of the wires. Such properties are due to the combination of the SMA properties and geometrical architecture. The experimental results concerning thermomechanical properties of the tubular structures under different loading conditions, particularly to quasi static and dynamical tension and compression tests and electrical actuation, are reported and discussed. Various in situ methods (electric resistance, infrared and optical) were employed to characterize the geometrical changes and material state in the individual segments of NiTi wires in the structure. As a result of the work, it is possible to determine key material and geometrical parameters for a model developed in parallel to predict the responses of the tubular NiTi textile structures to various thermomechanical loadings.

A-10.3: L09 **Functional Properties of Ti-Ni-based Shape Memory Alloys**

I. KHMELEVSKAYA, S. PROKOSHKIN, I. TRUBITSYNA, A. KOROTITSKIY, M. BELOUSOV, Moscow Inst. of Steel and Alloys, Moscow, Russia; V. BRAILOVSKI, Ecole de Technologie Superieure, Montreal, Canada; S. DOBATKIN, Baikov Institute of Metallurgy and Material Science, Moscow, Russia; E. TATYANIN, Institute for High Pressure Physics, Troitsk, Russia; V. STOLYAROV, E. PROKOFIEV, Institute of Physics of Advanced Materials, Ufa, Russia

Main functional properties (FP) of Shape Memory Alloys (SMA) are the critical temperatures of martensitic transformations, maximum completely recoverable strain (er,1max) and maximum recovery stress (srmax). Control the Ti-Ni-based SMA FP develops by the way of forming of

well-developed dislocation substructures or ultra fine grained structures using different types of thermomechanical treatment (TMT), including severe plastic deformation (SPD). The present work shows that TMT including SPD under conditions of high pressure torsion (HPT), equal-channel angular pressing (ECAP) and cold rolling with high true strains (e > 1.5) and post-deformation annealing which creates nanocrystalline or submicrocrystalline structures is prospective for future improvement of SMA FP in comparison with regular quenching and traditional TMT which creates a well-developed dislocation substructure. The ECAP and low-temperature TMT by cold rolling allow formation of submicro-crystalline or nanocrystalline structure with grain size from 20 to 300 nm in bulk and long-size samples of Ti-50.0; 50.6; 50.7%Ni and Ti-47%Ni-3%Fe alloys. The best combination of FP: srmax = 1400 MPa and ermax = 8%, is reached after LTMT with e = 1.9 and annealing at 400°C which results in nanocrystalline (grain size of 50-80 nm) structure formation. Application of ultra- fine grained SMA materials allows economizing of a metal in various medical implants and elements of devices based on shape memory and superelasticity effects.

A-10.3: L10 **Influence of the Temperature and the Way of the Preliminary Plastic Deformation in Austenitic State of the Shape Memory Effect in Ti - 50.0 at. % Ni**

N. RESNINA, S. BELYAEV, I. UCHAEVA, Saint-Petersburg State University, Saint-Petersburg, Russia

In previous works it was found that the main reason of strain recovery decrease on increase of the plastic strain was the two-way shape memory effect induced by oriented internal stresses. Therefore shape memory effect can be controlled by the value and the orientation of the internal stresses. In the present work the value of the internal stress was given by the temperature of the preliminary plastic deformation and the orientation - by the torsion direction in the austenitic and the martensitic states. Increase of the preliminary strain temperature resulted in the decrease of the internal stress value. In this way the two-way shape memory effect was small and the shape memory strain weakly depended on the plastic strain. The modification of the internal stress orientation by the change of the plastic strain direction let to obtain the unusual dependence of shape memory strain on preliminary strain. As the preliminary plastic strain given in the austenitic state rose the shape memory strain increased. These results have shown that the plastic deformation may not only decrease the shape memory effect but improve the ability of the strain recovery as well.

Session A-10.4
Composites & Coatings

A-10.4: IL01 **Submicronic Technology of Ferromagnetic Martensites: Scientific and Applied Aspects**

V.A. CHERNENKO, Institute of Magnetism, Kiev, Ukraine

The underlying physics and results of the investigation of the structural and transformation characteristics as well as magnetic, thermoelastic, magnetomechanical and mechanical properties of martensitic Ni-Mn-Ga/substrate thin film composites are reviewed. The submicron thin films having two compositions facilitating the formation of 10M- or 14M-martensitic phase have been prepared. Alumina ceramic, Mo foils, Si(100) and MgO(100) wafers were used as the substrates. (110)-texture and twin plates of about 50 nm thick as well as out-of-plane orientation of magnetic moments are found in the films. Films on alumina and Si show a considerable thickness dependence of transformation temperatures which is correlated with in-plane tensile stress. In bending or tensile tests, thin film composites demonstrate a conventional shape memory effect. Magnetoelastic response of films was measured to be maximum of 600 ppm for 0.1µm thick films attached to Mo. The thermal and magnetic actuation capability found in the Ni-Mn-Ga/substrate thin film composites have a great potential for microsystems applications.

A-10.4: L02 **Ni2MnGa - Polymer Composites for Active Vibration Dampening**

O. GUTFLEISCH, N. SCHEERBAUM, J. LIU, D. HINZ, L. SCHULTZ, IFW Dresden, Dresden, Germany

Composites consisting of magnetic shape memory (MSM) particles embedded either in polyester or polyurethane matrices were prepared. Single-crystalline MSM particles were obtained by mortar grinding of melt-extracted and annealed Ni50.9Mn27.1Ga22.0 (at.%) fibres. The crystal structure of the martensite is tetragonal (5M). Magnetic characterizations of the deformed composites show indirect evidence for stress induced twin boundary motion in the MSM particles, as the compressed composite is easier to magnetize in the direction of compression compared with the directions perpendicular to it. The magnitude of this effect depends on the stiffness of the matrix material used and is therefore more pronounced for polyester than for polyurethane. The texture of all embedded MSM particles in a polyester composite is investigated before and after compression by means of synchrotron radiation In the initial state, the MSM particles in the composite have a random texture, i.e., there is no preferred orientation of the c axes. After 30% compression (height reduction), the MSM particles show a (004)-fibre texture in the direction of compression. This is unambiguous evidence for stress-induced twin boundary motion within the MSM particles, thus being suitable for active dampening.

A-10.4: L03 **Selection of Polymer Matrices for SMA Composite through DSC Analysis**

D. CLAUSI, D. REYNAERTS, J. PEIRS, J. VAN HUMBEECK, Katholieke Universiteit Leuven, Leuven, Belgium

SMA composites have an apparent potential for micro-applications, where their intrinsic adaptive capabilities, related to the reversible martensitic transformation in the SMA elements, can be exploited favorably in terms of bandwidth and could form a cheap and reliable alternative to sputtered films when high stroke-high force actuators are required. Nevertheless, the development of this class of materials for micro-systems is still in its infancy and several issues are yet to be addressed. Among them, the selection of the proper matrix material, along with the evaluation of bonding strength and maximum actuation temperature, is crucial when reliability for hundreds of thousands cycles is at stake. In the present work, samples of SMA composites are fabricated by embedding prestrained NiTi wires into several polymers and their transformational behavior is investigated by DSC measurements. By examining the transformation enthalpy of each SMA composite, and more specifically the temperature at which the stabilized martensite starts transforming into parent phase, it is possible to evaluate when the degradation of the interface SMA wires-polymer matrix starts. Comparison of these data serves as a support in choosing the optimal matrix and assessing the maximum actuation temperature.

A-10.4: IL04 **Ferro Magnetic Shape Memory Alloy Composites**

R.C. O'HANDLEY[a], R. TECHAPIESANCHAROENKIJ[a], J. FEUCHTWANGER[a, b], J. KOSTAMO[a, c], B. PETERSON[a, d], M. MAHENDRAN[a, e], M. RICHARD[a, f], S.M. ALLEN[f], [a]MIT, Cambridge, MA, USA; [b]University of Basque Country, Bilbao, Spain; [c]Helsinki University of Technology, Espoo, Finland; [d]NSWC, West Bethesda, MD, USA; [e]Thiagarajar College of Engineering, Madurai, India; [f]Richard Stockton College, Pomona, NJ, USA

Ferromagnetic shape memory alloys (FSMAs) based on the martensitic, tetragonal phase of off-stoichiometry Ni_2MnGa show a variety of promising engineering properties. Here we focus on two potential applications of these materials: actuators and mechanical energy absorbers. The absorption of mechanical energy by FSMAs, when their twin structure is rearranged by a magnetic field or an applied stress, makes this class of materials interesting as vibration dampers, but this energy loss is a source of inefficiency in their use as actuators. FSMA composites have been found to offer advantages for both actuation (FSMA/piezoelectric macro-scale composites) and energy absorption (FSMA/polymer micro-scale composites). Single crystals of tetragonal Ni-Mn-Ga can show magnetic field-induced strains up to 6%, however, an alternating magnetic field or order 400 kA/m is required. Such a large field is necessary due to the significant threshold field for the initiation of twin-boundary motion, $H_{th} \approx \sigma_y / \mu_0 M_s$, (here σ_y is the twin-boundary yield stress, $\varepsilon_0 = 1\text{-}c/a \approx 0.06$, and $\mu_0 M_s$ is the saturation magnetization). Application of an acoustic (1 – 10 kHz) stress wave during magnetic-field-induced deformation has been demonstrated to have three beneficial consequences: i) it reduces the hysteresis loss and heating associated with twin-boundary motion (smaller field needed to actuate), ii) it enhances the output strain, and iii) it increases the output stress. Consequently, output work has been shown to almost double and operational heating halved. Spherical particles of Ni-Mn-Ga measuring a few 10s of µm have been dispersed in a polyurethane (PU) matrix. The pre-poled particles are oriented and aligned by application of a magnetic field prior to curing of the PU, effectively forming 3:1 composites. These composites have been shown to absorb up to 80% of applied quasi-static mechanical energy over selected

strain ranges. Also, they show enhanced effectiveness in absorbing acoustic energy up to at least 1 kHz. X-ray and neutron diffraction studies confirm that twin-boundary motion is responsible for this mechanical energy loss.

A-10.4: L05 **Surfactant Modified Nickel-manganese-gallium Powder and Silicone Composites**
R.S. UNDERHILL, K.A. STEVENS, Defence R&D Canada - Atlantic, Dartmouth, Nova Scotia, Canada

The limiting factor to many electronic devices is their power supply. Their batteries contribute significantly to their weight and impose limitations on operational longevity. Harvesting energy from the environment for conversion to electrical energy has been proposed to address these problems. DRDC Atlantic has shown that nickel-manganese-gallium powder/polymer composites may be suitable for use in energy harvesting. In these composites, the active component is the magnetic shape memory alloy (MSMA) powder, while the polymer acts as a supporting matrix. In order to transfer the maximum mechanical force from the environment through the polymer to the powder, the interfacial adhesion between the powder and the polymer must be understood and optimized. Surfactants can alter interfacial interactions. The surfactants investigated here were 3-aminopropyl trimethoxysilane, Dow Corning Z6020 and Z6030. The surfactant modified powders were characterized by SEM, EDX and ICP-MS. The powder/polymer composites were characterized by optical microscopy and dynamic mechanical analysis was used to determine the storage modulus. The results suggest that the powder/silicone polymer interaction is strong, and that the use of surfactants did not significantly alter this interaction.

A-10.4: L06 **Thermomechanical Modelling and Experimental Testing of a Shape Memory Alloy Hybrid Composite Plate**
F. DAGHIA, University of Bologna, Bologna, Italy; E. SACCO, University of Cassino, Cassino, Italy; G. FAIELLA, University of Naples, Naples, Italy; V. ANTONUCCI, M. GIORDANO, CNR, Naples, Italy

Shape Memory Alloys (SMA) exhibit functional properties associated with the shape memory effect, responsible of the SMA shape recovery after a cycle of deforming-heating and of a simultaneous generation of mechanical work. Composite systems incorporating SMA wires have the ability to actively change shape and other structural characteristics. The functional properties of such adaptive composites are related to the martensitic transformation in the SMA elements and to the constraining behavior that the composite matrix has on the SMA wires. In this work the behavior of a shape memory alloy hybrid composite (SMAHC) is numerically and experimentally investigated. A plate was fabricated using prestrained SMA wires embedded in an epoxy resin pre-preg glass fibres composite system. Upon calorimetric and mechanical material characterization, a finite element model was used in order to predict the structural behavior of the SMAHC. In the experimental tests, the plate was clamped at one side and actuated via electrical heating. Temperature and displacement data were collected and used to validate the model. The results show that the model is able to predict the behavior of the SMAHC and highlight the crucial role of a correct choice of the SMA and composite material parameters.

Session A-10.5
Applications

A-10.5: IL01 **SMA Fatigue in Civil Engineering Applications**
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The Shape Memory Alloys shows particular properties associated to their martensitic transformation between metastable phases. The use of SMA dampers requires a deep knowledge of SMA properties and their coherence with the application requirements. In damping of earthquakes the available experimental conditions shows that, after several years or decades in still conditions, an excellent behavior is required for one or two minutes or 200 working oscillations. When the target is the damping of stayed cables in bridges under the wind or rain actions a big number of oscillations is expected per day in working situation. The talk analyze the study of CuAlBe and, in particular, the available experimental improvements in the fatigue life of NiTi.

A-10.5: L03 **Control Characteristics of Shape Memory Alloy Actuator Using Resistance Feedback Control Method**
YUJI TAKEDA, TAKE R&D, Kasukabe, Japan; TAKEI YAMAMOTO, TOSHIO SAKUMA, Oita University, Japan

The actuators using shape memory alloy (SMA) can work as an actuator to control or retain positioning without using sensor device. SMA has a characteristic that electric resistance varies due to the phase transformation in the process of heating and cooling. Actuators applying this characteristic to position control of SMA with resistance feedback, have been reported. However, the resistance values of SMA show non-linear characteristics with hysteresis, resulting in giving different position information for rising and lowering processes of temperature. Some attempts have been carried out to realize a position control system using the PID control by resistance feedback, but they remain only at the continuous positioning control or power control. If positioning can be achieved for an arbitrary position, the applications of such actuators will be wide spread. In this work, a position control model combined with a biasing mechanism and an antagonistic mechanism is produced. The produced model is controlled by resistance feedback using the method of setting OFF time and Blanking time and can be set and retained at an arbitrary position. Investigation is made on such positioning characteristics as settling velocity and position accuracy.

A-10.5: L05 **Generation of Smart Structures on the Basis of in-situ Configuration of Shape Memory Alloys**
S. LANGBEIN, E.G. WELP, Ruhr-University Bochum, Bochum, Germany

An outstanding feature of shape memory alloys (SMAs) is their potential to produce different functional effects like thermal shape memory or super elasticity in one component. The purpose of the present study is to find a way to create an universal component with properties adjustable for various applications solely by modifying the local material properties. We refer to this process as in-situ configuration. The basis of in-situ configuration of the materials' properties is generated by first deactivating the shape memory effect in the whole element and then local activation of the shape memory effect by use of local heat treatment. The NiTi-structues presented in this study offer various options, since they do not feature perceptible thermal shape memory or super elasticity due to a high dislocation density. Instead, to achieve a specific local function, the elements are subjected to in-situ heat treatment carried out by a local resistive heating element. The structure of such a smart SMA-component can be understood as an integrated modular system, with different local operating centers, which can be activated and linked by in-situ configuration. There is a need to adjust the duration and intensity of the heat input in order to obtain the different functional properties.

A-10.5: L06 **The Mechanical Response of Shape Memory Alloys under a Rapid Heating Pulse**
S. WALLACH, D. SHILO, Technion, Israel

Shape Memory Alloy (SMA) actuators are very promising due to their large strains but are considered to be very slow due to the time which takes for the SMA to cool. In this presentation we explore the capabilities of a fast one-directional actuation mode based on one-occasional rapid Joule heating of SMA elements. For this purpose a unique experimental system has been developed which applies a high-voltage electric pulse to a detwined NiTi wire and measures the resulted displacement due to the martensite to austenite phase transformation. The electric pulse is tuned to produce a temperature jump of 40-100 °C within a risetime of few microseconds. One end of the wire is clamped while the displacement of the other end is monitored with a MHz sampling rate by an optical encoder and a grating device. The response of the SMA under different dead-weight loads allows studying the kinetics of temperature induced austenitic transformation. A comparison with several previous studies of stress induced martensitic transformation will be presented. The results demonstrate the great potential of SMA for applications that require high speeds and large displacements one-occasional actuation.

A-10.5: IL07 **Superelastic NiTi Thin Films for Medical Applications**
E. QUANDT, C. ZAMPONI, CAU Kiel, Kiel, Germany

Shape memory alloys are able to provide high work output when undergoing the martensitic transformation. Therefore, they are a

promising candidate for actuation mechanisms in microsystems, e.g. in microvalves. Sputter deposited SMA thin films are already in use as free-standing films or as composites. Since it is also possible to deposit and structure the SMA composites on Si substrates by photolithographic steps, the fabrication process is compatible to MEMS and therefore most favorable for an number of applications. Superelastic shape memory materials are of special interest in medical applications due to the large strains at constant stress and their biocompatibility. Superelastic TiNi thin films have been fabricated by magnetron sputtering using cast melted targets. Special heat treatment was performed to adjust superelastic properties and transformation temperature. A superelastic strain of up to 6.5% at 37°C was obtained. Although NiTi shows an excellent biocompatibility enhanced antibacterial properties would significantly broaden its application range. Coatings containing Ag have already been used for this application. Thin films of different TiNiAg compositions were prepared by sputtering and compared.

A-10.5: L09 **Smartflex® NiTi Wires for Shape Memory Actuators**
A. CODA, F. BUTERA, G. VERGANI, L. FUMAGALLI, L.L. TOIA, SAES Getters SpA, Lainate (MI), Italy

Shape Memory Alloys (SMAs) are active metallic materials classified nowadays as “smart” or “intelligent” materials. One of the main areas of interest is that of actuators. NiTi SMAs proved to have the best combination of properties. Due to its relatively high recovery stress and strain, actuators providing significant force and stroke can be designed. There are a large number of applications of NiTi-based actuators mentioned in the literature and in patents. Successful applications are building on SMA strengths whilst taking into account its weaknesses. SAES Getters S.p.A., thanks to its vertically integrated process and to the scientific and quality approach, developed SmartFlex a NiTi-based wires family which can represent a very good solution for shape memory actuators. The mechanically stabilized SAES SmartFlex NiTi wire actuators show a very sophisticated profile of properties. In this paper the mechanical, thermal and electrical response of these shape memory wires, at diameters ranging from 20 to 500 µm, will be examined in depth and discussed. Tests will be presented under conditions simulating the actual operating ones in real devices, in order to direct the design of the actuators so that the functional properties of the material can be completely exploited.

A-10.5: L10 **Structuring of Sputtered Superelastic NiTi Thin Films Tubes by Photolithography and Wet-etching**
R. LIMA DE MIRANDA, C. ZAMPONI, E. QUANDT, University of Kiel, Kiel, Germany

Off-stoichiometric NiTi sputtering targets were manufactured by cast melting in order to sputter Ni-rich NiTi thin films. Crystalline samples, which reveal a martensitic transformation, were fabricated by magnetron sputtering and subsequent thermal treatment. Sacrificial layer technique was used to obtain free-standing NiTi films. At 37°C, the films show superelastic properties with closed-loop hysteresis in tensile testing and a plateau of more than 6% strain. It has been shown that the deposition process can be transferred to sputtered NiTi tubes, which have high potential for medical applications. Glass tubes with diameters between 3 mm and 5 mm were used as substrates. Typical deposition rates of approximately 0,5 µm/h at 450°C allowed the fabrication of crystalline thin film tubes. Photolithography and wet etching technology were applied in order to fabricate tubular thin film devices. Structure size ranges in the order of the NiTi film thickness, typically between 5 and 15 µm. To transfer the planar mask geometry to a non planar sample, a synchronized movement of the mask and the substrate was used.

FOCUSED SESSION A-11
Smart Textiles

Session A-11.1
Adaptive / Active Textiles

A-11.1: IL01 **Nanotechnology for Functional Textiles**
T. STEGMAIER, M. DAUNER, H. PLANCK, Institute for Textile and Process Engineering Denkendorf (ITV), Denkendorf, Germany

Using nanotechnology in spinning and surface treatment of fibre based materials is a great chance to change physical and chemical properties in a large scale. At ITV Denkendorf the focus in research and development is on following subjects: - Spinning of nanofibres using electrospinning; - Generation of special fibres using bi-component spinning; - Activation of natural and artificial fibres and textiles by atmospheric plasma at high speed; - Finishing of textiles with considerable increased performance like superhydrophobic surface, electrostatic behaviour, light reflexion.

A-11.1: IL02 **Optical Responses of Nano- and Micro-structured Polymeric Photonic Fibers for Flexible Intelligent Structures**
XIAOMING TAO, The Hong Kong Polytechnic University, Kowloon, Hong Kong

This paper presents a series of investigations on nano- and micro-structured polymeric photonic fibers, which generate, transmit, modulate photons. The fabrication and characterization of photosensitive optical fibres, fibre FBG gratings and electrically switchable FBG gratings are described. Furthermore the optical responses of FBG sensors under different modes of deformation are discussed. Both the polarization and optical spectrum behaviour of FBGs are used to analyze the deformation perturbations. In the case of an FBG under tension, the wavelength-sensitivity to tension is significant. In the case of torsion, the wavelength-sensitivity is very small, and the polarization behaviour is sensitive to it. In the case of lateral compression, the wavelength-sensitivity is much smaller than that under tension, but the deformation induced birefringence can broaden and split the reflection peaks. The lateral compression can be sensed by the spectrum behaviour in some sensing schemes. Both the polarization behaviour and the optical spectrum of FBGs can be used to analyze lateral compression. Bending of FBGs can be analyzed for both the polarization behaviour and the optical spectrum, but it is difficult to measure the polarization evolution of fibre under bending. Finally principle, fabrication and application of fibre random laser made from polymeric composite systems are presented.

A-11.1: IL03 **Fabrication and Multifunctional Applications of Carbon Nanotube Yarns and Self-woven Transparent Sheets**
R.H. BAUGHMAN, S. FANG, M. ZHANG, A.A. ZAKHIDOV, M. KOZLOV, A.E. ALIEV, University of Texas, Dallas, TX, USA; K.R. ATKINSON, CSIRO Textile & Fibre Technology, Belmont, Victoria, Australia; T. MIRFAKHRAI, J.D.W. MADDEN, University of British Columbia, Vancouver, Canada; P. GALVAN-GARCIA, M.I. ROMERO, Scottish Rite Hospital, Dallas, TX, USA

We describe novel methods for producing polymer-free carbon nanotube yarns and transparent sheets and describe their properties and applications as multifunctional materials. The yarns are strong, highly resistant to creep and to knot or abrasion-induced failure and provide the giant surface areas needed for diverse multifunctional applications. The nanotube sheets have higher gravimetric strength than the strongest steel sheet or the polymers used for ultralight air vehicles and proposed for solar sails. Applications evaluations are described for artificial muscles, thermal and light harvesting, energy storage, field-emission electron sources, electrically conducting appliqués, three types of lamps, displays, and sensors. These yarns and sheets provide biocompatible substrates for directed neuron growth for potential electronic-biological interfaces.

A-11.1: IL04 **The Investigation about the Shape Memory Behavior of Wool**

JINLIAN HU, ZHENG-E DONG, YAN LIU, YIJUN LIU, The Hong Kong Polytechnic University, Kowloon, Hong Kong

Shape memory polymers are a promising class of stimuli-responsive materials that have dual-shape capability. This kind of materials can recover their shape in a predefined way from temporary shape to desired permanent shape when exposed to an appropriate stimulus. In the development and extensive application of synthetic shape memory polymers on textile industrials, the thermal and hygrothermal effects of wool materials have attracted considerable attention. In this article the fundamental concept of the shape memory polymers and the fundamental aspects of the shape-memory effect were reviewed. On the other hand, the thermal and hygrothermal effects of wool materials were summarized to discuss the shape memory behavior of wool materials. Besides the effects of synthetic shape memory polymers on the thermal and hygrothermal of the woven wool fabrics were introduced to show the shape memory behavior of treated wool further. The results show that the treatment of synthetic shape memory polymers will help the nature wool to obtain the shape memory effect under outer stimulation and recover to their desired shape.

A-11.1: IL05 **Production, Properties and Applications of Spun Carbon Nanotube Yarns and Knitted Tubes**

K.R. ATKINSON, S.R. HUTTON, C. SKOURTIS, CSIRO Textile & Fibre Technology, Geelong, Victoria, Australia

Carbon nanotubes (CNTs) are of great technical interest because of their high strength, good electrical conductivity, excellent thermal conductivity, and good thermal stability at both low and high temperatures. A particular difficulty has been absence of reliable methods of controlling assembly of the large numbers of CNTs required for practical applications. We have developed, in collaboration with our partners at the NanoTech Institute, University of Texas at Dallas, a solid-state process for spinning CNTs into yarns without the use of binders that usually degrade the properties, particularly electrical conductivity. The singles yarns were twisted together to give coarser, stronger yarns that were knitted into 2 mm diameter tubes. Extensive tensile tests have been carried out on the yarns and plies for which special test equipment was developed for the simultaneous measurement of diameter, resistance, tensile force, and extension. Textile applications of the CNT yarns and knitted tubes are of great interest and specific investigations underway include using the CNT yarns as filaments for lights, as electrodes for biomedical applications, and as composites with high toughness. The biocompatibility of the CNT yarns with selected cell lines has been found to be high.

A-11.1: IL06 **Polymeric Nanofibers Reinforced with Multi-wall Carbon Nanotubes for Applications Ranging from Filters to Tissue Scaffolds**

R.E. GORGA, L.I. CLARKE, NC State University, Raleigh, NC, USA

Conductive nanofibrous mats have many potential applications for filtration (electrostatic dissipation), sensors, and tissue engineering. Here, strategies to obtain unique morphologies (including core-sheath structures) of multi-wall carbon nanotube reinforced nanofibrous mats are discussed. The morphologies of these materials are characterized using electron microscopy. The mechanical properties (accounting for the porosity of the mat) and the electrical properties (including percolation behavior) are measured. Demonstration of mechanical enhancement and electrostatic dissipation is shown. Efficacy as a tissue engineering scaffold is also demonstrated. Finally, future trends and new innovations are discussed.

A-11.1: L07 **Photochromic Wool Fabrics with Enhanced Durability and Photochromic Performance**

TONG LIN, TONG CHENG, REX BRADY, XUNGAI WANG, Deakin University, Geelong, Vic, Australia

Our previous work have demonstrated that a photochromic fabric can be prepared via surface coating the fabric with an alkyl/aryl silica coating embedded with a photochromic dye. The photochromic coating showed a fast optical-response and minimal influence on the fabric handle, but low in durability against repeated washing and abrasion. In the present study, we have improved the photochromic coating durability via introducing epoxy groups to silica by co-hydrolysis and condensation of two silane precursors, octyltriethoxysilane (OTES) and glycidoxypropyl-trimethoxysilane (GPTS), in the silica preparation. We have observed that the presence of a certain content of epoxy groups in silica not only improved the washing and abrasion resistance, but also increased the response speed. Also OTES/GPTS ratio affected both the fabric properties and photochromic performance.

A-11.1: L08 **Designing with a Responsive Colour Palette: The Development of Colour and Pattern Changing Products**

S. ROBERTSON, R.M. CHRISTIE, S.E. TAYLOR, Heriot-Watt University, Galashiels, UK

This paper presents results of a current research programme at the design/technology interface involving an AHRC funded practice-led PhD project on the application of colour change technology in interior textile design. The research involves a collaborative team of designers working at the technology interface with a colour chemist and an electronic engineer. The paper provides an illustrated discussion of the creative potential of thermochromic textiles brought into contact with specifically-designed heat profiling circuitry. Examples are given of textile design collections combining printed thermochromics with circuitry that demonstrate the aesthetic qualities which arise from integration of the technologies in a flexible fabric system. The visual dynamic colour change effects when controlled by prototype circuitry and power electronics are demonstrated. These visual observations are leading further design development using more complex flexible circuitry in textile design with a wide range of thermochromic systems. The paper concludes with an analysis of the potential for product/artefact development in this area of "smart" design and how, as a consequence, a responsive interior might be envisaged in the future.

A-11.1: IL09 **Investigating SMART Membranes and Coatings by In Situ Synthesis of Iron Oxide Nanoparticles in PVA Hydro Gels**

G.K. STYLIOS, T. WAN, Heriot-Watt University, Galashiels, UK

This paper reports a novel method of developing SMART nanocomposite membranes and coatings by *in situ* synthesis of iron oxide particles in a Poly(vinyl alcohol) (PVA)matrix, using co-precipitation of different amounts of Fe(II) and Fe(III) taken in an alkaline medium. Magnetic PVA fibers were prepared by a wet-spinning method from solutions containing magnetite nanoparticles. Magnetite particles with an average diameter of 20-40 nm were obtained homogeneously within the matrix because of the tridimensional structure and chelating capacities of PVA. Calcium-alginate PVA gel was used to encapsulate the iron oxide/PVA nanocomposite. The mechanical properties and the saturation magnetization of the system were measured. The combination of magnetic properties of iron nanoparticles with the biocompatibility of calcium-alginate suggests that these materials have great potential for use as controlled delivery systems activated externally by magnetic stimuli.

A-11.1: IL10 **Lotus-effect®: Biomimetic Super-hydrophobic Surfaces and their Application**

M. SPAETH, W. BARTHLOTT, University of Bonn, Bonn, Germany

The majority of organismic surfaces, like the plant cuticle, is not smooth but micro-structured. Moreover, they are often covered with hydrophobic wax crystals, some hundred nm in size. The combination of micro- and nanostructures, together with a hydrophobic chemistry, generates the phenomenon of super-hydrophobicity: Water-droplets on such surfaces exhibit contact angles above 140°. Furthermore, dirt particles can barely adhere and are removed by running water only, hence they are called 'self-cleaning'. The underlying physico-chemical principles were successfully applied to technical prototypes. This technical conversion was patented and the trade mark Lotus-Effect® was introduced in the mid 1990s. Since then several Lotus-Effect® products like a façade paint, a glass coating or a spray were introduced. Another area of application for which prototypes exist, are textiles for awnings, tents or other outdoor purposes. Recently a different aspect of such surfaces is investigated: structures retaining air under water. Several floating plants and semiaquatic animals show this ability. The aim of this project is to develop technical surfaces for long-time application in ships and pipelines, as an air film between surface and liquid leads to drag reduction and thus savings of energy.

A-11.1: IL11 **Characteristics of Carbon-polymer Composite System Prepared by Gelation Crystallization from Solution and the Application to Clothing Materials**

MASARU MATSUO, S. ISAJI, Q. CHEN, Nara Women's University, Nara, Japan

Good positive temperature coefficient (PTC) effect was achieved using polyethylene and carbon fiber (CF) blends prepared by gelation/ crystallization from dilute solution, in which low molecular weight (LMWPE), the molecular weight being 4×104, and ultra-high molecular weight polyethylene (UHMWPE), molecular weight being 6×106, were adopted. The PTC effect exists in the wide fiber content range. The maximal PTC effect, the intensity of which being about 9 orders of magnitude, was presented with a LMWPE/UHMWPE composition of 9/ 1 containing 23.5 vol% CF much higher than the percolation threshold value. As one of the experiments, an increase in surface temperature of the composite surfaces by heat generation was measured as a function of current and voltage, in which CFs were covered by nickel. The composite plates were much more flexible in comparison with the plate on the market. The temperature measurement was done on the surface covered by cotton cloths or empire cloths as a function of time. The optimum volt in the range of 1.5 V was investigated for the composites with various CF contents in order to control the surface temperature of the composite in the range of 30~35 °C. After then, the two composite plates were put into a jacket. The jacket was found to be used without an overcoat in winter season and to be very comfortable in wearing because of the flexible plates. Incidentally, the optimum content of CF in the composite was determined to maintain 25~30 °C in the jacket at 10 °C atmosphere.

A-11.1: L12 **Gold Coated Yarn for Medical Applications**
A. SCHWARZ, J. HAKUZIMANA, E. GASANA, P. WESTBROEK, L. VAN LANGENHOVE, Ghent University, Zwijnaarde (Gent), Belgium

Textiles are increasingly studied to use them as sensing and measuring devices of body parameters. For this purpose they need to be modified to provide, on the one hand, reliable and stable electroconductive properties and, on the other hand, they should be biocompatible. This can be achieved by depositing electroconductive materials such as metals on the textile surface. Gold is an ideal material to use as it offers the aforementioned criteria and can be applied as a thin coating on the surface of a fibre, yarn or fabric. We developed gold coated yarns that are highly electrically conductive, skin-friendly and stable. In this presentation, we describe the gold coating method on a synthetic yarn and show first results of the characterisation of the coated yarn. A commercially available polyester yarn was coated with a thin layer of gold by using an electroless plating method. The plating solution was optimised towards the concentration of each component, the working temperature and the pH-value. The quantitative analysis of the surface coverage of gold carried out by EDX and cyclic voltammetry measurements showed in both cases a surface coverage of more than 90%. For the future, research will be continued to characterise the long-term behaviour of the coated yarn.

A-11.1: IL13 **Thin-film Silicon for E-textiles**
S. WAGNER, Princeton University, Princeton, NJ, USA

E-textiles can be woven from yarn with optical or electronic functions, or circuits may be attached to textile substrates. Industry is developing hybrid e-textiles by placing active components on passive e-textiles. Eventually the architecture of e-textiles may differ radically from that of conventional integrated circuits, perhaps to the same degree as integrated circuits of active nanotubes and nanowires will. However, industrial realization of a new technology moves far into the future if it needs many new components and techniques. Therefore established technologies for fabricating flexible electronic surfaces, such as thin-film silicon on polymeric substrates, merit analysis of their applicability to e-textiles. I will discuss the advantages and drawbacks of amorphous silicon (a-Si). Although a-Si is made and processed to circuits using conventional planar technology, it can be incorporated in flexible, conformally shaped, and even elastically stretchable surfaces, and it is inert against aqueous corrosion. However, high-performance a-Si devices require relatively high process temperatures, and a-Si process chemistry may attack textile materials. I will illustrate thin-film silicon for e-textiles with examples from our laboratory.

A-11.1: IL14 **Fabrication and Characterization of High Surface Electric Conductivity Nanowebs for Intelligent Textile Systems**
TAE JIN KANG, BYUNG WOOK AHN, YONG-SEUNG CHI, CHUNG HEE PARK, Seoul National University, Seoul, Korea

Electrospun multi-walled carbon nanotube (MWCNT) / Polyacrylonitrile (PAN) nanowebs were fabricated. MWCNTs were added into the PAN solution or adsorbed on the PAN nanoweb. For uniform dispersion of MWCNTs in the polymer solution, MWCNTs were functionalized by acid. Introduction of carboxyl groups onto the surface of MWCNTs was examined by Fourier transform infrared(FT-IR) spectroscopy and X-ray diffraction(XRD) analysis. Further carbonization was carried out on both nanowebs. The morphology of MWCNT/PAN nanowebs were observed using field emission-scanning electron microscopy(FE-SEM) and transmission electron microscopy(TEM). The tensile and thermal properties and crystallinity of the nanowebs are discussed. The electric conductivities of the MWCNT/PAN nanowebs are compared and their application for intelligent textile systems is also discussed.

Session A-11.2
E-textiles

A-11.2: L02 **Printed Textile Antennas for Off-body Communication**
C. HERTLEER, L. VAN LANGENHOVE, H. ROGIER, Ghent University, Zwijnaarde (Gent), Belgium

Garments are ubiquitous but still have a lot of potential in terms of functionality. In recent years they became host of body area networks, transferring them into wearable textile systems. These are garments able to monitor the wearer's vital signs and environmental conditions in a comfortable and unobtrusive way. The off-body communication of the sensor data to a nearby base station is therefore preferably operated by a fully integratable and flexible antenna. This paper will report on microstrip patch antennas, designed to operate in the 2.45 GHz Industrial, Scientific and Medical (ISM) band and screen printed on a textile substrate. Based on field simulation, the antenna design is optimized to guarantee a broad bandwidth. The employment of conductive ink will be critically evaluated. In order to simulate real life situations, the radiation characteristics of the antenna in planar and in bent state and additionally covered by extra textile layers, will be discussed. Moreover, attention will be given to the connection between the antenna and the transceiver in order to facilitate garment integration. This research contributes to the new generation of upcoming wearable textile systems.

A-11.2: L03 **A Smarter Life**
M. PEDLEY, D. EMERY, SmartLife Technologies, Manchester, UK; T. DIAS, P. GAYDECKI, University of Manchester, Manchester, UK

SmartLife® Technology Limited from Manchester in the United Kingdom will be demonstrating a garment system for the monitoring of vital human functions. SmartLife has created a garment system capable of monitoring heart rate, ECG morphology, respiratory rate, tidal volume and temperature sensing. The system enables continuous monitoring of those with certain incipient health conditions without the frequent attendance by health professionals. The characteristics include: - A garment that the user can put on and take off without assistance, necessarily including the automatic correct location of sensors; - A garment that the user can wear for extended periods without either discomfort or deterioration in monitoring performance; - A garment that survives many care cycles in normal domestic facilities; - Monitoring performance suitable for the diagnosis of the onset of potentially dangerous conditions; - The ability to exploit the monitored results for a variety of applications and modes including locally directly to the wearer and remotely to diagnostic centres. The sensor structure is patented and unique and the garment system includes proprietary complex digital signal processing elements and custom electronics to extract the diagnostic information from the sensed signals.

A-11.2: IL05 **Current Solutions for Integration of Electronic into Garments**
I. LOCHER, Sefar AG, Heiden, Switzerland

Fabrics augmented with electronic functionality show their advantages in application fields where flexibility and drapability is desired. Among these applications we can find clothing, seats, curtains and architecture. We present our technological approach to integrate electronic components in fabrics. We address critical technical pitfalls and our solutions to them. Further, we point out important aspects for a successful combination of the two worlds of electronics and garments. Therefore, we present the view from the business as well as from the technological side. In conclusion, we talk about some existing deficiencies in combining the two worlds along with our roadmap in the field of electronic fabrics.

A-11.2: IL06 **STELLA - STretchable ELectronics for Large Area Applications - A New Technology for Smart Textiles**
C. KLATT, Freudenberg Forschungsdiense KG, Weinheim, Germany

As a consequence of the ambient intelligent vision where the citizen carries along more and more electronic systems near the body wearable electronics is needed. Typical applications are intelligent textiles and clothes, personnel healthcare or fitness monitoring. The electronic systems for these applications have to be stretchable with soft touch nature in order not to hamper the comfort of the user and to be ideally almost non-noticeable to him. They should be reliably withstanding all mechanical and chemical requirements of clothes, in which they are integrated. In the EU- project "STELLA" the consortium has developed a platform technology of enabling interconnection, packaging and assembling technologies. For example a new generation of stretchable substrates based on non woven with stretchable conductor pattern for large area application has been developed. In order to realize low-cost high volume stretchable electronics printed circuit methods have been modified and applied so far. The author will report about the latest progress in the STELLA-project to develop substrates with stretchable conductors, assembling methods adapted for stretchable substrates and manufacturing process for stretchable electronic systems.

A-11.2: L07 **Future Intelligent Textiles**
T. DIAS, The University of Manchester, Manchester, UK

The presentation describes a novel research on encapsulating electronic chips within the fibres of a yarn. A polymer resin is used to bind the chip with the fibres of the yarn. The concept is to position encapsulated chips along the length of the yarn at a predetermined interval, which could be acceptable as minor thick places. The encapsulated area would form a hermitically closed seal around the chip thus protecting it from all forms of stresses, such as mechnical, thermal, chemical. The encapsulation of an electronic chip within the fibres of a yarn would craft an intelligent yarn with the ability of physical sensing, signal processing, transmitting and receiving. The resultant E-yarn could be processed using conventional fabric manufacturing technology. The design and development of an experimental rig to encapsulate RFID chips and LED will be explained in the presentation. The presentation would also report on the development of knitted heating structures, knitted switches, knitted electrodes and EL yarns, which have resulted from the research carried out in the School of Materials.

A-11.2: L07B **Innovating for the future. The rise of "soft machines", "smart" ICT and materials that start to think**
R. OLIVER, Centre for Emerging Nano, Micro & Photonic Systems, The Fabrian Centre, Newcastle upon Tyne, UK

The 21st century will be the century of materials! We will by 2100 understand how to fully manipulate and control both the nano and molecular manufacture of materials by design. Innovation at the interface between Materials and Biology therefore is probably the most important area of applied technology for the foreseeable future and will be a central thrust of 21st century interactive consumer products and healthcare applications. i.e. It will produce and enable a huge range of consumer and health related product opportunities which in turn will lead to even greater integration and use of increasingly invisible material systems and devices, 'around-the-body', 'on-the-body' and 'in-the-body'. This talk will focus therefore on the convergence of Biology, Polymers and Electronics which will be driven increasingly by the needs of the individual, through smart textiles for safety, security and fashion to applications in medicine and ambient assisted living. How these needs may manifest themselves will be discussed through long term scenarios and trends putting the human at the centre of (all) technology. Finally, some of these beneficial applications will require new innovative fabrication and manufacturing routes to implementation. A number of these can be highlighted as follows: (a) Materials for renewable energy. New ideas for Energy harvesting, storage and management; (b) Materials for printable electronics. New ideas for materials fabrication in transistors, circuits, small devices and systems; (c) Intelligent materials development. From passive/active to responsive/adaptive to ultimately emotional materials and intelligent systems; (d) Covergence of Bioscience (Genes), Information Technology (Bits), Nanoscience and Technology (Atoms) and Cognitive Science (Neurons) to form G-N-R interactive technology and ultimately an electronic nervous system (e-n-s).

A-11.2: IL08 **Embroidered Interconnections and Encapsulation for Electronics Applications in Textiles**
T. LINZ, C. DILS, R. VIEROTH, Fraunhofer IZM, Berlin, Germany

This paper describes the integration of a flexible electronics module into a textile fabric with embroidered interconnections and embroidered wiring. Furthermore it discusses the results of extensive reliability tests. A test substrate has been designed and has been assembled with different electronics components like daisy chain flip chip or CSP. Conductive yarn has been embroidered through metalized contact pads on the flexible substrate to interconnect the textile embroidered wiring with the electronics circuit. To protect the module and its embroidered interconnections the whole has been encapsulated using two different techniques for comparison: transfer molding and hot melt encapsulation. Finally the devices have been tested in wash cycling tests and temperature cycling tests.

A-11.2: IL09 **Woven Logic with Electrochemical Transistors**
O. INGANAS, M. HAMEDI, R. FORCHHEIMER, Linköpings Universitet, Linköping, Sweden

Electronic functions are typically embodied in materials in the form of planar structures in flat geometries. The development of fibre based electronic functions could enable a new mode of integrating electronic technologies with the space of humans, through electronic textiles. We have recently demonstrated digital logic circuits woven from electronic fibres, marrying the technologies of textiles and of polymers for a new function. The electrochemical transistor on a fibre is the basic prerequisite for these circuits, and this is created by crossing two insulating textile fibres coated with an electroactive polymer. The crossing between these fibres is bridged with an electrolyte, creating an electrochemical transistor. This transistor has a current-voltage characteristic quite similar to a field effect transistor, but operates via electrochemical oxidation and reduction of the two fibers, assisted by a flow of ions through the electrolyte. Because of the electrochemical mode, the device operates at low voltages(< 3V) but also with very low speeds(Hz). Systems based on these electrochemical transistors therefore can function as slow electronics, but housed in textiles and clothes.

A-11.2: L10 **Strains Sensors and Chemical Sensors Printed onto Textiles**
P. CALVERT, P. PATRA, D. DUGGAL, A. AGRAWAL, University of Massachusetts, N. Dartmouth, MA, USA

Conducting polymer strain sensors and silver connecting leads have been inkjet printed onto fabrics in order to monitor joint motion during rehabilitation or sports. Under tensile strain the sensors show a decrease in resistance that can be attributed to improved contact within bundles of fibers, each having a conductive coating. The gauge factor, the ratio of resistance change to strain is in the range from 6-12, compared to 2 for conventional strain gauges. Patterns of sensors are being applied to sleeves over the joints in robotic arms in order to develop methods to characterize complex motions. Similar sensors based on conductive gels are being developed to sense pH, glucose and soluble biopolymers. These are printed onto textiles with a view to continuously monitoring the composition of sweat during exercise. These sensors comprise conductive carbon particles embedded in hydrogel at close to the percolation threshold. Enzymes bound in the gel cause local changes in pH that change the swelling of the gel and so its conductivity.

A-11.2: L11 **Photonic Textiles**
L. VAN PIETERSON, R. BHATTACHARYA, K. KRIEGE, O. VAN LOON, P. BOUTEN, Philips Research Labs, Eindhoven, The Netherlands

Many types of textiles are used in our every day life. When electronics is unobtrusively integrated into these textiles, new application fields emerge. For instance, light-emitting textiles could open up a wide range of new interior and apparel applications, ranging from illumination to atmosphere creation to messaging. At Philips, we are creating fabric indicator systems by incorporating arrays of inorganic LED packages into textiles. The LEDs can be addressed individually, allowing to display dynamic images. When incorporated in e.g. clothes, this gives rise to surprising and attractive effects. In this presentation, we will slowly built up the photonic textile display, that consists of conductive yarns in a fabric matrix with attached components. We will present electrical and mechanical data on yarns, fabric and attachment methods. Furthermore, we will discuss data on water resistance and washability. We will conclude with showing some recent (application) demonstrators and expectations for the future.

Session A-11.3
Functionality and Applications

A-11.3: IL01 **Fiber Sensory Bioengineering**
YI LI, The Hong Kong Polytechnic University, Kowloon, Hong Kong

Fiber sensory bioengineering is defined as the application of a systematic and integrative way of approaching the solutions to translate consumers' biological sensory responses, psychological feelings and preferences about a product into perceptual elements of design. Sensory engineering design is an iterative decision-making process in which the physics, mathematics, neurophysiology and engineering techniques are applied to convert resources optimally to meet a specific and/or a combination of various sensory requirements from visual, audio, smell, thermal to mechanical touch sensations. It is the link between scientific discoveries and commercial applications by applying mathematics, science and advanced technologies to research and to develop economical solutions to practical technical problems. Fiber sensory bioengineering can be considered as the extension of the concepts of Kansei Engineering and Sensory Engineering, with emphasis on integrative application of the sciences behind the human sensory perceptions. Human sensory perception of clothing involves a series of complex interactive processes, including (1) the physical processes of generating various external physical stimuli; (2) the neurophysiological processes of receiving, encoding, transporting and decoding the stimuli by relevant biosensors and nervous systems residing inside of human body; (3) neuropsychological processes to the formulation of psychological sensations from the neurophysiological signals; and (4) the psychological processes of making judgments, formulating preferences and making behavioral and/or psychological adaptive feedback actions. This paper reviews the latest development in this research area.

A-11.3: IL02 **E-textiles Applications in Emergency Scenarios**
R. PARADISO, Smartex Srl, Prato, Italy

Textile integration of smart sensor systems based on micro- and nano-technological architectures is the key technology for the success of future e-garments oriented to emergency operators. Ubiquitous recording and transmission of human and environmental data will allow to combine comfort and protection leveraging with the existing smart textile, microelectronics and telecommunication technologies. The challenge offered by emergency situation is mainly in the difficulty to acquire data in a very aggressive environment, during hard physical activity; conditions that will increase the risks of signals artefacts, as well as the presence of positive and negative false events. Security is addressed through the implementation of systems combining body sensing platform, for health alertness and environment sensing platform for context awareness, the full system has also to guarantee protective functionality. State of art textile technology allows the monitoring of heart and respiratory rate, humidity rate, activity rate, GSR and EMG, while core and external temperature, posture via accelerometers, absolute position via GPS are easily monitored through standard sensors. The body sensing platform requires a direct contact with the operator skin leading to the implementation of a sensing inner garment, at the same time environment platform is integrated in a protective jacket that is also hosting the alarm systems and the electronic unit for signal processing and transmission hardware. Data are transmitted from the operator to the external control unit by using a textile antenna, embedded on the outer garment.

A-11.3: L04 **Photo-catalysis of Red Wine Stains using Titanium Dioxide Sol-gel Coatings on Wool Fabrics**
C.J. HURREN, P.G. COOKSON, X.G. WANG, Deakin University, Geelong, Vic, Australia

This study investigated the use of a nano coating titanium dioxide sol-gel to photo-catalyse and degrade red wine stains on wool fabrics. Coatings were produced by the hydrolysis and condensation of titanium butoxide [Ti(OC4H9)4] on the surface of wool fabrics after pad application. After prolonged immersion in boiling water, the coatings were partially converted to the anatase form of titanium dioxide. The presence of anatase in the coating was confirmed using scanning electron microscopy, Raman spectrophotometry and atomic force microscopy. Coated samples were measured for photo-catalytic activity by degrading red wine stains on the surface of the coated fabric. The rate of photo-catalysis was determined for each of the coating systems. The level of staining was reduced significantly on the UV-exposed surface of the coated wool fabric.

A-11.3: L05 **Modification of Cotton to Improve its Water Repellency and Thermal Stability**
C. PISUNTORNSUG, N. YANUMET, Chulalongkorn University, Bangkok, Thailand; E.A. O'REAR, The University of Oklahoma, Norman, OK, USA

3,4-dichloro-1-butene is used to coat poly(3,4-dichloro-1-butene) on cotton by the admicellar polymerization process using a linear alkyl benzene sulfonate (LAS) as the surfactant. Important process variables are the surfactant:monomer ratio and the initiator:monomer ratio. The treated cotton was found to resist penetration of a water droplet for more than 30 minutes and to have improved thermal stability. SEM micrographs show the treated cotton to have a thin film coated on its surface indicating that the admicellar polymerization process has been successfully carried out.

A-11.3: L05B **Optimization of the Electrospray Process by PIV Analysis in Nanostructured Membranes Preparation**
D. PLISZKA[1], S. SUNDARRAJAN[1], A. JAWOREK[2], A. KRUPA[2], M. LACKOWSKI[2], S. RAMAKRISHNA[1], [1]National University of Singapore, Singapore; [2]Polish Academy of Sciences, Gdansk, Poland

Metal oxides nanoparticles like MgO are known as detoxifying chemical warfare and biological warfare agents. Composites consisting of polymer nanofibers made by electrospinning coated with metal oxides by electrospray are used to produce membranes. Such membranes have a potential wide range of applications and can be used as a part of protective suits for protection against warfare agents, or as disinfecting tissues to clean. Here we present studies on electrospraying process of metal oxides solutions. Examination is performed by the Particle Image Velocimetry technique which allows detailed studies of structure and character of electrospray. An experiment allows us to optimize the electrospray process to obtain well defined and uniform nanoparticles sizes and good coverage distribution.

A-11.3: IL06 **Haptic Sensing in Intelligent Textile Develop-ment**
H. MEINANDER, Tampere University of Technology, Tampere, Finland

The haptic properties of textiles are of crucial importance in most application areas and particularly for skin contact garments. Extensive research work has therefore been done both in defining the mechanical textile properties which influence the haptic sensations, in measuring these textile properties, in defining procedures for subjective evaluation of the haptics of textiles, and in simulation of the properties in a virtual environment. In the development of new smart or intelligent textiles it is particularly important to consider the haptic properties. The introduction of non-textile elements (e.g. sensors, transmitters) in the garments or other textile products easily cause impaired haptic or other comfort properties, which might not be accepted by the markets and end-users. A primary application area for smart garments is in health care, where tight fitting underwear garments for the monitoring of body functions (heart rate, ECG, temperature) have been developed. Good haptic properties are particularly important for unhealthy or elderly persons with very sensitive skin.

A-11.3: L07 **Carbon-based Textiles as Gas Diffusion Layers (GDL) for Polymer Fuel Cells**
P. GALLO STAMPINO, D. BRIVIO, G. DOTELLI, Politecnico di Milano, Milano, Italy; P. FRACAS, Saati Group Spa, Appiano Gentile, Como, Italy; P. GRASSINI, 3SEAL SpA, Legnano, Milano, Italy

A Gas Diffusion Layer (GDL) is a sandwiched conductive and porous material interposed between the catalyst layer and the bipolar plates in a Proton Exchange Membrane Fuel Cell (PEMFC). This electrode substrate is a multi-functional material with several properties. All these requirements are best met by carbon fibres based materials, woven carbon or paper. In this work, the attention is focused on a new family of GDL which are produced by an Italian company, SAATIgroup. In particular a new class of carbon cloth with different surface treatments have been considered: a sample without surface treatment, two samples with different plasma treatments (standard and atmospheric plasma) and a sample coated with PTFE. All these GDLs were coated with a microporous layer (MPL) to optimize the water management and the ultimate electrochemical performance of a PEM. The morphological and electrical characterization of all the samples was carried out by means of different techniques. Moreover, as the aim of this work was to study the effects of gas and water transportation on cell performance by applying MPLs, fuel cell tests have been conducted to relate their characteristics to the polarization curves.

A-11.3: L08 **Enzymatic Functionalisation of Proteinous and Chitosan Fibres with BioPhenolics and their Bioactive Properties**
F. SOUSA[1], S. JUS[1, 2], G.M. GUEBITZ[2], V. KOKOL[1], [1]University of Maribor, Slovenia; [2]Graz University of Technology, Austria

Over the last decade, considerable research effort has been focused on creating functional textile materials among which bioactive properties, especially antimicrobial resistance, are in the particular interest. Accordingly, many groups have concentrated their efforts in screening of new biocompatible and non-toxic natural substitutes or even developing of new fibre-forming polymers from natural renewable resources possessing such a properties. In the contribution, tyrosinaze-catalysed coupling of functional biomolecules (flavonoids and non-flavonoids) possessing antimicrobial, antiviral and/or antioxidant properties onto polysaccharide (chitosan) as well as protenious (wool) fibre-forming polymers will be presented. The reaction mechanism was followed by UV/Vis spectroscopy and the grafting was determined by FTIR and Raman spectroscopy. An increase of antioxidant and antimicrobial activities of biophenolics-functionalized fibres using well established methods was proved, depending on the type of the phenolic applied. Introduction of new bioactive functionalities to the fibres gives the possibilities for development of new medical, therapeutic and healthy textile biomaterials. This research has been supported by a Marie Curie TOK 6th FP project MTKD-CT-2005-029540 POLYSURF.

A-11.3: IL09 **Medical Sensor Applications of Photonic Textiles**
M. ROTHMAIER, M. CAMENZIND, B. SELM, EMPA, St. Gallen, Switzerland

Customized and wearable health monitoring devices, incorporated into textiles and garments, shall become medical attendants in the future for monitoring the vital physiological indicators of professionals, patients and elderly persons. Most known specimens utilize metal threads and microelectronics to interface with the human body and to acquire and transport biosignals like ECG or respiration rate. However, optical fibers assembled into so-called photonic textiles are a relatively new subject matter, but with a promising future to complement existing medical devices. Their use today already covers applications for body surface and cavity illumination during medical treatment, light therapies such as photodynamic cancer therapy and sensors. In this presentation, recent applications of photonic textiles are discussed in the field of physiological monitoring. The design of woven and embroidered textiles, incorporating plastic optical fibers, is introduced and their potential for pulse oximetry and tissue oxygenation measurements, using near infrared spectroscopy, are addressed.

A-11.3: IL10 **Smart Textile Embedding Optical Fibre Sensors for Healthcare Monitoring during MRI**
F. NARBONNEAU, D. KINET, Multitel, Mons, Belgium; F. PIROTTE, Centexbel, Brussels, Belgium; R. SHISHOO, Shishoo Consulting, Askim, Sweden; J.L. WEBER,Tamtelesanté, Aix en Provence, France; J. DE JONCKHEERE, P. CHAUD, ITM CHRU de Lille, Lille, France; J. WITT, M. SCHUKAR, M. WENDT, N. DANTAN, K. KREBBER, BAM, Kiel, Germany; T. THIEL, AOS, Dresden, Germany; G. KUKA, Fiberware, Mittweida, Germany; S. WEBER, TUM, Munchen, Germany; A. DEPRÉ, Elasta, Kortrijk, Belgium

Healthcare monitoring is a general issue for patients requiring a continuous assistance and treatment. In order to increase mobility of such patients, a huge effort is pursued worldwide aiming to the development of wearable monitoring systems for monitoring of physiological parameters, such as respiration movements, cardiac activity, oxymetry, and body temperature. Technical and smart textiles that incorporate many different sensors play a growing role in these developments as they are well suited for wearability and ensure a better comfort to the user. Moreover, because of their insensitivity to the electromagnetic fields, optical fibre sensors are the ideal candidates for monitoring vital parameters under Magnetic Resonance Imaging (MRI) environment. The EU OFSETH (FP6 call IST 4), on healthcare monitoring explores all suitable techniques for integrating optical fibres in textile yarns for future generation of medical textiles with embedded optical sensors. Efforts are also focused on development of optical sensors with full MRI compatibility (research on non-magnetic connectors or equipment to achieve EM insensitivity is leaded). The core of the project is hence to provide new facilities for a better patient survey, namely during MRI exam.

A-11.3: IL11 **Position and Motion Sensing for Sport, Entertainment and Rehabilitation**
R.J.N. HELMER, CSIRO Textile and Fibre Technology, Belmont, Vic, Australia

Innovation in textiles and clothing has embodied various combinations of new and existing materials to meet conventional societal needs of comfort and fashion. Interactive and intelligent textiles are emerging as many new textile materials are being used to form sensors in garments to intimately interact with the human form. Interactive textiles typically contain sensors located within a garment to detect physiological function that are wirelessly connected to digital infrastructure and application specific software. These devices can be realised in conventional garments and have scope for application in diverse fields including entertainment, education, sport, military and medicine. Position and Motion Sensing devices will be discussed for each application, in terms of the value proposition, performance requirements, regulations, and existing technology. A case study of an entertainment device that uses limb motion to achieve an imaginary instrument, the Wearable Instrument Shirt (WIS) will be discussed in this context. The WIS combines a wearable sensor interface with software to map gestures and audio data files to form an easy-to-use gesture driven instrument that allows real-time interactive musical performances without any need for significant instrument or computer skills.

A-11.3: IL12 **Design for Ageing Well: Improving the Quality of Life for the Aging Population Using a Technology Enabled Garment System**
J. McCANN, University of Wales, Newport, UK

We are at the beginning of a new industrial revolution with the merging of textiles and electronics. Current markets for clothing & electronics have been separate. Medical devices have been developed for 'ill people' with little aesthetic appeal and wearable technology has not been readily accepted by some intended markets due to badly designed user-interfaces. Little has been done to address the design requirements of older wearers with regard to aspects of human physiology in terms of sizing, fit, predominant posture, thermal regulation, moisture management, protection & the psychological 'feel good factor'. Emerging technologies may be confusing to traditional clothing designers, while electronics & medical experts are not normally conversant with textile technology. A shared 'language' & vision is needed to easily communicate between these sectors & older wearers. The application of smart textiles in a clothing 'layering system' may enhance the quality of life of the active ageing. To be acceptable, clothing must be comfortable, stylish & function reliably in relation to the technical, aesthetic & cultural user-needs. This paper will focus on the needs of the 65 - 75 year old age group who have experienced the influence of design throughout their lives. A design methodology, driven by meaningful end-user research, will be introduced that addresses the potential for a comfortable & stylish clothing system to promote the wellness and autonomy of this growing community.

A-11.3: L13 **Monitoring and Control System of Discomfort in Disability, Bed Rest People and Surgical Patients**
M.A.F. CARVALHO, F.B.N. FERREIRA, H. CARVALHO, J.G. ROCHA, L.B. MARTINS, University of Minho, Guimaraes, Portugal; J.A. SANTOS, University of Minho, Braga, Portugal

Project aims to develop a system that allows to provide to the People with Special Needs (PSN) a relief to the level of the sensitive perception of discomfort, assuring greater independence, welfare, quality of life, prevention of illnesses/wounds, through the development of textile and polymers applications (cushions, mattresses and mattresses overlays) with functions of monitoring and control of pressure in the body's areas in contact with the support surfaces. In this group of PSN will be enclosed the people with serious motor limitations conditioning their mobility/ deambulation, such as bed rest people, patients under effect of sedatives or anesthesia during long surgeries (intra and post operative), patients and users in general of wheelchairs. These people have, for the most part of the cases, a commitment of sensitivity in the body's areas in contact with the support surfaces, or its motor capacity does not allow them to move regularly of position autonomously, as it would do a healthy person unconsciously. Than, insufficient sanguineous irrigation occurs as result of pressure exceeding too long the tissue capillary pressure depriving tissues of oxygen and essential nutrients, owing to ischemia and hypoxia, which then causes the pressure ulcers (UP) development.

FOCUSED SESSION A-12

A joint Session with Symposium E

Artificial Muscle Actuators Using Electroactive Polymers

Session A-12.1
Materials

A-12.1: IL03 **Synthesis and Characterization of IPNs for Electrochemical Actuators**
F. VIDAL[1], C. PLESSE[1], G. PALAPRAT[1], J. JUGER[1], J. CITERIN[2], A. KHEDDAR[2], C. CHEVROT[1], D. TEYSSIÉ[1], [1]Université de Cergy-Pontoise, Cergy-Pontoise, France; [2]Université d'Evry, France

Interpenetrating polymer networks (IPNs) have been developed for many years leading to materials with controlled properties. When an electronic conducting polymer (ECP) is incorporated into an IPN, this one becomes a conducting IPN (CIPN). The synthetic pathway ensures a gradual dispersion of the ECP through the IPN thickness of the material. The system is thus similar to a layered one with the advantage that the intimate combination of the three polymers needs no adhesive interface. The last step in making the CIPN into an actuator is to ensure the ionic conductivity by incorporation of an ionic salt. The highest ionic conductivity through the IPN matrix is necessary in order to ensure the best actuation of CIPN actuators. The chosen salt is an ionic liquid, i.e. the 1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide (EMImTFSI). Various IPNs have been synthesized and the ionic conductivity has been measured at various temperature for a series of EMImTFSI swollen IPN matrixes. CIPN actuators have been optimized using the best IPN matrix. Based on IPN architectures, bending and linear actuators have been designed and actuation in open air will be detailed during the presentation.

A-12.1: IL06 **Fault-tolerant Dielectric Elastomers**
QIBING PEI, WEI YUAN, University of California, Los Angeles, CA, USA

We report our recent progress in improving the performance of dielectric elastomer actuators. Single wall carbon nanotubes were studied as new compliant electrodes for dielectric elastomers. The sprayed coated SWNT electrodes drove electromechanical strains greater than 200%. When a fault was present due to pin puncture or internal defect in the elastomer films, dielectric breakdown caused localized self-clearing of the SWNT electrodes and isolation of the fault. The increased fault tolerance was found to enhance the actuation reliability of dielectric elastomers actuators.

A-12.1: IL07 **Electroactive Polymer Actuator with Ionic-liquid-based Bucky Gel**
KINJI ASAKA, KEN MUKAI, ICHIRO TAKEUCHI, TAKUSHI SUGINO, KENJI KIYOHARA, NAOHIRO TERASAWA, AIST, Osaka, Japan

Recently, much attention has been focused on soft materials that can direcly transform electrical energy into mechanical work. Especilly, electromechanical polymer actuators which can work quickly and softly driven by low voltage, are very useful, since they can be used as artificial muscle-like actuators for various bio-medical and human affinity applications. In previous papers, we have reported the first dry actuator that can be fabricated simply by layer-by-layer casting, using 'bucky gel', a gelatinous room-temperature ionic liquid containing single-walled carbon nanotubes (SWNTs). In this presentation, we will present the recent developments of its performance. The bucky-gel actuator has a structure composed of ionic-liquid gel sandwiched by two polymer-supported bucky-gel electrodes. The actuators show a bending response when applying low voltage between two electrodes, which should be caused by the double layer charging on the carbon nanotube in the bucky-gel electrodes. The performance of the bucky gel actuator has improved by developing the preparation of the bucky-gel electrode and the ionic-liquid gel. Some of the recent results will be presented and discussed.

A-12.1: IL08 **Metal Ion Implanted Compliant Electrodes in Dielectric Electroactive Polymer (EAP) Membranes**
P. DUBOIS, S. ROSSET, M. NIKLAUS, H. SHEA, EPFL, Lausanne, Switzerland; M. DADRAS, University of Neuchâtel, Switzerland

One of the key factors to obtain large displacements and high efficiency with dielectric electroactive polymer (DEAPs) actuators is to have compliant electrodes. Attempts to scale DEAPs down to the mm or micrometer range have encountered major difficulties, mostly due to the challenge of micropatterning sufficiently compliant electrodes. Simply evaporating or sputtering thin metallic films on elastomer membranes produces DEAPs whose stiffness is dominated by the metallic film. Low energy metal ion implantation for fabricating compliant electrodes in DEAPs presents several advantages: a) it is clean to work with, b) it does not add thick passive layers, and c) it has a limited impact on the PDMS optical transmission properties. We use this technology to fabricate DEAPs micro-actuators whose relative displacement is the same as for macro-scale DEAPs. With transmission electron microscope (TEM) we observed the formation of metallic clusters within the elastomer (PDMS) matrix, forming a nano-composite. We focus our studies on relating the properties of this nano-composite to the implantation parameters. The optimal conditions where an implanted electrode presents excellent combination of electrical conductivity and compliance corresponds to well defined implantation parameters.

A-12.1: IL09 **Conducting Polymer Actuators: Rate Limits**
J.D. MADDEN, CHI-WAH E. FOK, T. SHOA, T. MIRFAKHRAI, University of British Columbia, Vancouver, BC, Canada

Actuators that involve ion transport operate at low voltages, and can generate large stresses and strains, but are slow relative to field driven actuators and muscle. Approaches to designing materials and tailoring device geometries to enable rates to be dramatically increased are presented. Muscle relies on diffusion to operate and is faster than artificial muscle. A key reason is that ion transport in muscle is largely through a liquid medium, whereas in ionic actuators, including conducting polymers, transport is via a polymer phase, which is typically orders of magnitude slower. Creating a porous material helps speed transport and actuation by enabling ions to be transported in liquid phase for large parts of their journeys. The final insertion into the polymer phase is very quick because the transit distance is small. In situations where field within the material drives ion flux, maximizing field without damaging the sample can also lead to substantial rate enhancement. Conducting polymers and other ionic actuators behave as capacitors or batteries, so minimzing internal and contact resistance or overcoming them by applying overpotential speeds response. The design of a conducting polymer driven active catheter is used to motivate and illustrate these concepts.

A-12.1: L10 **Potential Electroactive Actuators Based on Liquid Crystalline Elastomers and Ferroelectric Nanoparticles**
V. DOMENICI[1, 2], B. ZUPANCIC[1], M. REMSKAR[1], V. V. LAGUTA[3], C.A. VERACINI[2], B. ZALAR[1], [1]Jozef Stefan Institute, Ljubljana, Slovenja; [2]Dipartimento di Chimica e Chimica Industriale, Pisa, Italy; [3]Ukrainian Acad. Sci., Inst. Problems Mat. Sci., Kiev, Ukraine

The field of nanostructured materials has been developing in a very fast and intense way[1, 2]. An interesting aspect is related to the ferroelectric and dielectric properties of inorganic materials, very promising for potential applications in constructing nanoscaled electronic and opto-electronic devices. On the other hand, soft materials like liquid crystalline elastomers can exhibit very interesting mechanical and optical properties due to the interplay between the elasticity of the polymeric network and the orientational properties of mesogenic liquid crystalline units. Insertion of individual electrically active nanoparticles in a liquid crystalline elastomeric environment has been investigated combining ferroelectric properties of nanoparticles based on titanates with the thermo-mechanical response of polysiloxane based liquid single crystal elastomers[3]. The preparation and the physical-chemical properties of these new composites is discussed in terms of new technological applications, such as electroactive actuators[4].

[1]T. Kasuga et al, Languimir, 14, 3160 (1998); [2]G.H. Du et al, Appl. Phys. Lett., 79, 3702 (2001); [3]H. Finkelmann et al, Makromol. Chem. Rapid Commun., 2, 317 (1981); [4]V. Domenici, Marie Curie Intra-European Fellowship report (2007).

A-12.1: IL11 **Tough Hydrogel - Learn from Nature**

JIAN PING GONG, HIDEMITSU FURUKAWA, Hokkaido University, Sapporo, Japan

Gel is a fascinating material for its unique properties, such as phase-transition, chemomechanical behavior, stimuli-responsiveness, low surface sliding friction, and for its possible wide application in many industry fields. Recently, hydrogels have drawn special attraction in biological field due to its possible applications as soft man-made tissues. However, conventional hydrogels, especially polyelectrolyte gels, are mechanically too weak to be practically used in any stress or strain bearing applications. Inspired by the structure of articular cartilage, we discovered a general method to obtain very strong polyelectrolyte hydrogels containing 60-90% water by inducing a double-network (DN) structure for various combinations of hydrophilic polymers. The soft and wet gel materials with both a high strength and an extremely low surface friction would find wide applications not only in industry but also in biomedical field, for example, as substitutes of articular cartilage or other bio-tissues.

A-12.1: L12 **Enhancing the Electro-mechanical Response of Maxwell Stress Actuators**

G. GALLONE, G. LEVITA, F. CARPI, F. GALANTINI, D. DE ROSSI, University of Pisa, Pisa, Italy

The need for high electric fields to drive dielectric elastomers is still retraining their diffusion as actuators in some areas of potential application, as in the case of biomedical disciplines. The development of new materials offering superior electromechanical properties is thus an essential requirement in order to effectively reduce the driving fields. In this light, the present work is aimed to enhance the electromechanical properties of two silicone and polyurethane based dielectric elastomers, both by making particulate composites with high-permittivity ceramic fillers, and by blending with a highly polarisable polymeric phase. Due to a consequent worsening of the mechanical properties, pure composite architectures yielded only limited results on the overall electromechanical response. With the blend approach, instead, both an increase of the dielectric permittivity and an unexpected reduction of the tensile elastic modulus where observed, leading to an overall increase of the electromechanical response. In any case, a key role appears to be played by the nature and intensity of polarisation phenomena arising at interfaces between different phases, as it was evidenced by results obtained on blends of the two base elastomers and on hybrid blend-composite systems.

A-12.1: L13 **Conducting IPN Fibers: A New Design for Linear Actuation in Open Air**

C. PLESSE, F. VIDAL, D. TEYSSIE, C. CHEVROT, University of Cergy-Pontoise, Cergy-Pontoise, France

In the field of electronic conducting polymer (ECP) based actuators, those presenting linear deformations are among the most promising "artificial muscles" precursors. However, even if linear ECP actuators have been widely studied when immersed in an electrolytic solution, only few linear electrochemical actuators have been described to be able to work in open air. We will present here the results obtained with a new design of ECP based actuators presenting linear deformation when operating in air. These devices have been synthesized in the shape of hollow fibers (outside diameter 3 mm, inside diameter 1 mm and length 30 to 50 mm) with Interpenetrating Polymer Networks (IPN) architecture. The poly(3,4-ethylenedioxythiophene) [PEDOT] has been chosen as the ECP and an ionic liquid (1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide) as the electrolyte. To the best of our knowledge, this is the first time that truly "one piece" conducting IPNs fibers have been used to built linear actuator working in air. These devices have already shown linear deformations above 4 % and a generated stress higher than 300 mN with operating voltages of 2 V. The synthesis, actuation characteristics and lifetime of these devices will be presented here and discussed.

A-12.1: IL14 **Ionic Polymer-metal Composite Paint**

KWANG J. KIM, IL-SEOK PARK, University of Nevada, Reno, NV, USA

This paper presents on-going research activity regarding our effort to develop Ionic Polymer-Metal Composite (IPMC) paints. The concept of making "IPMC paints" is new and can be carried out by spraying IPMC-making constituents directly onto the surface of a structure. The advantage of this type of IPMC artificial muscle/sensor is that it can be sprayed directly onto any complex structures and cured at an ambient temperature. Similar to piezoelectric paints, it is a thick-film technology. Unlike piezoelectric materials, the IPMC paints do not need poling and/or other processes to make IPMC materials active. The technique that we are currently adopted is to utilize liquid Nafion. The drying induced the recast film to be obtained but is mechanically poor (cracked and brittle) and is also easily dissolved in polar solvents, including water and alcohol. A number of answers to this problem have been thought and presented in this paper.

A-12.1: IL15 **Electromechanical Actuation of Carbon Nanotube Yarns**

T. MIRFAKHRAI[1], JIYOUNG OH[2], M. KOZLOV[2], S. FANG[2], M. ZHANG[2], R.H. BAUGHMAN[2], G. ALICI[3], G. SPINKS[3], J.D MADDEN[1], [1]University of British Columbia, Vancouver, Canada; [2]University of Texas at Dallas, Richardson, TX, USA; [3]University of Wollongong, NSW, Australia

Carbon nanotubes have attracted extensive attention in the past few years because of their appealing mechanical and electronic properties. Yarns made through spinning multiwall carbon nanotubes (MWNTs) have been reported. Here we study the application of these yarns as electrochemical actuators, and as force sensors. MWNT yarns are mechanically strong with tensile strengths reaching 700 MPa. When charge is stored in the yarns they change in length. This is thought to be because of electrostatic and quantum chemical effects in the nanotube backbones. We report strains up to 0.7%. The charged yarns can also generate current and change in voltage in response to a change in the applied tension. These properties together make them a candidate for applications such as fast sensors and actuators as well as light-weight current carriers. Electrostatic and quantum effects contributing to actuation are introduced along with the effect of the yarn geometry on actuation and contributing factors such as the effects of the electrolyte and the load are studied.

A-12.1: L16 **Electrode Reactions in Cu-Pt Coated Nafion® Actuators**

U. JOHANSON, U. MÄEORG, D. BRANDELL, A. PUNNING, M. KRUUSMAA, A. AABLOO, Tartu University, Tartu, Estonia

Composite actuators consisting of sheets of the solid polymer electrolyte (similar to Nafion®) with $Cu2+$ counter-ions inserted and coated with platinum and copper metal layers (so called Ionomeric Polymer-Metal Composites; IPMCs) have been synthesised and their electromechanical performance upon actuation has been monitored. Resistivity measurements on the electrodes show that the electrical conductivity of the membranes metal surface increases on the cathode side during the actuation process, contradictory to the situation when Cu is absent from the metal coating. This phenomenon is explained by the subsequent reduction of $Cu2+$ ions on the cathode upon actuation; Cu layer growth in this side prevents it from cracking and decreases its electrode resistance. The phenomenon opens up for longer life-times for Cu-based IPMCs.. However, additional problems with Cu layer oxidation and Cu dendrite growth on the electrodes should be considered.

Session A-12.2
Analysis, Physical Mechanisms and Characterization

A-12.2: IL01 **Finite-elasticity Models of Actuation**
G. KOFOD, University of Potsdam, Potsdam, Germany

The actuation behaviour of dielectric elastomer actuators is fundamentally non-linear. The actuation pressure due to an applied voltage, known as the Maxwell stress, is proportional to the applied voltage squared. The very large strains observed (both pre-strain and actuation strain) results in the entire stress-strain behaviour of the actuator material to influence to observed actuation. Furthermore, variations in mechanical loading will directly influence the possible actuation strain. The choice of geometry and subsequently the boundary conditions means that materials properties obtained independently, for instance through stress-strain measurements, can be employed directly to construct models, which with fair accuracy may predict the actuation behaviour of a given elastomer material. The simplicity of employing analytical modelling instead of numerical methods allows for easy manipulation of material parameters, which can then guide the search for new elastomer materials for dielectric elastomer actuators.

A-12.2: IL02 **Models for High-strain Deformation of Dielectric Elastomer Actuators**
R.M. McMEEKING, S.M.A. JIMENEZ, University of California, Santa Barbara, CA, USA

Actuators with large displacements are now fabricated from sheets of silicone having flexible electrodes attached. When an electric field is applied the electrodes attract causing the silicone rubber to thin. By volume conservation the sheets extend as much as 1000%. Such large deformations occur by elastic response, and an Ogden model is favored. Linear dielectricity is the most likely form for the electrical response, but with the permittivity matrix depending on strain, i.e. electrostriction. Such features have been assembled into a constitutive model and a finite element code that is capable of providing simulations of the deformation and the electric field. This tool is used to investigate the electrostrictive Coulombic and elastic deformations of such actuators. It enables the investigation of instabilities such as thinning necking and compressive wrinkling in the actuator. The effect of pre-stretch is also assessed including reasons why it improves the performance and electrical failure limits of devices. Actuators can also be designed with the finite element code. The simulations and the analysis enable us to suggest experiments to clarify the critical unresolved issues relating to the deformation and electric response of dielectric elastomer actuators.

A-12.2: L03 **A Model for a Thermally Induced Polymer Coil-to-globule Transition**
I.C. SANCHEZ, D. SIMMONS, University of Texas, Austin, TX, USA

A quantitative model for a thermally induced (upon heating) polymer coil-to-globule transition (CGT) is developed with no adjustable parameters. This model also yields correct qualitative trends for the more familiar CGT upon cooling. Solvent equation-of-state properties are determined via the lattice fluid model, but in principle any equation of state could be used. Calculated thermally induced CGT temperatures show good agreement with experimental lower critical solution temperatures. A qualitative phase diagram containing two CGTs is developed for a single chain. Both the low and high temperature globular states are characterized by the energetic dominance of attractive polymer self interactions over unfavorable excluded volume interactions. A single chain phase diagram is constructed that is very similar to the semi-dilute polymer branch of a two-phase, multi-chain phase diagram. This model can be easily generalized to treat cross-linked gels and their contraction-expansion characteristics. Enhancements of this model that include electrostatic interactions will be relevant for smart synthetic polymers used in biomedical applications as well as for understanding cold denaturation of proteins.

A-12.2: L04 **Monte Carlo Simulation of Electroactive Polymer Actuators**
KENJI KIYOHARA, KINJI ASAKA, AIST, Ikeda, Osaka, Japan

The electroactive polymer (EAP) actuators that have the terlamellar (anode-separator-cathode) structure show bending motion as voltage is applied between the electrodes. In order to understand the mechanism of the bending motion from the molecular interaction, we performed Monte Carlo simulations. Noting that the electrodes of the EAP actuators have porous structures, we modeled the anode and the cathode by the porous electrodes where the ions are confined in the space with the dimension comparable to the ion size. We found that significant osmotic stress arises in the porous electrodes when voltage is applied. The osmotic stress was found to be sensitive not only to the voltage but also to the ion size and the pore width of the electrodes. The asymmetric stress distribution in the EAP actuators, which is the cause of the bending motion, can be attributed to the asymmetry in ion size between the anions and the cations.

A-12.2: L05 **Dielectric Elastomer Actuators as Elements of Active Vibration Control Systems**
F.G. PAPASPIRIDIS, I.A. ANTONIADIS, National Technical University of Athens, Athens, Greece

Dielectric elastomer actuators (DEA) are a new class of actuators, exhibiting electric field-induced strains. Upon electrical stimulation they can provide large strains and concequently electrical forces. These abilities along with their high compliance make them candidates for active vibration control. This parer presents a general framework for the usage of DEA as elements of active vibration control systems. The electrical and mechanical model of the DEA and a basic control law, for varying the voltage, is reviewed. The basic idea is to reduce the acceleration of the vibrating equipment when the system approaches its equilibrium. The application of the actuator in a single-dof-mass-spring system is modeled. The results with and without control are presented and show the large capabilities of the actuator to suppress the vibrations induced by an external force. DEA has viscoelastic properties, which can further increase the damping capabilities of the vibration absorber but on the other hand produce a time delay, which must be taken into account. Furthermore, the technological issues arisen -structure of the actuator, power and equipment needs, effect of prestrain and frequency, distributed actuation- are discussed.

A-12.2: IL06 **Electrochemomechanical Actuators Touching and Sensing both, Physical and Chemical Ambient**
T.F. OTERO, Universidad Politécnica de Cartagena, Cartagena, Spain

The actuation of a natural muscle requires: an electric pulse arriving from the brain trough the nervous system, liberation of calcium ions inside the sarcomere, conformational changes of the polymeric molecules (myosin heads) stimulated by the chemical reaction and movement of water. Similar processes are involved during working processes in most of the natural organs and functions.Conducting polymers are the closer materials we have developed to those developed by nature to produce living creatures. Film of a conducting polymer used as electrodes oxidizes and reduces in presence of aqueous electrolytes, interchanging ions and water to produce a reactive gel that swells and shrinks driven by the sense of the current. This is a soft and wet material including macromolecules, water and ions. Reverse changes of volume induced by electrochemical reactions (electro-chemo-mechanical property) involves: electric pulses, water and ions interchange, conformational movements and mechanical energy. This electro-chemo-mechanical property looks quite suitable for the development of new actuators or artificial muscles very similar to those produced by nature.Any physical or chemical variable acting on the chemical reaction must change the electric potential of the electrons on the connecting metal wires. The movement rate is under control of the driving current and the muscle acts, at the same time, as a sensor of: the electrolyte concentration, the working temperature or the weight of steel pins adhered at their bottom[1]. As a consequence the muscle potential is able to sense the moment of the physical contact with an obstacle and the mechanical resistance opposed by the obstacles: is a tactile muscle[2].

[1]T.F. Otero y M.T. Cortés. Sensors and Actuators B: Chemical. 2003, 96, 152-156; [2]T.F. Otero y M.T. Cortés. Adv. Mat. 2003, 15, 279-282.
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A-12.2: IL07 **Work Behavior of Polypyrrole Artificial Muscles**
KEIICHI KANETO, HIROTAKA SUEMATSU, KENTARO YAMATO, Kyushu Institute of Technology, Kitakyushu, Japan

Conducting polymers swell and shrink upon oxidation and reduction by changing their conductivity and keeping the flexibility of polymeric

materials. The deformation is named as electrochemical deformation (ECMD) and can be utilized as soft actuators. The swelling is induced mainly by the insertion of bulky ions. The maximum strain, stress and strain rate of polypyrrole (PPy) films obtained so far are 39%, 22-34 MPa and 14%/s[1], respectively, which can be compared with those of skeletal muscles being approximately 30%, 0.4 MPa and 300%/s, respectively. Electrochemically prepared PPy film demonstrated excellent performance in the characteristics of actuation among conducting polymers. In this talk, ECDM and the work behaviors based on PPy films are reported. PPy actuators employed are based on cation and anion driven films. The cation driven PPy actuators contracted and stiffened upon oxidation with increasing the conductivity, which is similar to natural muscles. The ECMD and work behavior of cation driven PPy are discussed in terms of strain and conversion efficiency, cycle life, training effects, fatigue and aging as the functions of tensile loads and sort of electrolytes.

[1]S. Hara, T. Zama, W. Takashima and K.Kaneto, Smart Mat. Struct., 14 (2005) p1502.

A-12.2: L08 **The Coupled Energy - Density Function of Dielectric Composites in Finite Deformation Elasticity**

G. DeBOTTON[1], M. GEI[2], A. LEWINSTEIN[1], [1]Ben-Gurion University, Beer-Sheva, Israel; [2]University of Trento, Trento, Italy

One of the limitations that prevent wide-spread application of actuators based on dielectric electroactive polymers is the poor electro-mechanical coupling in typical polymers, so that a large electric field is required to produce relatively small forces and energy density. Recent experimental findings [Huang et al., Applied Phys. Lett. 84, p. 4391 (2004)] suggest that these difficulties can be resolved with the aid of composites made out of flexible matrices with inclusions of high dielectric materials. In this work, starting from the fundamental balance laws for the energy stored in the composite, and assuming that the energy-density functions for the individual phases are known, we derive an expression for the coupled macroscopic energy-density function of the composite. In a way of an example, we determine the actuation strains of a laminated composite, demonstrating that indeed these strains can be improved by considering composite dielectrics. We compare the overall response determined for these composites with the experimental findings cited above. We also compare our findings with the corresponding results of deBotton et al. [Mech. Adv. Mat. Struct. 14, p. 13 (2007)] that were determined by direct solution of the governing equations for the same class of composites.

A-12.2: L09 **Optimization of IPMC Actuators Conversion Efficiency**

P. BRUNETTO, L. FORTUNA, P. GIANNONE, S. GRAZIANI, S. STRAZZERI, Università degli Studi di Catania, Catania, Italy

IPMCs are suitable candidates to realize artificial muscles for possible autonomous applications. In such a field power budget is of great importance. The goal of this paper is to maximize the IPMC's electro-mechanical conversion efficiency in order to increase the performances of these transducers. Two different approaches were investigated to obtain this target. The first approach regards the dimensions of the adopted contacts to impose the voltage signal to the IPMC electrodes. For each free length of the IPMC actuator, it can be possible to set the size of the contacts in order to maximize IPMC energy conversion efficiency. The second approach regards the optimal frequency, amplitude, and shape to be used for the driving of the IPMC membrane. By using a novel model of IPMC actuators, the shape of the applied voltage signal that maximize the IPMC conversion efficiency was found. More specifically the amplitude of the first ten harmonics of the IPMC driving signal was determined, for different constrains such as the minimum output power, the maximum input power, and the maximum input voltage. The manuscript will report about the proposed IPMC model, the optimization algorithm, the optimal driving signals, and the experimental validation of the approaches.

A-12.2: L10 **Tuneable Membrane for Electromagnetic Devices Using Dielectric Elastomers**

C. BOLZMACHER, K. BAUER, EADS Innovation Works, Munich, Germany; M. HAFEZ, Commissariat à l'Energie Atomique, Fontenay aux Roses, France; H. SEIDEL, U. SCHMID, Saarland University, Saarbrücken, Germany

The amplitudes of miniaturized electromagnetic actuators are clearly enhanced if the membrane eigenfrequencies are used for actuation. However, the bandwidth for such operation is very limited. This can be overcome to some extent by employment of membranes with electrically tuneable stiffness. In this context we experimentally investigated membranes of dielectric elastomer (DE) materials and present experimental results to following points: The tuning range for the membrane eigenfrequencies for different material types (acrylic and silicone based DEs) depending on mechanical prestress and electric activation voltage of an application typical membrane size. The visco-elastic properties of the membranes for the above materials under cyclic electric loading for different levels of mechanical prestress are given. The parameters for the stiffness and viscoelasticity are derived from the experimental data by using the Kelvin-Voigt-Model and integral models. This allows us to extrapolate the membrane properties to different parameters of the electromagnetic micro actuator. Apart from this configuration the combination of tuneable membranes with other actuation technologies are given.

A-12.2: IL11 **Synthesis and Characterization of Electro-thermally Sensitive Gels**

K.-F. ARNDT, A. RICHTER, S. KLATT, G. PASCHEW, Technical University of Dresden, Dresden, Germany

Stimuli-sensitive hydrogels change their properties in dependence of a liquid environment. Widespread used smart gels take advantages of the volume phase transition induced by a change of temperature. For application, e.g. in MEMS, an easy and controlled stimulation of volume phase transition is required. The degree of swelling (Q) and therefore the dimension of gel structures are determined by temperature. It is possible to regulate Q to a predetermined value by heating/cooling. The temperature of volume phase transition depends on the interaction between gel and solvent. For a gel with defined chemical structure it can be changed by the composition of swelling agent. Thermal energy inside a gel-based device can be easily generated and regulated by incorporated heating resistors and temperature sensors. Different structures (micro-spheres, pads, patterned layers) of smart hydrogels (PNIPAAm, PVME, PAS) are applied. The switching between two swelling degrees is induced by changes of temperature or by changing the environment. On example of gel-based micro valves, sensors, sensor arrays, pumps, and chemostats (concentration control of chemical substances) the sensor-actuator properties and advantages of this group of polymers are discussed.

A-12.2: IL12 **Distributed Impedance Model of Ionic Polymer-metal Composite Actuators**

KENTARO TAKAGI, KINJI ASAKA, GOU NISHIDA, YOSHIHIRO NAKABO, ZHI-WEI LUO, RIKEN, Nagoya, Japan

This paper discusses the modeling of the electrical impedance of ionic polymer-metal composites (IPMCs) from the point of view of the frequency response. It is well known that the electrical impedance of an IPMC is capacitive. However, we found that its frequency response cannot be approximated by a simple ideal capacitor or even by low-order transfer functions. From the observation of the frequency response especially in the case of TEA ion, the bode diagram of the gain slope and the phase properties are about -0.5(-10[dB/dec]) and about -45[deg], respectively. This experimental observation implies that the impedance is appropriate to be modeled as a non-rational transfer function. One of such models is a distributed circuit (transmission line) whose transfer function consists of the square root of 's'. This distributed circuit model is represented by a diffusion-like equation. Furthermore, interestingly, a fractal electrode model for the rough electrodes can be regarded as a special class of the distributed circuit whose elements are not spatially uniform. In the experiment, the electrical impedance of an IPMC is measured under various conditions. The parameter identification of the model is also discussed using the experimental data.

A-12.2: L13 **A Distributed Electromechanical Model of Ionomeric Polymer Metal Composite (IPMC)**

A. PUNNING, U. JOHANSON, M. ANTON, M. KRUUSMAA, A. AABLOO, University of Tartu, Tartu, Estonia

We present a novel model of an IPMC (Ionomeric polymer metal composite). IPMC is modeled as a distributed RC transmission line. Unlike other electromechanical models of an IPMC, the distributed nature of our model permits to model the non-uniform bending of the material. Instead of modeling the tip deflection or uniform deformation of the material, we model the changing curvature. The analytical model is shown to be consistent with the experimental results. We also demonstrate that this analytical model can be used to determine the optimal configuration of the sheet. From the described model we finally derive a more elaborate model that also considers the non-linear parameters of the sheet during bending.

Session A-12.3
Devices and Applications

A-12.3: IL01 **Multilayer Actuator and Sensor Sheets with Smart Compliant Electrodes**
P. SOMMER-LARSEN, K. HANSEN, Risoe National Laboratory, Roskilke, Denmark; M. BENSLIMANE, Danfoss A/S

Dielectric elastomer actuators with smart compliant electrodes (DESCE) combine position sensing and actuation in one macroscopic and mechanical uniform structure. The DESCE is a rubber band capable of extending upon application of an electrical potential, and at the same time allow for measurement of the extension. Compared to other smart materials and structures, the DESCE is second to only piezoelectric ceramics in this respect. A DESCE is a sheet of silicone elastomer actuator with microstructured electrodes on both sides. Such sheets may be used either as actuator upon application of a potential or as sensor by measuring the capacity of the film. We have assembled such sheets to form a multilayer actuator. One sheet is used as sensor and the others as actuators. The talk will describe performance and use of such actuators for control applications as well as their potential for use in space applications. That latter part was investigated in a project on Electroactive polymer actuators for the European Space Agency (ESA). The primary application considered is vibration damping of large lightweight structures in space. Basic materials properties as well as performance under space environment - vacuum, temperature, and radiation stability - will be discussed.

A-12.3: L03 **Bio-inspired Distributed Electroactive Polymer Actuators for Future Space Applications: Concept Design**
F. CARPI[1], C. MENON[2], D. DE ROSSI[1], [1]University of Pisa, Pisa, Italy; [2]Simon Fraser University, Burnaby, Canada

Technologies for space applications are often considered to be rather conservative, aimed at ensuring reliability and robustness. Nevertheless, novel concepts coming from research activities have been and are always the lymph for the development of successful and competitive new solutions. This paper presents new concepts and ideas inspired by natural systems with distributed actuation embedded in their structure, considered as ideal models for possible uses in space applications. Preliminary concepts for possible technical solutions for long-term future implementations are here proposed and briefly analyzed. Peristaltic-like actuations obtained by the use of dielectric elastomer actuators is proposed as one of the most promising solutions. Experimental performances of a single actuation unit are here presented and directions for future implementations are proposed.

A-12.3: L04 **Contractile and Buckling Actuators Based on Dielectric Elastomers: Devices and Applications**
F. CARPI, G. FREDIANI, A. MANNINI, D. DE ROSSI, University of Pisa, Pisa, Italy

Dielectric elastomer (DE) actuators are able to typically show significant electromechanical performances, which make this electroactive polymer technology particularly attractive for so-called 'artificial muscle' devices. This paper deals with two types of DE actuators recently developed in our lab. The first type is represented by the so-called 'folded actuators', based on a simple configuration suitable to easily implement linear contractile devices. The structure consists of a monolithic electroded sheet of elastomer, which is folded up and compacted; the resulting contractile actuator is functionally equivalent to a multilayer stack with interdigitated electrodes, but can be manufactured more easily. The second type of devices is represented by the so-called 'buckling actuators'. They operate with out-of-plane unidirectional displacements of an elastomer membrane. This paper describes the structure and the properties of both these actuators, along with different examples of applications currently being developed in our lab for the biomedical, the robotic and the space fields.

A-12.3: IL05 **Variable-stiffness-mode Dielectric Elastomer Devices**
R. PELRINE, SRI International, Menlo Park, CA, USA

Dielectric elastomers are a relatively new class of materials for variable-stiffness and variable-damping devices. Dielectric elastomers (DEs) offer significant potential advantages compared with previous variable stiffness smart materials including simplicity, broad dynamic range, ability to reach zero stiffness, low cost, minimal mass, shock tolerance, simple drive circuitry, and design flexibility. DE devices in the variable-stiffness mode convert electrical and mechanical energy back and forth to change mechanical impedance. This type of electromechanical transduction distinguishes the variable stiffness mode from simply using a DE actuator to alter the geometry, and hence the stiffness, of the device. Stiffness using a variable-stiffness mode depends heavily on the electrical loading of the DE material. Analysis shows that a constant voltage loading reduces stiffness, down to zero in some cases, while a constant charge loading increases stiffness. Many applications can be considered for DE variable-stiffness mode such as vibration control, suspensions, and tuning consumer devices for user comfort or preference. As with DE actuators and generators, silicones and acrylics are the most promising materials for variable-stiffness-mode DE devices.

A-12.3: IL06 **EAP Nanofibers for Biomedical Applications**
SEON JEONG KIM, Hanyang University, Seoul, Korea

Electroactive polymer (EAP) nanofibers have potential applications as bio-nano sensors, artificial muscles, drug delivery systems, and scaffolds in biomedical areas. Electrospun nanofibers have been often produced forming helical or coiled structures that are randomly oriented on a metal or semi-conducting collector. However, many biomedical applications require aligned or other type nanofibers because nanofibers are accompanied by patterned electrodes fabricated for transporting electrons, or are designed as polymeric components for artificial muscles and actuators with axially improved strength in chemical and electrical stimuli. Therefore, it is important to control the shape and alignment of the nanofibers and elucidate their controlled mechanism. We fabricated polymer nanofibers containing bimolecular ferritin nanoparticles exhibited the enhancement of elastic modulus as compared to pure nanofibers due to chemical interactions between the ferritin and the polymer matrix. The elastic modulus of the nanofibers was measured using a three-point bending test employing an atomic force microscope (AFM). To improve the reliability of the AFM measurements, uniform nanofibers were oriented linearly on an AFM calibration grating by introducing parallel subelectrodes in an electrospinning system. The composite nanofibers reinforced by ferritin are applicable as artificial muscle system.

A-12.3: IL07 **Electroactive Polymer - Overcoming the Obstacles to Real Products**
C. DUNCHEON, Artificial Muscle, Inc., Menlo Park, CA, USA

Electroactive Polymer Artificial Muscle (EPAMtm) represents the first true technological breakthrough in the $50b+ actuator market since the invention of the electric motor. SRI International recognized the commercial potential for its patented developments in EPAMtm and granted a broad exclusive license for EPAMtm to Artificial Muscle, Inc. in 2003. Over the past five years AMI has overcome mutiple challenges in the creation of EPAM-based products. This paper addresses these obstacles including but not limited to: - Development of a materials qualification process; - Creation of a platform for the technology that expedited materials qualification, product application qualification, product design, product testing, and manufacturing process development; - Optimization of materials, the manufacturing process, and power supply design to reduce operating voltages and minimize power supply size and cost; - Development of an automated manufacturing process to minimize cost and increase product reliability and performance consistency; - System level optimization of materials and electronics to address growing environmental challenges with clean-tech applications ranging from energy efficient valves to sea wave energy harvesting.

SYMPOSIUM B

Smart Optics

Session B-1
Smart Optical Materials

B-1.1 Spectrally Active Materials and Devices

B-1.1: IL01 **Semi-metallic Materials for Spectral Variation**
SANG H. CHOI, NASA Langley Research Center, Hampton, VA, USA; YEONJOON PARK, National Institute of Aerospace, Hampton, VA, USA

The purpose of investigation is to develop the fundamental materials and fabrication technology for field-controlled spectrally active optics that are essential for industry, NASA, and DOD applications such as: membrane optics, filters for LIDARs, windows for sensors and probes, telescopes, spectroscopes, cameras, light valves, light switches, flat-panel displays, etc. The proposed idea is based on the materials tailored with quantum-dots (QD) array, thin-film of field-sensitive Stark and Zeeman materials, or the bound excitonic state of organic crystals that will offer optical adaptability and reconfigurability. To see the benefits of quantum-confined Stark effect, semi-metallic materials doped with rare earth elements were developed and tested with electric field injection. The scandium nitride is a semi-metal as a base material and doped with rare earth element to show spectral shift or refractive index shift according to applied fields. Other dopant materials were also considered to discover the same aspect of shifts in spectrum and refractive index. The efforts are continued to develop the demonstration materials and their database for field-controlled spectrally smart active optics (FCSAO) on a selected spectral range.

B-1.1: IL02 **Advances in All-solid-state Switchable Mirror Devices**
K. YOSHIMURA, K. TAJIMA, Y. YAMADA, AIST, Nagoya, Japan

We have developed and demonstrated the all-solid-state switchable mirror as a new electrochromic device. This device changes its optical property reversibly from a reflective state to a transparent one as a result of hydrogenation and dehydrogenation of magnesium-nickel alloy thin film by applying voltage. Our all solid state device is based on the multi-layer structure of Mg-Ni/Pd/Ta2O5/WO3/ITO/glass. Each material of Mg-Ni, Pd, Ta2O5 and WO3 in the device plays optical switching, proton injector, solid electrolyte and ion storage, respectively. The switching response is about 20 sec between 0.1% (reflective state) and 45% (transparent state) in transmittance at 670 nm, and it can be repeated more than 2000 cycles. The preparation condition of Ta2O5 layer is crucial to obtain the device with high performance. We also have succeeded in preparation of a switchable mirror device on a transparent sheet of PEN, and realized a 'flexible switchable mirror sheet'. This technique enables us to widen the application field of switchable mirror as well as to reduce the production cost.

B-1.1: IL03 **Hydrogen-driven Switchable Mirrors**
R. GRIESSEN, B. DANN, H. SCHREUDERS, M. SLAMAN, VU University, Amsterdam, The Netherlands

Hydrogenography[1] is a completely new optical high throughput technique for the search and optimization of thin films for specific applications involving ab- and desorption of hydrogen. It makes it possible to measure simultaneously a huge number (thousands) of samples of different elemental compositions on only one wafer. This enormously facilitates the search for new metal-hydrides with specific switchable physical properties. I describe how Hydrogenography is used to optimize black switchable mirrors. These mirrors exhibit a reversible transition between shiny metallic and a strongly absorbing state at moderate hydrogen content. They offer interesting possibilities for applications as fiber optic hydrogen sensors (for fast hydrogen multisensing in cars), smart solar collectors and variable reflectance rear-view mirrors. Quite amusingly the same Mg-Ti-H system seems to have optimal properties for these three applications. In addition Mg-Ti-Ni-H alloys have promising hydrogen storage properties. Hydrogenography is also of great help in the search and optimisation of the catalytic layer covering switchable mirrors, which determines to a large extent the response time of a hydrogen driven device/sensor.

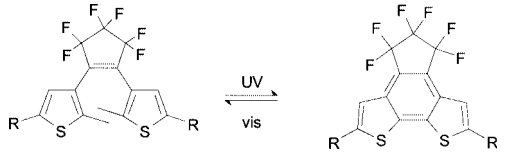
[1]*R. Gremaud et al, Advanced Materials 19 (2007) 2813-2817*

B-1.1: L04 **Towards Electrochromic Devices Active in the Infrared Region**
K. SAUVET[1, 2], L. SAUQUES[2], A. ROUGIER[1], [1] Laboratoire de Réactivité et Chimie des Solides, Amiens, France; [2] DGA, Délégation Générale pour l'Armement-CEP, Arcueil cedex, France

In the past few years, electrochromic devices, which show change in their optical properties under applied voltage, have received a great attention in respect of their promising potential in the defence area. In particular, the preparation of coatings for vehicles and persons, which would be able to blend into their surrounding under an external stimulus and, therefore become invisible to an infrared camera is highly desirable. Such property requires an electrochromic device, with a good memory, and which rapidly and reversibly switches from 80 to 40% in infrared emissivity in particular in the atmospheric transmission windows called the MW band (mid-wavelength 3-5 µm) and LW band (long wavelength 8-12 µm). In this presentation, all-solid-state devices will be suggested in respect of the position and the thickness of the WO3 electrochromic layer. Based on a combination of experimental and modelling approaches, the choice of the counter electrode as well as of the electrolyte will be particularly discussed in respect of the highest contrast in reflectance in the IR region of the full WO3 based electrochromic devices.

B-1.1: L05 **Realization of Photochromic-polymeric Films for Optical Applications**
A. BIANCO[1, 2], C. BERTARELLI[2], G. DASSA[2], G. TOSO[2], G. ZERBI[2]; [1] INAF-IASF, Istituto di Astrofisica Spaziale e Fisica Cosmica, Milano, Italy; [2] Politecnico di Milano, Milano, Italy

Photochromism is a reversible chemical transformation which is induced at least in one direction by an electromagnetic radiation between two molecular states with different chemical structures, thus showing two different absorption spectra. Organic photochromic materials have attracted great interest for their possible use in rewritable optical devices. Among all the applications, we focused our attention on the realization of *Holographic Optical Elements* (*HOEs*) whose function is based on the modulation of refractive index of the photochromic materials.



Diarylethenes are an interesting class of photochromic materials since they undergo thermally irreversible photochromic process with high sensitivity and fast response. Moreover, we have demonstrate that it is possible to modulate the variation of the *refractive index* (Dn) between the two state acting of the chemical structure. This property is a fundamental requirement to obtain efficient HOEs. In order to achieve large modulation of the refractive index, we synthesized new photochromic polymers belonging to the class of polyesters and polyurethanes which show good photochromic properties (i.e. conversion, thermal stability, thermal irreversibility) and good processability. The films based on photochromic polyesters show a large modulation of the refractive index (i.e. $\Delta n = 0.02$ measured at 1500 nm by using spectral ellipsometry) which is large enough to realize diffraction elements for NIR. Using such material we realized the first rewritable VPHGs (*Volume-Phase Holographic Gratings*).

B-1.1: L06 **Infrared Thermal Properties of RNiO3 Compounds**
C. NAPIERALA, Université François Rabelais, IUT Blois, and Centre d'Expertise Parisien, DGA, Arcueil, France; M. EDELY, Université du Maine, France; P. LAFFEZ, Université François Rabelais, IUT Blois, France; L. SAUQUES, Centre d'Expertise Parisien, DGA, France

The RNiO3 compounds (R= rare earth) exhibit a sharp metal insulator transition whose temperature depends on the composition. In the infrared range, this transition is characterized by an abrupt switching in infrared transmittance from opaque to transparent according to the temperature. This property is likely to result in a strong contrast in emissivity provided absorbance also varied. Such property presents a great interest for the infrared furtivity. Previous studies have synthesized thin films of these compounds by RF sputtering and annealing under oxygen pressure. The aim of this study is to validate these materials for the infrared furtivity and using them like active pigments. Consequently, we undertook the study of the synthesis of submicronic particles prepared by a modified sol-gel method. The X-rays diffraction, optical spectroscopy and scanning electron microscopy are used to evaluate the quality of the powders and to correlate their optical and structural properties. Some preliminary results are presented.

B-1.1: L07 **SmxNd1-xNiO3 Thin Films with Tunable Emissivity Coating**
P. LAFFEZ, C. NAPIERALA, Université F. Rabelais de Tours, Blois France; M. EDELY, S. GOUJON, Université du Maine, Le Mans, France; L. SAUQUES, Centre d'Expertise Parisien, Arcueil, France

The reversible metal insulator phase transition of SmxNd1-xNiO3 is associated with strong changes in electrical, magnetic and infrared properties. In this work, Infrared Transmittance and emissivity of Sm1-xNdxNiO3 thin films are measured at diffrent temperature. Emissivity versus temperature shows a sharp transition at the metal insulator transition. By comparing thermal images of the sample with a constant reference, we show that SmxNd1-xNiO3 is a candidate for infrared thermal coating.

B-1.1: L09 **Self-supported Electrochromic Devices Based on Interpenetrated Polymer Network: A Novel Competitive Monoblock Architecture**
P. VERGE, P.H. AUBERT, F. VIDAL, L. BEOUCH, F. TRAN-VAN, DE TEYSSIÉ, C. CHEVROT, Université de Cergy-Pontoise, Cergy-Pontoise, France

The low manufacturing cost, faster commutation rates and possibility of carrying out flexible devices offers the possibility to use Electronic Conducting Polymers (ECPs) as an alternative solution toward inorganics for the construction of electrochromic devices. In an attempt to design a very simple device, we have investigated the possibility to mix apoly(3,4-ethylenedioxythiophene) (PEDOT) in a poly(ethyleneoxide) (PEO) network in order to obtain a free standing and one-piece material. The system is similar to a layered device with the advantages that (i) it can work using only one ECP (ii) the intimate combination of the PEO Solid Polymer Electrolyte (SPE) and the ECP on each side of the film increases tremendously the interface and requires no adhesion process and (iii) the ECP, used as the electroactive layers can also serve as current collectors. In such configuration, the transparent electrodes are not required and the device exhibit tunable infrared signature in a reflective mode. The visible and NIR-MIR charactarization of the devices have been performed (spectroelectrochemical, transmissive and reflective properties) as well as their performances such as optical contrast, switchability, memory effect and stability. An overview of these results will be presented.

B-1.2 Functional Materials and Liquid Crystals

B-1.2: IL01 **Advances in Nanostructured Holographic Polymer-Dispersed Liquid Crystals**
L.V. NATARAJAN[1, 2], V.P. TONDIGLIA[1, 2], T.J. WHITE[1, 3], P.F. LLOYD[1,4], J. WOFFORD[1, 5], R.P. SUTHERLAND[1, 2], T.J. BUNNING[1], [1]Air Force Research Labs, RX, Wright Patterson Air Force Base, OH, USA; [2]Science Applications International Corporation (SAIC); [3]General Dynamics Information Technology (GDIT); [4]UES, Inc.; [5]SOCHE

Holographic polymer dispersed liquid crystals (HPDLCs) are a polymer/liquid crystal composite with wavelength selective diffraction that can be turned on and off in microseconds with application of an electric field. Due to their dynamic capabilities, HPDLCs have been examined for optical or photonic devices such as optically switchable Bragg reflectors, distributed feedback elements, active photonic bandgap materials, and display devices. Recently, HPDLC performance has been significantly enhanced by switching from acrylate to thiol-ene based polymer chemistry. This work summarizes our recent effort towards developing and enhancing the performance of HPDLCs based on thiol-ene polymer, mostly focusing on the formation of near-IR reflection gratings in visible-light initiated systems and the application of an in situ shear technique. Recent results regarding the use of holographic photopolymerization to stabilize cholesteric liquid crystal materials will also be reported. At optimized conditions, stabilizing CLC materials with holographic photopolymerization increased clear state transmission by 20% and reduced switching voltage by 3 V/um as compared to an analogous floodlit irradiated sample.

B-1.2: L02 **New Class of Highly Conjugated Nanomotors: Catenanes and Rotaxanes as Potential Candidates for Nonlinear Optical Applications**
R. CZAPLICKI, Z. ESSAIDI, F. KAJZAR, B. SAHRAOUI, University of Angers, Angers, France

The wide part of research is focused on design and synthesis of new addressable, functional molecules for use in different types of applications. The rotaxanes are a new class of functional organic molecules, designed for use in various types of practical applications, particularly in switching. They have been proposed as nanoscale devices such as switchable molecular brakes, shuttles, ratches and electronically configurable logic gates. Theirs architectures are very attractive because the components of molecule are held together by a dynamic mechanical bond which can be controlled at the molecular level by external stimulation. The different degrees of freedom of movement present in these molecules are expected to contribute significantly to the cubic susceptibility.

B-1.2: IL03 **Coordinating Superaromatic Ligands: Synthetic and Photophysical Considerations**
S. DRAPER, University of Dublin, Dublin, Ireland

N-heterosuperbenzenes (N-HSB) are a new family of aromatic fluorescent molecules. As nanomaterials they possess a highly desirable set of physical and opto-electronic properties. The founding member of the family, tetra-peri-(tert-butyl-benzo)-di-peri-(pyrimidino)-coronene 1 is formed by a versatile synthetic route which has allowed for the generation of a further set of N-heteroaromatic compounds. The extensive electron delocalisation and the readily available low lying pi* orbitals of this type of N-doped graphene render them uniquely electron-accepting. The recent isolation of N-½HSB and N-$^2/_3$HSB has provided another generation of N-HSB systems for spectral comparison. All show tunable, pH and solvent dependent, fluorescence and differing degrees of aggregation in solution as a function of the planarity of their aromatic platform. The potential of the ortho N-atoms in these compounds to provide a bidentate coordination site has been realised in the formation of Ru(II) and Os(II) homo and heteroleptic complexes. Metal complexation reveals a tantalising array of spectro-electrochemical properties. [Ru(bipy)2(1)](PF6)2 exhibits an exceptionally low energy 1MLCT absorption (615nm) and an associated 3MLCT emission (880 nm). It is a black-absorber and near IR emitter.

B-1.2: IL04 **Domain Reversal Patterning of Nanoscale Structures in Lithium Niobate**
P. FERRARO, S. GRILLI, CNR, Pozzuoli, Napoli, Italy

Domain engineering in ferroelectric crystals is an increasingly important technique for applications in areas such as nonlinear optics for quasi-phase-matching interactions. Fabrication of periodically poled lithium niobate (PPLN) continues to attract interest, and most efforts have been devoted to one-dimensional and two-dimensional 2D-PPLN crystals. Eelectric field overpoling is used in combination with two-dimensional resist gratings exhibiting modulated topography and obtained by moiré interference lithography. The technique allows one to fabricate shallow submicron domains with lateral size and depth modulated according to the resist profile. Simulations of the electric field distribution in the crystal, in this specific poling configuration, are performed to interpret the mechanism leading to the formation of those surface domains. The results show that in principle complex domain structures could be designed for applications in the field of photonic crystals.

B-1.2: IL05 **Ferroelectric and Mesoscopical-Magnetic Properties of All-organic Chiral Nitroxide Radical Liquid Crystals**
R. TAMURA, Kyoto University, Kyoto, Japan

Paramagnetic liquid crystals have attracted great interest as soft materials to enhance the effect of magnetic field on the optical and electrical properties of liquid crystals. Particularly, paramagnetic calamitic liquid crystalline (LC) compounds with magnetic and electric orders are extremely attractive with respect to the development of ferromagnetic LC materials and the exhibition of hitherto-unknown magnetoelectric coupling in the ferroelectric LC state. With a view to obtaining a series of paramagnetic, all-organic, calamitic chiral LC compounds that can exhibit various stable LC phases with low viscosity, we have successfully prepared prototype LC compounds 1, which contain a chiral cyclic-nitroxide unit in the mesogen core and show chiral (or achiral) LC phases such as N* (N) and SmC* (SmC)[1]. Here I talk about 1) the molecular design, synthesis, and characterization of both racemic and 2S,5S-enriched LC compounds 1 and 2) their ferroelectric and magnetic properties on the basis of their magnetic susceptibility data measured on a SQUID magnetometer and their variable temperature EPR spectral data, and show 3) the response behavior of the LC grains of 1 on water to a weak permanent magnet (0.5 T).

[1]N. Ikuma et al, Angew. Chem. Int. Ed. 2004, 43, 3677; N. Ikuma et al, Adv. Mater. 2006, 18, 477; N. Ikuma et al, Ferroelectrics 2006, 343, 119; Y. Noda et al, J. Phys. Chem. B 2006, 110, 23683.

B-1.3 Light Emitting Materials

B-1.3: IL01 **Characterization and Control of Recombination Dynamics in Low-dimensional InGaN-based Semiconductors**
Y. KAWAKAMI, A. KANETA, M. FUNATO, Kyoto University, Kyoto, Japan; Y. NARUKAWA, T. MUKAI, Nichia Corporation, Tokushima, Japan

We have recently proposed the re-growth technique, where c-oriented (0001) GaN is used as a seed, where the growth on GaN templates patterned with a striped geometry along the [1-100] direction form (0001), <11-22>, and <11-20> facets. We found that the InGaN/GaN QWs on the <11-22> semipolar facets show higher photoluminescence (PL) efficiency, compared with conventional (0001) QWs. Consequently, nanoscopic optical characterization was performed on <11-22> microfacet QWs using scanning near field optical microscopy (SNOM). Unlike the phenomena observed in (0001) QWs, there is not a difference between the PL spectra acquired under the illumination-collection and illumination modes, which indicates that the carrier diffusion length in the <11-22> QW is less than the probing fiber aperture of 160 nm due to a much faster radiative recombination processes as a result of a well-reduction of internal electric field. The correlation between IQE and emission wavelength shows that the highest internal quantum efficiency (IQE) is approximately 50% at 520 nm, which is about 50 nm longer than in (0001) QWs, suggesting that the <11-22> QW is a suitable green emitter. Moreover, tailored emission color synthesis has been achieved using the combination of microfacet QWs without phophors.

B-1.3: IL02 **Nano-engineering of III-nitride Semiconductor Optoelectronics and New Applications**
N. TANSU, R.A. ARIF, YIK-KHOON EE, HONGPING ZHAO, HUA TONG, M. JAMIL, G.S. HUANG, Lehigh University, Bethlehem, PA, USA

High-performance III-Nitride light emitting diodes (LEDs) and laser diodes emitting at 450-550-nm have applications for display, DVD, medical, and solid-state lightings. In this work, we present approaches for achieving high-efficiency III-Nitride LEDs and lasers, in particular the solutions related to: 1) low radiative efficiency from the polar InGaN QW, 2) large dislocation density in GaN on sapphire and Silicon substrates, 3) challenges in achieving high light extraction efficiency of III-Nitride LEDs. The existence of the spontaneous and piezoelectric polarization field inside III-Nitride materials result in significantly reduced radiative efficiency and optical gain, in particular for devices emitting in the green (535-nm) regimes. Extensive experimental and theoretical studies on nanostructure engineering of novel III-Nitride active regions with significantly-enhanced radiative recombination rate and optical gain will be presented, using 1) type-II InGaN-GaNAs QWs, 2) staggered InGaN QWs, and 3) self-assembled InGaN quantum dots. The experiments showed good agreement with theory. The current transport and its impact on LEDs efficiency will be addressed. Novel approaches for addressing light extraction efficiency and dislocation density reduction will also be presented.

B-1.3: IL03 **Efficiency Limiting Processes in Semiconductor Lasers: Challenges and Solutions**
S.J. SWEENEY, University of Surrey, Guildford, UK

Since their invention over 40 years ago, semiconductor lasers have become a pervasive technology forming the backbone of many technological developments such as optical communications and data storage. There have been several advances in semiconductor laser technology but there remain many challenges, most notably to minimise the “threshold current” above which the lasers operate, and the extent to which it, and the overall device efficiency, vary with temperature. The talk will address the importance of understanding and manipulating semiconductor band-structure and controlling the interactions of carriers and photons in semiconductor lasers. The extent to which new photonic materials such as quantum dots and “dilute” nitride semiconductors offer the possibility of improved device performance will be discussed. Particular attention will be placed on developments in the near infra-red region of the electromagnetic spectrum, key for optical communications where materials such as InAs/GaAs-based quantum dots and GaInAsN/GaAs-based quantum wells are being used to make more thermally stable lasers. Finally, the challenges for developing semiconductor lasers to exploit mid-infrared wavelengths which are key to the future of communications, sensing and security will be discussed.

B-1.3: IL04 **Glass Microspherical Lasers**
G. NUNZI CONTI, S. SORIA, Centro Studi e Ricerche "E. Fermi", Roma, Italy; S. BERNESCHI, M. BRENCI, S. PELLI, G.C. RIGHINI, IFAC-CNR, Sesto Fiorentino (FI), Italy; C. ARMELLINI, A. CHIAPPINI, A. CHIASERA, Y. JESTIN, M. FERRARI, IFN-CNR, Trento, Italy; L. GHISA, P. FÉRON, ENSSAT, Lannion, France

In dielectric microspheres light can be confined in “Whispering Gallery Modes” (WGMs) by continuous total internal reflections at the cavity surface, and a unique combination of strong temporal and spatial confinement of the light can be achieved. High Q factors and small mode volumes make WGMs cavities of great interest for the investigation of fundamental processes in quantum or nonlinear optics as well as for applications in photonics and sensing. In particular compact and efficient laser sources with intrinsic low lasing threshold and narrow linewidth can be implemented using microspherical resonators based systems. A short overview of recent works on rare earth doped and Raman WGMs lasers is presented. Then we focus on our experimental results on the laser properties of microspheres fabricated in different erbium doped oxide glasses and on the effect that the fabrication process has on the spectroscopic characteristics of the doped microcavities. A study of spherical glass microcavities combining active and photorefractive properties is also proposed. Finally we present a detailed investigation of silica microspheres coated with film of erbium doped sol-gel as well as of erbium activated monolithic microspheres fabricated by acid catalysed sol-gel route.

B-1.3: L05 **Structural and Spectroscopic Assessment of Er3+-activated SiO2-HfO2 Glass Ceramics Planar Waveguides**
L. MINATI[1], G. SPERANZA[1], V. MICHELI[1], C. ARMELLINI[2], A. CHIAPPINI[2], A. CHIASERA[2], Y. JESTIN[2], M. FERRARI[2], R. RETOUX[3], G.C. RIGHINI[4,5], [1]FBK-IRST, Povo, Italy; [2] CNR-IFN, Povo-Trento, Italy; [3]ENSICAEN, Caen, France; [4]CNR, Roma, Italy; [5]IFAC - CNR, Sesto Fiorentino (FI), Italy

xHfO2 - (100-x) SiO2 (x=10, 20, 30 mol%) glass-ceramics planar waveguides doped with 0.3 mol% Er3+ ions prepared by the sol-gel route and heat treated at 1000 °C to nucleate HfO2 crystals were analyzed by X-ray photoelectron spectroscopy, X-ray diffraction, high resolution transmission electron microscopy and photoluminescence spectroscopy. Formation of tetragonal HfO2 nanocrystals is detected in all samples, although the presence of interconnected SiO2 and HfO2 rich phases is indicative of a spinodal decomposition mechanism. The extent of this process wields a control on the crystals mean dimensions. The study of the degree of crystallization in these samples is important for photonic applications being the PL spectra line width very sensitive to the environment of the erbium ions. The aim of our work is to correlate structural and chemical information obtained by the different techniques used with the optical response of the devices.

B-1.3: L07 **Rhodamine 6G Encapsuled Mesoporous Silica Channels**

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We report the effect of pore size and solvent on the rhodamine 6G encapsuled into channels of mesoporous silica, synthesized by two-step process that gives intermediary stable hybrid micelles. Mesoporous materials have been obtained by the method that involves surfactant micelles and inorganic precursor of the structure to be obtained. MSU-X type mesoporous silica has been synthesized with polyethylene oxide surfactant as the directing-structure agent and tetraethyl orthosilicate as the silica source. The influence of pore size and the solvent on the encapsulation of rhodamine dye was systematically explored, specially its influence on the luminescence properties. Rhodamine 6G encapsuled into mesoporous silica channel was characterized by UV-Vis and luminescence spectroscopies, thermogravimetric analysis and elemental analysis. The pore size and the solvent effects into luminescence dye encapsuled into mesoporous silica channels are observed in the visible absorption and emission spectra of rhodamine 6G. The intense photoluminescence band of rhodamine 6G dye is in 500 to 600 nm region. The observed shift of the absorption and emission bands can be assigned to the effect of the solvents dielectric constant and pore size of mesoporous silica.

B-1.4 Metamaterials, Composite and Hybrid Materials

B-1.4: IL01 **Low Dimensional Composite Nanomaterials: Theory and Applications**

A. QUANDT, University of Greifswald, Greifswald, Germany

One- or two-dimensional nanomaterials are characterized by ballistic electron transport, i.e. the coherence length for electronic wavefunctions is much longer than the system sizes. Therefore these electron wavefunctions might be seen as one-dimensional or two-dimensional analogues of scalar optical wavefunctions, and many of the technological concepts known from photonic materials should have direct applications in the case of electronic nanomaterials as well. We will illustrate the theoretical background for these analogies, and point out some interesting applications. Then we will show how to obtain the necessary basic materials for such a technology by presenting a number of novel one- and two-dimensional nanomaterials similar to carbon nanotubes and graphene, but with rather different materials properties. In this context, we will also analyze the corresponding cluster chemistry, and show how it leads to nanomaterials with structural or electronic properties unknown for their standard bulk counterparts. Finally we will present recent results from an exemplary ab initio study of two-dimensional metamaterials based on carbon and boron nanomaterials, as a first step to create low dimensional nano-sized electronic devices inspired by photonics.

B-1.4: IL02 **Planar Photonic Metamaterials**

N. ZHELUDEV, University of Southampton, Southampton, UK

Regular patterning of thin metal films on the sub-wavelength scale can yield a range of functionalities invaluable for nanophotonic application. This includes mimicking the properties of conventional bulk media such as anisotropy and girotropy. However, most importantly nanoscale patterning can lead to new functionalities, not available in natural materials. This includes the stop bands and narrow resonances with strong dispersion analogues to that of the EIT media, invisibility and optical frequency superconductor behaviour. Nano-structured films can enforce asymmetry of light's propagation in the opposite directions and create sub-wavelength far-field concentrations of light.

B-1.4: IL03 **Quantum-dot / Dendrimer Based FRET Structured Functional Nanotubes for Sensitive Studies of DNA Hybridization**

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The functionalization of nanotubes (NTs) is an effective way to design new hybrid materials by coupling the properties of supramolecular building blocks or novel nanostructures to NTs, which have attracted considerable interest as biocatalysts, biosensors, or for bio-separation. One of the novel approaches to functionalize NTs is to integrate quantum dots (QDs) with their promising properties, such as narrow emission bandwidth, photochemical stability, and high quantum yield. A highly sensitive method for detecting oligonucleotide targets has been developed in quantum dot (QD) functionalized nanotubes (NTs) containing a gradient band gap architecture. The design of the functionalized NTs with multi-functionalities and their efficient assembly with different types of QDs was achieved by layer-by-layer (LBL) approach. This allowed for the formation of fluorescence resonance energy transfer (FRET) structures in the NTs resulting in an enhanced fluorescent emission from dye labeled oligonucleotide target DNA after hybridisation. The significant enhancement of the detection sensitivity and the selectivity for DNA hybridization in the NTs suggest that such types of nanostructures may find broad use in biomedical applications, e.g., in biosensors.

B-1.4: IL04 **Holographic Techniques to Study the Light Induced Diffusion of the Photosensitive Metal Alcoholates**

P.W. OLIVEIRA, P. KÖNIG, M. VEITH, Leibniz-Institut für Neue Materialen, Saarbrücken, Germany

The use of photosensitive inorganic particles for optical composite materials opens up an interesting route for the property tailoring. It is shown that by incorporating nanoparticles the refractive index can be tailored, while maintaining high optical quality. A synthesis and processing route, based on sol-gel techniques has been developed to prepare the matrix system (an inorganic organic molecular composite) as well as the nanoparticulate system and the route to obtain homogeneous dispersion. New photopolymers have contributed significantly to the recent growth of holographic and lithographic applications. Thick films (5 to 12 μm) of this composite system were prepared and volume diffractive gratings were fabricated by a two laser beam interference technique. The formation of the gratings is based on the diffusion of high refractive index components (ZrO2-nanoparticles) to areas with high irradiation intensity with subsequent immobilization by full irradiation of the film. The influence of the zirconia particles as the main component for obtaining highly efficient gratings is presented and the correlation between particle concentration and refractive index profile (refractive index amplitude =1,5*10-1) is shown.

B-1.5 Photonic Crystal Structures and Microstructured Fibers

B-1.5: IL01 **Negative Refraction in Photonic Crystals**

TOSHIHIKO BABA, TOMOHIKO ASATSUMA, TAKASHI MATSUMOTO, Yokohama National University, Yokohama, Japan

Negative refraction of light beam allows novel optic components such as superlens. It is generated by metamaterials and photonic crystals. But negative refraction at lightwave frequencies is a big challenge for metamaterials because of the strong absorption loss of metals used inside. On this point, the photonic crystal made from transparent materials is more advantageous. The negative refraction in photonic crystals arises from the unique dispersion characteristics caused from the multi-dimensionality. We successfully observed the negative refration and related phenomena at near infrared in a SOI-based photonic crystal slab. The key point was the careful design of input/output interfaces of the photonic crystal, which suppress unwanted reflection and diffraction losses. The clear focusing of light was observed inside and outside of the photonic crystal. Also, a very compact wavelength demultiplexer was demonstrated using a superprism and superlens. The resolution of the focusing and the demultiplexing is mainly dominated by the aberration caused by the non-ideal dispersion in a photonic crystal. But it can be reduced by combining two crystals with opposite aberrations.

B-1.5: IL02 **Properties of Nanostructured Resonant Leaky-mode Photonic Devices**

R. MAGNUSSON, University of Connecticut, Storrs, CT, USA

In this paper, we review the basic properties of resonant leaky mode elements implemented with periodic waveguide layers and consider their applicability in photonic devices and systems. Leaky waveguide modes can be exited when an incident light beam is coupled into the

waveguide structure through an inscribed periodicity under phase-matching conditions. This results in generation of a guided-mode resonance field response in the spectrum. Device operation can be explained in terms of the photonic band structure and associated leaky-wave effects near the second stop band. Resonant devices such as biosensors, tunable filters, display pixels, polarizers, bandpass filters, and wideband reflectors can be designed using this operational principle. In particular, highly accurate label-free biosensors have been implemented. The sensors are broadly applicable in terms of materials, operating spectral regions, and design configurations. Spectral tunability is another important attribute of these devices. Wideband tuning is achievable by perturbing the structural symmetry using nano/microelectromechanical methods. MEMS-tuned resonance elements may be useful as pixels in planar, ultra thin spatial light modulators and in tunable lasers.

B-1.5: IL04 **Developing Single-mode Tellurite Glass Holey Fiber for Infrared Nonlinear Applications**
XIAN FENG, J.C. FLANAGAN, K.E. FRAMPTON, P. PETROPOULOS, J.H.V. PRICE, N.M. WHITE, W.H. LOH, H.N. RUTT, D.J. RICHARDSON, University of Southampton, Southampton, UK

We review our progress on developing single-mode tellurite glass holey fiber for infrared nonlinear applications. Tellurite glass preforms with complex holey structure were fabricated by using glass extrusion technique. The fabrication of single mode tellurite holey fibers with the effective mode area ranging from 2.6-3000 µm2 and the effective nonlinearity y ranging from 0.23-280 W-1km-1 were demonstrated. By controlling the microstructured features in the holey cladding, the dispersion profile and the zero dispersion wavelength of this type of single material optical fiber were tailored within a broad range. Broadband 1.0-2.5µm supercontinuum spectra were generated from the fabricated fibers by using femtosecond laser. Attenuation due to the impurities, such as transition metal ions, rare-earth ions and hydroxyl group, were also investigated in the bulk tellurite glass and fiber from visible to mid-infrared regimes.

B-1.5: IL05 **Fabrication and Characterization of Silica Opals**
C. ARMELLINI, A. CHIAPPINI, A. CHIASERA, M. FERRARI, Y. JESTIN, CNR-IFN, Povo-Trento, Italy; E. MOSER, University of Trento, Povo-Trento, Italy; R. RETOUX, CRISMAT, ENSICAEN, Caen, France; G. SPERANZA, L. MINATI, FBK-IRST, Povo, Italy; G. NUNZI CONTI, Centro Fermi, Roma, Italy; S. BERNESCHI, I. CACCIARI, S. PELLI, IFAC - CNR, Sesto Fiorentino, Italy; G.C. RIGHINI, CNR, Rome, and IFAC - CNR, Sesto Fiorentino, Italy

Er3+-activated silica inverse opals were fabricated using colloidal route. A large and well ordered crystals of the inverse opal were pointed out by SEM images. Reflectance measurements showed the presence a pseudo photonic stop band in the visible regional. PL of ErSiO2 inverse opal exhibits a main emission peak at 1540 nm, where the spectral width of the emission band measured at 3 dB from the maximum of the intensity is 21 ± 1 nm, and the Stark structures at 1490 ,1567 and 1617 nm appear well defined. The 4I13/2 metastable state of the Er3+ ions decay curve presents a lifetime T(1/e) of 16.8 ± 0.1 ms corresponding to a very high quantum efficiency of the system. A simple and a cheap fabrication protocol was elaborated in order to obtain Er3+-activated microspheres suitable for microresonator. The protocol permit to obtain Er3+-activated microspheres of different dimensions that present a very high quality of the surfaces as revealed by TEM images. Typical PL spectra of Er3+ ions imbedded in silica matrix were observed for the single sphere. The decay curve of the metastable level 4I13/2 exhibits a single exponential profile with a lifetime tmeas of 13.7 ms for the spheres heat-treated at 1100 °C, and a Quantum Efficiency of the system of 76% was estimated.

B-1.5: L06 **Low Frequency Coherent Raman Scattering of Spherical Acoustical Vibrations of Self-organized Three-dimensional Germanium Nanocrystals**
M. IVANDA, M. BULJAN, U.V. DESNICA, D. RISTIC, Rudjer Boskovic Institute, Zagreb, Croatia; M. FERRARI, Instituto di Fotonica e Nanotecnologie, Trento, Italy; G.C. RIGHINI, IFAC - CNR, Firenze, Italy

The self-organization of germanium quantum dots (QD) in QD superlattice with rhombohedral structure is achieved by a substrate temperature control and by subsequent thermal annealing of the magnetron sputtering deposited (Ge+SiO2)/SiO2 multilayers. The polarized low-frequency Raman measurements shows the symmetric and quadrupolar spheroidal vibrations of Ge nanocrystals. The coherent efects on these vibration is observed on Ge nanocrystals organised in Ge supracrystall. It will be shown that the coherence effect is dependent on the degree of Ge-ordering in supracrystall.

Session B-2
Passive, Active and Adaptive Optical Devices & Systems

B-2.1 Optical MEMS, Smart Optical Sensors and Devices

B-2.1: IL01 **Nanowire Superconducting Single-photon Detectors**
R.H. HADFIELD, Heriot-Watt University, Edinburgh, UK; SAE WOO NAM, M.J. STEVENS, R.P. MIRIN, National Institute of Standards and Technology, Boulder, CO, USA

Single-photon detectors are a key enabling technology for a host of applications at the frontiers of science and technology, from quantum information processing to new types of imaging and remote sensing. A new type of single-photon detector based on a superconducting nanowire offers single-photon detection from visible to mid IR wavelengths with excellent signal to noise and low timing jitter. These detectors can be fibre-coupled and integrated into closed-cycle refrigerator systems, and have recently been employed in a succession of ground-breaking single-photon counting experiments, including quantum key distribution, characterization of single and entangled-photon sources and time-of-flight ranging.

B-2.1: IL02 **Elucidation of Interaction of SiO2 Glass with F2 Excimer Laser and Development of Optical Fibers for Deep UV**
HIDEO HOSONO, KOICHI KAJIHARA, Tokyo Institute of Technology, Yokohama, Japan

Silica glass is an important optical material in deep-ultraviolet (DUV, $\lambda < 300$nm) and vacuum-ultraviolet (VUV, $\lambda < 200$nm) spectral regions. However, DVE-VUV transparency of silica glass is significantly influenced by the presence of structural imperfections (point defects). This talk presents point defects in silica grasses of low metallic impurity contents (“synthetic” silica glasses), and optical and chemical properties of these point defects. It is shown that controlled doping with specific point defects can improve the transparency and radiation hardness of silica glass in DUV-VUV spectral region. Such doped species include network modifiers that relax the glass structure and mobile interstitial hydrogen molecules. Utilization of these techniques in developing photomask substrates for F2 laser photolithography and DUV optical fibers for ArF laser transmission is presented. Optical fibers for the deep ultraviolet region were developed using fluorine doped silica glasses called modified fused silica. Optimizing the fiber drawing conditions improved the transmission of the fiber in the deep UV region. The transmittance of the fiber at 193nm reached more than 65% per 1m long (65% m-1 without reflection loss. Significant absorption bands from defects were not observed throughout the wavelengths of the deep UV-visible-infrared region. Hydrogen-impregnation into the fibers suppressed the degradation of the transmission induced by irradiating with an ArF excimer laser. Transmission in the DUV region and resistance to laser irradiation were drastically improved compared to high OH silica fibers. Dipping the fibers into a hydrofluoric acid solution automatically prepared fibers with a sharp-pointed edge that were suitable for optical microprobes in scanning near-field optical microscopes.

B-2.1: IL03 **Fiber-Bragg-grating Sensors and Sensor Arrays**
H. BARTELT, Institute of Photonic Technology, Jena, Germany

Fiber -Bragg gratings are finding widespread and steadily growing fields of sensor applications. They make especially use of their specific properties such as small size, integrability in smart materials and multiplexing in arrays. New techniques are further expanding the

possibilities of use for such fiber-Bragg-gratings, including the use of microstructured fibers, femto-second pulse recording of fiber-Bragg-gratings in different glass materials or gratings in small diameter fibers and for short wavelength reflection. Based on a description of different technologies applied for making fiber-Bragg-gratings, such new developments will be discussed and analyzed. Then examples of current sensor application developments will be presented, which will illustrate the potential of the fiber-Bragg-grating sensor technology.

B-2.1: IL04 **Enabling Devices Using MicroElectroMechanical System (MEMS) Technology for Optical Networking**
D.M. MAROM, Hebrew University, Jerusalem, Israel

Optical communication systems are the premier conduit for providing broadband data across continents, nations, cities, neighborhoods, and are now starting to penetrate into private homes. This spectacular achievement is the culmination of years of research and development efforts in diverse fields. Recently we are witnessing the evolution of these communication systems towards optical networking. The advent of optical networking has been enabled by a suite of complementary optical subsystems that are pivotal to the operation and management of these networks. These optical microsystems directly interact with the optical signal and -through functionality afforded by design- are able to filter, switch, attenuate, and adapt the optical communication channels carried by the network. In this talk I will review a sampling of these enabling devices and focus on the MEMS technology required for its implementation.

B-2.1: IL05 **P-OLED / CMOS Microdisplays**
I. UNDERWOOD, A. BUCKLEY, C. YATES, M. NEWSAM, R. WOODBURN, MicroEmissive Displays Ltd., UK

Microdisplays are an emerging class of tiny high-resolution electronic information displays that are typically viewed under high magnification. The main applications areas are in projection display systems such as data projectors & rear projection televisions and in near-to-eye (NTE) systems such as electronic viewfinders & video-glasses. A proportion of microdisplays use standard CMOS technology for the active matrix backplane. This opens the possibility of integrating useful amounts of electronic functionality into the periphery, and even into the individual pixels, of the microdisplay. (That functionality would be otherwise either not possible or would require the support of additional display driver chips.) Such a display merits the description “smart display”. Historically, the optical read-out of microdisplays has typically been achieved by modulating an external light source (or backlight) on a pixel-by-pixel basis by means of, say, liquid crystal or micro-systems. Improvements in polymer organic light emitting diode (P-OLED) material performance have allowed the development of emissive microdisplays that require no backlight for NTE applications. We review the progress to date and future potential of smart microdisplays using P-OLED/CMOS.

B-2.1: L06 **Characterization of Brightness of Electrolumi-nescent Device Using Powder Phosphor Composite with ZnO or TiO2**
MUN JA KIM[1], SUNG MIN PARK[1], SANG HYUN PARK[2], JIN YONG KIM[1], IN TACK HAN[2], AND JI-BEOM YOO[1], [1]Sungkyunkwan University, Suwon, Korea; [2]Samsung Advanced Institute of Technology, Suwon, Korea

For the growth of Electroluminescent (EL) device market, the attention of many researchers is centered on improving the properties such as brightness, power consumption, device reliability, etc. The powder EL device is one of solutions for the easy mass production, the simplification of structure, and low cost. Although the powder process is the solution, that has the problem with the poor brightness than the film process. So, we focused on increasing the brightness of powder EL device. The emissive layer was made up the composites adding metal oxide nanopowder such as TiO2 and ZnO to powder phosphors. As the data of previous researcher, the TiO2 and ZnO had the different dominating traps by photovoltage measure, that is, TiO2 show hole traps, ZnO show electron traps. The brightness of powder EL device proportions to the high electricfield formation. The TiO2 or ZnO in the powder phosphor composite can help the emission that may be advantageous to form high electricfield at low voltage. The EL devices with green ZnS phosphor were fabricated using spin coating method. The effect of TiO2 and ZnO on the luminescent property of EL device was investigated. The brightness was obtained as applied driving voltage at 400 Hz and frequency variation at 50 V.

B-2.1: L07 **Interferometric Sensors Realized with Micro-mirrors**
M. SICILIANI DE CUMIS[1], A. SEVERINO[1, 2], C. FREWIN[3], S.E. SADDOW[3], F. CATALIOTTI[4], F. MARIN[4], E. RIMINI[1, 2], G. D’ARRIGO[2], [1]University of Catania, Catania, Italy; [2]IMM-CNR, Catania, Italy; [3]University of South Florida, Tampa, FL, USA; [4]Universita’ di Firenze and INFN Sezione di Firenze, Sesto Fiorentino (FI), Italy

Optical interferometric sensors are extremely precise and sensitive position detectors with a wide range of applications spanning from fundamental physics to road construction. Micro-mechanical mobile passive structures, as high sensible transducer element, can be fabricated with present technologies on silicon wafers.Our innovative contribution is the fabrication of the sensible element in 3C Silicon Carbide ethero-epitaxilly growth on Silicon substrate. This material gives more freedom degree for the fabrication of a new class of high performances MEMS. The ultimate limit for the optical detection of small movements is given by the thermal motion of the optical elements and by the fundamental granularity in mechanical back-action of light. Active techniques for the reduction of thermal noise have been applied to single modes of macroscopic mirrors. Starting from these techniques and the innovative 3C-SiC structures we intend to develop a new technology to control the motion of micro-optical elements to a few vibrational quanta. The possible application of these new devices span from the detection of single electrons to the realisation of new quantum circuits. On the other hand quantum sensors offer the possibility of evolving into quantum logical devices.

B-2.1: L08 **Two-wavelength Contouring of High Speed MEMS with Digital Holography Using Femtosecond Laser Pulses**
T. HANSEL, R. GRUNWALD, G. STEINMEYER, U. GRIEBNER, Max Born Institute, Berlin, Germany; J. BONITZ, C. KAUFMANN, Technical University Chemnitz, Chemnitz, Germany

Digital holographic deformation and shape measurements of high-speed MEMS using a novel dual-wavelength femtosecond light source is reported. The laser system is based on a commercially available ultrashort-pulse laser making use of its inherently broad spectrum. The spectrum was shaped to simultaneously generate two spectrally separated pulses with an energy >2 µJ. Our approach allows for a spectral separation of 8 to 40 nm, enabling holographic scan depths between 10 and 80 µm. Stroboscopic two-wavelength contouring of MEMS with a resonance frequency of about 1 kHz was performed using a Michelson-type interferometer employing two CCD-cameras. The simultaneous recording of the two interferograms was realized by polarization encoding of the wavelengths. The phases of the holograms and the difference phases are numerically calculated. The resulting image contains a fringe pattern which allows to deduce the contour lines of the topology of the MEMS. Measurements of dynamic deformation of circular and rectangular shaped MEMS at their resonance frequency are presented. The results open up the perspective for using digital holography as a tool for recording rapidly occurring deformations on otherwise inaccessible depth scales.

B-2.1: L09 **Optic Fiber Hydrogen Sensors Based on Mg-Ti**
M. SLAMAN, B. DAM, R. GRIESSEN, VU University, Amsterdam, The Netherlands

The large optical reflectance changes, which occur when hydrogen enters the lattice of a thin Mg-Ti based metal film, are used to detect the presence of hydrogen. This type of alloys absorbs hydrogen at pressure typically 2 orders of magnitude lower than Pd. A cheap and sensitive hydrogen safety detector can be made by coating the sensing metal layer on the bare end of an optic fiber and measuring the reflection of the light sent into the fiber from a LED. The great advantage of this type of sensor is that no current leads are used in potentially explosive detection areas. The sensitivity and optical response upon hydrogen loading can be tuned by selecting the optimal metal composition for the sensing layer. In the present configuration a change in reflectance of a factor 10 is detected within 1 s in presence of 0.4% hydrogen in air at temperatures up to +80 °C. It is important to note that our optic fiber sensor works below 0 degree C as well as in oxygen-free atmospheres. A catalytic Pd-Ag layer and a protective coating are used to improve the sensitivity of the detector and prevent its degradation in time. In this way we obtain a cheap, fast and versatile optical fiber detector[1].

[1]M. Slaman et al, Sensors & Actuators B: Chemical 123 (2007) 538-545

B-2.2 Adaptive Optical Elements and Adaptive/Smart Structures

B-2.2: IL02 **MEMS-based Photonic Modulators**
W. NOELL, Y. PÉTREMAND, S. WALDIS, M. ZICHAR, N.F. DE ROOIJ, University of Neuchâtel, Neuchatel, Switzerland; M. EPITAUX, Formerly at Intel Corporation, Newark, CA, USA; T. OVERSTOLZ, R. STANLEY, CSEM, Neuchatel, Switzerland; F. ZAMKOTSIAN, Lab. d'Astrophysique de Marseille, Marseille, France; R. HAUFFE, Hymite GmbH, Berlin, Germany

Silicon-based photonic MEMS modulate light by displacing microoptical elements such as micromirrors and microlenses. We present three recent MEMS-based device developments as representatives for micro-photonic systems: a) A tip-tilt micromirror with integrated vertical comb-drive actuators and large stroke ideally suited for optically cavity tuning and as a versatile MEMS actuator for deflective mirror membranes, b) A high fill-factor micro-mirror array working in a cryogenic environment, which will be utilized in multi-object spectrometers for astronomy, and c) A laser-fiber coupler utilizing a 2D MEMS actuator for the lateral displacement of the coupling microlens.

B-2.2: IL04 **Adaptive Optics and the Human Eye**
L. DIAZ-SANTANA, City University, London, UK

Adaptive optics was first implemented in the human eye in 1994. Since then, this technology has advanced enormously, however a number of challenges still remain open for it to make the leap into widespread use. One important challenge is the dynamics of the eye. Eye movements, and aberration dynamics impose limits to current performance of AO systems. Moreover there is little work in the literature about how these dynamics vary with different eye conditions or the mechanisms driving them. In this talk we will discuss the past work and current state-of-the-art of adaptive optics, followed by current work in the VISOR laboratory at City University on aberration dynamics and adaptive optics. Dynamics of eye aberrations have been measured in a small sample of subjects of several minutes. A number of optical quality metrics like Strehl ratio, Root Mean Square Error and the wavefront gradient have been measured and their temporal evolutions analysed. Previous works have concentrated on the frequency content of the temporal series of the RMS only, whether authors looked at its power spectrum or used other methodologies like coherence functions. In this work we extend the analysis to the time domain, considering probability density functions, temporal correlations, cumulative distributions, and look in the power domain to the power spectra of very long data sets for first time. Results and modelling will be presented and their implications to optimisation of closed-loop adaptive optics systems will be discussed.

B-2.2: L07 **Electrochemistry for Variable Optics**
C.W. MONROE[1], L. DAIKHIN[2], M. URBAKH[2], A. SLEIGHTHOLME[1], A. KUCERNAK[1], A.A. KORNYSHEV[1], [1]Imperial College London, UK; [2]Tel Aviv University, Ramat Aviv, Israel

Working on the theory of functionalized liquid-liquid interfaces our group has predicted and then experimentally realized a novel electrowetting system, based on interfaces between two immiscible electrolytic solutions (ITIES). Such interfaces have been used in a number of electrochemical applications, e.g. phase-transfer catalysis, but their unique electrowetting properties have not been recognized before. We discovered a new, ITIES-based, electrowetting system which can change the shape of a liquid micro-lense (contact angle) at voltages, orders of magnitude smaller than those used in the existing devices. Fundamentals of the theory were published (C.W. Monroe, L.I.Daikhin, M.Urbakh, and A.A.Kornyshev "Principles of electrowetting with two immiscible electrolytic solutions," J.Phys.: Cond.Matter 18 (2006) 2837-869; "Electrowetting with Electrolytes," Phys.Rev.Lett.97(2006)136102; C.W.Monroe, M.Urbakh, and A.A.Kornyshev, "The distinctive properties of electrowetting with ITIES," J. Phys.: Cond.Matter(2007),in press; for News and News about our discovery, see also H.H.Girault, "Electrowetting: Shake,Rattle, and Roll," Nature: Materials 5 (2006) 851-852). We will overview them and report latest experimental findings, including measures speeding up the rate constant of the device.

B-2.3 Advanced Material Processes and Fabrication Technologies

B-2.3: IL01 **Glass Ceramic Phosphors: all Inorganic Solution for Solid-state Lighting**
SETSUHISA TANABE, Kyoto University, Kyoto, Japan

Since the development of high-power InGaN-based blue LEDs followed by that of white LEDs, there is no doubt that the solid-state lighting technologies have bright futures even for general illumination. With increasing brightness and total flux of white LEDs, thermal management of device packaging is becoming an issue of greater importance especially in the phosphor-converting white LEDs. Several types of organic resins have been developed with better thermal conductivity, heat- and radiation-resistance as a packaging medium with blue-, violet- or near-UV LEDs. Because of excellent durability, thermal stability, easy fabrication and molding into any shapes, the inorganic silicate glass ceramics can be an excellent solution if the phosphors keep optical performances equivalent to the powder- packaged white LEDs. We have developed the Ce:YAG silicate glass ceramics (GC) in which single-phase Ce:YAG microcrystals of 20μm-size precipitate homogeneously, through crystal growth from a Ce-doped yttrium aluminosilicate glass of specific composition by simple heat treatment (cerammization)[1]. The material showed a good luminous efficacy comparable to the commercial Ce:YAG-based white LED, when it was packaged on a 460nm-blue-LED. Since this GC material is composed of a matrix with 50% volume fraction of silica-rich glass, it shows high bending strength, Young's modulus and excellent heat-resistance[2]. I will also discuss a great variety of Eu^{2+}-doped alkali-earth silicate phosphors with efficient broadband spectra due to the $4f^6\,5d^1$-$4f^7$ electronic transition.

[1]S.Tanabe, S.Fujita, A.Sakamoto, S.Yamamoto, "Glass Ceramics for Solid State Lighting", Ceram. Trans. 173, (2006) 19-25.

B-2.3: IL02 **Micro- and Nano-fabrication Technologies for Micro-optical Elements & Systems**
E.-B. KLEY, Friedrich-Schiller University Jena, Jena, Germany

As a consequence of today's miniaturization trends the micro- and nanotechnologies are challenged to realize complex micro-optical elements as well as artificial materials, both on the base of 2D and 3D microstructures. In order to fabricate such optical elements and materials, special demands on lithography or micro- and nanomachining arise from the wave nature of light. This refers to the accuracy as well as to special 2D and 3D fabrication techniques. The lecture will explain briefly basics, shows the vision of micro- and nano-structured optics and give an overview of the relevant lithographic fabrication technologies. Specific problems and limitations of the technologies will be described as well. Keywords are continuous profiles, multilevel profiles, binary patterns, high aspect ration patterns, e-beam lithography, laser writing, analogue lithography, dry etching and proportional etching.

B-2.3: IL03 **Smart Processing of Micro Ceramic Structures: Development of Photonic Crystals and Fractals for Terahertz Wave Control by Using Micro-stereolithography**
SOSHU KIRIHARA, Osaka University, Ibaraki, Osaka, Japan

Micro-sterelolithography system has been newly developed to realize freeform fabrication of micrometer order ceramic structures. In this process, the photo sensitive resin paste mixed with nanometer sized ceramic particles is spread on a glass substrate by using a mechanical knife edge, and a two-dimensional image of UV ray is exposed using Digital Micro-mirror Device. Through the layer by layer stacking process, micrometer order three-dimensional objects are formed. Dense ceramic structures can be obtained by dewaxing and successive sintering. In our recent investigation, micro photonic crystals and fractals composed of Al2O3 were fabricated in order to control electromagnetic wave propagation in a terahertz (THz) frequency range. The micro photonic crystals with a periodic structure of diamond type exhibited perfect band gaps in the THz range. The photonic fractals with a self-similar structure of Menger sponge type composed of Al2O3 resonated and confined the THz wave. In near future, the THz wave will be expected to apply for novel sensors which can detect gun powders, drugs, bacteria in foods, micro cracks in electric devices, cancer cells in human skin. Micro photonic crystals and fractals have potentials to be used as various types of THz wave devices.

B-2.3: IL04 **Photomasks for Semiconductor Lithography: from Simple Shadow Casters to Complex 3D Scattering Objects**
A. ERDMANN, D. REIBOLD, T. FÜHNER, P. EVANSCHITZKY, Fraunhofer Institute IISB, Erlangen, Germany

Lithographic processes belong to the most critical steps in the fabrication of microelectronic circuits. Optical projection lithography which transfers the layout of a mask into a photoresist at the top surface of a silicon wafer is still the workhorse of semiconductor industry. Many innovations regarding the optical imaging system and the introduction of new mask technologies have pushed optical projection techniques close to their theoretical limits. Nowadays, optical projection lithography is used to create 60nm features with a wavelength of 193nm in production. This talk discusses the impact of the mask on the performance of a lithographic process. For large feature sizes the mask can be considered as infinitely thin and its local transmission and phase can be directly derived from the design. For mask features comparable to the wavelength of the used light and below, the mask becomes a complex scattering object which has a pronounced impact on the intensity, phase, and polarization of the diffracted light. The light diffraction from the mask has to be computed by rigorous electromagnetic methods. Several consequences with respect to the choice of most appropriate mask materials and geometries will be discussed.

Session B-3
Ongoing Applications and Perspectives

B-3: IL01 **The Smart Bridge of the Future**
B. CULSHAW, University of Strathclyde, Glasgow, Scotland

The concept of the ‘smart bridge’ implies a responsive structure capable of adapting to demand. The first stage - sensing - is well founded with optical sensing and other technologies making critical contributions to assessing load, operational conditions and wear or damage. Much is still needed in the interpretation of the data collected by sensor networks. There are several layers at which the ‘smart bridge’ may operate. The simplest is in monitoring repair and rebuild strategies and there are numerous examples. We can also observe road surface and traffic conditions and again some example systems have been installed. The next stage moves into automated structural monitoring and damage assessment and whilst the sensor systems exist in principle, their detailed design and interrogation techniques continues to require detailed study except for very simple laboratory demonstrations. The ultimate though is the adaptive self adjusting and when necessary self repairing structure. Some simple demonstrations certainly exist, but beyond the basic implementation this remains the designer’s aspiration. There are other factors too - cost effectiveness, political and social environments. In the paper we shall discuss these points using practical examples.

B-3: L03 **Alumina Sol-gel Protective Coatings on Multi-spectral ZnS Windows**
G.S. GRADER, M. MANN-LAHAV, G.E. SHTER, D. ESTERLIS, Technion, Haifa, Israel

An increasing number of military applications in electro-optical systems in recent years are associated with high velocity windows (missile domes) operating in the Visible - Far IR range. The requirements from the windows are to remain functional and durable under extreme environmental conditions (high velocity water drop and dust particles impact) while retaining optical transparency. Multispectral ZnS is an attractive window material having desired optical transmission in the visible -Far IR range (0.5-11.5 microns). The main drawback of ZnS is an insufficient chemical and mechanical strength which leads to optical degradation of the window’s properties when exposed to erosion caused by airborne particles and raindrops. To retain the optical properties under erosion conditions various protective coatings have been developed. Amongst these are diamond-like carbon (DLC)/hard carbon, Ge(1-x)C(x) and GaP/BP. These protective coatings however have a limited transmission range of 3-12 micron and are prepared by expensive and time consuming methods such as PVD, CVD and Sputtering. The goal of this work was to develop a sol-gel derived protective coating on multispectral ZnS windows. Alumina was selected as a coating material due to its optical transparency in the desired range (0.5-4.6 microns), as well as its ability to function under harsh conditions. The main challenge with Alumina coatings is however to obtain the desired properties at sufficiently low processing temperatures, in order to avoid damaging the underlying ZnS window. CSD processes offer a low-temperature, low cost route to ceramics, and therefore was the method of choice in the current research. We initially studied the thermal degradation of ZnS under ambient and inert atmospheres to determine the optimal thermal treatment conditions for the coated windows. Alumina coatings were then applied using the CSD method and preliminary results showed that it is possible to obtain stable alumina coatings up to 5 micron thickness over 1" diameter multispectral ZnS windows. A TiO2 film, 50-200 nanometers in thickness, was used as an intermediate adhesion layer. The designed alumina films were thermally stable, uniform and crack-free. The coated windows withstood a standard humidity test, followed by a pulling test, pointing that a chemical attack on the window was prevented. In addition, the good optical transmission over the full range was not affected by the humidity test. Preliminary results obtained in this project will be described.

B-3: L05 **Nanostructured Functional Coatings for Optical Applications**
L. RABOIN, M. MATHERON, T. GACOIN, J.-P. BOILOT, Ecole Polytechnique, Palaiseau, France

Our activity concerns synthesis, characterization and physical properties of divided materials with a high surface area. The inorganic phase is generally prepared from molecular precursors, as porous films deposited on substrates or as nanoparticles in a colloidal suspension. The microstructure of these systems has a characteristic length lower than some tenths of nanometers. Their physical properties are depending on the surface state and can be modified by functionalization and grafting of organic molecules at the surface of the inorganic skeleton. We show here some functional coatings prepared from these divided materials and the presentation concerns the following points: - The synthesis of nanophosphors and their surface functionalization, to perform optically transparent coatings for lighting applications; - The understanding of mechanisms for the formation of micellar phases in organic-inorganic matrices, leading to the elaboration of low refractive index coatings and the realization of interferential devices for ophthalmic applications; - The use of mesoporous silica binders to exalt photocatalytic properties of titania coatings for self cleaning applications; - The synthesis of photoactive films to optically induce nanostructuration for information storage applications.

B-3: IL06 **Smart Focal Plane Technologies for Optical and Infrared Astronomy**
C.R. CUNNINGHAM, UK Astronomy Technology Center, Edinburgh, Scotland, UK

The operating costs and demands for time on current and future Astronomical Telescopes provide intense pressures to maximise the scientifically productive use of the focal plane. I will describe Smart Focal Plane developments for mult-object and 3D spectroscopy carried out within the OPTICON Framework 6 programme, and how they are leading to new concepts for instrumentation for Extremely Large Telescopes. Ideas for future developments will be outlined, along with prospects for applying these technologies in other research sectors and for industrial benefit.

B-3: IL07 **Smart Windows**
C.G. GRANQVIST, Uppsala University, Uppsala, Sweden

Smart Windows are able to change their transmittance of visible light and solar energy as a result of an external stimulus. This paper first gives a general introduction to smart windows technologies. The emphasis is then put on electrochromic (EC) technology, which allows electrical regulation of the optical properties. Specifically, focus is on recent work in the author’s laboratory on foil-type devices embodying sputter deposited WO3 and NiO films joined by a polymer electrolyte. Apart from serving as a general introduction to a new and vibrant field of research and development, the purpose of the paper is to present a number of new results showing that (i) double-sided antireflection coatings based on dip coating can enhance the transmittance significantly, (ii) tandem foils can yield a ratio between bleached-state and colored-state transmittance exceeding fifty, (iii) solar irradiance onto the EC device can enhance its charge insertion dynamics and thereby its optical modulation, and (iv) electromagnetic noise spectroscopy may serve for quality assessment of EC devices.

B-3: IL08 **Fiber Bragg Grating Sensors Advancements and Industrial Applications**
A. CUTOLO, A. CUSANO, OptoSmart Srl, Napoli, Italy and University of Sannio, Benevento, Italy

Over the last few years, optical fiber sensors have seen increased acceptance and widespread use for a variety of applications ranging from structural sensing and health monitoring of composites and structures in civil and aeronautic areas; to pressure and temperature sensors for oil and gas reservoir monitoring; to acoustic sensors for underwater applications; to high voltage and high current sensing systems for the power industry to name just a few. Among the large number of fiber optic sensors configurations, FBG based sensors, more than any other particular sensor type, have become widely known and popular within and out the photonics community and seen a rise in their utilization and commercial growth. Given the intrinsic capability of FBGs to measure a multitude of parameters such as strain, temperature, pressure, chemical and biological agents and many others coupled with their flexibility of design to be used as single point or multi-point sensing arrays and their relative low cost, make them ideal devices to be adopted for a multitude of different sensing applications and implemented in different fields and industries. On this line of argument, here, an overview on the significant advancements in design and development of novel sensors based on FBG technology as well as a review of the principal industrial applications of this technology will be presented.

B-3: IL09 **Smart Optics in Defence and Security Applications**
A.H. GREENAWAY, Heriot-Watt University, Edinburgh, Scotland, UK

Applications of optics in defence and security range from remote sensing to surveillance and through to directed-energy weapons, encompassing needs for chemical and biological capabilities. In all of these applications it has become progressively more important for the optical systems employed to be 'smart' in the sense that they can react to the application environment in order to optimize the effectiveness of the system. Such 'smart' performance is required not only to achieve extended capability range in a small number of physical systems, but also to maximize the changes of covert operation whilst minimizing the opportunities for counter-measures. This presentation will examine the roles of 'smart' functionality in such applications.

SYMPOSIUM C

Emboding Intelligence in Structures and Integrated Systems

Key-note Lectures

C: KL01 **Structural Intelligence: Self-monitoring, Actuation and Adaptation**
A. PREUMONT, R. BASTAITS, A. DERAEMAEKER, B. DE MARNEFFE, M. EL OUNI, G. RODRIGUES, Université Libre de Bruxelles, Brussels, Belgium

The paper reports on the current research performed at the Active Structure Laboratory of ULB in the area of structural intelligence. The subjects covered in the presentation include: (a) A six-axis vibration isolation platform for precision (optical) payloads in spacecrafts. A passive solution based on the "relaxation isolator" is compared to an active one based on the "sky-hook" damper. (b) A bimorph silicon mirror actuated with an array of 91 piezoelectric patch actuators is proposed for adaptive optics; closed-loop experimental results are compared with numerical simulations. The design of large reflectors from elementary segmented mirrors is also addressed. (c) An experimental set-up for structural health monitoring of cable stayed bridges. This set-up is used for detecting the drop of tension in the stay cables.

C: KL02 **Controlling Processes for Aerospace Materials - Challenge's and Opportunities**
T.P. RUSSELL, Air Force Office of Scientific Research, Arlington, VA, USA

An overview of the basic materials driven research needs, challenges and highlights within the Aerospace, Chemical and Material Sciences Directorate will be presented. The fundamental portfolio and integrated initiatives endeavor to discover chemistry, physics and engineering principles for complex materials and material systems. The specific goals are to enable higher performance aerospace and space systems through improving performance of material components for structural and non structural applications by exploiting multi-functional materials, holistic material systems, and the discovery of new material microsystems.

C: KL03 **Microvascular Autonomic Composites**
S.R. WHITE, University of Illinois at Urbana-Champaing, Urbana, IL, USA

Autonomic materials systems are inspired by biological systems in which an external trigger produces an autonomic functional response. As an example, structural polymers and polymer matrix composites have recently been developed that possess the ability to *self-heal*. Self-healing is accomplished via microencapsulated healing agents embedded within a polymer matrix. Damage triggers the release of the healing agent and subsequent polymerization and repair. One promising healing chemistry based on the ring-opening-metathesis-polymerization (ROMP) of dicyclopentadiene and Grubbs' catalyst has yielded static fracture recovery in excess of 90% and greatly extended fatigue life. Beyond this version of self-healing, autonomic materials systems may one day provide self-sensing, thermal stasis, regrowth, and other biologically-inspired functions. Recent advances in healing, damage detection, and microvascular systems will be reviewed.

Session C-1
Smart Materials, Sensors / Actuators and Microsystems

C-1: IL01 **Conductive Nanoparticle Liquids and Proto-Assemblies: Regenerative Surfaces for Relays and MEMs**
R. VAIA, S. DIAMANTI, R. MacCUSPIE, KYOUNGWEON PARK, H. KOERNER, S. PATTON, A. VOEVODIN, Air Force Research Laboratory, WPAFB, OH, USA

Gold nanoparticles are a mainstay of NST. With such a diversity of applications, developing a better understanding of the impact of additives on fabrication routes and on the interfacial composition and structure is critical to optimize performance and lower production cost. For example, by minimizing the volume fraction of organic corona necessary to generate net long-range repulsion (and thus maximize inorganic volume fraction), neat nanoparticle assembles exhibit liquid-like or elastomeric behavior. These zero-VOC, monolithic nanoparticle liquids (NPLs) minimize the need for processing aids and afford intriguing possibilities for applications previously compromised by a large, rigid inorganic content, such as conductive lubricants and contacts and solvent-less inks for micro-fabrication. Specifically, noble metal NPLs, comprised of a metal core (3-20nm) surrounded by an ~2nm ionic-liquid corona, extend the life-cycle of an RF MEMS relay simulator by six orders of magnitude relative to SAMs surfaces and by one hundred times relative to uncoated gold contacts. Mechanistically, this performance enhancement is believed to be associated with the dynamic character of the NPL between contacts that results in a reduction in adhesion and shorting failure mechanisms.

C-1: IL02 **Mechatronics: The Innovation Request**
H. IRSCHIK, Johannes Kepler University of Linz, Linz, Austria

Mechatronics deals with overlapping areas in mechanics, electrodynamics and computer sciences. It represents an interdisciplinary science, which aims to disseminate innovations rapidly into the industrial practice. The latter goal requests a firm strategic foundation. A valuable strategy dates back to E. Mach, who postulated the principle of analogy as a guideline for research. In short, seeking for analogies between problems in different fields enables to transfer innovative solutions from one field to another in due time. It is our belief that this strategy perfectly suits to Mechatronics and is worth to be followed systematically. In the present contribution, we particularly report about Mechatronic research based on an eigenstrain analogy. This research has been performed during the last years in the framework of the peer-reviewed Linz Center of Competence in Mechatronics (LCM), Austria, together with high-ranking industrial partners. Via the eigenstrain analogy, innovative mechatronic methods and solutions can be successfully applied to different complex problems, e.g. for suppressing or generating sound and vibration in light-weighted structures by piezoelectric actuation, or for accurately predicting permanent deformations in advanced machinery.

C-1: IL03 **Current Research Activities in Mechatronic Applications at AM-TUM**
H. ULBRICH, Technical University of Munich, Garching, Germany

The research field Mechatronics combines the various engineering and science topics of mechanics, electronics, physics, mathematics and computer science into an integrated approach. This interdisciplinary view on technical issues enables the improved design of sophisticated systems meeting the increasing demands on performance, size and weight. Almost any research topic in this exciting field comprises new developments or optimisation in general using state-of-the-art techniques. The presentation will focus on case studies like electromagnetic actuators, rotor rubbing control using actively controlled auxiliary bearings, hydraulic controlled cam phasing systems, biologically inspired low-cost inertial measurement systems, enhanced cognitive driver assistance systems with inertial measurement systems and gaze control, modelling of haptic contacts for telepresence applications, free walking in the real worlds and humanoid walking machines (from JOHNNIE to LOLA). All research work is always based on a proper modelling of the entire mechatronic system. The models facilitate the optimisation of structural issues as well as the development of control laws that are investigated in simulations as a basis for the experimental verification. Finally, the application of theoretical results in experiments is an integral part of our work and comprises all the related issues as sensors, signal analysis, power supply and controller implementation.

C-1: IL04 **Piezoelectricity Experimentation, Modelling and Simulation: Common Practices and Realistic Considera-tions**
A. BENJEDDOU, Institut Supérieur de Mécanique de Paris, Saint Ouen, France

During the last three decades, piezoelectricity was the focus of intense fundamental and applied researches within the relatively new and growing multidisciplinary field of smart materials, structures and systems. However, its experimentation, modelling and simulation require special practical and theoretical considerations regarding the piezoelectric materials initial poling orientation and electric wiring since these define their response mode, model electric boundary conditions and application performance. For example, depending on the bonding configuration, co-localised piezoceramic patches could have same or opposite poling orientations, might be electrically wired in series or in parallel, and subject to various electric boundary conditions. Hence, to reach satisfactory test/model correlations, above realistic considerations have to be well modelled and simulated. Besides, numerical model updating with measured electromechanical characteristics is also necessary to reach such goal. This invited lecture aims to discuss common practices and realistic considerations for piezoelectricity experimentation, modelling and simulation and will be illustrated, for vibrating shunted piezoceramic damped cantilever beams, on the so-called effective electromechanical coupling coefficient.

C-1: L05 **Bio-inspired Autonomic Structures**
R.A. SHOURESHI, University of Denver, Denver, CO, USA

This paper presents an architectural concept of an anatomical-based autonomous structure that mimics human nervous system. For this research, we have examined and attempted to understand some of the intricacies of the human sensory and nervous system. Sensory information is conveyed to the brain as trains of action potentials traveling along individual sensory neurons, with pools of neurons acting together. To savor the richness and diversity of perception, the central nervous system must integrate the activity of an entire sensory population. Among five basic types of sensory receptors in the human body, mechanoreceptors detect mechanical compression and stretching of the receptor, or of tissues adjacent to the receptor. Stimulation of mechanoreceptors in the skin leads to a wide range of touch pressure experiences, deep pressure vibrations, and superficial touch. The operating principles of mechanoreceptors have inspired our development of autonomous structures with an analogous nerve system. This paper describes the building blocks of such self-powered nervous system for civil and defense structures. Activation of rapidly adapting receptors in this structural nervous system gives rise to the sensations of movement, fatigue,and vibration. Experimental results will be presented.

C-1: L06 **Soft Development Modules for Microcontroller-based Systems**
M.C. EDMONDSON, L. TANG, Massey University, Palmerston North, New Zealand

Microcontrollers are small control devices that are commonly used for control purposes over a wide range of applications. As the control strategies and the selection of hardware differ from one application to another, it is a common practice for engineers to develop the application programs based-on the selected hardware and the control methodologies. Such a development process requires time for programming and testing, especially for large projects which need to interface and integrate with a number of different hardware and software. This paper presents an approach using the concept of soft development modules to shorten the application program development time for control systems using microcontrollers. A set of soft modules have been developed for a commonly used microcontroller. Testing made on the serial communication and fuzzy logic control modules successfully produced application programs within a much shorter time and reduced human programming errors. The application of soft development modules will allow system developers focus on the system design level without the need to spend large amount of time on generic programming details. Such an approach provides a useful programming development platform for future applications using microcontrollers.

C-1: L07 **A Self-sensing Wedge-wave Ultrasonic Motor Using Modal Sensors**
TAI-HO YU, CHING-CHUNG YIN, National Chiao Tung University, Hsinchu, Taiwan, R.O.C.

This paper experimentally and computationally investigates the modal sensors integrated with a recently developed rotary ultrasonic motor (USM) driven by continuous wedge waves of the fundamental modes with integer circumferential modal number. The traveling wave is formed from constructive interference of two equal-intensity standing waves induced by two comb transducers using dual sinusoidal excitations in 90 degree phase difference. The transducers and modal sensors are segmented in strips around the circumference of piezoelectric tube in the circular wedge-like motor stator. The latter are used to monitor dynamic response of the stator during operation. Response of USM

acquired by the proposed modal sensors has distinct vital characteristics in different frequency bands. The high-pass signals are used not only to observe the variation of phase difference between excitations but to detect the resonant frequency, which is altered by payload, wear situation, etc. The low-pass signal reveals revolution speed and dynamic reaction of the motor stator that is exerted by frictions and contact forces due to the rotor. The time-frequency response of stator is further characterized during the period in which the revolving direction of rotor is switched over.

C-1: L08 **Development of a New Ferroelectric Shell Finite Element. Application to a Smart Micro-component Design**

W. ZOUARI[1], M. ELHADROUZ[2], T. BEN ZINEB[1], [1]LEMTA, Nancy University, CNRS, Vandoeuvre-lès- Nancy, France; [2]LPMM, ENSAM, CNRS, Metz, France

Ferroelectricity and ferroelasticity are the non-linear behaviours exhibited by piezoceramics, especially in the application of high electric field or stress. Actually, the demand for numerical tools taking into account these non linear phenomena is increasing to reliably design applications using piezoceramics. In this context, a shell finite element based on the Reissner/Mindlin's theory and integrating a simplified bi-dimensional macroscopic constitutive law for domain switching effects (ferroelectricity and ferroelasticity) is developed. This element is implemented into the finite element code ABAQUS using the subroutine UEL (User ELement). The thermodynamical framework of the law is based on three scalar valued functions: the Helmotz free energy and two switching functions. Internal variables (the remanent polarization and the irreversible strain) are introduced and a kinematic hardening process is considered. An implicit integration of the law based on the return-mapping algorithm is developed. Finally, the importance of developing this element to design micro-components like micro-actuators, using piezoelectric ceramics acting at high electric fields, is showed.

C-1: L09 **Multi-scale Characterization of Ferroelectric Materials**

S. PRUVOST, G. SEBALD, A. HAJJAJI, L. LEBRUN, D. GUYOMAR, INSA-Lyon, Villeurbanne, France

The configuration in domains of ferroelectric materials influences significantly properties variations under compressive stress or electric field driving. A fine description of domain organization can help to understand the role of dopants in these materials. Moreover, the multi-scale characterization can be used both to improve material properties and models based on energetic parameters. The explanation of depolarization mechanisms and the determination of key parameters pass by quantifying polarization from microscopic data which separate intrinsic to extrinsic contributions. For this purpose, X-ray measurements have been performed on ceramics with tetragonal and rhombohedral symmetry in order to evaluate the percentage of switched domains (PSD). The macroscopic polarization was simulated from PSD and depolarization mechanisms under stress were established for both compositions. From these results, it can be concluded that domain switching induced by compressive stress was controlled by a mechanical parameter and that dipole-dipole interactions seemed to be small compared to strain induced domain switching.

C-1: L10 **Dynamic Displacement Tracking for Frame Structures with a Piezoelectric Patch Network based on Plate Theory Calculations**

D. HUBER, Linz Center of Mechatronics, Linz, Austria; M. KROMMER, H. IRSCHIK, Johannes Kepler University, Linz, Austria

In our previous work on dynamic displacement tracking of frame structures the flexible side walls of the structure were modelled as Bernoulli-Euler beams. Based on this kinematical assumption a network of piezoelectric patch actuators was designed, for which the parameters of the actuator network were calculated such that the frame structure performed a desired transient displacement. In a comparison with 3D-FEM calculations it turned out that in the vicinity of the natural frequencies plate eigenmodes were excited by the designed actuator network. In the present paper we consider a novel approach to calculate refined weights for each member of the actuator network in order to reach the goal of dynamic displacement tracking for the frame structure. For the latter sake the flexible side walls are modelled within the classical theory for thin plates. In contrast to the previous beam solution, this novel approach facilitates to take into account the orthotropic behaviour of the patches as well as to account for the correct boundary conditions for the flexible side walls. The results of the novel approach are compared with 3D-FEM calculations, validating the superiority of the plate solution over the beam solution for frame structures with flexible side walls that are not slender.

C-1: L12 **Enhanced Piezoelectric Nanocomposites Fabricated through Electrospun Piezoceramic Nanowires**

H.A. SODANO, Arizona State University, Tempe, AZ, USA; J. FEENSTRA, Michigan Technological University, USA

The use of monolithic piezoceramic materials in sensing and actuation applications has become quite common over the past decade. However, these materials have several properties that limit their application in practical systems. Piezoelectric nanocomposites are desirable because they can be spayed or painted on and can be used with abnormal surfaces. However, the piezoelectric paint developed in prior studies have resulted in low coupling, limiting its application. In order to increase the coupling of the piezoelectric paint, this effort has investigated the use of piezoelectric nanowires rather than spherical piezoelectric particle, which are difficult to strain when embedded in a polymer matrix. The piezoceramic wires were electrospun from a Barium titanate (BaTiO3) sol to produce fibers with 500-1000 nm diameters and subsequently calcinated to acquire perviskite BaTiO3. An active nanocomposite paint was formed using the resulting piezoelectric wires and was compared to the same paint with piezoelectric nanoparticles. The results show the piezoceramic wires produces significantly enhanced coupling.

C-1: L13 **Ultrasonic Extension Sensing of Actuators Using Integrated Piezoelectric Transducer for Adaptive Optics**

A. UZGUR[1], S. KIM[1], J. M. D. STRACHAN[2], K. J. KIRK[1] , [1]University of Paisley, UK; [2]UK Astronomy Technology Centre, Edinburgh, UK

Ultrasonic techniques have been proposed to determine the extension of piezoelectric actuators for adaptive optics, either in time or frequency domain. In the time domain approach, pulse-echo experiments are carried out using a PZT transducer attached to an actuator and monitoring an echo signal through the actuator. The time shift of the echo is related to the extension of the actuator. In the frequency domain approach, the frequency shift of the attached transducer is used to estimate the extension. Strong correlation was observed between the time shift of echo and the measured displacement of the actuator. It was also noted, contrary to common prediction, that the arrival time of echo is earlier when the actuator is extended. The concept of ultrasonic extension sensing has been proved using the time domain approach in large actuators (7x7x25 mm3). Further investigation is currently being carried out to adapt the technique to smaller actuators (2x2x2 mm3) for a miniaturised deformable mirror. Also, monolithic integration of transducer and actuator using part of the layers in the multilayer actuators has been successfully demonstrated. We will present results on the development of the fabrication, the characteristics of the prototype and the accuracy of sensing technique.

C-1: IL16 **Microsystems Technologies for Use in Structures and Integrated Systems**

A. SCHÖNECKER, Fraunhofer IKTS, Dresden, Germany

Ceramic films gain increasingly importance for the design and fabrication of functional components in planar design. Showing superior mechanical, conductive, dielectric, pyroelectric, ferroelectric and piezoelectric properties they are considered as key functional materials in microsystems offering new products for sensing and actuation, energy supply, health monitoring as well as structural control. The feasibility of various applications such as MEMS, pyroelectric and acoustic sensors, and integrated passive devices has been demonstrated. Substrates of interest are those, forming the integration basis of microsystems, like Si wafer, alumina and LTCC. Another field of application concerns active structures in space, automotive or machine building industry. Progress was achieved by introducing flexible laminates with integrated piezoceramic fibers and plates. Design and packaging are seen as the key points for progress in custom applications. Latest results on device processing and feasibility studies on integrated device structures are summarized in the present paper.

C-1: IL17 **Constitutive Model of Shape Memory Alloys: One-dimensional Phase Transformation Model**

TADASHIGE IKEDA, Nagoya University, Nagoya, Japan

Shape memory alloys (SMA) have unique properties of pseudoelasticity and shape memory effect. Hence they have been widely used as a

member of smart structures. However, these properties are based on transformation between austenitic and martensitic phases and reorientation among martensitic variants, and their deformation behavior has a hysteresis which depends on strain rate and temperature. Hence, to understand this complicated thermo-mechanical deformation behavior and to design the SMA member optimally, a simple yet accurate macroscopic constitutive model has been proposed. The features of this model are (1) energy-based phase transformation criterion, (2) one-dimensional phase transformation rule based on a micromechanical viewpoint, (3) dissipated energy with a form of a sum of two exponential functions, (4) duplication of a strain rate effect, and (5) adaptability to multi-phase transformation. In this lecture, I will show an outline of this model and that this model can easily yet accurately duplicate stress-strain relationship including minor hysteresis loops and strain rate effect of not only a wire under a tensile loading and unloading but also a bar under a tensile-compressive loading and a tube under a bi-axial tensile-torsional loading.

C-1: IL18 **Design of Actuators Based on Ferromagnetic Shape Memory Alloy Composites**
MINORU TAYA, University of Washington, Seattle, WA, USA

Ferromagnetic shape memory alloys(FSMA) are attracting a strong attention among actuator designers and materials scientists, as they are considered to provide a larger force and stroke at fast actuation speed. There are three mechanisms of actuation associated with FSMA, (1) phase change by magnetic field, (2) variant rearrangement mechanism in martensite phase under constant magnetic field and (3) hybrid mechanism under magnetic gradient field. The University of Washington (UW) group identified that the hybrid mechanism is best suited for compact actuators with higher force and stroke capability. In this talk, I will discuss the fundamentals of the hybrid mechanism of FSMA. Although FSMA has been studied by many materials scientists in the world , its applications to compact actuators are still very limited. If the hybrid mechanism is utilized, one can expand the application area of FSMA. However, the cost of FSMA is still expensive. Thus, UW group proposed the concept of FSMA composites whose actuations can be easily realized under the hybrid mechanism. FSMA composites which are best suited for use in the design of compact actuators. The technical challenges facing us are, processing of FSMA composites, MEMS design, analytical modeling. As to the modeling, I would like to introduce the FSMA composite modeling based on the Eshelby type model and laminated composite theory. The modeling will provide an actuator designer with optimized microstructure of FSMA composite.

C-1: L19 **Damping by SMA in Civil Engineering Structures**
F. MARTORELL, V. TORRA, A. ISALGUE, M.LL. PEREA, Polytechnic University of Catalonia, Barcelona, Catalonia, Spain; P. TERRIAULT, Université du Québec, Montreal, Québec, Canada; F.C. LOVEY, Centro Atómico Bariloche e Instituto Balseiro, S.C. de Bariloche, Argentina

Two complementary aspects of the SMA application in Civil Engineering are outlined, the first, the SMA dampers in earthquake damping of a family house. The characteristic behaviour of SMA applied to damping is briefly outlined and the damper effects in the structure with and without pseudo-semi-active elements under the action of earthquake are simulated with the support of the ANSYS program. The work shows the advantages of pre-stressed SMA and of the use of cylindrical pillars. For instance, related to centering the working trajectories inside the hysteresis cycle in SMA and to an increased symmetric behaviour in comparison with classical H-shaped pillars. The second aspect: an elementary approach to the damping of stayed cables in bridges, using, some data, from the Iroise Bridge. The SMA requirements for damping of the cables are more stringent that in the damping of earthquake. In cables the number of cycles is extremely higher in comparison with quakes As the fatigue life is critical for the application, in this work is proposed the use of damper that only smooth the bigger oscillations guaranteeing a practical increase of SMA life.

C-1: L20 **Precision Motion Control of a Smart Structure using an Enhanced Stick-slip Model**
MIN-GYU JANG, CHUL-HEE LEE, SEUNG-BOK CHOI, Inha University, Incheon, Korea

In this paper, a smart structure for the micro position control is proposed using the piezo stack actuator. The smart structure is comprised with PZT based stack actuator, mechanical displacement amplifier and positioning devices. Based on the bridge-type flexural hinge mechanism, a displacement amplifier is designed and integrated with a piezo stack actuator to produce a desirable positioning stroke of the device. In order to achieve the high precision control performance in a positioning device, a stick-slip phenomenon should be suppressed in contacting surfaces of the device, which is generally indispensable in the mechanically connected systems and particularly obvious for the micro-scale system. Therefore, the stick-slip model is enhanced by theoretically calculating the static friction based on the statistical rough surface contact model. Then, a PID feedback control algorithm with the developed stick-slip model is formulated for achieving accurate positioning of the device. Using the proposed smart structure, simulations of precise position control under the representative operating condition of positioning are conducted to demonstrate the stick-slip suppressing and micro positioning performance.

C-1: L21 **Investigation of Functional Properties of Lead-Zirconate-Titanate Ceramics Under Combined Electro-mechanical Load**
M. NICOLAI, A. SCHÖNECKER, Fraunhofer IKTS, Dresden, Germany

Piezoelectric ceramics are widely used in technical systems as sensing and actuating device. According to the state of-the-art piezoceramics are applied on the surface of active structures or assembled in engineered mechanical constructions. Structural integration during processing, like die castings of light weight metal composites or production fibre reinforced plastics is seen as very promising for the effective fabrication of smart structures. Reduced expenses and labour-related costs are expected by increasing productivity and functionality, thus offering new application areas. So fare, the understanding of materials properties under the related complex electromechanical loads is very limited. The configuration of ferroelectric domains is one of the key factors that influence the properties of polar piezoelectric materials. The present study is focused the experimental investigation of the poling state of the material in correlation with time dependent sequences of applied electrical, mechanical and thermal load.

Session C-2
Integration Technologies

C-2: IL01 **Integrated Design of Smart Structures**
G.P. CIMELLARO, T.T. SOONG, A.M. REINHORN, State University of New York, Buffalo, NY, USA

Much of structural control research and applications in civil engineering have been concerned with structures equipped with passive, hybrid, or active control devices in order to enhance structural performance under extraordinary loads. In most cases, the structure and the control system are individually designed and optimized. On the other hand, an exciting consequence of structural control research is that it also opens the door to new possibilities in structural forms and configurations, such as lighter buildings or bridges with longer spans without compromising on structural performance. And this can only be achieved through integrated design of structures with control elements as an integral part. This paper addresses the integrated design of structures with imbedded control systems and devices. Simultaneous optimization of such controlled structures is considered, showing that new structural forms and configurations can be achieved through integrated design. Optimization procedures for both linear and nonlinear structural/control systems are developed. As an example, optimal design of buildings with a reduction in weight by incorporating active control elements or equivalent passive systems while preserving the same performance objectives is presented.

C-2: IL02 **Adaptive Solutions for Intelligent Cable-vibration Mitigation**
L. FARAVELLI, C. FUGGINI, F. UBERTINI, University of Pavia, Pavia, Italy

The mechanics of cable vibration is currently catch either by sophisticated numerical models or by approximate schemes which however were proved to be sufficiently accurate for applications covering suspension and cable-stayed bridges. In addition, there is experimental evidence that rain and wind actions excite a bridge cable in large deformation and for a number of cycles which seriously reduce their durability. The mitigation of cable vibrations has been pursued by active,

passive and semi-active control, but no one of these approaches showed to solve satisfactorily the problem. The main difficulty is met in the need of localizing the control devices somewhere along the cable and, often, in areas close to the cable ends. Provided a localization of the device, the effectiveness of the control turns out as a consequence. Some distributed passive solutions were also proposed but, as usual in these cases, the tuning is focused on a few modal components and a low control robustness results. This contribution considers two alternative paths toward an adaptive control of cable vibrations: 1) a semi-active control policy is associated with a distributed passive control implementation; 2) a moving set of semi-active control devices is conceived and designed. The two solutions are first investigated and optimized in a numerical mechanics environment. The more effective schemes are then implemented in laboratory so that their feasibility can be proved and their actual effectiveness compared. Special care is devoted to the design and implementation of the controller supervisor, with the associated stability issues.

C-2: IL05 **Optimal Simulations for Large Dynamic Systems**

R. SKELTON[1], F. LI[2], M. DE OLIVEIRA[1], [1]UCSD, La Jolla, CA, USA; [2]Xerox Corp.

The errors in a digital simulation of continuua include roundoff errors and errors in model order (the truth model is essentially infinite). This paper shows how to trade these two types of errors to obtain a "minimal error" simulation of a linear dynamic system. The interesting result shows that even if one were to have a PERFECT model for a large dynamic system (i.e. NO errors in model order), this model should NOT be programmed for simulation. Indeed, it is better to INTRODUCE errors of model order by programming a smaller model, than to be subject to the large roundoff errors that would be associated with the large model. Roundoff errors increase with model complexity (order), whereas model-order errors decrease with model size. Hence, the total error in simulations is smallest for a particular size model, and this size depends upon the wordlength of the computer used for the simulation. An Algorithm is given to minimze the errors in simulating a linear dynamic system, when the roundoff errors are zero-mean whites noises whose variance is a function of the wordlength.

C-2: IL06 **The Art of Control Algorithms Design and Implementation**

J. RODELLAR, F. IKHOUANE, Universitat Politecnica de Catalunya, Barcelona, Spain

Automatic control has played an important role in the advance of engineering and science in many different areas. The main objective of the control design is to develop efficient controllers with minimal information on the process. This lack of information is represented as an uncertainty on the model, like disturbances, unknown parameters, unknown dynamics, lack of measurements and others. A typical control problem can be formulated in the following way: given the measurements of some variables, and given some type of uncertainty on the system, how to design a control strategy so that the system behaves under some given specifications. Once the control law has been designed, its real time implementation requires integration of sensors, actuators, communications and computers. At this stage, practical issues arise sometimes beyond the theory used for developing the control law. The objective of this paper is to highlight some relevant issues from the theoretical development to the implementation stage when dealing with the control of structures. The role of control as contributing to give some degree of smartness and autonomy to the dynamical behaviour of structures is also discussed.

C-2: L07 **Control of Vibratory Energy Harvesting Systems with Optimized Passive Networks**

J. SCRUGGS, Duke University, Durham, NC, USA

There has been a growing interest in the generation and storage of power from ambient vibration using piezoelectric transduction. It is well-known that by connecting a piezoelectric energy harvester to a power-electronic switching network, proper switching control can yield favorable energy transduction. It has also been shown that in broadband response, the switching controller maximizing power flow to storage can be solved as an H2 optimal control problem. For extremely small-scale applications, however, the background power necessary to keep a controller online continuously may exceed the average harvested power. In such circumstances, it is necessary to restrict feedback controllers to a class which can be realized with very little power. This paper investigates the use of passive networks to impose transducer voltage feedback laws on energy harvesting systems. Such control implementations only require external power to gate the transistors in the power-electronic drive circuitry. However, the optimization of the passive network for optimal power generation is a challenging, nonconvex problem. This paper presents some preliminary results on a sub-optimal LMI-based design approach for this problem. An example is given for a stochastically-excited piezoelectric bimorph beam.

C-2: L08 **Integration of Piezoceramic Modules into Die Castings. Procedure and Functionalities**

M. RÜBNER, C. KÖRNER, R.F. SINGER, University of Erlangen, Germany

The integration of piezoceramic sensor/actuator-modules into metal matrix structural components using high pressure die casting is a promising approach for the fabrication of adaptronic systems. Especially due to the short cycle time die casting offers the possibility to produce thin-walled components out of light metals like aluminium or magnesium in high volume. Hence, the integration of piezocomposites using this established process provides a combination of properties of conventional castings with adaptronic functionalities. This is of particular interest for the automotive industry with the objective of controlling vibrations of structural light-weight components. Thus, active noise reduction can be realized. A technique is presented which provides stabilization and protection of the module during the highly dynamic mould filling. Furthermore, this technique guarantees a complete encasing of the module with liquid metal. Moreover, the sensor and actuator application of these die castings with integrated module is discussed and the effect of the piezocomposite position inside the structural components on the performance of the adaptronic system is shown.

C-2: L09 **Performance Characteristics of a Jetting Dispenser Featuring Piezostack and Flexible Beam Mechanism**

QUOC HUNG NGUYEN, SEUNG-BOK CHOI, CHUL-HEE LEE, Inha University, Incheon, Korea

This paper presents a new type of jetting dispenser driven by the piezostack actuator. Via a flexible beam mechanism, the amplitude of a needle motion is amplified to such a value that can make a dispensing of adhesive. By designing the flexible beam with high resonant frequency, the dispenser can operate at a frequency much higher than that of conventional dispensers. Therefore, it is expected that the dispenser can provide very small dispensing dot size at high dispensing flow rate, which is imperatively required in modern semiconductor packaging processes. Furthermore, the dispensing flow rate and dot size can be effectively controlled by driving voltage applied to the piezostack actuator. After describing the mechanism and operational principle of the dispenser, a mathematical model of the system is derived by considering dynamic behaviors of structural parts such as the piezostack, the flexible beam, the needle structure, and the adhesive fluid dynamics. In the modeling, a lumped parameter method is applied to model the adhesive dynamics and the governing equation of the whole dispenser is then derived by integrating the structural model with the fluid model. Based on the proposed model, the dispenser is designed and manufactured, and dispensing performances are evaluated.

C-2: L10 **Adaptive Control of Nonlinear Structures Using RBF Networks**

S. NARASIMHAN, University of Waterloo, Waterloo, Ontario, Canada

In this paper, a direct adaptive control scheme using Radial Basis Function networks (RBFs) is presented for the active control of nonlinear buildings. The control scheme is based on direct adaptive control where the system response is made to follow a desired trajectory. The number of basis functions is adaptively estimated using a growing and pruning strategy which results in the reduction of the computational overhead. Stable adaptive parameter update laws for the Gaussian bases are derived using Lyapunov approach. Performance of the proposed control scheme is evaluated on the recently developed nonlinear three-dimensional base isolated benchmark structure. Control action is provided by eight actuators distributed at the isolation level in each principal direction of the structure, and utilizing the state information corresponding to the base of the structure only. The main advantages of the adaptive controller are that the control algorithm does not require state or parameter estimation and the exact nature of the nonlinear dynamics need not be known. The control synthesis is non-iterative in nature and conducive to online applications.

C-2: L11 **Control Algorithms for Semi-active Structural Systems: Do they Really Matter?**
A. OCCHIUZZI, Università degli Studi "Parthenope", Napoli, Italy

The design of semi-active control systems includes considerations and judgement about various different issues, like control technology, structural design and control algorithms. Based on the experimental data of a shaking table testing activity on a steel structural model equipped with semi-active magnetorheological (MR) dampers, a numerical model able to reproduce the laboratory data has been developed. The model has been subsequently adopted to simulate the structural behaviour in the if-what scenario of different control algorithms and different semi-active devices. Numerical data seem to show that the amount of structural response reduction is almost independent of the particular algorithm adopted, provided that, for any algorithm, the various parameters involved be adequately set with regard to a) the structural model; b) the control technology chosen and c) the intensity of the ground motion. A simple 1+1 DOF model has been utilized in the paper to investigate the behaviour of many control algorithms proposed in the literature to drive a semi-active MR damper. The real control operations behind different control algorithms turned out to be quite similar, if not equal, once each algorithm is properly tuned according to an accurate selection of the relevant parameters.

C-2: L12 **Model Development and Control Design of Smart Functionally Graded Structures**
D. MARINOVA, Technical University - Sofia, Sofia, Bulgaria

This paper reviews the modelling of weight intelligent structures with tensions for the development, analysis and control of a low energy active system. The structure composite couples functionally graded material and PZT and longitudinally piezoelectric fibre reinforced composite for sensing and actuating. The exogenous influences and internal material conditions are sensing. The process history, taking into account possible adhesive degradation during cycles of debonding and rebonding, is reflected in the modelling. Active and semi-active control techniques based on feedback concept are considered for vibration control and shape regulating. The problem for optimal selection of the sensors/actuators number and locations is considered. The case of multiple sensing and possible data fusion process for simplifying the controlling is studied. A fully discrete numerical scheme is proposed for the model and implemented in a computer code. Numerical simulations are presented.

Session C-3
Smart Structures and Integrated Systems

C-3: L01 **Monitoring Prestress Level in Seven-wire Prestressing Tendons by Inter-wire Ultrasonic Wave Propagation**
F. LANZA DI SCALEA, I. BARTOLI, S. SALAMONE, R. PHILLIPS, University of California, San Diego, La Jolla, CA, USA; C. SIKORSKY, California Department of Transportation, USA

Many bridges, including 90% of the California inventory, are post-tensioned box-girders. Prestressing (PS) tendons are the main load-carrying components of these and other post-tensioned structures. Despite their criticality, much research is needed to develop and deploy techniques able to provide real-time information on the level of prestress and on the presence of structural defects (e.g. corrosion and broken wires) in the PS tendons. In collaboration with Caltrans, UCSD is investigating the combination of ultrasonic guided waves and embedded sensors as an approach to provide both prestress level monitoring and defect detection capabilities in concrete-embedded PS tendons. This paper will first present the results of load-unload tests conducted at the UCSD Powell Laboratories on seven-wire, 0.6-in diameter twisted strands typically used in post-tensioned concrete structures. The experiment showed the sensitivity of the ultrasonic inter-wire energy leakage to applied load level. These tests also identified specific load-sensitive ultrasonic frequencies, and optimum sensor lay-outs for these measurements. A series of wave propagation models were then developed to provide a theoretical explanation for the observed sensitivity of inter-wire ultrasonic leakage to applied loads. These models include a Semi-Analytical Finite Element (SAFE) analysis to predict wave dispersive solutions in multi-wire strands (including the effect of helical geometries of the peripheral wires and inter-wire contact stresses), and a Global-Local (GL) analysis to examine the interaction of the ultrasonic waves with the strand anchorages. The second analysis is particularly relevant as it was determined that the strand anchorages are primarily responsible for changes in ultrasonic measurements as a function of applied loads. The prestress monitoring method was then validated in embedded strands by testing a series of post-tensioned concrete beams constructed at the Powell Labs. The beams hosted PS tendons with varying prestress levels. The tendons were instrumented with the embedded ultrasonic transducers. Sensitivity, repeatability, and ease for deployment of the proposed ultrasonic prestress monitoring technique will be discussed based on the outcome of these studies.

C-3: L02 **A Vibration Excitor for Evaluating Cable Damping of a Cable-stayed Bridge**
JAE-MIN KIM, Chonnam National University, Yeosu, Chonnam, Korea; JONG-JAE LEE, Saejong University, Seoul, Korea; SANG-SUP AHN, Korea Expressway Corporation, Hwa-Sung, Kyunggi, Korea; JUN-SEONG CHOl, KMC lnc., Seoul, Korea

It is necessary to estimate the dynamic characteristics of stay cables, such as the natural frequencies and the damping ratios, to design cable damper for suppressing excessive cable vibrations and/or to estimate the tension of cables in service. The natural frequencies and associated tension of cable may be evaluated using ambient vibration measurements. However, in order to evaluate energy absorption capability of the damper, cable vibration which is excited enough to include nonlinear damper behavior, shall be measured. For this purpose, a cable exciting robot system to conduct vibrational test for evaluating dynamic characteristics of the stay cable has been developed in this study. The performance of the excitor has been demonstrated through a field test on the stay cable installed at the test yard of Highway and Transportation Technology Institute (HTTI) in Korea. Finally, results of estimated dynamic characteristics of the stay cable, which were obtained based on acceleration data as well as displacement measured by digital image processing technique, are presented.

C-3: L03 **Performance Evaluation of a Nonlinear Cable Damper for a Stay Cable Using Wind Vibration Analysis**
SAANG BUM KIM, S.J. LEE, W.J. YU, Samsung E&C, Sungnam-Si, Korea

Wind induced vibration of a stay cable with a nonlinear friction damper is investigated. Stay cables are likely to vibrate under several wind-related environments, and cable dampers can be used to suppress the excessive vibrations of stay cables. Conventional design of cable dampers are based on the equivalent modal damping achieved by the cable damper. However, the equivalent modal damping achieved by nonlinear dampers depends on the vibration characteristics like the amplitude of the vibration. In this paper, not only the achieved equivalent modal damping, but also the vibration levels under several wind-related environments are analyzed through the time domain buffeting analysis. Numerical simulation results show the efficacy of a nonlinear friction damper for suppressing the excessive vibration of a stay cable.

C-3: L05 **Response Control Performance Evaluation of MR Damper by Shaking Table Tests and Real-time Hybrid On-line Tests**
HIDEO FUJITANI, HIDEKI FUJII, MAI ITO, HIROAKI SAKAE, Kobe University, Kobe, Japan

Magnetorheological damper (MR damper) has been expected to control the response of civil and building structures in recent years, because of its large force capacity and variable force characteristics. The first objective of this paper is to verify the capability of the MR damper to control the response displacements and accelerations of structures against earthquake by shaking table tests and real-time hybrid on-line test. To determine the control force of the MR damper, skyhook control and optimal control theory were employed. As results of the shaking table tests, MR damper controlled by optimal control theory reduced the response displacements without increase of the absolute accelerations, against long period earthquake ground motions and near fault earthquake ground motions. Then, a series of real-time hybrid on-line test was conducted. The second objective of this paper is to verify the validity of real-time hybrid on-line test by comparison with the test results of shaking table tests by using the same MR damper. This paper describes the capability of MR damper to control the structural response.

C-3: L06 **A Reliability Assessment Model for MR Damper Components within a Structural Control Scheme**
M.H.M. HASSAN, British University in Egypt, Al-Shorouk City, Cairo, Egypt

Smart control devices have gained a wide interest in the seismic research community in the recent years. Such interest is triggered by the fact that these devices do not infuse any external forces to the structural system. Magneto-Rheological (MR) dampers have emerged as one of the most promising smart control devices being considered for seismic applications. However, the reliability of such devices as a component within a structural control scheme, still poses a viable question regarding their performance during an actual seismic event. In this paper, a reliability assessment model for MR dampers employed as devices within a structural control scheme is proposed. A hypothetical fuzzy controller is proposed, which employs a single MR damper to reduce the seismic response of a single-degree-of-freedom system. The proposed procedure employs the fuzzy controller, together with a theoretical model of the MR damper, to estimate the damper resistance force available to the system. On the other hand, an inverse dynamics model is utilized in suggesting the required damper resistance force in order to reach a predefined displacement pattern. Such forces are, then, used in order to evaluate the reliability of the MR damper, utilizing the proposed model.

C-3: L08 **Anti-overturning Control of Serially Connected Isolation System Using Piezo Electric and MR Tube Support**
YONGFENG DU, YANHUI LIU, HUI LI, Lanzhou University of Technology, Lanzhou, PR China

This paper presents a numerical simulation of anti-overturning control of serially connected isolation system using an imagined novel device by combining piezo electric foot and MR tube Support. In the vibration isolation of a serially connected electric device which is a real project and was installed on an overhead frame, overturning was observed as a determinant failure mode. To counter for this overturning problem, several additional bolts were used in the isolation layer which decreased the isolation effect. This paper further proposed a semi-active solution using a device for providing anti-overturning moment without increasing the seismic response of the superstructure. This paper presents the idea of the control device set-up and provides a vibration control algorithm, as well the range of validity of parameters of the plant.

C-3: L09 **On Behavior of Multi-layered Bases-foundations and Seismoisolators**
L.A. AGHALOVYAN, R.ZH. HOVHANNISYAN, Inst. of Mechanics, National Academy of Sciences of Armenia, Yerevan, Armenia

The asymptotic method is used to solve the three-dimensional dynamic problem of the elasticity theory on forced vibrations of multi-layered orthotropic plate under full contact conditions between the layers. The analysis of the obtained mathematically exact solutions is conducted and the usage of seismoisolators is proved. For a three-layered packet (foundation-seismoisolator-base) it is shown that in case the layers are rigid enough, the displacements imparted to the lower layer are basically transmitted to the upper layers, and when the middle layer is considerably soft, the amplitudes of the upper layer vibrations are essentially diminishing. The results prove the necessity of using seismic isolators, particularly in the construction of especially responsible buildings, such as schools, hospitals etc., with the aim of decreasing negative influence of earthquakes. The simple algorithm is built in order to calculate the amplitudes of forced vibrations in case of any quantity and configurations of layers. The behavior of the multi-layered packets under various layers configurations is graphically illustrated.

C-3: L10 **Fault Tolerant Neural Controller for Seismically Excited Smart Structures Experiencing Online Failure**
M. CONTRERAS[1], S. NARASIMHAN[2], S. NAGARAJAIAH[1], [1]Rice University, Houston, TX, USA; [2]University of Waterloo, Waterloo, Ontario, Canada

The study presented validates analytically and experimentally an adaptive control algorithm capable of compensating for online sensor and actuator failure. Online failure is a relevant problem when considering actively damped, multi-story smart buildings experiencing an earthquake event. In recent years, Artificial Neural Networks (ANNs) have proven very efficient in pattern classification and control applications. In this study, the unique application of ANNs involving a Radial Basis Function (RBF) approach combined with a Minimal Resource Allocation Network (MRAN) has demonstrated three significant characteristic advantages: (1) a large range of real time adaptability, (2) optimal convergence and computation time, and (3) no offline training. The novelty of the RBF-MRAN solution is elucidated by performing both numerical and shake table simulations involving a scaled down two degree of freedom shear frame. The laboratory specimen is instrumented with piezo-electric actuators and accelerometers at each floor and ground. In real time, the shear frame is subjected to a complete actuator or sensor failure at a particular floor. The neural controller is shown to enhance the performance of a baseline H-infinity controller with respect to five performance measures.

C-3: L11 **Optimal Placement of Smart MFC Actuators for Vibration Control of Cylindrical Shell Structure**
JUNG WOO SOHN, SEUNG-BOK CHOI, Inha University, Incheon, Korea

Many research works have been conducted to investigate active vibration and noise control of cylindrical shell structure using piezoelectric actuators for the possible applications in the aerospace and underwater vehicles. In the present paper, active vibration control to suppress structural vibration of the system is conducted based on optimized actuator placements. Advanced anisotropic piezoelectric actuator named as Macro Fiber Composite (MFC) is adopted for vibration control. The MFC consists of piezo-ceramic fiber and inter-digitated electrode and can provide great flexibility, large induced strain and directional actuating force. The governing equations of motions of the cylindrical shell structure including the MFC actuators are derived from Lagrange's equation. For the verification of the proposed analytic model, numerical results of modal analysis are compared with those of experimental modal test results. Optimal locations and direction of the MFC actuators are determined with the genetic algorithm for the effective control performance. Then, a robust controller is designed to suppress structural vibration of the proposed smart structure and control performances are evaluated.

C-3: L12 **Mitigation of Wind-induced Vibration with Liquid Column Vibration Absorber**
HONGJIN KIM, W. KIM, Kyungpook National University, Daegu, Korea; S.-G. LEE, Chonnam National University, Gwangju, Korea; J.-S. CHO, D. KIM, K.-J. LEE, POSCOENC, Seoul, Korea

Increasing heights of tall buildings often require supplementary damping system for occupant comfort in windy condition. This paper presents the liquid column vibration absorber (LCVA) installed for the 64-story building, which is the highest residential building with flat slab structural system in Korea, for mitigation of wind-induced motion. LCVA is a special type of secondary mass-type dampers relying on the motion of a column of liquid in a U-shaped container to counteract the forces acting on the structure. Since it has different dimensions for vertical and horizontal portions of container, it has benefits of easy tuning and wide natural frequency range. To evaluate the control performance of LCVA, an experiment using 1/20 scaled model is performed. The effectiveness of the LCVA is examined tuning LCVA to 90%, 100%, and 110% of the building natural frequency, 0.74Hz. The test structure is excited using a sinusoidal signal ranging 0.3 ~ 1.2Hz with 5.5mm displacement, and acceleration and displacement of structure, water height, and shear force are measured. Experiment results indicate that a reduction in the maximum wind response up to 70% can be achieved using a LCVA when subjected to sinusoidal excitation with resonant frequency.

C-3: L13 **Fundamental Study on Simple Quantitative Approach of Damping Performance for Variable Hydraulic Damper**
TAKESHI HIWATASHI, Toa Corporation, Yokohama, Japan; HIDEO FUJITANI, Kobe University, Kobe, Japan

Structural vibration control is categorized into passive control, active control and semi-active control. Semi-active control using a variable damper stabilizes building responses in an earthquake better than the conventional passive control and active control. Recently, the semi-active control method has attracted significant attention from many researchers and engineers. This paper used variable hydraulic damper. The servo valve of variable hydraulic damper controls the oil flow between two rooms of the cylinder divided by the piston. This method aims to minimize a structure's response by changing the damper capacity according to the state of the structure and the external loads, and various kinds of semi-active control algorithms have been proposed. A lot of them utilize mathematically difficult algorithms that require complicated computer systems. With these methods, we can not evaluate the effectiveness and overall safety of the system under various

kinds of loads. One reason is that the behaviors of structures incorporating such complicated control systems can not be evaluated by conventional means such as equivalent viscous damping factor based on hysteresis. Therefore, a semi-active control system is wished in which the control effects can be easily quantified as with passive control systems. As the first step of the research, in order to evaluate the performance expected from the theoretical study, a dynamic loading test was conducted. Next, authors conducted experiment by the base-isolated specimen of two-degree-of-freedom structure. Finally, this paper describes the result of having proposed the simple quantification approach for the semi-active control effectiveness.

C-3: L14 **Experimental Assessment of Structural Control Devices Used to Protect Civil Buildings**
G. MAGONETTE, EC - Joint Research Centre, Ispra, Italy

This paper presents the latest developments realized at the European Laboratory for Structural Assessment (ELSA) of the Joint Research Centre (JRC) to extend the 'on-line testing method with substructuring' to the experimental verification of civil buildings protected by semiactive devices. Recent works have indicated that semiactive control systems can achieve significantly better results than passive control systems and demonstrate significant potential for controlling structural responses to a wide variety of dynamic loading conditions. These factors explain the considerable interest in the practical implementation of these systems for protection of civil infrastructures against earthquake and wind loading or, more generally, for vibration mitigation. Commonly, cyclic tests are initially performed to characterize the semiactive device behaviour but a complete validation requires the simulation of realistic dynamic loads incl! uding the effects of the protected structure and the evaluation in real world of the performance and robustness of different control laws and related instrumentation before the final hardware implementation. Experimental verifications satisfying such requirements can be achieved by using the novel extension of the on-line testing procedure presented here.

C-3: IL15 **Current Directions of Structural Control and Monitoring in USA**
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Extensive research and development of structural control devices have occurred in recent years, with particular emphasis on the alleviation of wind and seismic response of buildings and bridges. Full-scale implementations of active control systems have been accomplished in a number of structures; however, cost effectiveness and reliability considerations have limited their wide spread applications. Because of their mechanical simplicity, low power requirement, and large and controllable force capacity, semi-active systems provide an attractive alternative to active control systems for structural vibration reduction. In this paper we review the recent and rapid developments in semi-active structural control and its implementations in full-scale structures. Several recent full-scale seismic and wind benchmark problems have been developed and studied extensively, which will also be reviewed in this paper. Smart structures technology is centered around innovative sensors, system identification, structural health monitoring, damage and fault detection. Structural health monitoring (SHM) represents one of the primary applications for new sensor technologies and sensor networks. In recent years much attention has been paid to SHM due to declining state of the aging infrastructure in the U.S. These concerns apply not only to civil engineering structures, such as the nation's bridges, highways, and buildings, but also to other types of structures, such as the aging fleet of aircraft and space craft. The dense information produced by array of smart sensors requires use of advanced networking and information technology. In this paper the recent and rapid developments in structural health monitoring, smart sensors and sensor networks and its implementations in full-scale structures is reviewed.

C-3: IL16 **Examples of Future Potential Smart Civil Structures**
A.E. DEL GROSSO, University of Genoa, Genoa, Italy

Moving from academic research into practice, the conception of smart civil structures is perhaps becoming the most challenging innovation that pushes modern structural engineers to face problems and techniques that will deeply change a long tradition. The paper starts reviewing the problems that the structural engineer of tomorrow will have to solve by taking advantage of the smart technologies: lowering energy and material consumption, exploit renewable energy sources, adapt to a rapidly changing environment and usage conditions, ensure safety and security to the environment and potential users, optimize maintenance and operational costs. As a second aspect, the paper will summarize the smart technologies already available or that will most likely become available in the near future, in order to individuate the opportunities that these technologies will offer for the conception of innovative smart civil structures. Among these, embeddable sensing elements, self-diagnosing and self repairing systems, ultra-light high resistance materials, MEMS based wireless sensing platforms, shape memory alloys, actuators, control algorithms, data manipulation and damage recognition algorithms will be specifically addressed. Some examples of future smart civil structures that can be based on such technologies will be finally presented. In particular, applications will be discussed for the following systems: 1. deployable and adaptive structural systems; 2. structural systems for "green" buildings; 3. integrated monitoring systems for buildings and infrastructure; 4. integrated diagnostics; 5. integrated decision support systems for building and infrastructure management.

C-3: L18 **Chemical Monitoring of Composite Matrices by Evanescent Wave Spectroscopy**
P.B.S. BAILEY, S.A. HAYES, R.J. HAND, B. ZHANG, University of Sheffield, Sheffield, UK

This paper presents the results of an initial investigation into the potential for monitoring water absorption and chemical degradation in epoxy matrix composites using evanescent wave spectroscopy. Several chalcogenide compositions have been investigated, by embedding fibres in representative matrix resins. Samples of epoxy resin were cast around sections of fibre, the end faces polished to allow an infrared beam to be passed along the fibre. These samples were subjected to hygrothermal aging and the change in transmitted spectra observed, while the photoelastic effect in the resin was used to monitor fibre fragmentation. Fibre sensing with arsenic selenide compositions with gallium or tellurium has been successfully demonstrated in other applications. Here they present a number of issues, most significantly they exhibited such minimal bonding to the epoxy resin that matrix changes of interest caused loss of signal due to interface separation. Alternative fibres were fabricated from germanium-antimony-lead sulphide glass, with the aim of improving on both fibre adhesion and glass transition. This paper presents test results for this glass composition and discusses the potential for application as an embedded sensing element in fibre reinforced composites.

C-3: L19 **Robustness Improvement of Modal Active Control on On-board Electronic Boards Using Inline Identification Method**
B. CHOMETTE, D. REMOND, S. CHESNE, L. GAUDILLER, INSA-Lyon, Villeurbanne, France

Modal active control, based on a nominal modal model, increases lifetime of electronic boards through piezoelectric components. In case of industrial mass production, dispersions induce mechanical and electromechanical properties changes. Moreover, initial operating conditions such as boundary conditions can change during plant lifetime. Therefore, an adaptive modal control strategy in differed time is described and evaluated with experiments. Firstly modal control gains are calculated using LQG algorithm with the nominal model including mode shapes. Then I/O data of the plant are collected by system identification using on-board piezoelectric components. A subspace method is carried out to estimate modal matrices. After a study of their sensibility, estimated plant frequencies and damping are finally used to update modal control gains. The effectiveness of the proposed method is examined through experiment with different boundary conditions. This adaptive control / identification design increases highly the nominal controller robustness.

C-3: L20 **An Experimental Study on the Use of Active Constrained Layer Damping for Thin Curved Smart Shell Structures**
P. SAINI, A. PANDHI, A.K. DARPE, Indian Institute of Technology Delhi, New Delhi, India

Thin Open Curved Shell Structures constitute the major building block of many critical structures such as Aircraft Cabins, Ship Hulls and bodies of rockets and missiles. In the present work, an open thin curved shell made of Aluminium material has been chosen to investigate the potential of ACLD effectiveness with MFC Actuator. The shell ACLD system has been modeled using system identification method and converted into state space form for designing the control law of the LQR controller. Finite Element Analysis of the bare structure has been performed in ANSYS. Using modal solution results, the best possible location for the placement of patches has been found out for combined vibration control of first three modes using Modal Strain Energy (MSE)

approach. The FEA Modal Solution results have been correlated with the experimental modal analysis results obtained with the help of ICATS (Imperial College's Modal Analysis and Testing Software). Significant vibration attenuation resulted for partially covered PCLD and ACLD treatments on open curved shell. Thus, ACLD provides a practical means for controlling the vibration of complex structures such as an open curved shell with currently available piezoelectric (MFC) actuators without the need for excessively large actuation voltages.

C-3: L21 **Verification of Robustness in Smart Composite Structures**

N. KIPNIS, R. TKACH, E. SHPITZER, D. KIPNIS, Rafael, Hasolelim, Israel

In order to implement health monitoring methods in composite material structures that are being developed and manufactured, a series of preliminary tests was conducted. The aim was to check the influence of an implemented smart® layer on a graphite-epoxy structure, its durability and its ability to detect changes in the structure. A series of preliminary tests was conducted, in order to check the mechanical and electrical properties of the plate-sensors system (strength, rigidity, pzt capacitance, response to voltage input). The outcome of these experiments showed that the smart layer® increased the graphite-epoxy plate's flexibility, and the piezo-sensors were found to survive this procedure with no distinguishable damage. Subsequently, experiments were performed, to detect changes in boundary conditions imposed on the plate. A visual verification indicating changes in boundary conditions or the presence of simulated damage was received.

C-3: IL23 **Holistic Design of Smart Piezoelectric Composite Structures**

U. GABBERT, University of Magdeburg, Magdeburg, Germany

The paper presents a holistic design approach for smart structures, which are able to actively reduce vibration and noise and to increase the performance of the system. As smart materials piezoelectric patches are used as actuators and sensors. The basis of the approach is an overall finite element model, which includes the passive composite structure, the piezoelectric patches, attached to the structure or embedded between layers of the composite, the acoustic fluid as well as the controller. Several new finite elements have been developed recently, e.g. a powerful composite shell type element consisting of any number of passive and piezoelectric layer, which is used to simulate smart thin-walled lightweight composite structures, and 3D acoustic finite elements which can be coupled with the shell type elements to simulate the fibro-acoustic coupling. For active piezoelectric fiber materials the 3D material tensors of the constitutive equations are required, which are hardly to measure. In the paper a representative volume element approach is presented, which allows to homogenize the active fiber composite. The finite element approach results in the semi-discrete form of the fully coupled electro-mechanical-acoustic field equations, which can be used for design purposes as well as for the analysis of the overall behavior of the controlled system. For controller design purposes the original finite element model has to be reduced. We applied a model based reduction, which is performed on the basis of selected eigenmodes. The reduced model can be transformed into the state space form and transferred to special control design software (e.g. Matlab/Simulink). In the paper this procedure is presented briefly. Such an holistic virtual model can be applied to study and to optimize the performance and the efficiency of a smart structure under different operation and disturbance conditions. In the paper a special focus is on the calculation of optimal positions for the piezoelectric patch actuators. Finally, as an example for testing the holistic design approach, a smart acoustic box is presented, which is used to compare the simulation results with measurements. The paper ends with an outlook to ongoing real engineering applications.

C-3: IL24 **Control of Properties of Composite Structures with the Use of Multi-functional Materials**

W.M. OSTACHOWICZ, Polish Academy of Sciences, Gdansk, Poland

This work is focused on two major applications of multi-functional materials. PZT elements have been used to monitor the health of plate-like composite structures. These transducers act as a sources and sensors of guided elastic waves in the investigated structure. Excited waves propagate in the material and reflect from discontinuities, such as: boundaries, notches, cracks and delaminations. Registered time responses are input to the signal processing algorithm that correlates arriving waves with discontinuities in the structure and enables to indicate the location of a discontinuity. Shape memory alloy components in various forms can be integrated with composite structural elements in order to control their mechanical properties, static or dynamic behaviour. This can be obtained thanks to two unique phenomena associated with the martensitic transformation. The two processes are associated with significant changes (Young's modulus, damping) in the material properties, which can also be applied for control purposes. In this way controllable properties of shape memory alloy components can be effectively used in active control of static (deflection) and dynamic (natural frequencies, modes of vibrations, amplitudes of forced vibrations) characteristics of structural elements.

C-3: L25 **Design and Development of a Green Storage Tank for Thermo-controlled Water Supply**

HUNG-CHENG TSAI, Nanhua University, Chiayi, Taiwan; HUNG-JUNG TSAI, FEI-KUNG HUNG, WuFeng Institute of Technology, Chiayi, Taiwan

Water is an essential requirement in everyday life and global demand for clean usable water is increasing year by year. Therefore, developing and implementing effective water resource management and conservation strategies is vital. Generally speaking, most individuals (particularly senior citizens) prefer to use warm water when washing their hands or taking a bath. When hot water is left standing in the hot water pipe (i.e. the faucet is turned off), it will gradually cool. Consequently, when the faucet is first turned on, the water is generally allowed to run until it becomes sufficiently hot. Meanwhile, the original cooler water is simply drained away. Clearly, this approach is wasteful of both time and water. Therefore, this paper develops a green storage tank to perform a thermo-controlled water supply function. The tank is positioned between the hot water supply and the faucet and its operation is controlled by an electro-thermal thin-film heater and a thermo-controlled valve. When the faucet is turned on, the cooler water in the hot water pipe is directed into the tank. Once this water enters the tank, it is mixed with hot water stored inside until it acquires the desired temperature. The warmed water is then supplied to the faucet. When the water flowing through the hot pipe to the tank is already sufficiently warm for use, the thermo-controlled water supply function is automatically overridden, and the warm water is delivered directly to the faucet. The proposed green storage tank not only provides effective water and energy resource savings, but also provides a more convenient operation.

C-3: L27 **Remotely Controllable SHM System for a Concrete Box-girder Bridge**

JONG JAE LEE, Sejong University, Seoul, Korea; K.Y. KOO, J.Y. HONG, C.B. YUN, KAIST, Daejeon, Korea

In this paper, a novel framework of remotely controllable SHM system for a concrete box-girder bridge is proposed. So far, one of major obstacles in implementing SHM systems for bridges was unavailability of tractable network connection methods from a control office to bridge sites where commercial internet services are not available. Recently, A 3.5 generation mobile wireless communication technology, HSDPA (High Speed Downlink Packet Access) commercialized in 55 countries is making the network connection tractable since HSDPA is available almost anywhere mobile phones are available. In this paper, feasibility study was carried out on a remotely controllable SHM system with HSDPA network connection for a real high-way concrete box-girder bridge locates in rural area, Korea. It was found that the HSDPA network connection was very stable and reliable with reasonable network cost. It is expected that HSDPA network connection may contribute wide-spread usages of SHM systems due to its tractability and low cost.

C-3: IL28 **Wireless and Self-powered Smart Structures**

D. GUYOMAR, INSA Lyon, Villeurbanne, France

This paper addresses the problem of piezoelectric conversion enhancement from mechanical to electrical energy and focuses on three specific applications. Considering a vibrating structure equipped with piezoelements bonded on its surface, it can be shown that a non-linear dedicated processing of the piezoelectric output voltage improves significantly the energy conversion. Consequently in such a technique the energy conversion is a highly non-linear process. This energy transfer is optimal if the switch occurs at times that are related to the structure displacement itself and very efficient to pump out mechanical energy or to convert it into electrical energy. A direct application is the energy harvesting on vibrations which can be used to self-powered wireless devices. The proposed processing leads to performances improvement in vibration control and energy harvesting close to one order of magnitude. The scavenged energy is high enough to generate Lamb waves in the

composite structures, thus opening a route for self-powered health monitoring systems. Theoretical aspects of the processing will be developed and experimental results on the three applications previously mentioned will be given for monochromatic and random vibrations.

C-3: IL29 **Some Advances in Energy Recycling Semiactive Vibration Suppression**
JUNJIRO ONODA, Japan Aerospace Exploration Agency, Sagamihara, Japan

This paper summarizes some studies performed by the author's group on energy-recycling semi-active vibration suppression using piezoelectric transducers embedded in the vibrating structures and shunted on switched inductive circuits. Basic idea of this method is to suppress the vibration by controlling the switches in the shunt circuit, which was first introduced by Richard C., et al in 2000. This idea has been upgraded by introducing (1) a multiple-input-multiple-output (MIMO) control method for the switching of the shunt circuits and (2) a self-sensing method to estimate the modal displacements and velocities from the voltage of the piezoelectric transducer, so that any additional sensors can be neglected. Several numerical and experimental results showed that the method works well against transient, sinusoidal, and random multiple-mode vibrations and suppresses the vibrations more effectively than other methods except for active methods. It was also shown that the method is very robust, and, with it, the system is always stable. Studies for applications of this method to acoustic transmission attenuation techniques and vibration suppression of an actual satellite structures are also going on.

C-3: IL30 **Experimental Investigation of Effectiveness of Smart Passive System for Seismic Protection of Building Structures**
HYUNG-JO JUNG, HEON-JAE LEE, DONG-DOO JANG, KAIST, Daejeon, Korea; SEOK-JUN MOON, KIMM, Korea

The newly developed smart passive system is based on a magnetorheological fluid (MR) damper, which is one of the most promising semiactive control devices, and an electromagnetic induction (EMI) part, which is a power harvesting device from vibration of a structure according to Faraday's law of electromagnetic induction. Numerical simulations recently conducted by the authors have verified that the smart passive system could be effective to reduce the structural responses in the cases of civil engineering structures such as buildings and bridges. On the other hand, the experimental validation of the system is not sufficiently carried out yet. In this study, therefore, a series of shaking table tests are conducted to experimentally investigate the effectiveness of the smart passive system for seismic protection of building structure. The model structure is a scaled six-story frame structure with the height of 3.5 m and the weight of about 8 ton. The smart passive system is installed between its base floor and the first floor. The responses of the structure are measured under several ground motions including scaled historic earthquake records. The experimental results in the smart passive system case are compared with those in the MR damper-based semiactive control cases.

C-3: IL31 **Amplification of Interstory Drift and Velocity for the Passive Control of Structural Vibrations**
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Energy dissipation systems are being increasingly employed to provide enhanced seismic protection for new and retrofit buildings or for bridge construction. These elements exhibit either hysteretic or fluid viscosity or viscoelastic behaviour. All these elements have the common characteristic that they dissipate energy so limiting or eliminating damage to the structural frames. In many applications diagonal and chevron brace configurations have been extensively used based on the common experience of engineers with bracing systems in steel constructions. However it has been shown that such a configuration of harmed brace is not the most convenient one since the reduced efficiency of any kind of energy dissipation equipment. This happens because the slope of the brace reduces the interstory relative displacement and velocity significantly. Moreover, stiff structural systems respond to dynamic excitation with small drift and small interstory velocities and then in order to dissipate a significant amount of energy a large number of seismic devices are necessary with an increasing cost of the seismic protection. In order to enhance the performance of the seismic energy dissipation systems in the past some novel configurations of energy dissipation devices have been proposed. All these configurations have the common characteristic that they are designed in such a way that the relative displacement and velocity on the dissipative device is increased with a resulting increment of dissipation. These novel configurations utilize toggle joint mechanism that in fact results in magnification of relative displacements that are larger than the structural drift. In this paper the goal of enhancing the performance of the seismic damper device is achieved by using a pantograph with very high magnification factor (order of magnitude is $4 \div 6$), The performance of the proposed system is compared with that proposed by Constantinou *et al* [1]. The seismic motion is idealized as a Gaussian stochastic process with a power spectral density function coherent with response spectrum, the damper device is characterized, as usual, by a nonlinear force ($F = C_D |\dot{X}|^{\alpha} \operatorname{sgn}(\dot{X})$). The analyses in term of displacements and dissipated energy are performed by stochastic linearization technique and Monte Carlo simulations.

[1]M.C. Constantinou, P. Tsopelas, W. Hammel, A.N. Sigaher, "Toggle-brace-damper seismic energy dissipation systems", Journal of Structural Engineering ASCE, Vol 127, 105-112 (2001).

Session C-4
Structural Monitoring

C-4: IL01 **A Reference-free Paradigm for Structural Health Monitoring**
HOON SOHN, KAIST, Daejeon, South Korea

In conventional structural health monitoring (SHM) techniques, structural damage is often identified by comparing the "current" data obtained from a potentially damaged condition of a structure with the "baseline" data collected from the pristine condition of the structure. However, it has been reported that this type of pattern comparison with the baseline data can lead to increased false alarms due to the SHM system's susceptibility to varying operational and environmental conditions of the structure. In this presentation, a new concept of SHM is conceived so that defects can be identified and located without direct comparison with the baseline data. The proposed reference-free SHM paradigm is two-folds: In the first step, features sensitive to a defect but insensitive to other ambient variations such as temperature are extracted from instantaneously measured signals. Then, an autonomous damage classifier is developed so that damage diagnosis can be accomplished without using predetermined decision boundaries. Applications of the reference-free diagnosis to crack, corrosion and delamination detection in metallic and composite plates are presented with explicit considerations of temperature variation, external loading, and complex boundary conditions.

C-4: IL02 **Vibration-based Structural Health Monitoring - Current Status and Future Perspectives**
C.-P. FRITZEN, University of Siegen, Siegen, Germany

This paper intends to give an overview on the current status of vibration-based methods for Structural Health Monitoring. All these methods have in common that a structural change due to damage results in a more or less pronounced change of the dynamic behaviour. We discuss the use of modal information as well as the direct use of forced and ambient vibrations in the time domain. From this information different strategies can be deduced which depend on the type of measurement data (time/frequency domain) but also on the frequency spectrum. The incorporation of actuation and sensing devices into the structure leads to modern concepts of Smart Structural Health Monitoring. Problems with changing environmental conditions and the detection of sensor faults are addressed. Examples from civil, aerospace and wind energy engineering show the applicability of these methods.

C-4: IL03 **Quantifying Performance of SHM**
FU-KUO CHANG, Stanford University, Stanford, CA, USA

Recent demonstrations show Structural Health Monitoring (SHM) technologies can offer promising solutions for condition-based maintenance, higher sustainability, and more efficient design for

structures. However, SHM systems are highly structure dependent, which means that they are sensitive to material properties, geometry, environment, and specific requirements of hosting structures. In order to achieve the best performance for a selected SHM technology, each SHM system must be quantified with respect to its hosting structure. In this presentation, we will introduce Technology Classification Levels (TCL) for defining the technology readiness level of SHM systems and discuss appropriate techniques and procedures that are required to quantify each level. As an example, we will quantify two SHM systems designed for detection of damage in composite structures.

C-4: IL04 **Limits of Elliptical Triangulation Algorithm for Structural Health and Usage Monitoring of Aeronautical Structures**
C. PAGET, Airbus, Bristol, UK

Several methods for locating structural damage use conventional various algorithms to locate the damage which are only valid for homogeneous material. Those conventional techniques are not adequate for inhomogeneous materials, such as composite and complex metallic structures. Previous work proved the great benefits in using an elliptical triangulation approach with such inhomogeneous materials. Based only on mathematical solutions, this technique has solution limits, initiated by both the number of solutions and errors in experimental input data used in the location calculation, potentially providing incorrect results. The input data concerned are the time-of-flight and wave velocity. The paper evaluates the mathematical limits of elliptical triangulation algorithm and simple technique to always provide a solution within a reasonable accuracy when the input data are inaccurate. The mathematical limits were herein defined, providing a clear understanding of present technique, and the foundation for next phase of the investigation. The technique was further improved, giving a unique solution with good damage location accuracy , when previously not solution was available due to inaccurate input data. Those improvements were achieved by using the best-fit solution field approach.

C-4: IL05 **SHM System Integration and Supporting Algorithms**
AKIRA MITA, Keio University, Yokohama, Japan

Structural health monitoring (SHM) systems that monitor the condition of large structures such as bridges and buildings in order to promptly and quantitatively evaluate their deterioration and damage due to natural hazards and aging are under keen attention for prolonging the lives of structures while keeping them in healthy conditions. As many research efforts have been accumulated extensively, the technology pool for SHM has been widened and deepened. However, in the course of developing such a system, it has become recognized that the establishment of a database that provides the statistical information on many structures is one of the most important issues for utilizing the sophisticated tools effectively. Although many researchers have advocated the necessity of such a database for gathering health information, designers and contractors are kind of reluctant to reveal the information to third parties. While, the purchasers, users, or owners of structures keep eager to know the safety and reliability of their properties. Thus, the specifications of the SHM systems vary widely depending on which stakeholders are involved. In this paper, some new technologies in SHM systems for integration and supporting algorithms will be explored.

C-4: IL06 **Piezoelectric Impedance Sensor-based Structural Health Monitoring for Critical Members of Civil Infrastructures**
CHUNG-BANG YUN, SEUNGHEE PARK, KAIST, Daejeon, Korea

This paper presents novel structural health monitoring techniques for critical members of civil structures using electro-mechanical impedance sensors. The basic concept of this technique is to monitor critical locations of a structure for changes in structural impedance that would indicate imminent damage. In this paper, several principal software and hardware issues on this topic are addressed. An active sensing node incorporating on-board microprocessor and radio frequency telemetry is introduced in a sense of tailoring wireless sensing technology to the impedance method. A data compression algorithm using a principal component analysis is embedded into the on-board chip of the active sensing node. A method for compensating the temperature effects on the impedance measurements using cross-correlation analysis with effective frequency shifts is presented. Finally, a new impedance model is proposed, which incorporates the effects of the sensor and bonding defects for sensor self diagnosis.

C-4: L07 **Damage Detection with Auxiliary Subsystems**
F. VESTRONI, S. VIDOLI, F. DELL'ISOLA, J. CIAMBELLA, Università di Roma "La Sapienza", Roma, Italy

The small sensitivity to local variations of mechanical characteristics turns out to be the major limit of frequency-based identification techniques. To overcome this limit, the use of sensitivity enhancement techniques is proposed: the monitored structure is coupled to an auxiliary electric system, whose constitutive parameters are optimally tuned to enhance the sensitivities relevant to the identification process. The damage identification problem in these augmented structures is introduced; its main advantages and drawbacks are discussed. A beam-like structure coupled to a network of piezoelectric patches supplies an enlightening example for the application of the proposed method. Although the forces exerted by the piezoelectric transducers are not large, the choice of such transducers implies the remarkable advantage of dealing with highly sensitive and easily tunable devices. From the experimental point of view the proposed method requires the acquisition and the storage of the system response for several values of the auxiliary electric parameters, whilst from the computational point of view it involves the solution of a possibly non-convex minimization problem; however, the procedure proves to be effective to identify both positions and intensities of simultaneous damages.

C-4: L08 **Development of a Structural Health Monitoring System for Guangzhou New TV Tower**
Y.Q. NI, Y. XIA, W.Y. LIAO, P. ZHANG, The Hong Kong Polytechnic University, Kowloon, Hong Kong

The Guangzhou New TV Tower (GNTVT), currently being constructed in Guangzhou, China, is a supertall structure with a height of 610 m. This tube-in-tube structure consists of a reinforced concrete inner tube and a steel outer tube with concrete-filledtube columns. There are several floors connecting the inner tube and the outer tube. The concrete-filled-tube columns are inclined along the height, and the outer structure forms decreasing ovals at the lower half of the tower and increasing ovals at the upper half. This hyperbolic shape makes the structure looks vital and attractive in aesthetics while complex in mechanics. A long-term structural health monitoring (SHM) system was designed and is being implemented by the Hong Kong Polytechnic University to GNTVT in parallel with its construction progress. It is accomplished for both in-construction monitoring and in-service long-term monitoring. 527 sensors of 10 types and 13 data acquisition substations are used for the in-construction monitoring stage, while 280 sensors of 12 types and 5 data acquisition substations are used for the in-service monitoring stage. Up to November 2007, the tower has been erected to the height of 250 m, and more than 200 sensors have been installed along with the construction progress. This paper outlines the design and implementation of the SHM system for GNTVT, and the preliminary analysis results of the monitoring data obtained by a wireless and remotely controlled data acquisition system. The devised SHM system is composed of six modules: (i) sensory system, (ii) data acquisition and transmission system, (iii) data processing and control system, (iv) structural health evaluation system, (v) data management system, and (vi) inspection and maintenance system. The technological and implemental issues of each functional module are explored in this paper. As the monitoring system for GNTVT is one of few SHM practices that integrate the construction monitoring and the operation monitoring, some advantages stemming from such an integrated monitoring system for structural damage detection and condition evaluation are also demonstrated.

C-4: L10 **Wireless Sensing and Embedded Monitoring Algorithm for Damage Diagnosis in PSC Girders**
JEONG-TAE KIM, JAE-HYUNG PARK, DONG-SOO HONG, Pukyong National University, Busan, Korea

Prestressed concrete (PSC) girder bridges suffer damages such as prestress-loss, flexural crack and support failure. Over the past two decades, many researchers have attempted to detect the damages in PSC girder bridges by using changes of vibration characteristics. However, the following problems still remain to be solved for successful damage detection in PSC girder bridges: damage types of PSC girder bridges cannot be easily recognized from the vibration-based approaches; costs associated with installation and upkeep of wired monitoring systems can be high; and data repositories with high capacity is needed for future engineering analysis. In this study, a hybrid health monitoring technique that combines wireless sensing and embedded software algorithms is proposed to realize the diagnosis of damage in PSC girder bridges. Firstly, a hybrid damage monitoring scheme that

can alarm damage occurrence, classify damage-types, and identify damage locations and severities in PSC girder bridges is designed. Secondly, a wireless sensor platform embedded the hybrid damage monitoring algorithm for the PSC girder bridge is developed. Finally, the performance of the developed wireless sensor platform is evaluated using a scaled PSC girder bridge model.

C-4: L11 **Smart Nonlinear Acoustic Based Structural Health Monitoring System**

M. MEO, U. POLIMERO, The University of Bath, Bath, UK

The objective of this work was to demonstrate the feasibility of nonlinear vibration/acoustic/ultrasonic piezo-based diagnostic tools to be implemented in a structural health monitoring system for damage detection and localisation. Examples of the capability and limitations of the proposed damage detection process to detect delamination damage due to low velocity impact (<12J) are presented for various composite laminated and sandwich panels. Two different NEWS methods are presented: single mode nonlinear resonance ultrasound (NRUS) and nonlinear wave modulation technique (NWMS). Both techniques, NRUS and NWMS, highlighted the presence of nonclassical non linear features in the spectrum responses caused by the damage presence. NRUS tests showed that impact damaged panels under resonance conditions, when the excitation is increased, a resonance frequency shift is observed. Using NWMS the intermodulation effects caused by microcracks, debonding, delamination, etc…were evident, highlighted by the presence and amplitude of frequency-mixing spectral components in the spectrum of the received signal i.e. harmonics and sidebands. The results showed that the proposed NEWS methods appear to be highly accurate in assessing the presence and magnitude of damage with very promising future NDT and structural health monitoring applications.

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C-4: IL13 **On the Development of Efficient Damage Diagnosis Algorithms for Local Sensor-level Processing**

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A statistical pattern recognition and signal processing approach appears to be particularly suited for the development of damage diagnosis tools for distributed dense wireless structural health monitoring systems. Our team has developed methods that utilize autoregressive (AR) modeling of the recorded signal and applying Gaussian Mixture models for damage identification. Damage measures for defining extent of damage have been developed that combine fundamental structural reliability formulations and mixture separation distances expressed in terms of a Mahalanobis distance. In addition to the AR models, a wavelet representation of the measured signal is used to identify damage onset. The two signal modeling methods - AR and wavelet analyses, together with the various damage measures were applied to data from laboratory and field tests to determine their robustness. The data used include the three story steel frame test benchmark structure built and tested at the National Center for Research in Earthquake Engineering at the National Taiwan University. The results of the application of the data show that the AR and wavelet based algorithms almost consistently identify damage. The methods and results from the applications will be presented in greater detail in the paper.

C-4: L15 **Strain monitoring of FRP structures using an embedded fibre optic sensor**

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This paper presents a srain monitoring approach for following up FRP elements (in this case a [90°] CFRP laminate) using an embedded fibre optic sensor. The sensor exists of two fibre Bragg gratings (FBGs) written in a polarization maintaining fibre (PMF). First, the strain response of the non-embedded sensor is determined which makes it possible to relate the different bragg peak shifts with the induced strain field in the core of the optical fibre. Secondly, a transfer coefficient matrix is presented and calculated using finite element simulations which relates the measured strain field of the sensor with the adjacent one existing in the structure as if no sensor would be present.

C-4: L16 **High Strain Monitoring During Fatigue Loading of Thermoplastic Composites Using Imbedded Draw Tower Fibre Bragg Grating Sensors**

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Fibre reinforced composites are today more and more employed as structural parts in advanced engineering constructions with high demands on performance. Among others they are today for instance used in windmills, helicopters and airplanes. As composites are complex materials, their long term behaviour is hard to predict. In this point of view and also for safety reasons one should think about (in-situ) structural health monitoring (SHM) technologies and real-time measuring of the strains and the stresses of the (critical) composite structural parts. In the past few years fibre Bragg gratings are extensively been imbedded and tested mostly in 'thermoset' composites where they already have proven that they are feasible for measuring (low) strains or even for sensing damage effects in the material. Within this research 'thermoplastic' composites with high elasticity are chosen as host material. High strength 'draw tower fibre Bragg grating sensors' are imbedded for measuring strains inside the thermoplastic composites during 'tension-tension' fatigue testing of the composite test-coupons. First results of the imbedded sensors are presented. They are very promising and show that the 'draw tower fibre Bragg grating sensors' are feasible for long term (high) strain measurements.

C-4: L17 **Self-detection of Delamination in Active Fiber Composites**

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This paper presents a novel method under development for monitoring the bonding condition of active fiber composites (AFCs), which are formed with unidirectionally aligned piezoelectric fibers embedded in epoxy matrix and sandwiched between two symmetrical interdigital electrodes. Because of their mechanical flexibility and toughness, AFCs can be tailored to fit smoothly with curved composite structures and used as integrated acoustic sensors/actuators to compose functional structures. Debonding between AFC patch and host structure should be avoid and surveyed through its service life. AFC excited by sinusoidal voltage works like a resonator. Its electric charge is proportional to the strain field experienced by the host material integrated over its coverage area. The electric impedance and mechanical displacement of the AFC patch adhered on an aluminum plate were investigated in a broad frequency range. The modal characteristics depend on the debonding size and stiffness of adhesive along the delamination front. Feasibility of self-detecting the debonding progressed between AFC patch and host plate is demonstrated in this paper through computational and experimental results.

C-4: L18 **Stochastic Vector AutoRegressive eXogenous (VARX) Identification of a Smart Composite Beam**

J.D. HIOS, S.D. FASSOIS, University of Patras, Patras, Greece

This study aims at identifying the dynamics of a smart composite beam. Smart structures constitute a technically appealing solution due to the vibration suspension and structural health monitoring requirements posed in many aircraft, civil and industrial applications. This interest motivates the need for precise mathematical modeling - presently addressed via Vector AutoRegressive with eXogenous (VARX) excitation models. The advantages of VARX modeling include i) simplicity of implementation, ii) high accuracy, iii) parsimony of representation and iv) capability of handling modal uncertainties. Two different approaches to assess the modal parameter uncertainties are investigated. The first is based upon linearizing the function that relates the VARX model parameters with the modal parameters, whereas the second is based upon simulations using the Monte Carlo and the Bootstrap techniques. Hence, a very

comprehensive study of the problem is established. The results indicate that VARX modeling accurately represents the system dynamics allowing for i) small prediction errors ii) correct identification of the system's prominent structural modes and iii) tight confidence intervals for the estimated modal parameters.

C-4: L19 **Optimisation of Signal Pre-processing for the Integration of Cost-effective Local Intelligence in Wireless Self-powered Structural Health Monitoring**

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Recent research in Structural Health Monitoring (SHM) showed the ability of guided-wave based sensors networks to detect, localise and classify damage in its early stage. But, most of them still require the wiring of numerous devices. To avoid this technical restraint, particularly in airborne structures, wireless SHM system offer mass and cost savings, but powering the devices remains heavy. In this paper, actuators and sensors are powered by piezoelectric microgenerators, which harvest energy from the environing mechanical stress. The efficiency of the extraction process is optimised by a non-linear processing of the piezovoltage named Synchronized Switch Harvesting. Previous work showed that such technique provide a stand-alone power source, whose performances meet the requirements of Wireless Transmitters and Receivers. Indeed, each sensing node has to feature its own power source in order to acquire its logical autonomy and thus, provide decentralised intelligence to SHM network. Although the diagnosis is centralised, the amount of data passed to the central core of the network should be reduce to preserve a positive energy balance of the node. Various algorithms are compared in terms sensitivity and computational cost, the latter directly impacting the node's consumption.

C-4: L20 **Numerical Simulation for Health Monitoring of Concrete Structure Based on Smart Piezoelectric Transducer Array**

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A new numerical method was proposed in this paper to apply finite element method (FEM) to simulate numerically a process for health monitoring of concrete structures based on PZT transducer array and structural impedances. The goal of the method was to detect levels and locations of damages in the concrete structure by the PZT transducer array. A FEM model for a damaged reinforced concrete shear wall pasted PZT transducers array was used for the simulation. A health shear wall model with the same parameters to the damage one was used for compare. The PZT patches were electrically excited in a sine wave at a high frequency. The patches were scanned for the acquisition this signature at health stage and damaged stage of shear wall. The signatures of the patches located in the vicinity of the damage were found to have undergone drastic changes, while those farther away from the damages were less affected. Damage was quantified using the root mean square of the deviation (RMSD) in signatures with respect to the baseline signature of health state. At last, the arrangement principles of the PZT transducers array were discussed detailed. The results of the FEM simulation showed that the proposed method was effective to detect the damage level and location of concrete structures.

C-4: L21 **Wavelet-Based Algorithm for Ultrasonic Structural Monitoring of Waveguides**

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Ultrasonic Guided Waves (UGWs) are a useful tool in those structural health monitoring applications that can benefit from built-in transduction, moderately large inspection ranges and high sensitivity to small flaws. This paper describes two methods, based on linear and nonlinear acoustics for structural damage detection based on UGWs. Both methods combine the advantages of UGW inspection with the outcomes of the Discrete Wavelet Transform (DWT) that is used for extracting defect-sensitive features that can be combined to perform a multivariate diagnosis of damage. In particular, the DWT is exploited to de-noise and compress the ultrasonic signals in real-time and generate a set of relevant wavelet coefficients to construct a uni-dimensional or multi-dimensional damage index. The damage index is then fed to an outlier analysis to detect anomalous structural states. The general framework presented in this paper is applied to the detection of fatigue cracks in an I-shaped steel beam. The probing hardware consists of Lead Zirconate Titanate (PZT) materials used for both ultrasound generation and detection at chosen frequency. The effectiveness of the proposed methods for the structural diagnosis of defects that are small compared to the waveguide cross-sectional area is discussed.

C-4: L22 **Damage Detection in Beam-like Structures Using Deflections Obtained by Modal Flexibility Matrices**

KI YOUNG KOO, C.B. YUN, Korea Advanced Institute of Science and Technology, Daejeon, Korea; J.T. KIM, Pukyong National University, Busan, Korea; Y.H. HUH, Korea Research Institute of Standards and Science, Daejeon, Korea

In bridge structures, damage may induce an additional deflection which may contain essential information about the damage. However, inverse mappings from the damage-induced deflection to the actual damage location and severity are generally complex, particularly for statically indeterminate systems. In this paper, a new load concept, so called the positive-bending-inspection-load (PBIL) is proposed to construct a simple inverse mapping from the damage-induced deflection to the actual damage location. A PBIL of an inspection region is defined as a load or a system of loads which guarantees bending moment to be positive within the inspection region. From theoretical investigations, it was proven that the damage-induced chord-wise deflection (DI-CWD) has the maximum value with an abrupt change in its slope at the damage location under a PBIL. Hence, a novel damage localization method is proposed based on the DI-CWD under a PBIL. Experimental verification has been carried out on a two-span continuous bridge model with a steel box-girder. It was found that the proposed method can clearly identify the damage location for relatively small damage cases of 12% reduction in the bending rigidity at a point with a narrow cut.

C-4: L23 **Development of a Structural Health Monitoring Benchmark Problem for High-rise Structures**

Y. XIA, Y.Q. NI, Y.F. DUAN, J.M. KO, The Hong Kong Polytechnic University, Kowloon, Hong Kong

The Guangzhou New TV Tower is deemed to be the most heavily instrumented high-rise structure in the world with the dual function of on-line monitoring of the structural behaviors at both construction and service stages. Under the auspices of the Asian-Pacific Network of Centers for Research in Smart Structures Technology (ANCRiSST), a structural health monitoring (SHM) benchmark problem for high-rise structures is being developed by taking the instrumented Guangzhou New TV Tower as a test bed. It will be delivered through a website to all interested participants in SHM community and serve as an international platform for comparison of different damage detection algorithms and dialog between researchers and practitioners. The finite element models and field measurement data at different construction stages and in the service life of the structure will be used to establish the benchmark problem that consists of the following four phases: (i) output-only modal identification and finite element model updating, (ii) damage detection using model-based simulation data, (iii) optimal sensor placement for structural damage detection, and (iv) damage detection using field measurement data. The proposed benchmark problem holds the following features: (i) it is the first SHM benchmark problem for high-rise structures; (ii) it is the first SHM benchmark problem in regard to a full-scale structure; (iii) field measurement data in both healthy and damage stages are available for the benchmark study (the monitoring data acquired shortly before the completion of the construction without the top connecting beams being erected and immediately after the completion of the construction will serve as the field measurement data posterior to and prior to structural damage for the first scenario study, and the monitoring data acquired before and after the installation of the 160 m high antennary master will serve as the field measurement data posterior to and prior to structural damage for the second scenario study); and (iv) this SHM benchmark problem in regard to a large-scale slender structure provides a paradigm to investigate the optimal placement of sensory networks for structural health monitoring. Some key issues related to the development of this benchmark problem are explored in this paper.

C-4: L24 **Continuing Structural Health Monitoring after Repair: Start from Scratch?**

J. KULLAA, Helsinki Polytechnic Stadia, Helsinki, Finland

Repairs are needed for aging structures if their lifetime is to be extended. The structure may include a health monitoring system already before repair, and monitoring will be continued thereafter. As repairs typically

change the dynamic behaviour of the structure due to the stiffness increase, the question arises whether monitoring must be started from the beginning by re-collecting training data during a full range of operational conditions. In this paper a method is proposed to decrease the time of building a new model for the repaired structure by utilising the training data acquired before repair. It is assumed that the environmental or operational influences on the structure remain the same as before repair. This assumption makes it possible to assess the damage extent in cases where damage occurs at the local repair or if the deterioration of the structure is similar before and after repair. However, if the damage after repair has a novel pattern, damage can still be detected, but no further information is available. The approach is solely based on measurement data. The proposed method is verified with a numerical model of a vehicle crane and in an experimental study using point masses of different sizes at different locations on the structure.

C-4: L25 **Multivariate Statistical Analysis for Detection and Identification of Faulty Sensors Using Latent Variable Methods**
M. HERNANDEZ-GARCIA, S.F. MASRI, University of Southern California, Los Angeles, CA, USA

In this paper, three latent variable methods are implemented in a multivariate statistical analysis scheme for detecting and identifying faults in a multi-sensor network. Structural health monitoring systems typically rely on data measured by multi-sensor networks. Consequently malfunctioning or faulty sensors can adversely affect the performance of the monitoring system by corrupting the available sensor information. For this reason, multivariate statistical monitoring approaches based on Principal Component Analysis (PCA), Independent Component Analysis (ICA) and Modified Independent Component Analysis (MICA) are integrated into a sensor fault detection and identification scheme. The basic idea of this approach is to extract dominant information from normal operating condition contained in latent variables by using PCA, ICA and MICA; and to combine it with statistical monitoring techniques and variable contribution plots to the monitoring statistics. The proposed methods are applied to fault detection and identification in several MDoF dynamical systems and the results from all of them are presented, compared and discussed.

C-4: L26 **Numerical Methods in the Dynamic Analysis of Buildings Provided with Viscoelastic Devices**
G. MUSCOLINO, University of Messina, Messina, Italy; A. PALMERI, University of Bradford, UK

Viscoelastic dampers have been successfully used with the aim of mitigating the structural vibrations induced by natural actions, such as ground shakings, wind gusts, or ocean waves (e.g. ref.[1] and [2]). Continuous improvements in the techniques of identification and analysis, in fact, paralleled by noticeable refinements of device hardware, made the use of viscoelastic dampers completely suitable for consideration in both new or retrofitted constructions[3]. Aim of this paper is to propose two novel integration schemes: the first one for the dynamic analysis of viscoelastically damped structures under deterministic loading; the second one in the case of excitations modelled as random processes. Accuracy and efficiency of the proposed approaches are demonstrated through numerical applications. It is also shown that the use of 'equivalent' Kelvin-Voigt models, with a simpler viscous damping, may be excessively unconservative.

[1]B. Samali, K.C.S. Kwok, "Use of viscoelastic dampers in reducing wind-induced and earthquake-induced motion of building structures", Engineering Structures, 17, 639-54, 1995; [2]H.H. Lee, "Stochastic analysis for offshore structures with added mechanical dampers", Ocean Engineering, 24, 817-34, 1997; [3]A. Palmeri, F. Ricciardelli, G. Muscolino, A. De Luca, "Effects of viscoelastic memory on the buffeting response of tall buildings", Wind and Structures, 7, 89-106, 2004.

C-4: IL27 **Dynamic Response-based Health Monitoring of Civil Structures Under Environmental Influences**
M.P. SINGH, H. NANDAN, Virginia Tech, Blacksburg, VA, USA

For health monitoring of bridge structures, vibration response-based methods offer several advantages. They identify damage by detecting the abnormal changes in the dynamic characteristics such as the frequencies and modeshapes extracted from the vibration response. However, the environmental fluctuations in temperature, radiation, convection, and humidity may change the dynamic characteristics of a bridge structure more than those caused by structural damage and thus mask the damage effects. Thus, the methods are being developed to predict the change in the dynamic characteristics directly from the environmental measurements to separate them from those caused by the damage. In this paper, we examine results of comprehensive thermal analyses of three bridge structures conducted for a nine-year record of the environmental temperature, radiation, and wind speed to predict the environmental induced changes. The effects of temperature on the material rigidity, asphalt layer, thermal gradients, boundary conditions, convection effect, and radiation are examined. The final objective of the study is to predict the modal properties in terms of the predominant thermal harmonics such as annual and diurnal variations as well as the hourly random fluctuations with minimal thermal analysis.

C-4: IL28 **Optimization Algorithms for System Integration**
C. PAPADIMITRIOU, E. NTOTSIOS, University of Thessaly, Volos, Greece

Health monitoring and diagnosis of structural systems depends on the integration of cost-effective intelligent sensing/actuating techniques, accurate computational models simulating system behaviour, sophisticated system identification and health diagnosis algorithms, as well as reliability analysis tools for data-driven prediction of safety under uncertainty. This work outlines the optimization algorithms involved in system integration, including algorithms for optimally placing sensors in the structure for extracting the most informative data, as well as algorithms for combining sensor information with computational structural dynamics models for structural identification and structural damage detection. These problems are formulated as single- and multi-objective optimization problems of continuous or discrete-valued variables. Gradient-based, evolutionary, heuristic and hybrid algorithms are presented that effectively address issues related to the estimation of multiple local/global solutions, unidentifiability and computational complexity arising in single and multi-objective optimization. Theoretical and computational developments are illustrated using data from sensor arrays placed on civil structures, such as full-scale bridges and small scale laboratory structures.

C-4: IL29 **On the Relationship between Robustness and Monitoring**
M.H. FABER, ETH Zürich, Zürich, Switzerland

The robustness of structures is the subject of the European COST action TU601. A special aspect of structural robustness results from the current trend to install a monitoring system in special purposes infrastructure components as bridges or wind turbines. This contribution investigates the relationship between robustness and monitoring on the basis of numerical models of the investigated case studies.

Session C-5
Ongoing and Perspective Applications

C-5: IL01 **Biosensing & Bioactuation: A New Research Frontier**
SHIH-CHI LIU, G. YANG, National Science Foundation, Arlington, VA, USA

Based on a grass-roots effort by program officers, an internal NSF symposium was held on July 31, 2007. The objective of the symposium is to assess the merit, interest, and feasibility of developing a new cross-directorate research frontier on *Biosensing* and *Bioactuation*. This initiative is expected to address fundamental biological questions pertaining to sensing and actuation, new functional materials to mimic biosensing and bioactuation capabilities, and novel fabrication and manufacturing technologies for such new materials. The program will aim to develop smart materials and systems with embedded human- or bio-centric intelligence that incorporate biologically-inspired sensor and actuator design, as well as control and monitoring technologies. This initiative will take advantage of advances in MEMS and NEMS, developed under the National Nanotechnology Initiative (NNI), advanced materials, wireless IT, etc., as well as the collective strength of programs currently exiting within NSF. Moreover, it will deepen our understanding of biological systems at the genetic, molecular, cellular, and tissue levels with new engineering motivations and tools and provide a road map to extend beyond today's chip electronics integration. This paper will report the program development effort and its outcome and impacts.

C-5: IL02 **Biologically Inspired Shape Changing Aerody-namic Profiles and their Effect on Flight Performance of Future Aircraft**
C. BOLLER, CHEN-MING KUO, NING QIN, The University of Sheffield, Sheffield, UK

Flying has been inspired by biology since the very early days. Although aircraft look to be established with regard to their structural design today active materials have again triggered as to what degree aerodynamic profiles could become more adaptive in their shape with regard to enhanced flight performance. Demonstrating the shortcomings of wing adaptiveness on manned aircraft size is time consuming and costly. This can however be overcome by performing such demonstrations on aircraft at much smaller scales. Such aircraft are micro aerial vehicles (MAV) which have spans far less than a metre and a weight of no more than a few hundred grams. To enhance manoeuvrability and stability birds and insects use actuation principles along their wings such as changing wing thickness or stiffness, or actuating individual flaps with their feathers. Similar effects will be shown for an MAV's wing thickness and stiffness change regarding flight stability and manoeuvrability and how this can be realised using active materials. It will be explained how active flaps could be realised on an MAV wing and the resulting effect on lift and performance. Results from wind tunnel and real flight tests will be included and conclusions will be based on the consequences regarding larger sized aircraft.

C-5: IL03 **Multifunctional and Smart Materials Research at the U.S. Army Research Laboratory**
E.D. WETZEL, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, USA

The complex missions and platforms of the U.S. Army require new materials with increasingly diverse and adaptive capabilities. This briefing will summarize some of the research activities underway to develop materials to address these new technology requirements. (1) Structural composite batteries and capacitors have been developed that simultaneously provide energy storage and load-bearing capabilities. These multifunctional structures are expected to provide system-level mass savings by replacing inert, monofunctional composite structures. (2) Waveguides with unique line-of-sight transceivers for optical communication have been embedded into structural composites. These transcievers allow for remote data communication into and out of structures through optical, non-contact coupling, resulting in a structural data bus that is more robust and non-invasive than conventional pig-tailed approaches. (3) Finally, emerging efforts to grow self-organizing, hierarchical vascular systems in composite structures will be presented. These vascularized composites could provide new opportunities for materials that self-clean, self-decontaminate, or adapt their properties based on changing mission requirements.

C-5: L05 **Innovations in Smart Materials and Integrated Structural Health Monitoring in the Australian Defence Force**
M.E. IBRAHIM, C.M. SCALA, Defence Science and Technology Organisation, Fishermans Bend, Victoria, Australia

The Australian Defence Science and Technology Organisation (DSTO) has established a breakthrough technology program to facilitate the development and transition of innovative Smart Materials and Structures from fundamental science into Defence Force field use. This program extends and harnesses technology in the area of Smart Materials, Sensors and Systems, in order to enhance military platform capability, increase platform safety and reduce the cost of platform ownership and operations. In this paper, we present an overview of key research areas that exist within the Smart Materials and Structures initiative, highlighting developments from the study of : (i) Smart Materials, including coatings that exhibit properties of greater flexibility and durability for aerospace applications, nano-crystalline coatings that provide increased wear resistance, and Defence applications for carbon nanotubes; (ii) Smart Sensing, including chemical, structural fatigue, fuel contamination, environmental degradation, corrosion and its precursors, and overheating and mechanical wear; and (iii) Smart Systems, that employ innovative techniques to acquire and process data from a range of sensors by harvesting energy from local structures to power micro-electronic circuits.

C-5: L06 **Vibration Damage Reduction of On-board Electronic Boards Using Modal Active Control**
B. CHOMETTE, S. CHESNE, D. REMOND, L. GAUDILLER, INSA-Lyon, Villeurbanne, France

On-board electronic boards are subjected to severe stresses, particularly vibration. In this paper, a method to increase the lifetime of electronic components by reducing vibration is proposed. A first physic of failures (PoF) analysis of the electronic components is carried out to determine the most damaging modes. The lifetime of the electronic circuit board is next estimated using Miner's rule. The control strategy is modal to focus the external energy on the most damaging modes. The industrial boundary conditions and the electronic components induce complex mode shapes which constrain the control design. This control uses piezoelectric components which are located to be effective on the damaging modes. A linear quadratic Gaussian algorithm applied on an experimental modal state space model is used. The effectiveness of the proposed method is then examined through experiment with high excitation levels. These levels correspond with real excitations when the electronic board is on-board. The designed control is finally validated with a new PoF analysis of the controlled structure. The lifetime of the electronic board is highly increased.

C-5: L07 **Monitoring Data for the Structural Assessment of Historical Buildings**
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A construction history that spans centuries often results in complex structural systems whose load-carrying behaviour cannot be easily assessed by visual inspections. The structural rehabilitation should be supported by numerical analyses during both the design and the implementation phases of a retrofit operation. Within this context, monitoring systems provide reliable information about the structure performance under serviceability conditions. Output-only measurements are used for the dynamic system identification before and after the intervention. A numerical model is developed and calibrated so that it matches the experimentally identified modal parameters. The collected data can then be used to assess both the original deterioration state of the structure, and the relative efficiency of the retrofit operation. The procedure is illustrated with reference to a specific case-of-study, which concerns a part of the Archbishop Palace located in Siracusa, Italy. Experimental and numerical studies are carried out to evaluate the actual loads supported by an ancient stone arch. The arch is surmounted by a "transverse body" which underwent several additions in elevation across the centuries. Experimental tests are performed using different excitation methods and accelerometer configurations. The measurements are taken before and after the retrofit of the arch. The elaboration of the collected data in view of the structural assessment of the system is the topic of this work.

C-5: IL08 **Protection of Mediterranean Historical Structures Against Earthquakes Using Fragility Curves**
C.A. SYRMAKEZIS, National Technical University of Athens, Athens, Greece

The seismic rehabilitation and retrofitting of historical structures is an important issue in the entire Mediterranean basin, which is characterized by its richness in historical masonry structures as well as its high seismicity. The exceptional character of historical structures imposes the respect of their originality, thus any protection measures should comply with the principles of reversibility and compatibility. As a result the application of passive control systems such as dampers is suggested for their retrofitting. For the restoration of historical structures and monuments, high demands are raised, due to their great significance as cultural heritage carriers. Economical, social and architectural motives impose the need of a clear insight into structural reliability, for decision-taking purposes. At the same time, the random character of characteristics that determine the structure's capacity to resist loads and the difficulty in establishing the magnitude of anticipated loads, lead to a probability-based design approach. The high importance of historical structures, the need for evaluation of their present state and often the determination of the extent and the possible ways of reinforcement, imposes the development of a methodology that could offer an estimation of their behaviour, taking into account the uncertainties that are introduced during the analysis. These uncertainties may come as a result of the variety of structural materials used in the same monument, and consequently of their mechanical properties, as well as of the approximate evaluations of materials' mechanical properties due to the difficulty of determining them with great precision. Furthermore, the inefficiency of simple reliable mechanical models in interpreting complicated historical structures, the interventions made through the ages that have altered their initial behaviour, past earthquakes, the degradation of structural materials' resistance and

general deterioration in time, increase the uncertainties effect. In addition to this, and taking into account the random action and intensity of the earthquake phenomenon, the vulnerability assessment presented in probabilistic terms is strongly recommended. Fragility curves are an extremely useful tool for decision-making, regarding the conservation and the restoration of the structures, especially in the case of historical monuments where reversibility is often difficult to achieve and interventions have to be of minimum scale, so as to avoid modifications to the historical character of the structure. In this paper a methodology for a probabilistic evaluation of the vulnerability of historical structures and monuments is presented. The need for such an approach is imposed by the probabilistic character of the parameters that determine the response of a structure subjected to random earthquakes. The methology developed leads to the construction of the fragility curves that can graphically represent the probability of certain damage ranks under the effect of various earthquakes intensities. Extending this methodology, families of fragility curves can be constructed, for various random parameters that define the response of a different type of structures (buildings, churches and bridges). Through this family of curves, investigation of the way each of these factors affects the vulnerability of the structures relatively to others, is possible. The application of the methodology proposed is illustrated through a case study. The selected structures are, three Byzantine monasteries situated in Athens, Greece, constructed between 11th and 12th century and three typically buildings with two stores, situated in Crete, Greece, constructed between 18th and 19th century, all the monuments are typically masonry structures. For its reinforcement various restoration mortars have been investigated, with diverse tensile strengths. The correlation of the earthquake intensity with the vulnerability of the structure proposed is shown in those examples.

C-5: L09 **Wireless Sensor Node Development for Bridge Condition Assessment**

CHUL-WOO KIM, M. KAWATANI, M. TSUKAMOTO, N. FUJITA, Kobe University, Kobe, Japan

An important problem that must be solved in system identification for the small and medium span bridges using vibration measurements is development of a cost-effective sensor system. Another important issue is how excite the bridge economically, reliably and rapidly. The authors have proposed a bridge condition screening method using an inspection car which has two important functions: one is as an actuator during running on bridges; and another deals with acquiring data from bridges synchronized during being actuated by the moving car. To realize the method, it also needs a cost-effective wireless sensor system such as smart wireless sensors which have recently been developed. The available sensors, however, are limited and not necessarily optimized for vibration-based bridge health monitoring. For instance, the typical Mote sensor board has low sensitivity and that its target frequency range is too high to apply on the vibration-based bridge health monitoring. This paper presents an on-going study within the Civil Engineering and Electrical and Electronics Engineering Departments at Kobe University on the development and testing of a wireless sensor node equipped MEMS accelerometer, which is designed to meet the specific requirements of bridge health monitoring applications.

C-5: L10 **Quantifying the Benefit of Smart Technologies in a Life-cycle Context**

D.M. FRANGOPOL, R.K. FAZLUR, Lehigh University, Bethlehem, PA, USA; T.B. MESSERVEY, University of Pavia, Pavia, Italy

Advanced materials, embedded devices, and smart technologies undoubtedly have the potential to change existing codes, design methodologies, assessment techniques and maintenance actions across engineering applications. However, unless the benefits of these new technologies can be quantified monetarily, they may undergo slower development, acceptance, and use in practice. This is especially the case in the resource constrained environment of civil infrastructure where the end product is one of public service instead of profit. In such an environment, it is essential that researchers, product developers, and practicing engineers develop and communicate the methodologies necessary to justify initial up-front costs. Success in this effort requires the continued development and adoption of durability-based design, performance-based design, the quantification of risk, and reliability-based life-cycle analysis. This paper discusses what metrics are available and those that require development such that smart systems can be evaluated appropriately when comparing design or maintenance alternatives.

C-5: L11 **Wing Mechanization Design and Analysis for a Perching Micro Air Vehicle**

J.M. LUKENS, University of Dayton, Dayton, OH, USA; G.W. REICH, B. SANDERS, Air Vehicles Directorate, WPAFB, OH, USA

Interest in the design and development of bird-like micro air vehicles (MAVs) has emerged in recent years. Research in this area has focused mainly on the aerodynamics of flapping and on the kinematic mechanism that makes the beating motion possible. What is missing is an investigation of how a bird-like MAV could be mechanized to land with approximately zero vertical and horizontal velocity, inspired by a bird perching maneuver. The objective of this project is to determine the degrees of freedom and motions necessary to complete this landing maneuver and to develop a mechanized model to perform the required motion while still meeting size, weight, and power requirements of a notional vehicle to perform the maneuver. This project focuses on the wing mechanization design and kinematic mechanism making the wing motion possible as well as the structure/mechanism integration. A mechanized wing concept for a perching micro air vehicle has been designed and manufactured with wings capable of rotating at two spanwise joints to simulate the rotational motion of a bird's wings during a perching maneuver. Wind tunnel testing and analytical simulation will also be completed to further develop the model.

C-5: L12 **Dynamic Material Application in Architectural Environments**

C. LELIEVELD, L. VOORBIJ, W. POELMAN, TU Delft, Delft, The Netherlands

In this research the possibilities are examined for the realization of adaptable architecture with the use of dynamic materials. Dynamic materials have the characteristics to change their physical appearance and characteristics in reaction of external stimuli. The term "dynamic" is used in this research instead of "smart", as the materials are controlled by human interference. After an exploration of the current dynamic material technology outside the field of architecture, a design is made with dynamic materials. With these materials a translation is made to the specific purpose of the material in the design. Scale and difference of application of the material may cause problems to solve. Different dynamic materials are integrated to construct a prototype. The prototype is made on small scale to investigate the possibilities of the behavior of the material for this purpose. This prototype will be a small part of an architectural space which will be able to be adjusted to the environment and/or users. The first step of the research is the solution of adjustment of the shape, what is called motion. Materials used in this research are Shape Memory Polymer and Shape Memory Alloy. This research is executed in an architectural framework.

C-5: IL13 **Maltese Falcon, Megayacht with Smart Masts and Yards**

D. ROBERTS, Insensys Ltd., Southampton, UK

"Few would disagree that every aspect of this ground breaking yacht-probably the most significant sailing vessel since the introduction of the Bermudan Rig is either an aesthetic or technological work of art" Roger Lean-Vercoe. This revolutionary award winning 88m long three masted sailing yacht features freestanding rotating Carbon Fibre masts and yards, each mast carries 800 sq m of sail set as 5 sails The loads on each 58m high mast are similar to those on Boeing 747 wings and are significantly higher than any other sailing vessel. The sails when not set are housed in the mast cavity and are deployed and recovered through a vertical slot in the front (compression) face of the mast. Embedded into the masts and yards is a network of FBG fibre optic strain sensors, with the output displayed on the bridge in real time as the current bending and torsional loads, lift and drag forces or more simply forward driving and heeling forces. The output from these sensors is used on board to help optimise sail set configurations and provide full load history for long term health monitoring.Since launching in June 2006 she has sailed some 28000 miles, endured 3 storms and spent half her time at sea.

C-5: IL14 **Multifunctional Textiles for Protection Against Natural Hazards**

D. ZANGANI, D'Appolonia SpA, Genova, Italy

Textile structures are extensively used in construction in forms of geotextiles. The retrofitting of existing masonry walls and soil structures is particularly important for earthquake protection of historic buildings and protection of earthworks against landslides. Unreinforced masonry structures are highly vulnerable because being originally designed mainly

for gravity loads they often cannot withstand the dynamic horizontal loads in case of strong earthquakes. Soil structures, such as embankments, are subjected to landslides after heavy rainfalls or during earthquakes. Hence the necessity to develop efficient methods for the retrofitting of existing masonry buildings and earthworks and of related monitoring systems to possibly prevent the structural damage. To solve the above issues new multifunctional textile structures are being developed for application in construction for the retrofitting of masonry structures and earthworks, integrating a combination of different functions, including structural health monitoring.

C-5: IL15 **Smart Patches for Repairing Aircraft Structures**
A. GÜEMES, Universidad Politecnica de Madrid, Madrid, Spain

Composite materials have demonstrated for the last ten years a high potential for repairing metallic parts of helicopter and aircraft structures. This potential is partially unexploited by the requirement to demonstrate the long term durability of the repair. Smart sensors, either PZT or fiber optic sensors, afford a simple solution for the permanent inspection of these repairs, ensuring its reliability. The results of an experimental programme, including both laboratory specimens and full scale tests, will be presented. Some practical issues, as the need for a robust design, or the reliability of the connectors, will be discussed.

C-5: IL16 **Adaptive Impact Absorption and Applications to Landing Devices**
J. HOLNICKI-SZULC, P. PAWLOWSKI, G. MIKULOWSKI, C. GRACZYKOWSKI, Institute of Fundamental Technological Research, Warsaw, Poland

This presentation demonstrates progress in Adaptive Impact Absorption (AIA) research field obtained recently in our research group and is based on previously published conference communicates. The monograph (Ref. [1]), under preparation, will present soon more detailed discussion of the considered problems. In contrast to the standard passive systems the proposed AIA approach focuses on active adaptation of energy absorbing structures (equipped with sensor system detecting and identifying impact in real time and controllable semi-active dissipaters, so called structural fuses) with high ability of adaptation to extreme overloading. A semi-active or fully-active solutions can be applied, which depend on constant or time-dependent modifications realised via controllable dissipative devices. Feasible, adaptive dissipative devices under considerations can be based on MR fluids or (hydraulic or pneumatic) piezo-valves. The presentation will be devoted to the following applications of AIA concept: Adaptive Landing Gears (ALG) for mitigation of exploitative aircraft loads and adaptive flow control based airbags for emergency landing of the helicopter.

[1]Holnicki-Szulc, J. (Ed.), Smart Technologies for Safety Engineering, J.Wiley, 2008.

SYMPOSIUM D

Biomedical Applications of Smart Materials, Nanotechnology and Micro/Nano Engineering

Session D-1

Advances in Smart Materials Synthesis and Functionality

D-1: IL01 **Carbon Nanotubes, Biomolecules and Cellular Interactions**
G.G. WALLACE, University of Wollongong, Wollongong, Australia

Carbon nanotubes (CNTs) have recently emerged as a candidate for addition to the biomedical engineer's materials inventory. Organic in nature and with an unprecedented combination of high strength and high electronic conductivity they have attracted the attention of numerous laboratories throughout the world. Coupled with the above physical attributes, is the more recent discovery that CNTs have an inherent affinity for naturally occurring biomolecules such as DNA, hyaluronic acid or chitosan[1]. The availability of highly stable aqueous dispersions wherein CNTs are "attached" to biomolecules opens up numerous options in terms of material processing and device fabrication. Highly stable conducting biogels can be obtained by simply casting these formulations. Conducting, mechanically strong CNT mats can be obtained by filtration. Alternatively, using wet spinning techniques long lengths of highly conducting micro-fibers can be obtained[2, 3]. These fibers have proven suitable as supports for mammalian cell growth. In other studies synthetic biocompatible polymers (e.g. styrene-isobutylene-styrene block copolymer (SIBS)) have proven useful in forming CNT dispersions. These may then be subsequently processed into practically useful structures such as CNT mats that can act as platforms for mammalian cell growth. Finally we will present an aligned CNT structure into which either naturally occurring or synthetic biopolymers may be imbibed[4]. The aligned nature of this CNT structure enables even further functionality to be introduced. For example, the individual CNTs can be capped with conducting polymers containing active proteins such as growth factors. These growth factors can subsequently be made available to the local environment via electrical stimulation. Each of these exciting new structures containing CNTs and biomolecules will be discussed here. How they interact with mammalian cells will also be presented.

[1]Moulton, S.E., Minett, A.I., Murphy, R., Ryan, K.P., McCarthy, D., Coleman, J.N., Blau, W.J., Wallace, G.G. Carbon 2005, 43, 1879-1884; [2]Lynam, C., Moulton, S.E., Wallace, G.G. Advanced Materials 2007, 19, 1244-1248; [3]Razal, J.M., Gilmore, K., Wallace, G.G. Advanced Functional Materials In Press; [4]Chen, J., Liu, Y., Minett, A.I., Lynam, C., Wang, J., Wallace, G.G. Chemistry of Materials 2007, 19, 3595-3597.

D-1: IL02 **Lab on a Chip Devices for Preventive Medical Engineering**
YOSHINOBU BABA, Nagoya University, Nagoya, Japan

This lecture will describe the recent development of nanobiotechnologies based on the nanofabrication, molecular nanotechnology, and nanomaterials for preventive medical engineering. The nanobiotechnologies allow us to develop novel methods to analyze several biomolecules, including DNA, RNA, protein, peptide, polysaccharide, and glycoprotein. Array of nano-pillar, which is 200 nm wide and 4000 nm tall, is successfully applicable to fast separation of DNA within 10-25 s. Nano-ball, fabricated by self-assembled molecular nanotechnology, of which diameter is 50 nm, is developed and successfully applied for

fast separation of DNA fragments from 100 bp to 15 kbp. The methods we have taken appear suitable for preventive medical engineering, including SNPs analysis, mutation analysis, haplotyping, DNA diagnosis, protein expression analysis, immunoassay, protein disease marker detection, point-of-care analysis and genomic drug discovery. The nanobiodevice coupled with quantum dots are also applicable to molecular imaging of cancer cell and photodynamic therapy of cancer.

Nature Biotech., 22, 337 (2004); Nature Biotech., 22, 1360 (2004); J. Am. Chem. Soc., 127, 9328 (2005); J. Am. Chem. Soc., 127, 11328 (2005); J. Am. Chem. Soc., 128, 629 (2006); Anal. Chem., 79, 3667 (2007)

D-1: IL03 **Self-oscillating Gel as Smart Materials**

RYO YOSHIDA, The University of Tokyo, Tokyo, Japan

Stimuli-responsive polymers and their application to biomaterials are widely studied. On the other hand, as a novel biomimetic polymer, we have been studying the polymer with an autonomous self-oscillating function by utilizing oscillating chemical reactions. So far, we succeeded in developing a novel self-oscillating polymer and gels by utilizing the Belousov-Zhabotinsky (BZ) reaction. The self-oscillating polymer is composed of poly(N-isopropylacrylamide) (PNIPAAm), in which Ru(bpy)3 is incorporated as a catalyst for the BZ reaction. Under the coexistence of the reactants (malonic acid, sodium bromate, and nitric acid), the polymer undergoes spontaneous cyclic soluble-insoluble changes or swelling-deswelling changes (in the case of gel) without any on-off switching of external stimuli. In this talk, our recent studies on the self-oscillating polymer and the design of functional material systems using the polymer are summarized.

D-1: IL04 **Biomedical Applications of Superhydrophobic Surfaces**

S.E.J. BELL, I.A. LARMOUR, H.J. ABRAHAM, G.C. SAUNDERS, C.P. McCOY, D.S. JONES, S.P. GORMAN, Queen's University, Belfast, UK

Superhydrophobic materials occur widely in nature, the most widely discussed are lotus leaves but hydrophobicity is also used by water striders to allow them to stand on the surface of ponds and is even used by fog-harvesting beetles. We have recently found a simple method to make the surfaces of some metals superhydrophobic (actually ultrahydrophobic: contact angles are >170° and roll off angles <1°) using low cost materials in a rapid, room temperature process. The lost cost makes the materials attractive from an engineering viewpoint but we have also been investigating their potential as biomaterials. In one application, these materials can be used to create platforms for microfluidic bioassays in which discrete droplets roll, essentially without friction, within channels that can be embossed into the materials. Similarly, the low contact with the surfaces and known self-cleaning abilities of natural superhydrophiobic surfaces have prompted us to test the resistance of these materials to bacterial adhesion. These studies have relevance both for biomedical devices and more generally in reducing biofouling of devices placed in the biologically active environments. Data showing significant reduction of bioadhesion on these surfaces will be presented.

D-1: IL05 **Bioinspired Polymer Surfaces for Nanodevices and Nanomedicine**

KAZUHIKO ISHIHARA, The University of Tokyo, Tokyo, Japan

A development of new biomaterials has been proposed based upon the mimicking of a simple component present on the cell membrane surfaces of the lipid bilayer that forms the matrix of the plasma membranes of cells, namely, the phosphorylcholine (PC) group of phosphatidylcholine. The PC-polymers, for example 2-methacryloyloxyethyl phosphorylcholine (MPC) polymers, are useful not only for artificial organs but also medical devices due to their excellent biocompatibility even in vivo and surface lubrication action. The PC-polymer surface technology (PCST) is one of the triggers for opening surface modifications of the substrate with phospholipid derivatives and these surfaces also demonstrated the usefulness of the improvement of protein adsorption and cell adhesion resistance. Therefore, the construction of the artificial cell membrane surface became a general concept to obtain not only blood-contacting medical devices, which can be safely and clinically applied for longer periods, but also devices or equipment for bioengineering and tissue engineering. It is convinced that the PC-polymers will become important materials in the not only biomedical and nano-scaled bioengineering and chemical engineering fields.

D-1: L06 **Functionalisation of Carbon Nanotubes for Improved Cellular Adhesion**

R.L. SPEAR, E. EDER, A.H. WINDLE, S.M. BEST, R.E. CAMERON, N. RUSHTON, R. BROOKS, University of Cambridge, Cambridge, UK

The design of orthopaedic scaffolding materials with the ability to promote the proliferation of bone cells and the development of new bone tissue affords a significant challenge for bone bioengineering. Osteoblast adhesion is an essential step in the process of new bone formation and the fixation of bone implant materials into the site of implantation. This process of cellular attachment and proliferation can be influenced by the chemical and physical properties of bone implant surfaces. Nanoscale modification of implant surfaces with chemically functionalised carbon nanotubes affords a potential route to enhancing osteoblast interactions with bone implant surfaces. Chemical modification of carbon nanotubes has been shown to support the growth of osteoblasts in vitro. In the present study, functionalised carbon nanotubes were investigated as substrates for the attachment and growth of osteoblast-like cells. The presence of hydrophilic functional groups on the treated carbon nanotubes was confirmed by TEM, CAM, and TGA. In vitro assays using osteoblast-like cells isolated from trabecular bone have indicated that functionalisation of carbon nanotubes with hydrophilic functional groups has a positive influence on the attachment and growth of osteoblast-like cells.

D-1: IL07 **Smart Hydrogels that Respond to Target Biomolecules**

TAKASHI MIYATA, Kansai University, Osaka, Japan

Stimuli-responsive hydrogels that exhibit volume changes in response to environmental changes such as pH and temperature have many future opportunities as suitable materials for designing smart systems in biomedical fields. We have prepared a variety of biomolecule-responsive hydrogels by using biomolecular complexes as reversible crosslinking points. This paper describes two types of biomolecule-responsive hydrogels that undergo volume changes in response to signal biomolecules, which were prepared using biomolecular complexes such as antigen-antibody complexes, saccharide-lectin complexes and DNA duplexes. One is a biomolecule-crosslinked hydrogel and the other is a biomolecule-imprinted hydrogel. The biomolecule-crosslinked hydrogels (glucose-, antigen- and DNA-responsive hydrogels) can swell in the presence of a target biomolecule due to the dissociation of biomolecular complexes that play a role as reversible crosslinking points. On the other hand, biomolecule-imprinted hydrogels (tumor marker glycoprotein- and DNA-responsive hydrogels) can shrink in response to a target biomolecule due to the complex formation between ligands and the target molecule. Thus, biomolecule-responsive hydrogels have many potential applications as smart biomaterials in biomedical fields.

D-1: L08 **Electrochemically Tailored Stability of Layer-by-layer Polyelectrolyte Films**

L. DIÉGUEZ[1, 2], T. ZAMBELLI[1], F. BOULMEDAIS[3], P. SCHAAF[3], J. VÖRÖS[1], [1]University and ETH Zurich, Switzerland; [2]University of Barcelona, Spain; [3]Inst. Charles Sadron, CNRS, Strasbourg, France

The layer-by-layer growth of DNA/PLL films on substrates covered with ITO as conductive layer (working electrode) was monitored by Electrochemical Optical Waveguide Lightmode Spectroscopy (EC-OWLS) at different applied potential from 0 V to 1.2 V (vs Ag/AgCl reference electrode). Moreover, those films can be dissolved by applying a potential above 1.8 V (or the correspondent galvanostatic current). The dissolution rate depends on the magnitude of the potential (or galvanostatic current) applied during the dissolution but also during the build-up of DNA/PLL film, and the number of bilayers. The dissolution rate increases as a function of the applied potential during the growth process. The electrochemical dissolution of DNA/PLL films could be also followed in-situ with Electrochemical Atomic Force Microscopy (EC-AFM) in a homemade three-electrode cell. Interesting considerations about the dissolution mechanism could be inferred by comparing EC-OWLS and EC-AFM data. These original results may be of great consequence for the fabrication of polyelectrolyte multilayer with controlled stability for drug release or gene transfection since preliminary experiments show the same behavior for the PSS/PLL and PSS/PAH systems.

D-1: L09 **Biocompatible Near Infrared Fluorescent Labels Based on Apoferritin-encapsulated PbS Quantum Dots**

L. TURYANSKA, B. HENNEQUIN, N.R. THOMAS, A. PATANE, University of Nottingham, Nottingham, UK; T. BEN, A.M. BELTRAN, S.I. MOLINA, Universidad de Cadiz, Puerto Real, Spain

This work describes the successful synthesis of a biocompatible aqueous near infrared fluorescent label based on a colloidal PbS quantum dot (QD) entrapped in the hollow core of a horse spleen apoferritin protein cage[1]. PbS QDs have stable optical properties[2]. We explore two routes to encapsulate PbS QDs within apoferritin. The first route involves disassembly of the apoferritin shell into its protein subunits and then reassembly of the protein shell in the presence of pre-formed PbS QDs. In the second route the apoferritin is used as a 'nanoreactor' to promote the formation of the dots from their precursors. In both cases, the apoferritin protein limits the size of the QD it can encapsulate to 8 nm and provides an efficient fluorescent label at ~1000nm. The morphological properties of this composite are studied by AFM and a combination of TEM, Energy Dispersive X-Ray and EELS experiments. Since this new composite provides an exterior protein coat that is amenable to the attachment of further proteins, saccharides or other biomolecules using standard conjugation chemistry, it offers an exciting system for novel biological and medical studies.

[1]B. Hennequin et al, submitted to Nature Materials (2007); [2]L. Turyanska et al, Appl. Phys. Lett. 90, 101913 (2007).

D-1: IL10 **Encouraging Nature with Ceramics**

K. HING, Queen Mary University of London, London, UK

The success or failure of a bioactive ceramic implant material in the body depends on a complex interaction between a synthetic foreign body and the host. These interactions occur at many levels from the nano-structural level, where subtle changes in surface physio-chemistry substantially alters the nature of the biomaterial-host tissue interface, to the meso- or macro-structural level where dependence on porosity mediates bioactivity through its effect on nutrient transfer and scaffold mechanics. Thus the factors that control the biological response to implant materials are a complex combination of mechanical, physical and chemical attributes which when combined favourably lead to 'bioactivity' in a material, or more correctly a 'bioactive' response to the material. This is illustrated in the successful use of porous bioactive ceramic scaffolds as synthetic bone graft substitute materials, where micro and meso-porosity, bulk and surface chemistry are manipulated to provide a framework that is highly conducive to the process of bone regeneration, balancing bone apposition and remodelling. Moreover, we now have the opportunity to developing an understanding of the complex balance of forces at play during bone grafting through investigation of these biological responses.

D-1: L11 **Synthesis of Bioactive Hydroxyapatite-zirconia Toughened Composites for Bone Replacement**

B. CIONI, A. LAZZERI, G. GALLONE, G. LEVITA, University of Pisa, Pisa, Italy

Hydroxyapatite (HAp) is a major inorganic component of human hard tissues, such as bones and teeth, and its content determines their microstructures and physical properties. Artificial HAp shows strong biocompatibility and bioactivity and thus it has found broad applications in tissue engineering for replacing damaged hard tissues. The artificial HAp, however, suffers from its intrinsic low mechanical properties, so to meet mechanical requirements, HAp can be incorporated with stiff mineral phases (mullite, zirconia, alumina). The performance and long-term survival of these biomedical devices are also dependent on the presence of bacteria surrounding the implants. In order to reduce the incidence of implant-associated infections, several treatments have been proposed, e.g. introduction of silver or fluoride in the HAp. The objective of this research is the sintering of composites based on calcium phosphate, mainly HAp supported on zirconia, for bone replacement with better microstructural features. In fact the use of zirconia can enhance the mechanical properties of bioceramics. Moreover the introduction of small amounts of silver, which should improve the antibacterial properties, will be taken into consideration since it is expected also to further toughen the whole structure.

D-1: IL12 **Generating and Optimising Geometry of Shape Memory Alloy-Textile Composites for Vascular Intervention**

T. ANSON, Brunel University, Uxbridge, Middlesex, UK; P. DYER, University of Brighton, Brighton, UK

Combining shape memory alloys with commonly used yarns, has the potential to improve technical and aesthetic product functional performance and to expand application possibilities. Two or three dimensional weaving or knitting techniques that intimately combine shape memory alloys with a yarn, generate essentially flat textiles, biased into that form, due to the "as received" shape of the metal alloy component. However, it would not be possible to undertake heat-treatment of the composite textile to generate alternative composite geometries due to the temperature required for shape setting the alloy: these temperatures, in the range, 420-500 °C. clearly would damage the textile. A method has been conceived to effect heat treatment of a composite that utilises resistive heating of the metal alloy in a current "burst" mode, under water: this acts as a heat sink, preventing damage to the thermally sensitive textile. The method described has potential to produce complex vascular grafts as mechanically optimised "net-shape" product for the endovascular treatment of aortic aneurysms.

D-1: L13 **Delinquent Sensors & Schizophrenic Materials: Using Molecular Switches to Make Materials with multiple personalities'**

D. DIAMOND, Dublin City University, Dublin, Ireland

Currently, there is very significant interest in the deployment of sensor networks, and many important applications require the involvement of chemical sensors and biosensors. However, for this to happen in large scale, there needs to be a revolution in the way chemical sensors/ biosensors are employed, as conventional calibration is inappropriate for large-scale deployments due to the cost of ownership (particularly maintenance) of these rather complex devices[1]. In this paper, I shall examine the use of 'adaptive' materials (i.e. materials that can be electrochemcially or optically switched reversibly between two or more different forms with radically different characteristics)[2]. For example, we are interested in materials that can exist in a passive form (non-binding) until a measurement is required, at which point the material is switched to an 'active' form. Binding then occurs and a signal is generated, and the material subsequently switched back to the 'passive' form[3]. We have demonstrated that binding of metal ions and amino acids at modified surfaces can be controlled photonically using LEDs[4]. It is possible that this may provide a route to more sophisticated materials whose host-guest binding behaviour and signal generation can be activated or deactivated on demand. Triggered release/uptake of components can also lead to interesting actuation effects, including swelling/contraction behaviour in conducting polymers that can be employed to produce biomimetic soft pumps[5] and valves[6]. More recently, similar effects have been demonstrated using optically responsive materials. These effects have many important potential applications in sensors, purification resins, separation science, miniaturised analytical devices and drug delivery. Control of other properties such as colour, viscosity, permeability, water retention, and their potential applications shall also be discussed.

[1]Internet Scale Sensing, Dermot Diamond, Analytical Chemistry, 76 (2004) 278A-286A; [2]Chemo/Bio-Sensor Networks, Robert J Byrne and Dermot Diamond, Nature Mater., 5 (2006) 422-424; [3]LED Switching of Spiropyran-doped Polymer Films, Shannon Stitzel, Robert Byrne and Dermot Diamond, J. Mater. Science, 41 (2006) 5841–5844; [4]Photo-Regenerable Surface with Potential for Optical Sensing, Robert J. Byrne, Shannon E. Stitzel and Dermot Diamond, J. Mater. Chem. 16 (2006) 1332-1337; [5]Biomimetic, low power pumps based on soft actuators, Sonia Ramýrez-Garcýa and Dermot Diamond, Sensors and Actuators A 135 (2007) 229–235; [6]Polypyrrole Based Switchable Filter System, Yanzhe Wu, Lorraine Nolan, Shirley Coyle, King Tong Lau, Gordon G. Wallace and Dermot Diamond, proceedings of the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Lyon, France, 22-26 August 2007, 4090-4091.

D-1: L14 **Synthesis and Characterization of Nanoparticles of La1-xAgyMnO2.95 for Biomedical Application**

O.V. MELNIKOV, O.YU. GORBENKO, M.N. MARKELOVA, A.R. KAUL, Lomonosov Moscow State University, Moscow, Russia; V.A. ATSARKIN, V.V. DEMIDOV, Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Moscow, Russia

In present work we demonstrate the way to obtain ceramic nanopowders of La1-xAgyMnO2.95 with characteristics necessary for the biomedical application (tumor hyperthermia), nanocrystalline powder with spherical particles of ~100 nm size with narrow normal distribution and Tc=314-317 K, by spray pyrolysis of the metal nitrates water solution. For the detail knowledge of P(O2)-T-X conditions effect on Tc 2 series of compositions were obtained (1 - x=0.2, y=x; 2 - x=0-0.2, y=x). The optimal ratio Mn4+/Mn3+ calculated from iodometric titration data is reached at 800 °C and P(O2)=1bar. Tc increases gradually with x and y increasing up to x=y=0.2. The water suspension of nanocrystalline powder sample of La0.8Ag0.15MnO2.95 under the alternating magnetic field of ~1 MHz reached the constant temperature 42 °C (during <1 min), with clear thermostatic behavior for longer time, what is necessary for the cancer hyperthermia.

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Session D-2
Enabling Tools

D-2: IL01 **Micro-nanotechnology for Biomedical Applications**
R. WECHSUNG, Boehringer Ingelheim microParts GmbH, Dortmund, Germany

Micro-Nano-Technologies main application field will be in life sciences for drug development, diagnostics and drug delivery. Typical examples are described for products already existing together with an outlook for new emerging products and applications. Existing market prognosis will be discussed critically.

D-2: IL02 **Multifunctional Magnetic Nanocarriers: from Material Design to Magnetic Manipulation for Diagnostic Applications**
T. VERES, Industrial Materials Institute, National Research Council Canada, Montreal, Canada

Functional nanostructures are of great interest especially for their potential as nano-carriers that can be chemically modified in order to attach with a high degree of specificity to biomolecules and cells. This together with the possibility to design and fabricate complex microfluidic systems to manipulate them has opened the way to the development and use of micro total analysis systems for a large variety of applications in the field of biosensing, diagnostic or molecular imaging. After presenting an overview of the methods currently used for the synthesis of multifunctional magnetic nanocarriers, this talk will also provide specific examples for their use for molecular diagnostics and pathogen detection.

D-2: L03 **Microsystems for Blood Cell Counting**
N. PIACENTINI, D. DEMARCHI, P. CIVERA, M. KNAFLITZ, Politecnico di Torino, Torino, Italy

This paper presents two biomedical microsystems for blood cell counting, designed and realized through “MultiMEMS Multi-Project Wafer” service and the “microBUILDER” European project. Dies 6 x 6 mm in size, made of a micromachined glass-silicon-glass triple stack, host two new kinds of multiple micro-counters, suitable to investigate the feasibility of blood cell differential analysis by means of Coulter principle in a monolithic lab-on-a-chip, which integrates a microfluidic network, sensing metal electrodes and light-guiding structures. Within these devices, impedance method gains some innovative features, both from microsystem technology itself (low consumptions of chemicals, better analytical performances, low dead volumes in multifunctional interconnected networks, parallel high-throughput processing, low-cost mass production) and from new project solutions: self-aligning illumination allows to use compact external sources (i.e, LEDs) and requires no delicate optics. Different working set-ups (ranging from series with fixed control volume to parallel differential) can be achieved by adding only few external components. It is finally possible to combine electrical and optical measurements, oriented to multi-feature classification of cell sub-populations.

D-2: IL05 **Polymer-biological Tissue Adhesion - A Conceptual Study**
AKIO KISHIDA, T. KIMURA, K. SHIBA, K. YAMAMOTO, Tokyo Medical and Dental University, Tokyo, Japan; A. KATO, T. MASUZAWA, Ibaraki University, Ibaraki, Japan; T. HIGAMI, Sapporo Medical University, Hokkaido, Japan

In surgical operation, tissues are normally bound using suture in almost cases and/or tissue adhesive agents. The effectiveness of these methods are well established. However, there are some problem are left, such as necessity of the highly-trained skill and difficulty to stop bleeding from large vein. Fibrin glue is one of the most successful one, whereas the low bonding strength to tissue sometimes become problems. Recently, it was reported that the ultrasonic scalpel could coagulate and incise vascular branches owing to mechanical vibrations, in which heat was generated at 80 °C and vascular proteins, such as collagen and elastin, were coagulated. This finding suggest us important fact, such as, the tissue could be adhered by itself when the adequate energy is dissipated. In the present study, we focused on the coagulation of tissue using ultrasonic scalpel and investigated that the bonding of tissue-tissue and tissue-polymer using ultrasonic scalpel. Also, in order to prove our idea for tissue adhesive technique, we prepared a pressing/heating/vibrating device and perform a preliminary study to establish the concept of bonding tissue and polymer.

D-2: L06 **The Effect of Magnetic Field on Magnetotactic Bacteria Behaviors**
HIDEHARU TAKAHASHI[1], H. KIKURA[1], T. IWASA[2], S. WATANABE[2], M. ARITOMI[1], [1]Tokyo Institute of Technology, Tokyo, Japan; [2]Muroran Institute of Technology, Muroran, Japan

Magnetotactic bacteria are a class of bacteria that has nano sized magnetic crystals inside their body and responds to geomagnetic field. Several different morphologies of magnetotactic bacteria are found - in spherical, spiral, and bent shapes. Magnetism of the bacteria is caused by the magnetosomes in their body - the chain structure consists of 10-20 magnetic particles in 50-100 nm size. This paper reports the experimental research on visualization of certain spiral-shape magnetotactic bacteria behaviors under magnetic field. The motion of magnetotactic bacteria was shot using a camera and measured using image processing techniques. Considering that the bacteria size are small, a dark-field microscope system was adopted, using oil immersion dark-field condenser lens. Though the sensitivity of the camera seemed to be insufficient, we finally succeeded in the visualization of the magnetotactic bacteria. Applying magnetic field, it was observed that the magnetotactic bacteria move towards the line of the impressed magnetic field direction. Observing the magnetotactic bacteria without and with magnetic field, usability of the optical dark-field microscopy to the magnetotactic bacteria visualization was examined.

D-2: L07 **Low Voltage Microgripper for Single Cell Manipulation**
B. SOLANO, D. WOOD, Durham University, Durham, UK

There is a growing interest within the biomedical and pharmacological communities in tools which enable the manipulation of single cells. This has become a challenging issue in applications such as cloning, cell replacement therapy, gene injection, or in vitro fertilisation. Contact manipulation techniques based on microgrippers (miniaturised tweezers) could confer several advantages over other non-contact techniques such as optical tweezers or electric/magnetic traps: they are generally cheaper, easier to implement and operate, and the design is flexible and non-cell-specific. In addition, there is no risk associated with high electric fields, radiation or heat interacting with the cell. Various microgrippers exist, but only a few among them are suitable for operation in liquid media where low actuation voltage is crucial. In this work, we present the full characterisation of a microgripper that operates in both dry and liquid media, and shows improved performance versus existing devices. It produces large displacements in liquid (<30 µm from opening), at low temperatures (<55C) and at low voltages (<2.5 V). The large opening range below the electrolysis threshold gives maximum flexibility to the design. Single cell manipulation experiments will be presented and discussed.

D-2: L08 **A New Force Controlled Liquid Injection System for Biomedical Applications**
M. GABI, ETH Zürich, Zürich, Switzerland; J. POLESEL-MARIS, A. MEISTER, M. LILEY, H. HEINZELMANN, Swiss Center for Electronics and Microtechnology CSEM, Neuchâtel, Switzerland; J. VÖRÖS, T. ZAMBELLI, ETH, Zürich, Switzerland

So far, glass micropipettes have been used for intracellular and extracellular injection of liquids for pharmacological investigations. The micropipette is manually approached to the cell only by visual control in phase contrast microscopy. Even highly skilled persons often rupture the cell membranes or remove the cell from the surface by applying too much force. We developed a force controlled cantilevered tip with built-in microchannels to overcome the limitation of the “classical” technique. The force feedback allows the control of the stress applied on the sample. Hence, a gentle contact, a deep indentation or a membrane penetration can be well defined by the user and liquids can be released through the hollow probe tip at any time. We show the capability of the new system by injecting Ca2+-sensitive dyes into single neurons of a small neuron networks to study their electrophysiological behavior by fluorescence microscopy.

D-2: L09 **Simulation of water flow in a coated nano pore by a molecular dynamics**
KEISUKE YAMAMOTO, T. IWATUBO, K. SAITOU, T. MORIUCHI, Kansai University, Suita-shi, Osaka, Japan

This paper presents on a new damping element called the colloidal damper which is used a principle of surface extension in nano pore. The surface extension force of water in hydrophobic nano pore is different in pressurization and decompressurization processes. This principle is applied to a damping element. The nano pore is constructed by silica gel. A silica gel ball of 100 - 200 micrometer dia. has many nano pores of 5 - 20 nanometer dia. in it. The coated spherical silica gel and water are inserted in a piston - cylinder unit in order to work as a damper. If compression and decompression forces are added to the piston - cylinder unit (damper), water flows into and moves out the nano pore under balance of pressure. The surface extension forces for compression are larger than that of decompression. This difference force produces a damping energy. In this paper, behavior of water in the pore of silica gel is investigated using the molecular dynamics. Dissipation energy of the colloidal damper is concerned with the contact angles of water in the pore. So the contact angles are calculated for changing parameters, i.e. size of the pore, length of the hydrophobic material, velocity(pressure) of water flows into the pore. Then these results are compared with the experimental ones.

D-2: IL10 **Biochemical Sensors Based on Specific Adsorption of Oligonucleotides**
M.R. BEGLEY, M. UTZ, J. LANDERS, E. SEKER, LING HUANG, University of Virginia, Charlottesville, VA, USA

Selective adsorption of molecules on the surfaces of compliant structures often leads to coupling between chemical and mechanical behaviors. A key challenge in developing devices to capitlize on this behavior is the ability to translate molecular characteristics into continuum frameworks useful in describing microscale behavior. This talk will describe a multi-scale framework that translates molecular interactions into continuum properties: this allows quantitative connections between binding energy, adsorption density, persistence length, etc. and the mechanical properties of adsorbed layers, such as surface stress and effective moduli. This framework, with accompanying experiments on gold-thiol adsorption of DNA, will be used to discuss the potential of microfabricated structures to: (a) extract molecular information (such as parameters utilized in intermolecular pair potentials) from microscale observations of deformation, and (b) develop on-chip sensing to replace fluorescent spectroscopy in micro-Total Analysis Systems. The talk will conclude with a brief discussion of our on-going development of highly flexible elastomer sensors, which utilize gold nanoparticles and nano-porous gold layers to facilitate surface functionalization without comprising mechanical sensitivity.

D-2: L11 **Field-effect Controlled Single-walled Carbon Nanotube Devices for Biomedical Sensor Applications**
U. SCHWALKE, Darmstadt University of Technology, Darmstadt, Germany

In this contribution we present a novel method for the realization of carbon nanotube field-effect sensors (CNTFESs) which will most likely have a strong impact on the next-generation of bio-sensors. CNTFESs are ideally suitable for biomedical sensor applications due to their excellent inherent properties: The response times of CNT-sensors are at least one order of magnitude faster than those based on solid-state sensors. CNT-based nano-sensors have the advantages that they are thousands of times smaller than even MEMS sensors. They consume much less power and have a high specific surface area leading to extremely high sensitivity. Therefore, CNTFESs are highly suitable as implantable sensors. The proposed CNTFESs are based on carbon nanotube field-effect transistors (CNTFETs) which are optimized for sensor applications. We have succeeded to develop a simple, reproducible fabrication process to grow individual CNTs and CNT-networks directly within the specified device area. No tedious manual manipulation and alignment of the CNTs is necessary. The method is suitable for mass-production. Electrical results of the fabricated fully functional CNTFETs are presented and the use of these devices as CNT-based field-effect controlled sensors for virus detection will be discussed.

D-2: IL12 **Multimodal on Body Sensing for Health Care Application**
P. LUKOWICZ, University of Passau, Passau, Germany

Complex on body sensors are increasing finding application in all areas of healthcare. This ranges from wellness and lifestyle oriented systems, through diagnostic quality mobile health monitoring, to task tracking applications for hospital staff. The talk will provide an overview of on body sensing technologies used in such application. We will discuss different sensing modalities with their advantages and disadvantages with respect to specific applications. Data signal processing and pattern recognition methods will then be presented on concrete monitoring system examples. The talk will conclude with application examples from large scale European Union funded projects.

Session D-3
Medical Diagnostics Applications

D-3: IL01 **DNA-based Transistor**
YUJI MIYAHARA, National Institute for Materials Science, and The University of Tokyo, Tokyo, Japan

We have been investigating a new approach to detect molecular recognition events by means of electrostatic interaction between charged biomolecules and electrons in silicon. We have developed the novel concept of a genetic field effect transistor (FET) which is based on the direct transduction of surface density change of charged biomolecules into electrical signal by the field effect. We combined a genetic FET with specific molecular recognition such as allele specific hybridization, intercalation, and primer extension to detect one base difference of target DNA. The hybridization events are followed by the introduction of DNA polymerase and all four deoxynucleotides. The sequence-specific extension can be controlled by a match or mismatch at the 3'-end of each oligonucleotide probe. As a result of extension reaction, negative charges increase at the gate surface of the genetic FET, because of intrinsic negative charges of polynucleotide. The allele specific primer extension on the gate surface could be directly transduced into electrical signal using the genetic FETs and that three genotypes could be distinguished without any labeling for target DNA molecules. The genetic FET platform is suitable for a simple, accurate and inexpensive system for SNP typing in clinical diagnostics.

D-3: IL02 **Superparamagnetic Iron Oxide Nanoparticles (SPION) as Probe in Living Cell**
H. HOFMANN, A. FINK-PETRI, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Nanoparticles with a superparamagnetic core are very multifunctional instruments for biomedical application, including contrast agent for MRI, vector for gene or drug delivery or as local heat sources. The key problem regarding broader use of the particles is the missing understanding of the interaction between particle and the biological systems like cells or organelles. Also the comportment in blood is still not very well controlled. To investigate how functionalized SPIONs interact with cell organelles, we covalently bound maleimide-PEG-NHS to the surface of the particle which allowed a further derivatisation by coumarin, c[RGDfK-(Ac-SH)] peptide and MTP. The proteins detected after re-separation of the particles could are: proteins associated directly in the transport of the nanoparticles to their target site (heat shock proteins), to the transport of the particles to the mitochondrial membrane, and are associated to the membrane of the mitochondria. These results show that we have developed a very useful tool for the investigation of the cell-particle interactions which will allow to conduct more detailed investigation regarding drug and gene delivery, toxicity of nanoparticles and the development of new diagnostic tools.

D-3: IL03 **Biocompatible Nanoparticles-based QDs for In-vivo Imaging**
M.G. SANDROS, M. BEHRENDT, D. MAYSINGER, M. TABRIZIAN, McGill University, Montreal, Canada

Fluorophores like CdSe@ZnS quantum dots (QDs) that emit in UV-vis range are absorbed within the first few micrometers of tissue thickness by deoxy- and oxyhemoglobin (HbO2). Herein a new bioprobe, where Indium-Gallium-based QDs coated with several monolayers of ZnS were covalently bound to chitosan is reported to address the challenges of developing highly biologically stable and fluorescent nanoparticle probes for deep tissue imaging. Chitosan coating enhances the emission band and modified the uptake efficiency. Cell counting after the exposure to InGaP@ZnS-chitosan and commercially available PEG-QDs 545 in different cell types after 24 hours showed no significant reduction in cell viability. InGaP@ZnS-chitosan nanoparticles are found to internalize into PC12 cells ten times more than the PEG-QDs. This data suggests

that these InGaP@ZnS-enriched chitosan nanoparticles have an advantage of being a more suitable probe for application in multiplex detection assays. Further, by carrying out experiments with phantom and Art imaging system developed for in vivo live animal imaging, we demonstrated that the maximal penetration of the luminescent signals from the InGaP@ZnS-chitosan nanoparticles (5 ul) was than ten folds higher at the lowest laser power comparing to commercial ones.

D-3: IL04 **Wearable Biosensors for Monitoring Wound Healing**
S. PASCHE, S. ANGELONI, R. ISCHER, M. LILEY, J. LUPRANO, G. VOIRIN, Centre Suisse d'Electronique et de Microtechnique SA, Neuchâtel, Switzerland

Online health monitoring often requires hospitalization, which can become an expensive and inconvenient choice for the patient. In this perspective, wearable sensors that allow in situ biosensing constitute a very promising technology. This work aims to develop immunosensors for continuous monitoring of the wound healing process, based on pH changes, as well as on the concentrations of relevant proteins such as the C-reactive protein and growth factors. Sensing principles include the use of responsive hydrogels that swell in response to changes in the environment, and the use of functional surfaces that specifically recognize the target protein. The detection principle is based on an optical signal, using the evanescent field of light propagating along a waveguide, probing refractive index changes. An optical sensing system that can be integrated in a wound dressing patch has been designed, including a white light source (LED), and a spectrometer for detection. The sensor will later be integrated into wound dressings or bandages, forming a sensing patch that is connected via optical fibres and electrical wires to the detection system and power supply. This novel technology will be particularly valuable in applications such as the supervision of skin grafts and ulcer treatments.

D-3: IL05 **Wearable Intelligent Systems Achievements, Challenges and Perspectives**
A. LYMBERIS, European Commission, Brussels, Belgium

Intelligent wearable personal systems, enabling continuous health monitoring and feedback to the user, have shown significant contribution to the enhancement of disease prevention, early diagnosis, disease management, treatment and home rehabilitation. Biomedical microsensors developments benefit largely from technological achievements in terms of intelligence, speed, miniaturization, sophistication and new materials at lower cost. Research and development during the last 10-15 years shows clear design and performances evolution with different approaches and platforms such as in-vivo (e.g. implants), in vitro (e.g. biochips), on-body and breath monitors. The symbiosis of textiles with wearable computing, augmented reality, human machine interfaces, media and interface design and the collaboration between established electronics and textile industries are leading to a totally new class of large-area, flexible, conformable informative and interactive wearable systems. Further research across disciplines like micro-nano technologies, materials, physiology/biology/medicine and information & communication technologies is necessary in order to achieve highly performing, user-friendly, and cost-effective wearable and implantable healthcare systems.

D-3: IL07 **Biocompatibility of Iron-oxide Magnetic Nanoparticles**
V. LABHASETWAR, Cleveland Clinic Foundation, Cleveland, OH, USA

Magnetic nanoparticles (MNPs) are explored for various biomedical applications, and hence it is essential to determine their biocompatibility to ensure safe clinical use. We have studied biocompatibility of our novel iron-oxide MNP formulation that can be used as a MRI agent and a drug carrier system. Changes in serum and tissue iron levels and other parameters were analyzed over 3 weeks after intravenous administration of MNPs to rats. Serum iron levels gradually increased up to 1 week but slowly declined thereafter. Biodistribution of iron in various body tissues changed with time but the increase in iron levels was greater in liver and spleen than other tissues. Serum alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase levels, and total iron-binding capacity showed a transient increase 6 to 24 hrs after MNP injection. Increase in oxidative stress was tissue dependent but reached a peak at 3 days, slowly declining thereafter. Histological analyses of liver, spleen, and kidney samples collected at 1 and 7 days showed no apparent abnormal changes. In conclusion, our MNPs did not cause long-term changes in the liver enzyme levels or induced oxidative stress, and thus can be safely used for drug delivery and imaging applications.

Session D-4
Regenerative Medicine and Tissue Engineering

D-4: IL01 **Self-assembly: Allowing Cells to Generate their Own Extracellular Matrix for Tissue Engineering Applications**
F.A. AUGER, Laval University, Québec City, QC, Canada

Tissue engineering and regenerative medicine are increasingly becoming a crossroads where engineering and medicine meet. A large number of scientific teams throughout the world are developing concepts that involve tissue substitutes in which cells are associated with a large range of biomaterials. In order to interact favourably with living cells, those biomaterials must meet various criteria. Scientists have typically approached the challenge from different directions, from the use of polymers (such as PLGA or collagen) to decellularized structures of animal or human origin (such as porcine intestinal submucosa or human placenta). The LOEX has followed another path called the “self-assembly”, where human cells in culture are induced to form their own extracellular matrix. The resulting living sheets of human biomaterial can be manipulated to create soft tissues. These sheets can form planar structures such as for skin substitutes, or tubular structures such as for blood vessels. If made with cells from the patients themselves, they are considered as autologous tissues that then display complete imunological acceptance. In this presentation, we will show the work done at the LOEX to develop various tissue susbtitutes and their applications in both clinic and research.

D-4: IL02 **Analysis of Material for Corneal Cell Therapy**
G. PELLEGRINI, University of Modena and Reggio Emilia, Modena, Italy; J. TORBET, CNRS, Lyon, France; V. HASIRCI, METU, Ankara, Turkey

The first example of cell therapy using cultured stem cells was the 1981 demonstration that human epidermis could be grown in the laboratory and then transplanted on burnt patients to reconstitute a functional epidermis. This observation actually represents the onset on regenerative medicine by means of adult stem cell cultures. Emerging cell therapies for the restoration of sight have focused on two areas of the eye that are critical for visual function, the cornea and the retina. The relatively easy access of the cornea, the homogeneity of the cells forming the different layers of the corneal epithelium and the improvement of cell culture protocols are leading to considerable success in corneal epithelium restoration. The first significant improvement of the technique for clinical application was the use of supporting materials for cell culture, transport and transplantation into patients, such as fibrin glue, amniotic membrane, collagen sponges or strips, devitalized membranes or polymers. The relevance of this approach will be discussed in function of the disease targeted.

D-4: IL03 **Novel Nitrogen Rich Plasma Polymers and Chitosan for Tissue Engineering of Intervertebral Discs**
F. MWALE, McGill University, and Lady Davis Institute for Medical Research, Montreal, Quebec, Canada

Degenerative disc disease has been implicated as a major component of spine pathology. However, though biological repair of the degenerate disc would be the ideal treatment, there is a lack of a universally accepted scaffold for tissue engineering of intervertebral discs (IVD) and little is known of how to differentiate mesenchymal stem cells (MSCs) to a disc like phenotype. We show that 2.5% Protasan® UP G213 cross-linked to 5% genipin might be a promising scaffold for disc tissue engineering. Furthermore, we have developed extremely N-rich plasma polymer layers, which we call “PPE:N” (N-doped plasma-polymerised ethylene, containing up to 36% [N]). We show that PPE:N almost completely suppresses the expression not only of type X collagen, but also of osteogenic marker genes such as alkaline phosphatase (ALP), bone sialoprotein (BSP) and osteocalcin (OC). In contrast, neither aggrecan nor type 1 collagen expression were significantly affected. These results indicate that PPE:N coatings may be suitable surfaces for inducing MSCs to a chondrocyte or disc-like phenotype for tissue engineering of cartilage or IVDs, in which hypertrophy and osteogenesis are suppressed.

D-4: L05 **Tissue Engineering Technology to Realize Regenerative Medical Therapy**
YASUHIKO TABATA, Kyoto University, Kyoto, Japan

A new therapeutic trial based on the self-healing potential of body to induce natural tissue regeneration, has been expected. Practical means to realize this therapy of regenerative medicine are cell therapy and tissue engineering. Generally cells transplanted cannot always function for tissue regeneration if the nutrients and oxygen are not sufficiently supplied. There are two approaches of tissue engineering to enhance the therapeutic potentials of cells. The first is to make use of bio-signaling molecules which activate cells in vivo and induce angiogenesis for nutrients and oxygen supply. Positive combination with drug delivery system (DDS) technology can enhance their in vivo biological activities. The second approach is to genetically engineer stem cells for the activation of biological functions. In addition to the research and development of DDS technology for plasmid DNA, a new cell culture system for gene transfection has been explored. After transplanted, cells genetically engineered functioned more efficiently to show the therapeutic efficacy in cell therapy-based tissue regeneration, compared with the original cells (cell-gene hybrid therapy). In this paper, experimental data of tissue regeneration by DDS technology with or without cells are presented to emphasize necessity of tissue engineering technology to realize regenerative medical therapy.

D-4: L06 **Electrospun Nanofibre Membranes as Wound Dressing Materials**
XIN LIU, T. LIN, J. FANG, X. WANG, Deakin University, Geelong, Vic, Australia

An effective wound dressing is not only able to protect the wound area from its surroundings to avoid infection and dehydration, but also to speed up the healing process by providing an optimum microenvironment for healing, removing any excess wound exudates, and allowing continuous tissue reconstruction. In this study, two biodegradable polymers, polycaprolactone (PCL) and polyvinyl alcohol (PVA), were used to electrospin nanofibre membranes and the performances of these two membranes as wound-dressing for healing the skin cut were evaluated in vivo. The wound dressing performances of two membranes were also compared with that of a conventional non-woven cotton wound dressing. In addition, fibre morphology, porous structure, mechanical properties of the nanofibre membranes, and their drainage capacity and possible bacteriology were examined.

Session D-5
New Therapeutics and Intelligent Delivery Systems

D-5: IL02 **Multifunctional Envelope Type Nano Device for Non-viral Gene Delivery: Concept and Application for Nanomedicine**
HIDEYOSHI HARASHIMA, Hokkaido University, Sapporo, Japan

New concept for gene delivery: For the efficient gene delivery into the nucleus of target cells, the non-viral vectors must overcome several barriers, such as the plasma membrane, the endosomal membrane and the nuclear membrane. Thus, to overcome the barriers, the non-viral gene delivery system must be equipped with various functional devices such as ligands for specific receptors, pH-sensitive fusogenic peptides for endosomal escape and a nuclear localization signal (NLS) for enhanced nuclear delivery.
Programmed Packaging: We recently proposed a novel non-viral gene delivery system multifunctional envelope-type nano device (MEND) to realize Programmed Packaging. The ideal MEND consists of a condensed DNA core and a lipid envelope structure equipped with the various functional devices. The compacted core has some advantages, such as the protection of DNA from DNase, size control and an improvement in packaging efficiency. Furthermore, separate structures, not a disordered mixture, of the DNA core and lipid envelope are necessary to control the topology of the functional devices.
Development of MEND: The MEND is constructed by a novel assembly method, the “lipid film hydration method”. The lipid film hydration method is comprised of three steps: (i) DNA condensation with polycations, (ii) hydration of the lipid film for electrostatic binding of the condensed DNA, and (iii) sonication to package the condensed DNA with lipids. This packaging mechanism is based on electrostatic interactions between DNA, polycations and lipids. Plasmid DNA is first condensed electrostatically with a polycation such as poly-L-lysine (PLL) by vortexing at room temperature. The kinetic control of this process is important for controlling the size and charge of the condensed DNA. The lipid film, which contains a negatively charged lipid such as cholesteryl hemisuccinate (CHEMS), is hydrated with an aqueous solution containing DNA/PLL particles (positively charged) for electrostatic binding. The packaging of the DNA/PLL particles into a lipid bilayer is achieved by sonication in a bath-type sonicator. The transfection activity of the optimized R8-MEND was compared with Adenovirus, one of the strongest viral vectors, using human cervical cancer HeLa cells and a human lung epithelial carcinoma cell line A549. Compared with the highest transfection efficiency obtained by Adenovirus using 1x105 particles/cell, the use of R8-MEND led to transfection activities as high as those for the Adenovirus. These high transfection activities result from the activation of macropinocytosis by high density or octaarginines on the surface of the MEND. Successful application of the MEND to in vivo siRNA delivery to tumor tissue will also be presented.

D-5: L03 **A new Drug Vehicle for Pulmonary Application - Lipid Coated Biodegradable Nanoparticles**
J. SCHÄFER, J. SITTERBERG, U. BAKOWSKY, Philipps University of Marburg, Marburg, Germany

Today the most new developed drugs have a short biological half-life (e.g., peptide drugs, proteins, nucleic acids) and highly potent drugs often have potentially dangerous side effects (e.g., immunosuppressants, glucocorticoids). One possibility to overcome this problem are nanoscale colloidal carriers which can be used for various applications such for a pulmonary, dermal or nasal administration. The kinetics of drug release can be controlled by using selected biodegradable polymers. Nanoparticles (NP) composed of biodegradable PLGA, have been investigated for their ability for various drug carrier systems. However, the major drawbacks in application of these particles include (i) their negative charge, and (ii) the poor transport characteristics of the PLGA NP‘s through mucosal barriers. We reasoned that “Lipid-coated PLGA NP’s” might overcome these problems and allow improved drug delivery especially to pulmonar mucosa. We developed a method to prepare cationic PLGA NP‘s with adjusted biophysical properties. This includes the preparation of the colloidal carrier systems, the adsorptive or covalent surface modification of the NP’s with various lipid mixtures and there characterisation with physico-chemical methods (DLS, AFM etc.) and in various cell-culture systems.

D-5: L04 **Base Invaders. Coupling Experiments and Multiscale Modeling of Dendrimer-Based siRNA Delivery Agents**
S. PRICL, P. POSOCCO, M. FERMEGLIA, University of Trieste, Trieste, Italy; G. SCOCCHI, A. DANANI, ICIMSI-SUPSI, Manno, Switzerland; C. CATAPANO, Iosi, Bellinzona, Switzerland; M. MALY, Academy of Sciences of the Czech Republic, Prague, The Czech Republic; J.-W. HANDGRAAF, H.J.G.E.M. FRAAIJE, Culgi B.V. and University of Leiden, Leiden, The Netherlands

Injected, nano-scale drug delivery systems, or ‘nanovectors’, are ideal candidates to provide breakthrough solutions to the time-honored problem of optimizing therapeutic index for a treatment. Even modest amounts of progress towards this goal have historically engendered substantial benefits across multiple fields of medicine, with the translability from, for example, a subfield of oncology to a field as distant as the treatment of infectious diseases being granted by the fact that the progresses had a single common denominator in the underlying technological platform. In this work we combine multiscale molecular modeling and experimental approaches to define the mode and the molecular requirements of the interaction of oligonucleotide-based (e.g., siRNA) therapeutics and dendrimeric delivery reagents. In details, by mimicking in silico the experiments performed in vitro, information at the molecular level (e.g., interaction forces, mechanisms, structures, free energies of binding, self-assembly, etc.), which cannot be accessed with any other experimental techniques, are obtained, and the critical molecular parameters for optimizing/de novo designing nanocargos for tissues and/or tumor specific uptake can be determined. This would provide valuable information to devise optimal delivery modalities that would increase the efficacy of the Transcriptional Gene Silencing (TGS) strategies in cells and laboratory animals and move them toward clinical applications.

D-5: IL06 **Multifunctional Pharmaceutical Nanocarriers for Drug Delivery and Diagnostic Applications**

V.P. TORCHILIN, Northeastern University, Boston, MA, USA

Drug carriers are used to protect drug molecules from the inactivation by biological surroundings and to improve drug delivery to the site of disease. Ideally, drug carrier should be able: (a) to accumulate in required organ or tissue, and then (b) penetrate inside target cells delivering there its load (drug or DNA). Organ or tissue (tumor, infarct) accumulation could be achieved by the passive targeting via the enhanced permeability and retention effect or by ligand(antibody)-mediated active targeting, while the intracellular delivery could be mediated by certain internalizable ligands (folate, transferrin) or by cell-penetrating peptides (TAT, polyArg). To be able to behave this way, drug carrier should simultaneously carry on its surface various moieties capable of functioning in a certain coordinated way. In general, many other "useful" moieties can be attached to the drug carrier surface, such as diagnostic/imaging groups, cell penetrating peptide groups, stimuli-sensitive groups, contrast moieties for visualization etc. One can think about the development of multifunctional drug delivery systems (let's say, long-circulating, specifically targeted, and capable of cell penetration) built in such a way that individual functions can "switch on" and "switch off" depending on specific surroundings or local pathological conditions. Contrast/ reporter group associated with such carriers can provide additional scientific or diagnostic information.

D-5: IL07 **Supramolecular Approach to Gene Delivery**

NOBUHIKO YUI, Japan Advanced Institute of Science and Technology, Nomi, Ishikawa, Japan

The most definite feature in polyrotaxanes, in which many cyclic compounds are threaded onto a linear polymeric chains capped with bulky end-groups, is the mobility of cyclic compounds: these cyclic compounds can rotate and/or slide along the polymeric chain. Our previous studies have clarified that the mobility of ligands linked to the cyclic compounds is closely related to enhancing multivalent interaction with biological systems. This concept is now exploiting more practical applications for drug delivery such as gene delivery. We have designed biocleavable polyrotaxanes that have a necklace-like structure between many dimethylaminoethyl-modified alpha-cyclodextrins (DMAE-alpha-CDs) and a disulfide (S-S)-introduced poly(ethylene glycol) (PEG) chain. The mobility of DMAE-alpha-CDs along the PEG chain in the polyrotaxanes was favorable to efficient polyplex formation with anionic DNA. The polyrotaxanes were found to show sufficient cleavage of S-S linkages under reducible, which led to triggering pDNA release via the dissociation of the non-covalent linkages between DMAE-alpha-CDs and the PEG chain. The polyrotaxanes were finally clarified to exhibit great transfection activity as well as few cytotoxicity.

D-5: IL08 **Electrohydrodynamic Forming of Capsules and Microspheres for Drug Delivery**

M.J. EDIRISINGHE, E.P. STRIDE, University College London, London, UK

Drug delivery is currently an area of intense research activity, in particular the development of biocompatible devices for targeted administration and controlled release. The high cost associated with drug development means efficient processing techniques for drug encapsulation are in great demand. Electrohydrodynamic forming offers a simple, one-step method for the mass production of both reservoir and monolithic microcapsules from a wide range of materials. In this paper we will present our recent work on the development of novel electrohydrodynamic systems for two specific applications: the preparation of surfactant coated microbubbles for ultrasound mediated drug delivery and of microcapsules for controlled release, based on a biopolymer system. Findings will be discussed firstly for a model glycerol-air system and a water-lipid system used to characterise the process with respect to the main control parameters in terms of microsphere size and yield, namely liquid and gas flow rate and the applied voltage. Results from optical microscopy, laser diffraction and acoustic scattering for the surfactant and polymer systems will then be shown to demonstrate the high degree of control over capsule size, uniformity and yield which can be obtained with this technique.

D-5: L09 **Multifunctional Nanoparticles Decorated by Trastuzumab for Targeted Chemotherapy of Breast Cancer**

BINGFENG SUN, S.-S. FENG, National University of Singapore, Singapore

Nanoparticles (NPs) of biodegradable polymers as a drug delivery system formulate drug devoid of harmful adjuvant, realize controlled drug release and achieve better therapeutic efficacy than pristine agent. However, the low selectivity of NPs towards cancer cells hinders the advantages of NP formulation for efficient chemotherapy. The novel system of paclitaxel-loaded, trastuzumab-decorated poly(D,L-lactide-co-glycolide)/montmorillonite(PLGA/MMT) NPs for targeted drug delivery was developed. Paclitaxel was used as a prototype drug with excellent therapeutic effects against a wide spectrum of cancers. Trastuzumab is a humanized monoclonal antibody directed against the human epidermal growth factor receptor-2(HER2), which overexpresses in 25-30% breast cancers. Moreover, synergistic effects have been found in combination of trastuzumab with paclitaxel. As a potent detoxifier, the medical clay MMT can adsorb toxins and reduce side effects. Our novel drug delivery system represents a new concept in developing drug delivery systems and can achieve four functions, i.e. to formulate anticancer drugs with no harmful adjuvant; to reduce side effects caused by formulated drugs; to have synergistic therapeutic effects; and to achieve targeted chemotherapy for HER2-positive breast cancer.

D-5: L10 **Inhibition of Alzheimer Amyloid Aggregation with Sulfated Glycopolymers**

YOSHIKO MIURA, KIYOFUMI YAMAMOTO, Japan Advanced Institute of Science and Technology, Nomi, Ishikawa, Japan; KIKUKO YASUDA, YOSHIHIRO NISHIDA, KAZUKIYO KOBAYASHI, Nagoya University, Nagoya, Japan

Glycopolymers carrying sulfated saccharides with modest sugar contents (11% and 28%) were found to suppress the formation of amyloid fibrils by amyloid b peptides (Ab(1-42), Ab(1-40), and Ab(25-35)), as evaluated by thioflavin T assays and AFM observation. Circular dichroism spectra showed that the confirmation of amyloid b peptides depended on the glycopolymer additives, and that the glycopolymer additives reduced the b-sheet contents. The sulfate group and the appropriate sugar contents were essential for the inhibitory effect.

D-5: L11 **A Novel Nanocomposite Microsphere for Controlled Drug Release**

YUFENG ZHAO, XIGENG MIAO[1], LINGXUE KONG, P. HODGSON, Deakin University, Geelong Campus, Victoria, Australia; [1]Queensland University of Technology, Kelvin Grove, Queensland, Australia

It has been recently demonstrated that ordered mesoporous bioactive glasses (MBGs) could work as an effective drug delivery system, having superior bioactivity in vitro as compared to conventional bioactive glasseses. However, reports on the controlled drug storage and their release from MBGs in a convenient and controllable way are still rare. The present work developed a novel MBGs/PLGA nanocomposite microsphere and achieved the "controlled release" of drugs in the real sense. In this work, the MBGs were encapsulated with biodegradable polymer poly (DL-lactide-co-glycolide) PLGA (75:25) through double emulsion solvent evaporation technique. A series of MBGs-PLGA microsphere with different MBGs/PLGA weight ratio (1:4, 1:3, 1:2 and 1:1) and porous structure on the PLGA shell were successfully prepared. An FDA approved drug alendronate (a bisphosphonate) was selected as a model drug for the controlled release study. The release rate was controlled by adjustment of the pH value in a narrow range, considering the potential for a low local pH in the infected bone. Here the PLGA works as a gate of the MBGs drug carriers. The degradation of PLGA will start as this drug-MBGs-PLGA system is put into the release medium, the gate will fully open with the complete degradation of PLGA. Characterization with BET/N_2 adsorption using a micromeritics porosimeter, SEM/FE-SEM and FTIR were applied to the PLGA/MBGs drug carriers to estimate any change in detail.

Session D-6
Advances in Mini/Micro/Nano Implantable Devices

D-6: IL01 **Intelligent Polymer Networks as Recognition and Actuation Elements**
J.Z. HILT, University of Kentucky, Lexington, KY, USA

In our laboratory, chemical engineering fundamentals are applied to the rational design, synthesis, and application of novel macromolecular materials. We are particularly interested in designing and fabricating intelligent polymer networks to exhibit unique properties providing for application as recognition and/or actuation elements in innovative devices for microsensing, microarray, and other micro- and nanoscale applications, primarily of medical and biological significance. For example, nanocomposite hydrogels are a new class of intelligent materials, which have recently attracted interest as biomaterials. The incorporation of nanoparticles into a hydrogel matrix can provide unique properties including remote actuation and also improve properties such as mechanical strength. The properties can be easily tailored by manipulating the properties of hydrogel and the nanoparticulate material. In particular, hydrogel nanocomposites with magnetic particles will be highlighted. This new class of biomaterials holds great promise as RC drug delivery systems for pulsatile release of drug molecules on demand and as active components of biomedical devices.

D-6: IL02 **Energy Efficient Biomedical Signal Processing in Implantable Devices**
V. ÖWALL, L. SÖRNMO, J. NEVES RODRIGUES, Lund University, Lund, Sweden

Implantable devices like cardiac pacemakers have very strict restrictions on energy consumption since battery change requires operation. Today the battery longevity of pacemakers during standard use is up to 10 years which might seem sufficient. However, new functionality is constantly being introduced requiring more advanced signal processing algorithms which in turn increase energy consumption. New battery technologies are of course beneficial, but compared to the progress of electronics according to Moore's Law, battery development is very slow and energy issues have to be solved by more efficient implementations. Technology scaling will help us by reducing capacitance and thereby lowering the dynamic energy. However, for technology nodes of 130 nm and below static energy consumption due to leakage currents, which traditionally could be ignored, are becoming increasingly important. This is especially true for low sampling rate applications were the dynamic energy often can be ignored. In this paper we will make an introduction to the topic, discuss the mechanisms of energy consumption and present some specific solutions regarding implementation of signal processing in implantable cardiac devices. Special attention will be given to reduced leakage and a dual mode operation.

D-6: L03 **Towards an Integrated, Fully-Implantable Vestibular Prosthesis for Balance Restoration**
T.G. CONSTANDINOU[1, 2], J. GEORGIOU[1], C. TOUMAZOU[2], [1]University of Cyprus, Nicosia, Cyprus; [2]Imperial College London, London, UK

Neuroprosthetics is a relatively new topic but it has already shown its potential. Since the application of this science, it has already significantly improved the quality of life of over 60,000 individuals who previously suffered from severely impaired hearing or total deafness. Today, through use of cochlear implants, children born totally deaf can enjoy going to regular schools and communicating normally. Handicapped individuals suffering from dizziness and balance disorders can also benefit from the progress made in cochlear prosthetics. The inner ear's vestibular system provides cues about self-motion and help stabilise vision during movement. Damage to this system can result in dizziness, imbalance, blurred vision and instability in locomotion, a leading cause of death in the elderly. We propose a hybrid CMOS/MEMS platform for bypassing a dysfunctional pathway in individuals that suffer from balance-related disorders. Combining MEMS-based inertia sensing with CMOS-based neural monitoring and processing electronics, this prosthesis aims to deliver a corrective artificial stimulus to the vestibulocochlear (VIII) nerve. We describe a novel system outlining the architectural aspects and implementation methodology used in the design.

D-6: IL04 **Implantable Electronics for the Recovery of Neuromuscular Functions**
M. SAWAN, Ecole Polytechnique, Montreal, Canada

This invited paper covers circuits and systems techniques for the construction of high reliability implantable microsystems. These smart medical sensing/microstimulation devices are dedicated for neural dysfunctions corrections. Low-power high-reliability wireless links are used to power up the implanted devices while bidirectional data are exchanged between the electronic implants and external controllers. Global view of main sensors/microstimulators will be given, case studies related to applications (bladder control, intracortical monitoring and microstimulation) will be discussed, and special attention will be paid to massively parallel recording of neural signals and stimulation of intracortical tissues.

Session D-7
Medical Applications of Shape Memory Materials and Smart Textiles

D-7: IL01 **Medical Applications of Shape Memory Alloys**
L'H. YAHIA, J. MOORE, R. AYERS, M. BEAUMIER, A. WARRAK, F. RAYES, Ecole Polytechnique, Montreal, Canada

Shape-memory alloys (SMAs) such as NiTi are metals that at a certain temperature revert back to their original shape after being strained. The combination of good biocompatibility, good strength and ductility with the specific functional properties of SMA such as the shape memory effect, damping capacity and superelasticity create a smart material for medical applications. Medical applications of SMAs are wide spread and diverse. They have impacted many fields of medicine such as: cardiovascular and endovascular interventions, orthopedics and dentistry. Some of the most innovative SMA devices include: the self-expanding stents, shape memory staples, vascular filters, orthodontic archwires and porous implants. SMAs are also being used in a variety of surgical instruments for minimally invasive surgery. The excellent compatibility with magnetic resonance imaging (MRI) has lead to the first MRI compatible needles for use in surgery. Other applications include graspers, baskets, scissors, and flexible puncture needles. The medical market is a continuing success story for the application of SMA products. Increasing life expectancy, advances in surgical and minimally invasive procedures mean that the medical market will remain an area of great opportunity for commercial applications.

D-7: L02 **Fatigue properties of superelastic Nitinol filaments for braided orthopedic cables**
Y. BARIL, V. BRAILOVSKI, P. TERRIAULT, Ecole de Technologie Supérieure, Montréal (Quebec), Canada

Superelastic Nitinol filaments of 0.1mm of diameter are used to manufacture braided orthopedic cable for bone tissue cerclage. For a given cable used in a specific application, the higher the magnitude of the installation force, the higher the strain applied. Biomechanical conditions of the application having generally a cyclic nature, it therefore becomes important to evaluate the influence of the installation (mean) strain on the fatigue life of the filament used for cable manufacturing. Uniaxial tension cyclic testing of Nitinol filaments is performed in water bath at 37degC with frequency of 2Hz up to 100 000 cycles. Strain-controlled conditions of testing are as follows: alternating strain magnitude varies between 0.66 and 3.96% with mean strain range between 1.32 and 6.6%. Based on the premises that the minimum strain should be high enough to prevent any loss of tension in the tested specimen and the maximum strain should not bring the specimen to failure during the first cycle of loading, the total strain magnitude is encompassed between 2 and 8.58%. The results obtained bring better understanding of the impact the mean strain has on the fatigue life of superelastic Nitinol and allows an optimal selection of the installation force to maximize service life of the superelastic orthopedic cables.

D-7: IL03 **Theory and Experiments for Mechanically-induced Remodeling of Tissue Engineered Blood Vessels**
R.L. GLEASON, Georgia Institute of Technology, Atlanta, GA, USA

There is a great unmet clinical need to develop small diameter tissue engineered blood vessels (TEBV) with low thrombogenicity and immune response and suitable mechanical properties. In this paper we describe experimental and computational frameworks to characterize the use of mechanical stimuli to improve the mechanical properties of TEBVs. We model the TEBV as a constrained mixture and track the production, degradation, mechanical state, and organization of each structural constituent. Specifically, we assume that individual load bearing constituents can co-exist within each neighborhood and, although they are constrained to deform together, each constituent within this neighborhood may have different natural (i.e., stress-free) configurations. Motivated by this theoretical framework, we have built a bioreactor and biomechanical testing device for TEBVs. This device can provide precise and independent control of mean and cyclic luminal flow rate, transmural pressure, and axial load over weeks and months in culture and perform intermittent biaxial biomechanical tests. This device also fits under a two-photon laser scanning microscope for 3-dimenstional imaging of the content and organization of cells and matrix constituents. These data directly support our theoretical models.

D-7: L05 **Design and Validation of a Progressively Expandable Stent**
P. TERRIAULT, P. LAFORTUNE, D. PLAMONDON, V. BRAILOVSKI, Ecole de Technologie Supérerieure, Montréal, Québec, Canada; D. LE PORHO, Polyconsult International Inc., Longueuil, Québec, Canada; R. GALLO, Montreal Heart Institute, Montréal, Québec, Canada

Nowadays, a minimally invasive surgery called stenting is extensively used to increase the lumen of partially obstructed arteries. Unfortunately, restenosis, a postoperative phenomenon for which the lumen of the artery is reduced due to traumatism of the artery, is still a concern. The most popular solution adopted by the stent manufacturers is the drug-eluting stents. This paper presents a new concept of stent for which the treatment of restenosis is carried out from a completely different angle. Indeed, instead of traumatizing the artery and trying afterwards to control restenosis with drugs, the new stent minimizes the traumatism of the artery by expanding itself not instantaneously, but progressively in a controlled manner. To do so, a Nitinol structure over which a series of polymer rings are installed tries to reach a fully deployed configuration, but the polymer rings that act as a retainer “soften” in time due to creep. Thus, after the initial deployment in the artery, the stent continues its expansion autonomously over a long period of time (a few weeks). It is believed that the artery has enough time to adapt to the expansion, leading to a minimized traumatism. In this paper, the design process, the manufacturing issues and the experimental validation are presented.

D-7: IL06 **Functional Materials for Wearable Sensors and Actuators**
D. DE ROSSI, University of Pisa, Pisa, Italy

To provide people with personalized healthcare, support, and information, technological advances should be brought closer to the subject by means of easy-to-use wearable interfaces between devices and humans. This can be achieved through electronic textiles (e-textiles),capable of making daily life healthier,safer,and more comfortable. Such fabrics are conceived as innovative and high knowledge content garments, integrating sensing, actuation, electronic, and power functions. Due to their multifunctional interactivity, enabled by wearable devices that are flexible and conformable to the human body, e-textiles are considered relevant promoters of a higher quality of life and progress in biomedicine. In this talk I will describe the early conception and latest developments of electroactive polymer(EAP-based sensors,actuators and electronic components, implemented as wearable devices for smart electronic textiles. After a brief outline on ongoing research this paper presents the most highly performing EAP-based devices developed by our lab and and other research groups with reference to their already demonstrated or potential applicability to electronic textiles.

D-7: IL07 **Bio-sensing Textile for Medical Monitoring Applications**
J. LUPRANO, Centre Suisse d’Electronique et de Microtechnique, Neuchâtel, Switzerland; N. TACCINI, Smartex, Navacchio, Italy; F. DI FRANCESCO, University of Pisa, Pisa, Italy; G. MARCHAND, CEA-LETI, Grenoble, France; C. CHUZEL, Sofileta, Bourgoin-Jallieu, France; H. DE MONCUIT, Thuasne, St-Etienne, France; C. BINI, Penelope, Montemurlo, Italy; K. LAU, Dublin City University, Dublin, Ireland

The commercial systems using intelligent textiles that start to appear on the market perform physiological measurements such as body temperature, electrocardiogram, respiration rate, etc. and target sport and healthcare applications. Biochemical measurements of body fluids combined with available health monitoring technology will extend these systems by addressing important health and safety issues. BIOTEX, standing for Bio-sensing Textile for Health Management, is a European project, which aims at developing dedicated biochemical sensing techniques that can be integrated into textiles. Such a system would be a major breakthrough for personalized healthcare and would allow for the first time the monitoring of body fluids with sensors distributed in a textile substrate. The potential applications include isolated people, convalescents and patients with chronic diseases, sports performance assessment and training. The project is addressing several challenges, among which: sweat collection and delivery to the sensors, high sensitivity with a wearable system, wearability issues, sensor calibration and lack of research in sweat analysis.

SYMPOSIUM E

Mining Smartness from Nature

Session E-1

Algorithms, Mechanisms and Structures in Nature as Inspiration for Mimicking

E-1.1 Biological Approaches and Solutions

E-1.1: IL01 **A Biomimetic Approach to Materials Science**
G. JERONIMIDIS, University of Reading, Reading, UK

Design and function in plants and animals have developed under evolutionary pressures over millions of years, a small step at a time. Our technological time-scales may be different but the design constraints and objectives are very similar: functionality, optimisation and cost-effectiveness. The basic materials of biology, i.e. the chemical substances used by organisms to provide the properties they need, are comparatively few. They do not have any especially outstanding characteristic; none of them has a particularly high Young's modulus, tensile strength or toughness (although they do have much lower densities). They are successful not so much because of what they are but because of the way in which they are put together. Biology is dominated by polymer fibres such as cellulose, collagen, chitin, and silks and hierarchical composite structures. It is the way in which these different structural materials levels are organised and the degree of interaction between that allow effective tailoring of properties for specific requirements (it is the same collagen that is used in low-modulus, highly extensible structures such as blood vessels, intermediate modulus tissues such as tendons and high modulus, rigid materials such as bone). Learning from nature how best to exploit fibrous structures would enhance functionality. Self-assembly and bottom up biosynthesis (molecular to tissue to organ) are two additional aspects of biological materials which can provide ideas and inspiration for man-made solutions.

E-1.1: IL02 **Spider Silk as an Inspiration for Biomimicking**
J. PÉREZ-RIGUEIRO[1], M. ELICES[1], G.R. PLAZA[1], G.V. GUINEA[1], P. CORSINI[2], E. MARSANO[2], [1]Universidad Politécnica de Madrid, Madrid, Spain; [2]Università di Genova, Genova, Italy

Silks spun by arthropods exhibit a set of unique properties that have emerged as the result of over four hundred million years of evolution. Silks show the most optimized combination of tensile strength and deformation at breaking, yielding the highest work of fracture of any known material. These outstanding features have thrust an increasing interest in reproducing or even improving the properties of natural silks. However, the advances in the field are hampered by an incomplete knowledge on the relation between microstructure and mechanical properties as well as by uncertainties related to the influence of processing in the performance of the fiber. In this work we present some of the most significant contributions of our groups to the field, stressing the possibility of controlling the tensile properties of silks and that of producing artificial regenerated fibers. Spider silk shows a large variability that it is thought to allow the spider to adapt the fibers to its immediate requirements, but represents a major drawback for its study or application. The development of the wet stretching process has allowed the modification of silk fibers in a controlled and reproducible way for the first time. Besides, recent improvements in the spinning of regenerated silkworm silk fibers have led to artificial fibers with properties that approach those of natural silks. These progresses allow envisaging the production of bioinspired fibers in a not too distant future.

E-1.1: IL04 **Sensorimotor Coordination Abilities of Animals as Inspiration for the Control of Robots' Locomotion**
A.J. IJSPEERT, Ecole Polytechnique Federale de Lausanne, Switzerland

Animal locomotion control is in a large part based on central pattern generators (CPGs), which are neural networks capable of producing complex rhythmic patterns while being activated and modulated by relatively simple control signals. These networks are located in the spinal cord for vertebrate animals. In this talk, I will present our work on developing numerical models of CPGs in lower vertebrates (lamprey and salamander), and how we test the CPG models on board of amphibious robots, in particular a new salamander-like robot capable of swimming and walking. The goal of the project is to explore three important questions related to vertebrate locomotion: (i) the modifications undergone by the spinal locomotor circuits during the evolutionary transition from aquatic to terrestrial locomotion, (ii) the mechanisms necessary for coordination of limb and axial movements, and (iii) the mechanisms that underlie gait transitions. I will also present how abstract CPG models can be used to control the locomotion of various robots (quadruped, humanoid and reconfigurable modular robots), and serve as useful substrates for doing online learning (i.e. learning while moving).

E-1.1: L06 **Multi-scale Optical Response of Structured Surfaces in Living Organisms**
J.P. VIGNERON, M. RASSART, University of Namur, Namur, Belgium

Natural photonic structures are complex objects : their geometry reveals several length scales, with different orders of magnitude. In principle, a complete vector-wave description of the optical response of such structures should be applied, but in many situations, the scattering surface is too large and too complex to warrant following such a path of analysis. The visual effects determined at all length scales are important to biology and should be considered, even if approaching this from ab initio Maxwell's equations is unfeasible. We propose an hybrid approach for calculating the reflectance spectra from such complex surfaces, which combine Monte-Carlo ray tracing for long-paths propagation and fully vectorial multiple scattering of electromagnetic wave for local color filtering. The procedure has been applied to explain the light scattering properties of several insect's coloring structures exhibiting short-range order and long-range disorder (ventral side of the wings of the Brazilian butterfly Cyanophrys remus), and the simple case of an hemispheric multilayer, as found on the cuticle of the brightly colored African shield-backed bug beetle Calidea panaethiopica.

E-1.1: IL07 **Cells, Gels and Water: A Fresh Approach to Cell Function**
G.H. POLLACK, University of Washington, Seattle, WA, USA

The cytoplasm is broadly acknowledged to be a polymer gel. Yet, textbook mechanisms build on the presumption that it is an aqueous solution. The concept of a gel-like cytoplasm is replete with power. Partitioning of ions between the inside and outside of the cell is directly explainable from the cytoplasm's gel-like character and the organization of its water molecules; such partitioning requires zero maintenance energy, unlike ion-pumping mechanisms. The cell's electrical potential is also explainable: substantial potentials are measured in gels, as well as in cells stripped of their membrane. Gels also undergo phase-transition - discontinuous transformation of protein and water from one physical state to another. In undergoing phase transition, the gels change volume, ion content, solvency, permeability, etc. - changes similar to those experienced by organelles within the functioning cell. The polymer-gel phase transition therefore has the potential to be a central paradigm for mediating many aspects of cell function. These ideas are explored in depth in a recent book (Pollack, "Cells, Gels and the Engines of Life," 2001, www.ebnerandsons.com), and will be discussed in the lecture. In considering these gel-based ideas, the state of water turns out to be of unexpectedly central significance. The cell is extremely crowded with surfaces; hence almost all water is interfacial. That interfacial water

may differ from bulk water has been known for decades, but the extent of the interfacial zone has remained unclear. In a series of experiments undertaken to explore this issue, we find that surfaces impact water out to distances up to hundreds of micrometers - much farther than had previously been envisioned. Evidence will be presented for this unexpectedly long-range impact, and how man-made systems can capitalize on nature's unique design.

E-1.1: IL08 **New Insights in Viral Symmetry**
R. TWAROCK, University of York, York, UK

An important part of a virus is its protein container, called the viral capsid, that encapsulates and hence provides protection for the viral genome. Based on the observation that the capsids of most viruses are organized with icosahedral symmetry, Caspar and Klug introduced a landmark theory in 1962 in which they predicted the locations of the proteins in viral capsids schematically based on triangulations that are compatible with icosahedral symmetry. However, information on the tertiary structures of the capsid proteins and on the organization of the genomic material is inaccessible with their approach. We show here that such information can be obtained via an extension of the symmetry principle underlying their theory. Based on various examples we demonstrate that the material boundaries in simple RNA viruses are completely determined at all radial levels from the capsid area down to the innermost RNA by our new symmetry principle, implying that symmetry is more important in virus architecture than previously appreciated. We conclude with a discussion of the implications of these results on virus assembly and virus evolution.

E-1.1: IL09 **Approaches to the Construction of the Minimal Cell**
P.L. LUISI, P. STANO, University of Rome3, Rome, Italy

The laboratory implementation of a minimal cell consists in the insertion of the minimal number of extant genes and enzymes inside a synthetic vesicle, so as to have an operational viable "semi-synthetic" cell. The main point, conceptually and operationally, is to clarify how to arrive at this minimal number of cellular components. The large majority of researchers in the field have approached the question by performing first single biochemical reactions into vesicle compartments; to pass then to the insertion into the vesicles of entire commercial cellular extracts, which permit the expression of proteins (mostly the green fluorescence protein (GFP) has been used). One first, important limit in these last studies is given by the fact that the composition of the mixture is not given, nor the number and the relative concentration of the enzymes. This hinders a rigorous synthetic approach to the problem. The other limit is that self-replication of these cellular models has not been succefull yet. Our present work stems from the effort of overcoming these limits by carrying out experiments employing a minimal set of enzymes (the PURESYSTEM), consisting of 36 enzymes. With this, we have been capable of expressing not only GFP, but also two membrane proteins involved in the synthesis of the phospholipids which make up the vesicles. And we are now using this system to test the self-replication of the entire cellular system.

E-1.1: IL10 **Molecular Biomimetics: Genome-based Molecular Materials for Technology & Medicine**
M. SARIKAYA, University of Washington, Seattle, WA, USA

With the recent developments of nanoscale engineering in physical sciences, and the advances in molecular biology, we are combining Mother Nature's genetic tools with synthetic nanoscale constructs, and create a hybrid methodology, molecular biomimetics. In this approach, we use biology as a guide and adapt bioschemes including combinatorial biology, post-selection engineering, bioinformatics, and modeling to select and tailor short peptides (7-60 amino acids) with specific binding to and assembly on functional solid materials. Based on the fundamental principles of genome-based design, molecular recognition, and self-assembly, we can now engineer peptides for solids and synthetic functional molecules as nucleators, catalyzers, growth modifiers, molecular linkers and erector sets, fundamental utilities for nano- and nanobio-technology. We will review the latest developments from our collaborative research groups in this rapidly developing polydisciplinary field, focusing on i. Fundamental issues in genetic design, molecular recognition, and assembly of peptides, ii. Discuss bioenabled nano-photonics, -magnetics, and -electronics, and ii. Practical implementation in inorganic biosynthesis and fabrication towards molecular and nano-imaging, sensing (diagnostics), and tissue regeneration.

E-1.2 Biomechanics

E-1.2: IL01 **Flight Control of an Insect**
SHIGERU SUNADA, Osaka Prefecture University, Osaka, Japan

My group has developed an airplane with its span length of 60cm and its weight of 260g. The wing loading of our airplane is close to that of an insect. The wing loading indicates the effect of a wind on the flight. Then, the effect of a wind on an insect is similar to that on the airplane. And understanding how an insect control its flight will contribute to improving our airplane. Recently, we made two researches about the stability and flight control of an insect. These studies will be introduced in this presentation. (1)A swallowtail Papilio xuthus during a gliding flight has the following two features. (i) The dihedral angle is very large (about 45deg). (ii) A part of the left hindwing, which is close to the body, and the counterpart of the right hindwing clap and they form a 'vertical tail'. These features enhance the stability of the gliding flight. (2)Flight behaviors of a bumblebee Bombus ignitus, when a plate is attached on its thorax, were investigated. Two kinds of flight patterns, which cannot be observed when the plate is not attached on it, were observed. One is a periodic pitching motion with a constant amplitude, and it was observed when the flight velocity is smaller than about 1.3 m s-1. The other is a diverged pitching motion and it was observed when the flight velocity is larger than about 1.3 m s-1. These pitching motions can be explained by using the flight controller, which is composed of a low pass filter and a proportional gain. It was shown that the bumblebees selected the maximum gain for making these pitching motions.

E-1.2: IL02 **Wood Biomechanics**
L. SALMEN, STFI-Packforsk, Stockholm, Sweden

Wood is a material of considerable complexity on different hierarchical levels all the way from the polymer assembly in the fibre cell wall to that of the morphological variation of different fibre types in for instance the annual growth rings. These structural levels play different roles in respect to the performance of the tree. Apart from the variation in fibre form in different tissues of the tree the largest variation comes from the orientation of the cellulose reinforcing micro-fibrils in the cell wall also controlling the strength properties in the fibre direction. However many characteristic properties of the fibre wall and wood are regulated by the properties of the matrix polymers, especially in the transverse direction. In understanding the property structural relations knowledge regarding the interaction between the polymer components of the fibre wall using dynamic FTIR have shown new insight. In for instance softwoods there is a clear coupling between cellulose and glucomannan whereas the xylan does not play the same role. Based on such data together with ultarstructural knowledge detailed ultrastructural models of the complex ultra-structural arrangement of the polymers in the fibre wall of both softwood and hardwood species are presented and analysed.

E-1.2: L03 **Different Influence of Surface Energy and Surface Roughness on the Adhesive Ability of Female and Male Beetles Gastrophysa Viridula**
NAOE HOSODA[1], S.N. GORB[2], [1]National Institute for Material Science, Tsukuba, Ibaraki, Japan; [2]Max Planck Institute for Metals Research, Stuttgart, Germany

The leaf beetle Gastrophysa viridula has three types of tenent setae on the ventral surface of their tarsi. Type 1 setae bear spatula (tape- or plate-like) on their tips. Type 2 setae are thin and elongated. Type 3 setae bear round mushroom-like tips. Type 1 and type 2 setae are known for both sexes, whereas type 3 setae from the male tarsi only. To understand functional mechanisms behind attachment systems, bearing different types of tenent setae, we studied influence of surface energy and surface roughness of the substrate on traction forces developed by females and males. Experimental results show that forces, developed by females, depend on the substrate surface energy. Interestingly, the host plant Rumex obtusifolius possesses leaf surface energy corresponding to the maximum of the female's traction force. Male's attachment is less influenced by the surface energy, but stronger by the surface roughness. We found critical roughness values for males between 40 nm and 80 nm with grain width of 0.9 µm. Above and below these critical values, male's attachment system can tolerate roughness rather well. Our results show that systems with different setal shape are differently influenced by geometrical and physico-chemical properties of the substrate.

E-1.3 Biologically Inspired Structures

E-1.3: IL01 **Micropatterned Adhesive Surfaces: Recent Advances**
E ARZT, A. DEL CAMPO, INM - Leibniz Institute for New Materials, Saarbruecken, Germany

Sticking forces betweent two surfaces: how can they be controlled, enhanced or even switched on and off? This subject area not only poses many inter- disciplinary fundamental questions but is also of great interest in microfabrication, biomedical industry, construction industry, sports equipment etc. Several materials strategies over the last years have been inspired by biological systems: the adhesion performance of flies, spiders and geckoes was investigated by nanomechanical techniques and traced back to van der Waals and capillary forces. A common feature seems to be the miniaturisation of the contact elements, which in the case of the gecko reach nanoscopic dimensions (100 nm). This talk will summarize results of our recent research: on the structure and function of biological attachment systems, results of adhesion performance and on new theoretical developments in the field of contact mechanics. We will also describe our latest attempts to produce bio-inspired microtextured polymer surfaces; they already exhibit adhesion strengths approaching those of biosystems and will very likely lead to “smart” surfaces surpassing their biological counterparts.

E-1.3: L03 **Investigating the Thrust Productions of a Myliobatoid-inspired Oscillating Wing**
K. MOORED, H. BART-SMITH, University of Virginia, Charlottesville, VA, USA

Myliobatidae is a family of large pelagic rays including cownose, eagle and manta rays. They are extremely efficient swimmers, can cruise at high speeds and can perform turn-on-a-dime maneuvering, making these fishes excellent inspiration for an autonomous underwater vehicle. Myliobatoids have been studied extensively from a biological perspective; however the fluid mechanisms that produce thrust for their large-amplitude oscillatory-style pectoral fin flapping are unknown. An experimental flapping wing has been developed that closely matches the camber and planform shapes of myliobatoids. The wing can produce significant spanwise curvature, phase delays down the span, and frequencies up to 1.5 Hz, capturing the dominant kinematic modes of flapping for myliobatoids. This paper uses dye flow visualization to qualitatively characterize the fluid mechanisms at work during steady-state oscillation. Quantitative pressure measurements are also obtained on the surface of the wing. The combination of qualitative and quantitative measurements gives a complete picture of the fluid dynamics. The lessons distilled from studying the fluid dynamics of myliobatoids are then applied to the design of a morphing tensegrity wing capable of efficiently mimicking the kinematics of the rays.

E-1.3: IL05 **Deployable Structures in Plants**
HIDETOSHI KOBAYASHI, Osaka University, Toyonaka, Japan

The deployment of leaves with plane surfaces and straight parallel folds, as observed in leaves of hornbeam and beech, were investigated by using numerical methods. In both species the secondary veins are angled at 30° to 50° from the midrib, when the leaves are outstretched. Although a higher angle allows the leaf to be folded more compactly within the bud, it takes larger energy to expand. The extension speed of leaf midrib is very low at an initial stage of unfolding and then it becomes almost constant. From the numerical simulation, it was found that this midrib extension pattern becomes the unfolding with the lowest energy. The deployment of flower was also investigated from mechanical point of view. It was found that the number of petals, five, in morning glory flower is the number compromised between the unfolding energy and storage manner in a bud. The release of the strain energy absorbed in petals plays one of the most effective roles in the unfolding of petunia and lily flowers. Although morning glory and lily flowers open continuously for 5 to 10 hours, petunia flower takes a rest for about 10 hours during two day unfolding.

E-1.3: L06 **A Bat-wing Aircraft Using the Smart Joint Mechanism**
E. LEYLEK, J. MANZO, E. GARCIA, Cornell University, Ithaca, NY, USA

Drawing from the bat’s ability to drastically vary camber for high maneuverability, aircraft wing shapes are developed to mimic the aerodynamic behavior of these structures for morphing into multiple flight regime configurations. Through two-dimensional airfoil simulations and wind tunnel experiments, a wing shape capable of performing well in both low-speed and high-efficiency states is selected as the testbed for morphing operations. In the first phase, a membrane-like wing and skeletal network demonstrates through quasi-static testing the aerodynamic parameters that are affected by morphological changes such as camber and wingtip twist. In the next phase, a fully actuated wing structure making use of the Cornell-developed Smart Joint mechanism will demonstrate actuation capabilities and corresponding aerodynamic variation. This smart joint uses shape memory materials to create an active rigidity system for both high efficiency and reduced weight, and is optimized using heuristic methods to find the best specific power density. Dynamic wind tunnel tests will show the ability of this system to perform morphing maneuvers under aerodynamic loading, matching expected results from the quasi-static test runs.

E-1.3: L07 **Analysis and Optimization-based Synthesis of Compliant Mechanisms**
A. HASSE, F.L. CAMPANILE, Empa, Zürich, Switzerland

Compliant mechanisms fulfil a desired force and displacement characteristic. The shape development of such structures having a defined kinematical motion and subjected to several constraints, like deformability, stiffness and activation force is extremely challenging. The current project deals with a methodology for analysing compliant mechanisms considering geometrically nonlinear deformations. By assembling pre-calculated nonlinear beam elements a new beam truss approach is introduced. The solution of each beam element is given by the circular arc procedure. This procedure is discussed and supplemented with a new subroutine for solution stabilization. The beam truss method appears to be time-efficient providing the same solution for thin beams as the classical nonlinear FE-analysis. The accuracy and quality of the mechanical model are verified by selected examples and compared to existing methods.

Session E-2
Biomimetic Materials

E-2.1 Bio-inspired and Bio-enabled Materials

E-2.1: IL01 **Two-dimensional Crystallization of Proteins on Lipid Surfaces**
A.R. BRISSON, N. ARRAUD, R. BERAT, A. BOUTER, B. GARNIER, C. GOUNOU, J. LAI-KEE-HIM, S. TAN, University of Bordeaux, Talence, France

Self-assembling proteins as 2D arrays at membrane surfaces is a generic strategy used by Nature for the construction of functional supramolecular edifices, e.g. bacterial S-layers, inter-membrane cadherin junctions or clathrin cages. Annexin-A5 (Anx5) is a member of the annexin protein superfamily, which share the property of binding to negatively charged phospholipids in a Ca2+-dependent manner and form various types of 2D ordered arrays at membranes. Anx5 presents unique properties of 2D crystallization on lipid surfaces[1]. The first part of this presentation will focus on the binding and 2D organization of Anx5 on membranes, and address the question of the functional role of Anx5 2D crystals. Molecular tools derived from Anx5 will then be introduced. A generic 2D platform based on fusion proteins between Anx5 and an IgG-binding moiety has been designed for anchoring antibodies or proteins, for applications in proteomics[2]. Gold particles functionalized with Anx5 or Anx5-fusion proteins have been developed for applications in diagnosis, e.g. plasmatic microparticles. These applications illustrate the potential of mimicking Nature’s strategy of protein 2D crystallization at lipid surfaces.

[1]Richter et al, Biophys. J. 2005, 89:3372; [2]Brisson, Patent WO2005114192

E-2.1: L02 **Nonlinear Self-excited Oscillation of a Synthetic Ion Channel-inspired Nano-actuation Membrane**
TAKEO YAMAGUCHI[1, 2], TAICHI ITO[1], HIDENORI OHASHI[2], NAOKO MIYAOI[2], YUMI OGINO[2], [1]Tokyo Institute of Technology, Yokohama, Japan; [2]University of Tokyo, Tokyo, Japan

An ion channel recognizes a specific ion, and controls its transport through biomembrane. Using the functions of the ion channels, some neurons show oscillation phenomena, which is considered to relate closely to brain functions. Inspired by the function of an ion channel, we have developed a synthetic nano-actuation membrane, which we call a molecular recognition ion gating membrane. This gating membrane was chemically synthesized from porous substrate, and the functions can be made by coordinating crown ether as a sensor and thermosensitive polymer as an actuator fixed in the pores of porous membrane. The actuation polymer swelling close the pores and the shrinkage leads to open the pores. The actuation is triggered by specific ion signal. The pore open and close phenomena can control hydrostatic pressure-driven flow and osmotic pressure generation, results in nonlinear self-excited oscillation. The membrane pores open and close autonomously. Also, the molecular recognition gating function can be made in cylindrical structured pores, and the phenomena can be controlled. This shows that nonliving materials can act vividly like a biological thing, and the synthetic membrane is very durable for long period unlike biomembranes.

E-2.1: L03 **Fractals to Model Hierarchical Biomaterials**

A. CARPINTERI, N. PUGNO, A. SAPORA, Politecnico di Torino, Torino, Italy

Biological materials exhibit several levels of hierarchy, from the micro- to the macro-scale. For instance, sea shells have 2 or 3 orders of lamellar structures, as well as bone, similarly to dentin, has 7 orders of hierarchy. These materials are composed by hard and strong mineral structures embedded in a soft and tough protein matrix. In bone and dentin, the mineral platelets are 3nm thick, whereas in shells their thickness is of about 300nm, with very high slenderness. With this hard/soft hierarchical texture, Nature seems to suggest us the key for optimizing materials with respect to both strength and toughness, without losing stiffness. Even if hierarchical materials are recognized to possess a fractal-like topology, only few engineering models explicitly considering their complex structure are present in the literature. In this presentation alternative and concise mathematical models will be presented, based on our previous experience on fractal geometry. Simple formulas describing the dependence of strength, toughness and stiffness on the considered size-scale are thus derived.

E-2.1: L05 **Synthetic Biology: Olfactory Receptors in Artificial Membranes**

R. ROBELEK[1], E. LEMKER[3], B. WILTSCHI[3], V. KIRSTE[1], T. LASSER[2], M. LEUTENEGGER[2], D. OESTERHELT[3], E. SINNER[1], [1]Max-Planck-Institute for Polymer Research, Mainz, Germany; [2]EPFL, Lausanne, Switzerland; [3]Max-Planck-Institute for Biochemistry, Martinsried, Germany

As a matter of fact: Membrane protein research depends largely on the availability of the protein of interest. Few examples are known, which can withstand the indispensable isolation and purification process prior to their investigation. An experimental platform is presented, which allows for synthesis and investigation of complex membrane proteins, such as G-protein coupled receptors, circumventing some of the most important difficulties described so far. This platform consists in an in vitro synthesis of a complex membrane protein in the presence of a planar lipid membrane. As a prominent and challenging example, we have chosen a member of the G-protein coupled receptor family, an odorant receptor from rattus norvegicus (OR5). We observe the directional insertion of OR5 proteins into an solid supported tethered lipid membrane - the orientation of the proteins is shown via immunolabeling in combination with the method of surface plasmon enhanced fluorescence spectroscopy (SPFS). Reversible ligand binding analyzed by surface enhanced infrared spectroscopy (SEIRAS) suggests intactness and activity of the inserted proteins. These experiments demonstrate that the in vitro synthesis of membrane proteins in solid supported membranes is feasible and may increase the availability of membrane proteins for experimental approaches.

E-2.1: IL06 **Study on Morph-genetic Materials Derived from Natural Materials**

D. ZHANG, T.X. FAN, L.H. SU, S.M. ZHU, J.J. GU, J. DING, Shanghai Jiaotong University, Shanghai, China

Scientists are always amazed by the biological materials, which are characterized by unique structures and morphologies. Inspired by nature, scientists struggle to fabricate artificial structures with certain functions in a biomimetic way. There has been a great interest in using biomaterials with subtle hierarchical structures as biotemplates to fabricate biomorphic inorganic materials. In recent years, different biotemplating technologies have been developed for the conversion of biological templates into biomorphic ceramics. In this review, the latest developments in this field will be discussed. The review is organized into four parts. In the first part, versatile inorganic materials using different wood issues as templates will be discussed. The second part will give an overview on the butterfly wings microstructure materials. The third part will give an intensive review on the latest developments on how to create inorganic materials with unusual structural specialty and complexity using the eggshell membrane as the templates, whereas the last part deals with investigations on the bacteria transforms by various analytical techniques. Finally, we will give the summary, expectation and our own perspectives on these active areas.

E-2.1: L07 **Functional Surfaces in Biology - Mechanisms and Applications**

S.N. GORB, Max-Planck-Institute for Metals Research, Stuttgart, Germany

Being interfaces between living organisms and an environment, biological surfaces serve many different functions: (1) They limit the dimensions, give the shape to the organism, and provide mechanical stability of the body. (2) They are barriers against dry, wet, cold or hot environments. (3) They take part in respiration and in the transport of diverse secretions, and serve as a chemical reservoir for the storage of metabolic waste products. (4) A variety of specialised surface structures are parts of mechano- and chemoreceptors. (5) The coloration and chemical components of surfaces are important components for thermoregulation, and are often involved in diverse communication systems. (6) A number of specialised surface structures may serve a variety of other functions, such as air retention, food grinding, body cleaning, etc. Biological surfaces hide virtually endless potential of technological ideas for development of new materials and systems. Because of the broad diversity of functions of biological surfaces, inspirations from biology may be interesting for a broad range of topics in engineering sciences: adhesion, friction, wear, lubrication, filtering, sensorics, wetting phenomena, self-cleaning, anti-fouling, thermoregulation, optics, etc. Since all biological surfaces are polyfunctional, it makes them even more interesting from the point of view of biomimetics. In the present talk, we discuss some functions of biological surfaces potentially interesting for biomimetics, and demonstrate several examples of materials and systems, which development was based on inspirations from biology.

E-2.1: L08 **Design Strategies for Hard Biomaterials in Marine Shells. Examples from the Phylum Brachiopoda**

E. GRIESSHABER, W.W. SCHMAHL, C. MERKEL, A. GÖTZ, Ludwig Maximilian University, Munich, Germany

Brachiopods are sessile marine invertebrates and they have been existing since the early Cambrian. Early on in their evolution two different material design strategies for their exosceleton (shell) have come into existence, which are both very different from the aragonite-nacre of molluscs: one is based on a hybrid fibre composite of inorganic single-crystal fibres of calcite-phase calciumcarbonate embedded in about 2 weight-% of organic polymer sheaths. A hard, thin nanocrystalline calcite layer covered by an organic outer sheath protects the fibre composite material base from the outside. The stiff and tough material is well suited for life on the sea floor outside the sediment. Brachiopods burrowing inside the sediment have developed a laminated shell where an organic fibre component dominates, but where thin mineralized layers featuring Ca-phosphate-nanoparticle-reinforced fibres are incorporated. The phosphate mineralization in thin laminae gives a longitudinal stiffness while it preserves the flexibility of the organic component in the transverse direction and provides hardness and fracture toughening. The Ca-phosphate nanoparticle reinforcement strategy is not unlike that in vertebrate bone.

E-2.1: L09 **New Fabrication Process of Nano-composites by Biomimetic Approach**

MITSUYO OKAMOTO, E. IWAI, H. HATTA, The Institute of Space and Astronautical, Kanagawa, Japan; H. KOHRI, I. SHIOTA, Kogakuin University, Tokyo, Japan

In bio-systems, complex fibrous structures are formed by self-assembling process with low energy. If these mechanisms of biological tissue are clarified, we possibly get new processes of composite fabrication. In order to identify mechanisms of such self-assembling, osteons in bone tissue and vascular cambium in plants were observed with an optical

microscope and SEM. The results showed that the cellulose in plants and collagen in animal bones possibly self-assembled via liquid crystalline phases. Then, self-assembling of collagen was attempted in vitro. Optical anisotropy was caused by a texture of aligned molecules when liquid crystalline phase was produced. Thus, cholesteric liquid crystal phase was observed in collagen solution. In order to ascertain fiber alignment, collagen fibrils were observed with AFM, SEM and TEM. From these experiments, it was concluded that concentration and pH were the most important factors for self-organization of collagen fibers via liquid crystal. The optimal concentration and pH are detecting to obtain homogeneous large volume of liquid crystal of collagen molecules.

E-2.2 Bio-inspired Manufacturing

E-2.2: IL01 **Biomimetic Materials Processing**
OSAMU TAKAI, Nagoya University, Nagoya, Japan

Living organisms produce a wide variety of materials at room temperature and atmospheric pressure. Moreover, each produced material plays a key role in each function in biological systems. “Biomimetic materials processing (BMMP)” is defined as the design and synthesis of new functional materials by refining knowledge and understanding of related biological products, structures, functions and processes. Hence the BMMP is not a simple imitation of biological materials processes, but is advanced materials processing for bionics, electronics, photonics, mechatronics and so on. By means of this BMMP we can prepare “biomimetic materials” or more widely “bioinspired materials”. For example, leaves of lotus show ultra water-repellency because of the precisely controlled roughness of their surfaces. Similarly, we can synthesize ultra water-repellent silicon oxide films by plasma-enhanced chemical vapor deposition using organosilicon compounds as row materials. Furthermore, we can add the transparency to the films. This transparency is an additional significant function, which the leaves of lotus do not have. For the preparation of the transparent ultra water-repellent films the key technology is the control of surface nanotextures. Hence the BMMP closely relates to nanotechnology.

E-2.2: IL02 **Recombinant Spider Silk - Remodelling a Fascinating Biomaterial**
T. SCHEIBEL, University of Bayreuth, Bayreuth, Germany

Biological materials often exceed the characteristics and properties of man-made ones. One well-known example is spider silk with superior mechanical properties such as strength and toughness. Most spider silks are used for building the web, which reflects an optimized trap for flying prey. Already thousands of years ago the excellent mechanical properties and low immunogenicity of spider webs have been acknowledged by men, employing them as fishing nets or as wound closure devices. However, large-scale farming of spiders has been quickly abandoned due to the territorial and cannibalistic behavior of most spiders. In order to avoid such complication, we developed a bio-inspired system using bacteria as production hosts which produce silk proteins mimicking the natural spider silks. Besides the protein fabrication, we have developed a spinning technique to produce spider silk threads closely resembling natural silk fibers. Importantly, we can employ the bio-inspired silk proteins also in other application forms such as hydrogels, spheres or films. Our bio-inspired approach serves as a basis for new materials in a variety of medical, biological, or chemical applications.

E-2.2: L03 **Bio-Inspired Nanofabrication of Semiconductors and Dynamically Adaptive Optical Materials**
D.E. MORSE, University of California, Santa Barbara, CA, USA

Our focus is the analysis of complex biological systems, and translation of the underlying mechanisms responsible for advantages exhibited by these systems to practical materials engineering: (1) From analyses of the mechanisms of silica nanofabrication in sponges, we developed a generic low-temperature method for synthesis of a wide range of nanostructured semiconductor thin films and perovskite nanoparticles without using organic templates. The method yields high purity semiconductors integrable with MOCVD and CMOS manufacturing. Materials made by this low-T process offer unique combinations of structures and properties not readily attainable by conventional mehtods; they exhibit potential advantages for improved energy conversion and storage, memory, IR and piezoelectric detectors, optoelectronics and flexible displays. (2) From analyses of molecular mechanisms governing the rapidly adaptive optical behavior exhibited by the skin of squids and octopi, we are working to develop a new class of dynamically adaptive optical materials. Our efforts are focused on the structure and regulation of the proteins discovered as the principal components of the Bragg reflectors discovered in cells exhibiting dynamically adaptive changes in reflectance that the animals employ for camouflage and communication. Successful translation of these mechanisms to practical materials synthesis would enable a wide range of applications in optics, IR, and optoelectronic communications.

Session E-3
Bio-inspired Sensors and Actuators

E-3.1 Sensors

E-3.1: L01 **Remote Electrical Sensing: Object Detection and Analysis Inspired by Electric Fishes**
G. VON DER EMDE, A. PADBERG, University of Bonn, Bonn, Germany

Inspired by the remarkable capabilities of weakly electric fish in detecting and recognizing objects in complete darkness with their electric sense, we designed technical sensor systems that can solve similar problems. We applied the principles of active electrolocation by building devices that produce electrical current pulses in a conducting medium (water) and simultaneously sense local current densities. Depending on the specific task sensors can (i) detect an object, (ii) localize it in space, (iii) determine its distance, and (iv) measure certain object properties such as material properties, thickness, or material faults. The biomimetic sensor systems proved to be relatively insensitive to environmental disturbances such as heat, pressure, or turbidity. They can be used in a wide range of applications including material identification, quality control, remote distance measurements, medical diagnostics and many more. Despite their capacities, our sensors still lack far behind to what electric fish are able to achieve during active electrolocation. The understanding of the neural principles governing electric fish sensory physiology and the corresponding optimization of our sensors to solve certain technical tasks therefore remain ongoing goals of our research.

E-3.1: L02 **Towards Biocompatible Sensing Devices: an IPMC Based Artificial Vestibular System**
C. BONOMO, L. FORTUNA, S. GRAZIANI, D. NICOLOSI, G. SICURELLA, Universita’ degli Studi di Catania, Catania, Italy; M. LA ROSA, STMicroelectronics, Catania, Italy

The biological vestibular apparatus (VA) is a sophisticated sensing system which detects information related to position and motion of human head. The peripheral portion of the VA acts as a miniaturized accelerometer which has two main sensing parts: otoliths organs, which sense gravity and linear acceleration caused by the head flexion and semicircular canals which sense the head rotational accelerations. Both systems are based on the bio-sensing performed by hair cells as moto-transducers. An artificial VA has been produced where IPMC sensors mimic the functionality of biological hair cells. The activity is part of the development of a whole organic artificial system miming the human VA for bio-engineering and bio-robotics applications. Following a top-down design strategy, two main topics will be illustrated in the proposed paper: the 3D simulation model of the biological VA and the implementation of a large scale hybrid artificial VA. The first one simulates the vestibular nerve fiber signaling during the motion of human head. The second one reproduce a large scale external VA with IPMC sensors performing the functionality of hair cells. The reported results will be used to develop a compact artificial VA integrating biocompatible materials and all-organic electronic devices.

E-3.1: L03 **Magnetic Field Sensing by Magnetotactic Bacteria and Elasticity of Cytoskeleton**
K. ERGLIS, A. CEBERS, University of Latvia, Riga, Latvia

Magnetotactic bacteria sense the magnetic field of the Earth by chain of magnetosomes coupled to the network of cytoskeletal filaments, which is carried out by proteins embedded in their membranes[1]. We are showing here that the stiffness of coupling to cytoskeletal network is by

several orders of magnitude smaller than due to the magnetodipolar interactions of magnetosomes. The coupling of the magnetosomes to the cytoskelet is studied by behavior of magnetotactic bacteria in the rotating and unidirectional AC magnetic fields. Energy of bacterium in AC field show that its orientation possess easy plane perpendicular to the AC field. The coupling of the magnetic particles to the cytoskeleton of the bacterium may be demonstrated by its motion in the rotating field[2]. It is shown that in dependence on the frequency of the rotating magnetic field the trajectory of the mobile bacterium is a circle or more complex trajectory containing the parts with a negative curvature. By observation of the trajectories of the mobile bacterium in the rotating field it is possible to visualize the reversals of the rotary motors of the bacteria.

[1]A. Komeili, Zho Li, D.K. Newman, and G.J. Jensen, Science, 311, 242 (2006); [2]K. Erglis, Qi Wen, V. Ose, A. Zeltins, A. Sharipo, P.A. Janmey, and A. Cebers, Biophysical Journal, 93, 1402 (2007)

E-3.1: IL04 **Bioelectronic Detection Schemes for Biomedical and Environmental Sensing**
A. OFFENHÄUSSER, Forschungszentrum Jülich, Jülich, Germany

An artificial nose or tongue could be a real benefit at times: this kind of biosensor could sniff or taste out poisons, explosives or drugs, for instance. The senses of living organisms func-tion using various mechanisms, among other things utilizing membrane proteins as recep-tors. Membrane proteins have several important functions in the cell, one of which is to act as receptors, passing on signals from molecules in the air or liquid, for example, to the cell interior. Our research activities are focusing on the functional coupling of biological signal processing and recognition elements with micro- and nanoelectronic semiconductor devices and circuits for the development of future biosensors and molecular diagnostics tools. In this talk we will describe the concept of directly interfacing genetically modified cells containing G-protein receptors with electronic devices. In particular we will focus on the characterization of the cell-device interface, the signal transfer between living cell and electronic device, and sensing properties.

E-3.1: L05 **Double Layer Sensors Reproducing Perception Dynamics of Olfactory Cells**
A. MACAGNANO[1], E. ZAMPETTI[1], B.R. PISTILLO[2], A. BEARZOTTI[1], S. PANTALEI[1], R. D'AGOSTINO[2], [1]IMM-CNR, Rome, Italy; [2]Università di Bari, Bari, Italy

In this work an attempt to obtain a more compact artificial system for gas sensing, designed directly on transducer, is presented. This new device can be applied for a wide application range such as environmental, bio-medical, agriculture etc. fields. In the Nature, a mucous layer covering olfactory receptor cells, selectively tunes chemical interactions among odorous molecules and sensing system. An odor, in fact, is perceived only if it is able to cross mucus of nasal cavity. A proper hydrophobic Teflon-like overcoating tunes chemical interactions, humidity free, between odorous molecules and sensing system, miming mucus covering olfactory receptor cells. The latters were represented by polyaniline, polyvinylphenol, polybenzimidazole and polytiophene. Furthermore, their interacting surfaces have been enormously enhanced creating nanofibrous coatings by electrospinning deposition technique. Such nanofibers can be compared with the olfactory cilia covered by mucus. Few modifications of both overlayers and nanofibrous polymers (e.g. metal doping) can encourage the developing of new chemical sensors for array sensor system generations. Surfaces analysis, electrical parameters and sensing properties of the double layers on interdigitated transducers have been investigated.

E-3.1: L06 **Determining the Binaural Signals in Bat Echolocation**
T. PAPADOPOULOS, R. ALLEN, University of Southampton, Southampton, UK

Echolocating bats are known to outperform manmade systems in the tasks of autonomous navigation and object detection and classification, especially when size, power and computational complexity requirements are considered. As a result, the individual physical mechanisms and processes involved in echolocation (types of signals used, properties of the emission mechanism, echoes created in different echolocation tasks, receptor characteristics as well as the bat's auditory system) have received significant attention as a possible source of bio-inspiration. However, not much attention has been drawn to optimisations that may arise as a combined effect of the above mechanisms. Of key importance in such an investigation would be the knowledge of the binaural signals generated in real echolocation tasks as those are the actual input signals utilised by the bat's auditory system. The direct measurement of these signals is severely restricted by the very small size of most bat species. We describe the development of an experimental facility that combines the measurement and modelling of the aforementioned subsystems for the determination of the binaural signals associated with echolocation. We present initial measurement results and compare them with analytical modelling predictions.

E-3.1: L07 **Generating Bio-Analogous Recognition in Artificial Materials - Sensors and Electronic Noses for Odours**
P.A. LIEBERZEIT, A. REHMAN, B. NAJAFI, F.L. DICKERT, University of Vienna, Vienna, Austria

Chemical sensing is a key application of bio-inspired smart materials. Artificial nanostructured layers mimicking biorecognition are synthetically accessible e.g. by imprinting techniques or affinity material nanoparticles. Hence, imprinting leads to highly selective cavities in polymers (polyurethanes, -styrenes, -acrylates) for detecting odorous compounds, e.g. aliphatic alcohols, ethyl acetate and limonene. With these materials, we designed an electronic nose for monitoring plant degradation processes based on a six-electrode QCM (quartz crystal microbalance) array. With a variety of degrading materials (grass, fruit, conifers), it determines the above analytes down to some ppm directly on-line. The concentration data can be extracted from the E-nose frequency shifts by Neural Networks and validated by GC-MS. For detecting extremely malodorous organic thiols (butane/octance thiol), we designed molybdenum disulphide nanoparticles. In contrast to soft metals (e.g. gold) they interact with the SH-group fully reversibly leading to one of the first real QCM sensors for these compounds. Changing the Mo:S-ratio by as few as ten percent doubles the sensor responses, similar effects can be observed when reducing the particle size from several hundred to some ten nanometers.

E-3.2 Actuators

E-3.2: IL01 **A pH-driven DNA Nanoswitch Array**
DEJIAN ZHOU, University of Leeds, Leeds, UK

An array of surface-immobilized proton-fuelled DNA nanomachines is reversibly actuated by cycling of the solution pH between 4.5 and 9, producing a conformational change between a 4-stranded and a double-stranded structure, which elongates or shortens the separation distance between the 5' and 3' end of the DNA. By labelling the DNA 3' end with a fluorophore and immobilizing it onto a thin-gold surface through its 5' thiol modification, the nanoscale motion of the DNA produces mechanical work to lift up and bring-down the fluorophore from the gold surface by at least 2.5 nm, confirmed by AFM thickness measurement. This transduces this motion into an optical "on-and-off" nanoswitch. This opens up many opportunities to exploit this well-defined and controllable nanoscale motions, for example, to produce micromechanical work, for pH-controlled drug release, movement of cargos, and changing the nature of the surface in response to a stimulus.

E-3.2: L04 **A pH-activated Biomimetic Actuator Derived from McKibben Artificial Muscle Structure**
B. TONDU, R. EMIRKHANIAN, S. MATHÉ, A. RICARD, University of Toulouse, Toulouse, France

Fluidic McKibben artificial muscle is actually one of the most biomimetic actuator, exhibiting static and dynamic behaviour in close analogy with skeletal muscle. It is also known that McKibben muscle can combine this analogical behaviour with a high force on mass and on volume ratio. This paper analyses the working possibility of a small-size McKibben muscle for which a chemical activation mode is substituted to the pneumatic energy, with the hope of deriving an original actuator for new applications in robotics and medecine. PH activation mode seems particularly well adapted to our approach: large range of pH-sensitive materials availability, easiness of a reversible control by acid and base flows. The use of ion-exchange resins is considered due to their high swelling ability and their ball-like microscopic structure favourable to flow circulation through the inner chamber of the McKibben muscle. Classic 'pH-muscle' prototypes are generally tested with 1N acid/base concentrations which are too aggressive for human tissues. With the aim of developping a 'pH-muscle' adapted to a human environment, 0.1 and 0.01 N concentrations are privileged. Results are reported of a 10 cm long and 1 cm diameter artificial muscle in isometric and isotonic conditions against loads until 3 kg.

E-3.2: L05 **Unraveling Cytoskeletal Transduction during Myogenesis with EAP Bioactuator**
E. THOMASSON, M. ASCHWANDEN, R. ENNING, A. STEMMER, A. FRANCO-OBREGÓN, ETH, Zurich, Switzerland

Activated myoblasts first undergo many rounds of cell division. They may next withdraw from the cell cycle to fuse to form myotubes. Division and fusion are differentially modulated by mechanical stimuli transmitted to the cell's biosynthetic mechanisms via the actin-based cytoskeleton; Specifically cyclic stretch promotes proliferation and inhibits fusion while ramp stretch induces the opposite reaction. We hypothesize that stretch-activated Ca^{2+} channels (SACCs) activate key enzymatic cascades that ultimately lead to muscle-specific gene transcription which determine whether the cell will proliferate or differentiate. A two-dimensional stretcher developed to produce well-defined stresses onto cells, was used. Our results suggest that the proliferation of myoblasts is inhibited by of Gd^{3+}. Given that Gd^{3+} blocks SACCs, proliferation should then be coupled to the activation of these ion channels. Consistent with the notion of stretch dependent (Insulin-like Growth Factor) IGF-I gene splicing, SACCs might then start the communication pathway leading to Mechano Growth Factor (MGF) synthesis. We will further be testing the hypothesis that both modalities of mechanical stimuli are segregated at the level of cell attachment to the extracellular matrix by testing the sensitivity to SACC blockage when conditioning the surface with distinct ECM components.

Session E-4
Biologically Inspired Systems, and Robotics

E-4.1 Systems

E-4.1: IL01 **Towards In Vivo Nanomachines**
E. FRIEDRICHS, R. JUNGMANN, A. TSOKOU, S. RENNER, F.C. SIMMEL, Technical University Munich, Garching, Germany

DNA has been recently used to construct a variety of nanoscale machines and switches, among them devices which can translocate, compute, or bind and release molecules. For future applications it is interesting to investigate whether these "artificial" functions can also be implemented in vivo. As one step towards in vivo applications, we currently utilize RNA molecules for construction or control of molecular devices. RNA molecules can be transcribed from "artificial genes" and either fold into functional nanoassemblies themselves or drive other nucleic acid-based devices as a "fuel". Furthermore, coupling of nanomachines to RNA transcription enables transcriptional control of their behavior using gene regulatory motifs.

E-4.1: IL02 **Morphing Aircraft in Perching Maneuvers**
E. GARCIA, A. WICKENHEISER, J. DIETL, J. MANZO, Cornell University, Ithaca, NY, USA

For the last century, aircraft have been essentially fixed-frame structures, with few exceptions. It has been have found that radical aerial maneuvers, unimaginable with conventional control surfaces, become possible with morphology changes of the aircraft itself. Specifically, an investigation of an aircraft in perching maneuvers will be presented. By morphing the aircraft in flight, it becomes possible to drastically change vehicle parameters and enable this biologically inspired landing. A variant of Weissinger's method has been developed to predict the aerodynamic performance of shape changing structures. Our vehicle model mixes both analytic and experimental aerodynamic data to arrive at a representation of the vehicle with 9500 permutations of the morphing configuration. Dynamic analysis is performed that reveals the effects of morphing on the overall vehicle stability. Optimization results of the perching maneuver show that a morphing vehicle performs this landing under greater control authority and can land in a more constrained environment than a traditional aircraft.

E-4.1: IL03 **Bio-inspired Control Architectures for Multifunctional Autonomous Robots**
F. KIRCHNER, University of Bremen, Bremen, Germany

New and intelligent Materials will allow us to create a new generation of robotic systems that incorporate so called proprioceptive information. This type of information has been largely absent in current robotic designs due to lack of intelligent materials. Instead of using standard materials to design and built limbs and structures in a robot, the new limbs, joints and supporting structures will be sensors that provide valuable internal information about the robots internal state. Using this information will allow us to tackle the tough problem of describing and representing external state information in a much more comprehensive way. Thus the possibility for a broader, more robust intelligence in technical systems will become real.

E-4.2 Robotics

E-4.2: IL03 **Neuromimetic Robots Inspired by Insects' Visuomotor Control Systems**
N. FRANCESCHINI, S. VIOLLET, F. RUFFIER, J. SERRES, CNRS & University of the Mediterranean, Marseille, France

The insect compound eye is a masterpiece of micro-optics, optronics, neuronics and micro-mechatronics. It has already given rise to major biomimetic applications: anti-reflection coatings, polarization-keeping optical fibers, tandem photodetectors, graded index optical fibers, polarization compasses, solar concentrators and X-ray telescopes. Insects are autonomous mobile creatures that use their compound eyes for immediate action upon the steering. With a one-milligram brain, flying insects navigate swiftly in complex environments without resorting to any sonars, laser range-finders or GPS. They can therefore teach us some shortcuts to designing innovative, agile, lightweight and power-lean autonomous systems. I will show how we formalized some insect navigational principles and applied them to the guidance of miniature aerial robots. Octave is a fly-by-sight helicopter that avoids the ground, Lora is a fly-by-sight hovercraft that avoids the walls of a corridor and Oscar is a twin-engined aerial robot that stabilizes in space or pursue a target. All these robots measure the optic flow on the basis of an 'electronic motion detector' derived from our electrophysiological analysis of the fly's eye.

E-4.2: L04 **CPG Control of a Tensegrity Structure**
T.K. BLISS, T. IWASAKI, H. BART-SMITH, University of Virginia, Charlottesville, VA, USA

The manta ray, Manta birostris, is a highly maneuverable creature, propelling itself through the water with the elegant and complex flapping of its wings. This animal is of interest for morphing structures applications, achieving outstanding efficiency and speed even with the enormous span of over five meters. This study aims at integrating biomimetic control systems with morphing structures to harness what ages of evolution have created. This study will begin by developing a linearized dynamic model of a tensegrity structure. Tensegrities, systems of bars held in compression by a network of cables in tension, are both statically and kinematically indeterminate. The dynamic model of a test will be used to shed light on the modal frequencies of the structure, a parameter of significance in the design of a biomimetic neural network control system. The structure will be controlled with a synthetic central pattern generator (CPG), the fundamental neural control mechanism for rhythmic motion in animals. The structure will be actuated using the CPG's output. With position feedback, we expect resonant entrainment of the control system and the structure.

E-4.2: IL05 **Hybrid Structures Composed of Photosynthetic System and Metal Nanoparticles: Plasmon Enhancement Effect**
A.O. GOVOROV, Ohio University, Athens, OH, USA

The efficiency of chemical energy production of a photosynthetic system can be strongly enhanced in the presence of metal nanoparticles. If a photosynthetic system is integrated into an electric circuit, metal nanoparticles can enhance the photocurrents. Two competing effects contribute to the photosystem efficiency: plasmon enhancement of photon fields inside the light-absorbing chlorophyll molecules and energy transfer from chlorophylls to metal nanoparticles. The first effect can

lead to strong enhancement of light absorption by the chlorophylls, whereas the second can somewhat reduce the quantum yield of the system. This talk will discuss one concrete example of hybrid photosystem that incorporates a photosynthetic reaction center bound to gold and silver nanocrystals[1]. The enhancement mechanism described here can be utilized in energy-conversion devices and sensors.

[1]*Govorov, A.O., Carmeli, I. Nano Lett. 7 (3), p. 620 (2007).*

E-4.2: IL06 **Biorobots, Nonlinear Dynamics and Perception**
P. ARENA, D. LOMBARDO, L. PATANE', University of Catania, Catania, Italy

Living creatures show distinct abilities to interact adaptively with their environment. These characteristics find their roots in the self-organizing dynamics of neural circuits. The lecture will explore the paradigm of biological inspiration for modelling and implementing adaptive locomotion patterns in bio-inspired walking machines. Once assessed the potentiality of lattices of nonlinear artificial neurons to lead to the emergence adaptive locomotion controllers, the field of perception will be faced with. Even if the term perception is being used more and more frequently in this period, rarely it is referred to considering nonlinear dynamical circuits and systems. In our framework the core of perception is conceived as an emergent, pattern forming, phenomenon, arising from the sensory information. This pattern will represent in a concise fashion the environment information. Recent results in neurobiology have shown that this is based on internal representations that combine aspects of sensory input and motor output in an unified way. This is the essence from which percepts are able to be produced in real time for guiding actions in complex environment. Some experimental results will be given to support this new methodology.

E-4.2: IL07 **On Human Interactive Adaptive Robotics**
ZHIWEI LUO, Kobe University, Kobe, Japan

Although machines have been made to imitate and to amplify special functions of human and animals, they are far from achieving the level of the autonomy, flexibility, environmental adaptability and functional variety of biological systems. When we dreamed of flying like a bird, the airplane was born, far outdoing the birds in speed and size. However, the airplane cannot realize the bird's agility to move from branch to branch. Nowadays, industrial robots can only perform predefined operations in a well-structured task space but do not have full capability to deal with unexpected situations in natural complex environment. Similarly, though the computer has increased enormous computational capabilities, it is nevertheless a serial sequential machine that can perform only pre-programmed actions. Under this background, biomimetic and biologically inspired control research is becoming a very important subject. This talk will review our recent advanced researches related on biomimetic system control. Especially, we concentrate our discussions on how to organize the system redundancy, the optimal motion formation and the environmental adaptive control. We will introduce detail the development of human interactive robot RI-MAN and discuss further problems for new challenges.

E-4.2: L08 **Anthropomorphic Talking Robot Based on Human Biomechanical Structure**
KOTARO FUKUI, YUMA ISHIKAWA, EIJI SHINTAKU, MASAAKI HONDA, ATSUO TAKANISHI, Waseda University, Tokyo, Japan

We have developed a new anthropomorphic talking robot, WT-6 (Waseda Talker No. 6), which generates speech sounds by mechanically simulating articulatory motions as well as aero-acoustic phenomena. WT-6 possesses 17 degrees of freedom (DOF): 5 DOF tongue, 1 DOF jaws, 4 DOF lips, nasal cavity and 1 DOF soft palate as articulators; and 5 DOF vocal cords and 1 DOF lungs as vocal organs. The vocal cords, tongue and lips are made from the thermoplastic rubber "Septon" which has a similar elasticity to human tissue. WT-6 has three-dimensional lips, tongue, jaw and velum which form the vocal tract structure. It also has an independent jaw opening/closing mechanism. The previous robot in the series had a 2D tongue and was not able to realize precise closure to produce human-like consonants. The new tongue, which can be controlled to form 3D shapes, is able to produce more realistic vocal tract shapes. The vocal cord model consisted of two folds, which was constructed with a similar structure to the biomechanical structure of the human vocal cords. The vocal cords could vibrate having complex phase like those of a human. With these mechanisms, the robot could reproduce human speech in a more biomechanical manner and could produce voices closer to those of a human.

E-4.2: L09 **Cyborg MAVs Using Power Harvesting and Behavioral Control Schemes**
T. REISSMAN, E. GARCIA, Cornell University, Ithaca, NY, USA

The focus of this research is to use flying insects, coupled with lightweight electronics, to develop cyborg MAVs, or CMAVs. The premise isn't simply to build telemetry devices on the insects, but to embed controls and power systems within the insects to create MAVs that are alive yet manipulated in their actions. The model insect implemented is the Manduca sexta moth, which has wingspans up to 12cm, body masses up to 2g, and can withstand payloads up to 1g. The technique used to create these CMAVs is an integration of MEMS and CMOS devices onto a single silicon device that is surgically inserted into the moth using trans-skeletal anchors in the late pupal stage. The control and sensor systems are powered by harvesting energy from the vibration of the insect flight by means of piezoelectric material and micro-coils generating electromagnetic induction. Methods for controlling the insect include behavioral responses to direct ultrasonic and visual stimulation. Guidance is achieved through a micro GPS system providing information on the location of the insect during flight as well as an ultra-wideband radio communication system. The primary discussion topics of this paper are the power harvesting devices employed and the control schemes used to manipulate the flight of the CMAVs.

E-4.3 Micro and Nano Systems

E-4.3: IL01 **Structural DNA Nanotechnology: Robots and Arrays**
N.C. SEEMAN, New York University, New York, NY, USA

Structural DNA nanotechnology uses reciprocal exchange between DNA double helices to produce branched DNA motifs. We combine branched motifs to produce specific structures, using sticky-ended cohesion. We have used this approach to make DNA stick-polyhedra, a variety of 2D DNA crystalline arrays and a number of sequence-dependent nanomechanical devices, such as a bipedal walker and a machine that translates DNA sequences into assembly instructions. The walker traverses a sidewalk in either direction as a consequence of the addition and removal of specific strands. The translation machine is based on a device that rotates one end relative to another by a half-turn; this device is also driven in a sequence-specific fashion by the addition and removal of specific strands. We have incorporated this device into a cassette that includes a domain to insert it into a 2D periodic array, along with a robotic arm that is reoriented by the motion of the device. By using atomic force microscopy, we are able to demonstrate that the device is active when it is inserted into the array, thereby laying the basis for a DNA-based nanorobotics.

E-4.3: IL03 **DNA Computing and Robotics**
M.N. STOJANOVIC, Columbia University, Fort Lee, NJ, USA

Deoxyribozymes are nucleic acid catalysts made of DNA. Using catalysts that can cleave other oligonucleotides we constructed a series of computing and moving irreducible functional elements, or primitives. We can combine these elements in solution in order to demonstrate that we can obtain complex and varied behaviors if we start from well-designed simple parts. I will mostly talk about game playing automata and guided movement of molecules on well-crafted surfaces.

SPECIAL SESSION E-6

Biomimetic Flow Control in Aquatic Systems and its Application to Bioinspired Autonomous Underwater Vehicles

E-6: IL02 **Vortex Method for the Analysis of Complex, Unsteady and Vortical Flows Around a Swimming Fish**
KYOJI KAMEMOTO, AKIRA OJIMA, Yokohama National University, Yokohama, Japan

This paper is to report a numerical study on the fluid-dynamic mechanism of action of thrust force on a swimming fish by using an advanced vortex method. Although it is known that swimming of a fish like trout or tuna is the motion of high speed and high efficiency, it is difficult to solve directly the propulsion mechanism of fish by living things. Therefore, it is necessary to analyze the complex, unsteady and vortical flows around the deforming body of fish by numerical simulation for the purpose of investigating the propulsion mechanism of fish and the parameter which affects propulsion force. On the other hand, the vortex methods have been developed and applied for analysis of complex, unsteady and vortical flows in relation to problems in a wide range of industry, because they consist of simple algorithm based on physics of flow. Nowadays, applicability of the vortex element methods to various engineering problems has been developed and improved dramatically, and it has become encouragingly clear that the vortex methods have so much interesting features that they provide easy-to-handle and completely grid-free Lagrangian calculation of unsteady and vortical flows without use of any RANS type turbulent models. Therefore, in the present study, in order to examine the applicability of the vortex methods to fluid dynamics of fish swimming, an advanced vortex method developed by the present authors was applied to Lagrangian numerical simulation of complex and unsteady flows around an isolated swimming fish. The calculations have been performed for the fish model based on a combination of NACA0010 and NACA0025 with the model of swimming motion, which has been obtained by observation of actual fish. From a set of numerical calculations for both two dimensional and three dimensional flows, essential mechanism of vortex formation in the unsteady flow around the fish, suitable condition for constant speed swimming (swimming number) and action of fluid dynamic forces on the swimming fish are clarified. In the manuscript of full paper, the mathematical background and numerical procedure of the advanced vortex method will be briefly explained, and the details of characteristics of calculated flows will be introduced. Also, some animated unsteady flows will be shown in the presentation at the conference.

E-6: IL03 **High Fidelity Modeling of the Hydrodynamics of Swimming**
R. MITTAL, The George Washington University, Washington, DC, USA

The last decade has seen a tremendous rise in the popularity of immersed boundary methods (IBM). The primary factor driving this is the relative ease with which this methodology allows researchers to develop computational models of flows with complex geometries and/or moving boundaries. The key feature of the immersed boundary method is that simulations with complex moving boundaries can be carried out on stationary, body non-conformal Cartesian grids. This approach eliminates the need for complicated re-meshing algorithms that are usually employed with conventional Lagrangian body-conformal methods. The IBM method developed here is accurate, efficient and scaleable, is especially well suited for biological flows. The solver is being used in an ongoing project, the objective of which is to design a flexible flapping foil propulsors inspired from fish pectoral fin. The study focuses on the labriform swimming of a bluegill sunfish and CFD modeling has been used to examine is detail, the hydrodynamics associated with the pectoral fin of this fish. Computational modeling and experimental analysis has driven the development of a robotic pectoral fin and the presentation will describe the salient features of this study.

E-6: IL04 **Applying Biomechanics to Swim Better**
P.R. BANDYOPADHYAY, Naval Undersea Warfare Center, Newport, Rhode Island, USA

Swimming and flying animals maneuver wonderfully. They integrate an array of seemingly counter-intuitive mechanisms of force production, control and sensing, among others. We distill the underlying principles and build a novel swimmer. We will discuss its capabilities.

E-6: IL05 **Evolutionary Optimization of Anguilliform Swimming**
P. KOUMOUTSAKOS, P. CHATELAIN, ETH Zurich, Zurich, Switzerland

Biological mimesis pertains usually to the translation of a natural feature into an engineering design. Mimesis however can pertain to the design process itself as one may apply the principles of natural evolution to engineering optimization problems. As an exemplary case study for this approach, we present the application of an Evolutionary Strategy to the optimization of anguilliform swimming. This investigation uses three-dimensional simulations of the flow past a self-propelled body. The motion of the body is not specified a priori but is instead the result of the optimization process. This procedure helps us identify systematically the links between swimming kinematics and biological function. Two objectives are considered: the swimming efficiency and the burst swimming speed. The fast swimmer is characterized by wide tail undulations and an anterior body that remains relatively straight, while the whole body of the efficient swimmer undulates. These differences in turn affect the distribution of thrust along the body and the morphology of the wake.

E-6: IL06 **An Exploration of Passive and Active Flexibility in Biolocomotion Through Analysis of Canonical Problems**
J.D. ELDREDGE, University of California, Los Angeles, CA, USA

Most aquatic creatures achieve motility through the dynamic interaction of their flexible body with the surrounding medium. This flexibility is used to provide a spectrum of active and passive control, allowing the creature to sometimes prescribe its shape changes and at other times extract energy from the fluid. This mix is particularly important in the moderate Reynolds number regime, in which wake vortices play an important energetic role. A well-devised control strategy for a bio-inspired vehicle should — perhaps must — exploit such flexion and energy exchange; as yet, we lack sufficient understanding to develop such a strategy. In this work, I will present several canonical problems that distill fundamental modes of fluid/flexible body mechanics in biological systems, which are analyzed using high-fidelity numerical simulation. The first system consists of an articulated three-link swimmer, considered in free-swimming as well as in a passive configuration in the wake of an obstacle. The second system consists of flapping of a two-component fin with a torsion spring, which allows a portion of the fin to passively deflect. The third problem involves an articulated jellyfish, in which the active/passive flexibility mix is explored by designation of the individual hinges.

E-6: IL07 **Modeling the Dynamics of Human Swimming**
MOTOMU NAKASHIMA, Tokyo Institute of Technology, Tokyo, Japan

Swimming movement of human being is quite distinctive compared to those of the other aquatic animals since the human does not have any features suitable for swimming such as streamlined body and fins. Instead of them, human swims with his/her four limbs in a particular method utilizing the large range of motion and many degrees of freedom for their limb's joints. Taking into account of such peculiarity, the authors recently have developed a simulation model for human swimming "SWUM" (SWimming hUman Model) and its implemented software "Swumsuit". In SWUM, the human body is represented as a series of truncated elliptic cones, and the joint motion as relative body motion for the whole body is given as inputs. The fluid force is decomposed into two components of the drag force and inertial force due to added mass effect of fluid. These components are computed for each local point along the longitudinal axis of the truncated elliptic cone, using the fluid force coefficients which are identified by experiments. The details of formulation, experimental identification of the fluid force coefficients, and applications into various fields are described.

E-6: IL08 **Geometric Mechanics and Aquatic Locomotion Through Vortex Shedding**
S.D. KELLY, University of North Carolina, Charlotte, NC, USA

The controlled shedding of vorticity and the development of liftlike forces

on control surfaces are fundamental to the hydrodynamics of macroscopic marine animals and underwater vehicles alike. Computational models can reproduce these phenomena with high fidelity, but such models are largely incompatible with analytical methods of model-based feedback control design. Problems in aquatic locomotion have recently attracted attention within the analytical mechanics community, leading to the framing of such problems in the context of Lagrangian systems and geometric nonlinear control, but efforts in this area have been limited to idealized problems in which the shedding of vorticity is conspicuously absent. This talk will describe preliminary work to reconcile the realistic modeling of biomorphic aquatic locomotion with the geometric formalism of Lagrangian and Hamiltonian mechanics and nonlinear control.

E-6: IL09 **Vortex Rings in Bio-inspired and Biological Jet Propulsion**

P.S. KRUEGER, Southern Methodist University, Dallas, TX, USA

Pulsed-jets are commonly used for aquatic propulsion, such as squid and jellyfish locomotion. The sudden ejection of a jet with each pulse engenders the formation of a vortex ring through the roll-up of the jet shear layer. If the pulse is too long, the vortex ring will stop forming and the remainder of the pulse is ejected as a trailing jet. Recent results from mechanical pulsed-jets have demonstrated that vortex rings lead to thrust augmentation through the acceleration of additional ambient fluid. This benefit is most pronounced for short pulses without trailing jets. Simulating vehicle motion by introducing background co-flow surrounding the jet has shown that vortex ring formation can be interrupted, but only if the co-flow is sufficiently fast. Recent in situ measurements on squid have captured vortical flows similar to those observed in the laboratory, suggesting thrust augmentation may play a role in their swimming performance. Likewise, recent measurements with a mechanical self-propelled pulsed-jet vehicle ("robosquid") have shown a cruise-speed advantage obtained by pulsing. On-going investigations are exploring the role of vortex rings and thrust augmentation at different scales, including microscale propulsion in both mechanical and biological settings.

E-6: IL10 **Probing the Hydrodynamics of Fish-like Swimming via Numerical Simulation: Recent Insights and Future Challenges**

I. BORAZJANI, F. SOTIROPOULOS, University of Minnesota, Minneapolis, MN, USA

We employ numerical simulation to investigate the hydrodynamics of in-line carangiform locomotion for three Reynolds numbers spanning the transitional and inertial flow regimes, Re = 300, 3000 (viscous flow simulations), and 8 (inviscid simulation). For each Reynolds number, the Strouhal number St of the undulatory body motion is systematically varied starting from zero (rigid body case) until the mean net force over a tail beat cycle acting on the body is of thrust type. We show that the critical Strouhal number for which the net mean force on the body becomes of thrust type making self-propulsion possible is a decreasing function of Reynolds number and approaches the range of Strouhal numbers at which most carangiform swimmers swim in nature (St ~ 0.25) only as Re approaches infinity. The corresponding swimming efficiency at the critical Strouhal number is found to be an increasing function of Reynolds number exceeding 80 percent as Re approaches infinity. These findings are entirely consistent with the fact that in nature carangiform kinematics are typically associated with fast and very efficient swimmers. We will also discuss how numerical simulations can be effectively used to investigate the energetics of carangiform swimming in the presence of ambient turbulence.

E-6: IL11 **Fluid-structure Interactions in Pelagic Trawls and Probable Consequences for the Selectivity of the Fishing Gear**

M. PASCHEN, H.-J. WINKEL, H. KNUTHS, University of Rostock, Rostock, Germany

Approximately for two decades mathematical models and engineering methods have been available for a trustworthy prediction of shape and hydrodynamic loads of complicate and complex fishing gears. In the meantime these methods have become powerful tools for a design of highly selective trawls. But, all methods of them are based on two significant assumptions namely all parts of the gear are exposed to the same undisturbed flow and the hydrodynamic loads may be represented by dimensionless hydrodynamic coefficients which depend on a couple of different geometrical and physical parameters. These coefficients had been ascertained by systematic tests in an uniform current in a wind tunnel respectively in a flume tank with two-dimensional net panels or grids. It is sufficiently known that the application of these coefficients leads to inaccurate results when they are used in context with the simulation tools mentioned above. The key for this phenomenon is to search in the different way of fluid-net-structure interaction of a trawl panel and a net panel. In the first case we generally assume a current through the meshes independent of the geometrical angle of attack because of the condition of continuity; in the second case we can observe that the current may avoid the net meshes especially when the geometrical angle of attack is small. The target of the paper is focused on the question: Are the fluid-net-structure interactions of a trawl panel and a net grid comparable if a so-called effective angle of attack will be a significant parameter instead the geometrical angle of attack. Results of systematic tests in a wind tunnel completed by P.I.V.-measurements will give information about this subject.

E-6: IL13 **Biomechanics in Swimming: from Hydrodynamic Propulsion to Dynamic Maneuverability**

HAO LIU, Chiba University, Chiba, Japan

Biomechanics in animal swimming are addressed in terms of hydrodynamic propulsion and dynamic maneuverability. An integrated simulator for modeling animal and bio-inspired swimming is established, which is very versatile, easily integrating the modeling of realistic animal morphology, flapping-fin and undulating-body kinematics, and unsteady hydrodynamics. A morphological model is built on a basis of a differential geometry-based method and a grid generator for fins and body; and a multi-block and overset grids method is utilized to deal with complex geometries and complicated flapping and undulating movements. A kinematic model is constructed capable to mimic realistic fin-body-kinematics; and an efficient analytical method combined with multi-coordinate systems is employed for dynamic grid regeneration. A FVM-based NS solver for highly moving multi-block and overset grids systems is verified to be self-consistent; and an integrated method of estimating propulsive energetics is established which involves inertial and hydrodynamic forces, powers and propulsive efficiency. Moreover a dynamic model is coupled with the CFD-based simulator, which is capable to analyze dynamic maneuverability of a freely swimming locomotor. Results are presented of larva zebra fishes undergoing quick-start-cyclic-coast swimming and puffer fishes swimming based on flapping fins; and a specific focus is made on the biomechanics in swimming from hydrodynamic propulsion to dynamic maneuverability.

E-6: IL14 **Biologically Inspired Control Surfaces and Propulsors for Underwater Vehicles**

A.H. TECHET, M.J. STANWAY, MIT, Cambridge, MA, USA

Biologically inspired control surfaces and flapping foil propulsors have received a great deal of attention over the last decade. The agility at which fish and seagoing animals maneuver, and the efficiency with which they swim, are unparalleled in man-made mechanisms. In order to achieve higher performance from biologically inspired actuators, a clear understanding of the hydrodynamic flow characteristics and propulsive capabilities of such devices are necessary. This talk will investigate at the flow structures generated by flapping foil mechanisms modeled after aquatic penguin and humpback whale flippers. Kinematic parameters used in flapping can be optimized to obtain high thrust without significant costs to efficiency. Force data for three-dimensional flapping foils, actuated in roll and pitching motions, will be compared with flow visualization results from particle imaging velocimetry and qualitative dye visualization tests. How the vortical wake structure relates to the forces generated by the fins will also be considered. Leading edge modifications, such as simulated humpback whale tubercles, appear to yield little performance change for flapping foil propulsion devices, however dramatically improve static lift performance. Since such modifications do not significantly degrade flapping performance, they may be useful on flapping foil vehicles or types conventional underwater vehicles that spend a considerable time in a gliding mode (e.g. gliders). Biologically inspired control surfaces and flapping foil propulsors have received a great deal of attention over the last decade. The agility at which fish and seagoing animals maneuver, and the efficiency with which they swim, are unparalleled in man-made mechanisms. In order to achieve higher performance from biologically inspired actuators, a clear understanding of the hydrodynamic flow characteristics and propulsive capabilities of such devices are necessary. This talk will investigate at the flow structures generated by flapping foil mechanisms modeled after aquatic penguin and humpback whale flippers. Kinematic parameters used in flapping can be optimized to obtain high thrust without significant costs to efficiency. Force data for three-dimensional flapping foils, actuated in roll and pitching motions, will be compared with flow visualization results from particle imaging

velocimetry and qualitative dye visualization tests. How the vortical wake structure relates to the forces generated by the fins will also be considered. Leading edge modifications, such as simulated humpback whale tubercles, appear to yield little performance change for flapping foil propulsion devices, however dramatically improve static lift performance. Since such modifications do not significantly degrade flapping performance, they may be useful on flapping foil vehicles or types conventional underwater vehicles that spend a considerable time in a gliding mode (e.g. gliders).

E-6: IL15 **Hammerhead: A Vision-guided AUV**
R.L. ALLWOOD, Cranfield University, Cranfield, Bedfordshire, UK

This paper describes the culmination of two separate programmes of work undertaken at the Offshore Technology Centre at Cranfield University. The problems of underwater vision in dark turbid water have been of interest to us over a number of years and a technique employing laser illumination has been developed to partially overcome them. The system incorporates a solid state frequency doubled cw diode pumped Nd:YAG laser emitting light at 532nm as a source of illumination. Using an oscillating mirror to form a stripe of illumination on the target, image processing techniques have been used on standard CCTV outputs to reduce backscattered light thus improving image quality and range of vision. Also, an Autonomous Underwater Vehicle (Hammerhead) has been developed for the purpose of investigating control and guidance strategies. This paper describes the installation of the above mentioned viewing system onto the vehicle and how data extracted from the sensor has been used in the control and guidance of the AUV. In addition, the use of image tracking software, that can be trained to recognise an object, has enabled the AUV to detect and follow a predetermined target, such as an underwater pipeline or subsea telecommunications cable - a truly bio-inspired operational technique.

E-6: IL16 **Bio-inspiration and Implementation of a Soft Undulatory Swimming Robot**
B.L. STOIMENOV, RIKEN, Nagoya, Japan; J.M. ROSSITER, University of Bristol, Bristol, UK; Y. NAKABO, AIST, Tsukuba, Japan; T. MUKAI, RIKEN, Nagoya, Japan

Most aquatic animals with elongate bodies swim by undulation. This mode of locomotion spans the scale range from sub-millimetre nematode worms to eels, salamanders and sea-snakes with length in the range of meters. Artificial undulatory swimmers are of interest to the engineer, because it is expected they will be able to swim efficiently at low and medium Reynolds numbers, similar to their biological counterparts. We analysed the kinematics of nematode worm, eel and salamander reported in the literature and we applied the knowledge to the design of a soft swimming robot. The propulsion force was generated by the undulation of a multi-segment IPMC (ionic polymer metal composite) artificial muscle. The robot can swim forward and backward and turn left and right, although less efficiently than the aquatic animals that have inspired it. We have taken steps to miniaturization of the robot by simplifying the control circuit and miniaturizing the controller board and expect to shrink the size of the robot to 5-8 cm. Increase of swimming efficiency is the next big challenge.

E-6: IL17 **Robustness of Biomimetic Underwater Vehicles under Disturbances**
NAOMI KATO, HIROYOSHI SUZUKI, Osaka University, Suita, Osaka, Japan

This paper describes the use of a mechanical pectoral fin as a new device for maneuvering and stabilizing an underwater vehicle. It is actuated by three servo-motors, which respectively generate a rowing motion, a feathering motion, and a flapping motion. After examining the hydrodynamic characteristics of a mechanical pectoral fin through experimental and numerical analyses and the optimal match of the fin motions to generate the maximum hydrodynamic forces, a biomimetic underwater vehicle equipped with 2 pairs of the mechanical pectoral fins was guided along the wall of a cylinder directing its head to the center of the cylinder and maintaining the set distance to the wall in water currents to demonstrate its ability for inspection of coastal underwater structures under disturbances. We constructed a motion simulator based on Computer Fluid Dynamics to simulate the biometic vehicle under disturbances. This paper describes the developments of new pectoral fins made of elastic materials to use as not only a propulsive device, but also other applications such as grippers, avoiding damages to environment by rigid fins. We carried out the verification tests for generating the propulsive forces and FEM analyses of the behaviors of two elastic pectoral fins.

SYMPOSIUM A
SMART MATERIALS AND MICRO/NANOSYSTEMS

A-1: P02 **Study of Langasite crystal Micro-resonators Using the Length-extension Mode: Temperature-compensated Cuts and Applications to Atomic Force Microscopy**

G. DOUCHET, F. STHAL, T. LEBLOIS, E. BIGLER, C. TELLIER, R. BOURQUIN, Femto-ST, UMR CNRS, Besançon, France

Quartz is the best known and most widely used piezoelectric crystal. However, its use at high temperatures is limited below 500 °C because its phase transition is at 573 °C. Materials such as Langasite (LGS), Langatate (LGT) and Gallium Orthophosphate (GaPO4) crystals are more piezoelectric than quartz crystal and they also have a much better high-temperature behaviour. It has been shown that a temperature-compensated cut exists for LGS length-extension resonators[1]. Thanks to this result, LGS crystal could be used to replace quartz crystal in several applications. For instance, quartz length-extension resonators have already been used to get atomically-resolved imaging by frequency-modulation atomic force microscopy[2]. In this paper, attempts to manufacture this kind of resonators in LGS temperature-compensated cuts by different methods (ultrasound, chemical) are presented. Properties of the LGS devices are compared with quartz crystal's ones.

[1]F. Sthal, E. Bigler, J. Maisonnet, R. Bourquin and B. Dulmet, "Langasite beam resonators: theoretical and experimental investigations" Proc. IEEE Int. Freq. Cont. Symp., Miami, Florida, 5-7 June, pp. 481-484, (2006); [2]T. An, T. Eguchi, K. Akiyama and Y. Hasegawa, Appl. Phys. Lett. 87, 133114 (2005).

A-1: P03 **Magnetic Temperature Transducers Made from Copper Based Soft Ferrite**

C. MICLEA, C. TANASOIU, C.F. MICLEA, M. ClOANGHER, National Institute for Materials Physics, Magurele - Bucharest, Romania; C. PLAVITU, I. SPANULESCU, C.T. MICLEA, Hyperion University, Bucharest, Romania

Soft ferrites in the CuZnTi system were investigated as a function of composition, sintering temperature and cooling speed, in order to obtain materials with different Curie temperatures, between 30 and 180 °C and very high change rate of permeability with temperature around their Curie points. Such materials are well suited to use as high sensitive magnetic temperature sensors and transducers for temperature controller. Zn and Ti additions to copper ferrite change the Curie temperature in a controllable manner, thus being possible to produce ferrite material with a fine controlled Curie point at the desired temperature. Most important was the behavior of magnetic permeability with temperature around the Curie point, where it may change about 50%/°C by a proper choice of the cooling speed of samples from the sintering temperature to room temperature. This makes such materials extremely attractive as magnetic temperature sensors of high sensitivity. Two applications of such materials as temperature sensors and transducers, namely an ultrathermostat and an on-off switch type relay which use such magnetic temperature sensors were designed. Their properties, functionality and performances are presented and discussed.

A-1: P04 **Ferroelectric and Magnetic Properties of Fe Doped PZT Nanoparticles**

P. SMITHA, P.K. PANDEY, S. KURIAN, N.S. GAJBHIYE, Indian Institute of Technology, Kanpur, India

Lead Zirconate Titanate, Pb(ZrxTi1-x)O3 (PZT) ceramics is an important class of piezoelectric, pyroelectric and ferroelectric material. These perovskite based system have been investigated by the addition of various acceptor and donor type additives for improving their sinterability, dielectric, electrical and piezoelectric properties. In the present work, Fe doped PZT of the formula PbZr0.50Ti0.50-xO3 (x = 0.02-0.2) is prepared by polyol mediated auto combustion process at a lower calcination temperature of 500 °C. X-ray diffraction studies revealed Fe doped PZT belongs to tetragonal structure. Iron oxide as acceptor-type dopants enhances oxygen vacancies while occupying the B sites and it exhibits various valence states. The valency of these ions when incorporated in the perovskite structured PZT has been evaluated using EPR and Mössbauer spectroscopy. Magnetic properties studied by using VSM measurements showed the paramagnetic nature of the material. Ferroelectric and dielectric studies are also been carried out. The change in structural, magnetic, dielectric and electrical properties of PZT with on doping with various amounts of Fe has been investigated.

A-2: P05 **Rapid Shrinking of Porous Hydrogel Prepared by Ice Templating**

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A simple and effective method of preparing microporous hydrogel was developed. The freezing and subsequent rehydration of hydrogel makes a variety of hydrogels porous and then their responsive shrinking rates are easily accelerated. The porous structure forming during the freezing process was determined by nucleation of ice crystal and its growing rate. After the lyophilization of bulk gel, the pore size sometimes depends upon the depth from the gel surface because of the difficulties of cooling rate control. As convenient way to give relatively homogeneous pores, hydrogels with different amounts of water were frozen and then rehydrated in water. It appeared that water content was the key factor to control the microporosity and the rates of expelling pore water or solutes. Since the response time of environmentally responsive gels can be drastically reduced by decreasing the characteristic diffusion path length, it is possible to enhance the response rate not simply by reducing the gel size but also by reducing the strut thickness of the pore walls. This method could be applied to polyacrylamide derivative gels, cellulose ether gels, nucleic acid gels and the organic-inorganic hybrid gel crosslinked by silsesquioxane domains.

A-2: P06 **Preparation of Microporous, Thermosensitive Organic-inorganic Hybrid Hydrogel with Simultaneous Control of Phase Separation and Sol-gel Process**

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To overcome the diffusion-limited slow network motion, microporous structures can be generated on the thermosensitive hydrogel by modified temperature-induced phase separation (TIPS) method. The TIPS method was applied to the poly(N-isopropylacrylamide) based organic-inorganic hybrid hydrogel with polysiloxane networks covalently attached to the side chains. The TIPS technique allows a great degree of control over the porosity, pore size, and strut size. After the embryonic network begins to form, the temperature is increased above a lower critical solution temperature of the polymer into the unstable region of the phase diagram. In the modified TIPS process, the polymer-dilute phase leads to pores while the polymer-rich phase forms the water-swollen struts in hydrogels. The microporous structures are determined by the kinetics of phase separation, radical polymerization, and sol-gel process. The TIPS method could successfully control the morphology, porosity, and thermally triggered shrinking rates of thermosensitive organic-inorganic hybrid gel crosslinked by silsesquioxane domains.

A-2: P09 **Dielectrophoresis Force and the Electromechanical Responses of Elastomers**

R. KUNANURUKSAPONG, A. SIRIVAT, Chulalongkorn University, Bangkok, Thailand

For many years, electroactive polymers are the well known materials for using in many applications such as actuators, MEMS devices, and artificial muscles. In our work, we investigated the effect of elastomers

types on the dielectrophoresis force and the electromechanical responses at various electric field strengths. The specimens were prepared by the solvent casting method and cut into thin films. We studied the dielectrophoresis forces of all elastomers by measuring the deflection distance under various electric field strengths (0-600 V/mm), and calculated the force from non-linear deflection theory of cantilever. The results show that the electromechanical responses and the dielectrophoresis forces of all elastomers increase almost linearly with increasing electric field strength. The acrylic elastomers (AR71) had the lowest electrical yield point (75 V/mm) and it generated the highest force (389 μN at E = 600 V/mm). On the other hand, AR70 had highest electrical yield point (300 V/mm) and it generated the lowest force (321 μN at E = 600 V/mm). The dielectrophoresis forces appear to depend on several factors such as dielectricity, electrical conductivity, and the storage modulus of elastomers.

A-5: P12 **Formation of Highly Transparent SiCN Films Prepared by HWCVD**

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The deposition of silicon nitride silicon carbon nitride (SiCN) has been widely studied due to its attractive properties, such as wear resistance, chemical inertness and wide band gap, which provides optical, electronic and other applications in aggressive ambient. Highly transparent SiCN films were prepared by hot wire chemical vapor deposition (HWCVD) at temperature as low as 100 °C. Hexamethyldisilazane (HMDS) and NH3 were used as the source materials for SiCN deposition. The SiCN film prepared by only HMDS was completely transparent in the wavelength of the visible region. Moreover, there was a little absorption in the ultraviolet region. However, SiCN prepared by using HMDS and NH3 showed almost transparent visible and UV regions. In this presentation, we will show x-ray photoelectron spectroscopy results.

A-5: P14 **Miscibility, Isothermal Crystallization / Melting Behavior, and Morphology of Poly(trimethylene terephthalate) / Poly(buthylene terephthalate) Blends**

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Blends of poly(trimethylene terephthalate)(PTT)and poly(buthylene terephthalate)(PBT)in the amorphous state were miscible in all of the blend compositioins studied,as evidenced by a single, composition-dependent glass-transition temperature observed for each blend composition.The cold crystallization temperature increased with increasing PBT content in the blends. The subsequent melting endotherms after melt crystallization exhibited melting point depression behavior in which the observed melting temperatures decreased with an increasing amount of minor component of the blends.LHW and NLHW were used to determine the equilibrium melting temperature of the blends. The values of the overall crystallization rate parameters for these blends were all found to increase with decreasing crystallization temperature, suggesting that these blends crystallized at low temperatures faster than that at high temperatures. As the content of PBT was further increased, these values dramatically decreased. This result is similar to that observed in the growth rate.From LH secondary nucleation theory, PTT ,PBT and their blends showed the transition temperatures between regime III and II about 194 °C.Banded spherulites were observed for PTT/PBT blends.The band spacing of PTT increases with increasing Tc.

A-5: P15 **Non-isothermal Crystallization Kinetics and Melting Behavior of Thermoplastic / Liquid Crystalline Polymer Blends of Poly(trimethylene terepthalate) / Vectra A950**

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Blends of a liquid crystalline polymer with thermoplastics have been widely investigated because of their unique physical, mechanical, rheological and thermal properties. Most LCP/thermoplastic blends are immiscible, with the dispersed LCP phase in the form of droplets of sub-micron size which can be deformed into fibers and reinforce the matrix. Therefore, these systems have been called 'in situ composites'. For the present contribution, the non-isothermal crystallization and subsequent melting behaviors of poly(trimethylene terepthalate), (PTT)/ Vectra A950, (VA) blends with VA contents of 0, 10, 30, 70 and 100 wt% were studied by differential scanning calorimetry at different cooling rates. The presence of PTT did not significantly affect the crystallization behaviors of VA, therefore only the effects of VA on the non-isothermal crystallization kinetics of PTT were studied. The values of half-time of crystallization t1/2, the crystallization rate parameter (CRP), the parameter K in the Ozawa method and F(T) in the combined Avrami and Ozawa equation which signify the kinetics of non-isothermal crystallization indicated that the incorporation of VA into PTT could enhance the PTT crystallization rates probably due to the nucleation effect. The degree of crystallinity of PTT also increased for blends with 10 and 30 wt% VA. Triple melting endotherms were found in the subsequent melting thermograms of all PTT samples and the blends.

A-5: P16 **Sulfonated Poly(ether ether ketone)(S-PEEK) as Derived from Bisphenol-S for PEM**

S. CHANGKHAMCHOM, A. SIRIVAT, The Petroleum and Petrochemical College, Bangkok, Thailand

The currently used Proton Exchange Membrane (PEM) in Direct Methanol Fuel Cell (DMFC) is Nafion, an excellent proton conductor in fully hydrated membrane. However, it has major drawbacks such as very high cost, and loss of conductivity at elevated temperature and low humidity. In our work, the novel PEM was based on sulfonated poly(ether ether ketone) (S-PEEK) which was synthesized by nucleophilic aromatic substitution polycondensation of bisphonol-S, 4,4'-dichlorobenzophenone (DCBP), and sodium 5,5'-carbonylbis(2-chlorobenzenesulfonate) (SDCBP). Bisphenol-S is expected to improve thermal stability due to its high melting point (245 °C). S-PEEK was characterized by FTIR, 1H-NMR, TGA, DSC, and titration to determine the degree of sulfonation (D.S.). Composite membranes were prepared by using S-PEEK as polymer matrix and heteropolyacid (HPA) as an inorganic filler. The phosphotungstic acid (PTA) was used due to its highly proton conductivity at high temperature and low water uptake. The membranes were characterized by SEM, TGA, DSC, DMTA, and by the measurements of water uptake (%), swelling ratio (%), ion exchange capability (IEC), methanol diffusion coefficient, and proton conductivity.

A-5: P17 **Two-layer Radar Absorbing Structures Composed of Carbon Black and Carbon Fiber Composites**

SANG-YOUNG KIM, SUNG-SOO KIM, Chungbuk National University, Cheongju, Korea

Radar absorbing structure (RAS) is a composite laminate with low reflection coefficient for electromagnetic illumination in microwave frequency range, and thereby playing a key role in the stealth technology and electromagnetic compatibility (EMC) problems. In this study, microwave absorbing properties of a two-layer composite laminate (carbon black impregnated rubber sheet attached on carbon fiber - epoxy composite panel) has been investigated. Complex permittivity and permeability were measured in C- and X-band frequencies (4-12 GHz) by the reflection/transmission method using coaxial waveguide and network analyzer. Complex permittivity can be controlled with the amount of carbon black in the rubber composite. High values of dielectric constant and dielectric loss are observed in the carbon fiber composite. Optimization of microwave absorption is conducted for the two-layer RAS using the transmission line theory. It is found that microwave absorption is strongly sensitive to carbon black content in the rubber composite and its layer thickness. Absorbing band moves to lower frequency with increase of carbon content. For rubber sheet containing 10 vol.% carbon black (with dielectric constant of 5), maximum microwave absorption (30 dB) is predicted at 10 GHz.

A-5: P21 **Synthesis of Carbon Nanofibers as Support Layer for Metal Catalysts in a Microreactor for Three-phase Reactions**

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The Smart Microreactors project is aimed at developing a micro-structured multiphase reactor, viz. a gas-liquid contactor with specially modified catalytic coatings on its microstructured internals, for studying 3-phase (G-L-S) reactions. The microreactor is fabricated using micromachining technologies in silicon and vitreous materials (fused silica, Borofloat glass) with microchannels containing hollow silicon pillars with porous walls for injecting gas into a liquid stream flowing around the pillars. Carbon NanoFibers (CNFs) synthesized on outer surface of pillars will be used as structured support for metal (Pt/Pd) catalyst. With their inherent high surface area-to-volume ratio, CNFs provide more catalytic surface area hence sufficient activity per unit volume of catalyst, while maintaining a low fluidic resistance. Manipulating the bulk density of the CNF layer helps to tailor porosity

and eliminate internal diffusion limitations in the CNF layer. CNFs are grown by CVD of ethylene catalyzed by nickel. Preparation of nickel thin-films along with various adhesion layers is done by evaporation and sputtering. The fundamental growth of CNFs is studied as function of CVD conditions. Different stages can be discriminated in time, of which details will be presented at the conference.

A-5: P23 **Functionalized Conducting Polymer-Magnetic Nanoparticles Hybrid Nanocomposites with Tailored Electrical and Magnetic Properties**

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We report the synthesis and characterization of hybrid organic-inorganic nanostructures consisting in the deposition of a conducting polymer layer (functionalized pyrrole copolymers) on the magnetic nanoparticles surface. Magnetic nanofluid, pyrrole and substituted pyrrole monomers were used as starting materials. The functionalized magnetic nanocomposites were obtained by oxidative polymerization of substituted and unsubstituted pyrrole in aqueous solution containing ammonium peroxodisulfate as oxidant and water based magnetic nanofluid. A core-shell structure was obtained with the magnetic core covered by the functionalized pyrrole copolymer. The properties of the nanocomposites were investigated by TEM, HRTEM, Dynamic Light Scattering (DLS), FTIR spectroscopy and magnetization measurements. We focus on the nanostructure-properties relationship and to the controlled modification of the nanocomposites electrical and magnetic properties by the synthesis parameters. The functionalization with polymer layer allows the introduction of reactive groups (COOH, NH2 or OH) onto the magnetic nanoparticles surface. These reactive groups were used to attach the specific biological entities for applications of magnetic nanoparticles in biotechnologies.

A-5: P24 **Smart Properties of an Irradiated High-Tc Superconductor**

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Effect of a high-energy, heavy ion irradiation on the properties of Y-Ba-Cu-O high-Tc superconductors is examined. The irradiating medium consists of accelerated Bi-ions, having atomic weight 114.82, energy 720MeV and flux $5x10^{10}$ ions/cm^2. The detected hysteresis loops have very different forms and sizes in unirradiated and in irradiated states, referring to the strong effect of the irradiation. The direct reason of the striking variation of critical current- and magnetic parameters up to the extent of 30-45% can be looked for in the change of the atomic-molecular microstructure of the specimens, as a nanometer effect due to the irradiation. This is decided by both of the energy and density of the ions arriving onto the surface of the samples. It means, that the effect produced by the irradiating individual ions depends also on the exact local place of the specimens, in nanometer scale, determined by their given molecular structure, bonding relationships and microstructural stability. In this way, the irradiation experiments can provide some new information on the atomic-molecular properties of the specimens in question. As a genuine smart material, the YBaCuO high-Tc superconductor is able to reply to any external influence, changing its own qualities according to that effect.

A-7: P26 **Encapsulation of High Dielectric Constant Particles via Miniemulsion Polymerization**

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A challenge in the field of dielectric elastomer actuators is to prepare an elastomeric material with a high dielectric constant which can be operated at low electric field and yet providing large strains. It is well known that the dielectric constant of a polymer matrix can significantly be increased by blending with conducting fillers, however the breakdown field as well as the elastic properties decrease due to the inhomogeneous dispersion of the particles. The encapsulation of conductive particles by miniemulsion polymerization might be a way to overcome these. This contribution describes such an attempt using polystyrene encapsulated particles blended into a polydimethylsiloxane matrix.

A-7: P27 **Four Growth Modes of Nano/Micro-sized Ge2Sb2Te5 Crystal by the Electrical Pulse Induced Evaporation Method**

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Phase change materials such as chalcogenide are of importance in optical and electrical memory device, especially a future universal memory that combines the best attributes of various memories. For the realization of a successful universal memory, both physical understandings and technologies on scaling down to nanometer cell sizes in the device should be overcome. The bottom-up approach of assembling nanostructure is a promising solution for scaling down the size of devices. Nanostructures can be a powerful approach to assemble memory devices at small length scales owing to their sub-lithographic size and unique geometry. On Si substrate, four growth modes; fractal-like, rod, dot, and tube structure of nano/micro-sized GST crystal structure were observed by SEM and non-contact atomic force microscope (AFM). We verified from the energy dispersive (EDX) analysis that the observed GST structures had same composition with that of Ge2Sb2Te5 film by the sputtering method. We proposed that the rod and the dot growth is related to 2D clusters of Ge, Sb, and Te element, which are formed after evaporating the heated Ge2Sb2Te5 film by applying an electric pulse to it. We also showed that the fractal-like growth was developed from the reactive rough surface or surface defects of the rod.

A-7: P28 **Synthesis and Characterization of Nanoparticles Strengthened LIGA Ni**

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Recently, there has been a rapidly growing demand on MEMS devices that can work in harsh environments like high temperatures and high pressures, where the conventional LIGA fabricated nickel (Ni) as a commonly used MEMS material cannot satisfy these challenging requirements. Therefore, Ni based nanocomposites have attracted many attentions due to their tailored properties and the wide availability of different nanoparticles. In this study, micro components of Ni based nanocomposite were obtained by electrochemical co-deposition of Ni and Al2O3 nanoparticles into microfabricated photoresist moulds from nickel sulfamate solution with the presence of multi-wall carbon nanotubes (MWCNTs). The examination of dispersing behaviour of Al2O3 nanoparticles in the nickel sulfamate solution with MWCNTs showed that their surfaces are positively charged, which favours the co-deposition of Al2O3 nanoparticles with Ni. SEM and EDX characterization showed that the Al2O3 nanoparticles in the Ni base are uniformly distributed and their contents are improved with the presence of MWCNTs in the solution. It was also found that the mechanical properties of Ni are strengthened by incorporating Al2O3 nanoparticles into the Ni matrix.

A-7: P29 **Low Temperature Growth of ZnO Nanorods by Chemical Bath Method**

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ZnO nanorods grown by chemical bath deposition (CBD) methods are of great interest in photonic and electronic device applications because they offer low cost, low temperature techniques compared to conventional vapor deposition and sputtering methods. Our recent studies of ZnO nanorods grown by CBD on indium tin oxide (ITO) coated glass substrates employed heating of an equimolar solution of Zinc (II) nitrate and hexamethylenetramine solution at 95 C. Morphology of ZnO nanorods exhibited both open and closed hexagonal shape under various deposition conditions at or above 95 C. In this study we report the results of ZnO nanorods grown on ITO coated glass at 85 C using molar compositions of Zinc (II) nitrate and hexamethylenetramine at 1: 2 and 1: 3. Scanning Electron Microscopy (SEM) images of 1: 2 ratio composition of Zinc (II) nitrate and hexamethylenetramine deposited at 85 C for 5 and 7 hours reveal structures of nanorods with multiple outer layers and open structure. At 1:3 molar ratio,the ZnO nanorod structures exhibit progressively more open structures compared to ZnO nanorods made from 2:1 molar compositions under CBD for the same duration (5 and 7 hours). We will present quantitative data on changes in ZnO nanorod diameter, orientation, length and morphology.

A-7: P31 **Characterization of Solvated Modified Natural Rubber Based Polymer Electrolytes for Lithium-ion Batteries**
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A series of modified natural rubber using poly(methyl methacrylate) grafted natural rubber based polymer (MG-49) electrolyte films were prepared using the solvent cast technique and characterized for ionic conductivity, thermal properties, infrared spectroscopy, and electrochemical window stability. All operation for samples preparation was conducted in the inert environment of glove box. The ionic conductivity calculated from bulk resistance of AC impedance data was at the level of 10^{-4} S cm^{-1} at room temperature. Thermal behavior showed an amorphous phase with a single glass transition temperature. Infrared spectroscopy data indicate that the lithium ion is predominantly interacts with oxygen atom of the carbonyls of methyl methacrylate monomer unit attached to natural rubber backbone. The potential stability of polymer electrolyte against electrochemical oxidation was obtained at 5.1 V measured by linear sweep voltammetry.

A-7: P33 **Characteristics of TiO2/SnO2 Thick Film Gas Sensor Added by Metals (Pd, Pt, In, Ru and Rh) for Trimethylamine Gas**
JI-YOUNG JUNG, JAE-MOK JUN, CHANG-SEOP LEE, Keimyung University, Daegu, Korea

This study investigated the use of TiO2, Pd, Pt, In, Ru, and Rh that greatly improves the sensitivity to trimethylamine gas. SnO2 nano-sized powder was prepared by the chemical precipitation method. Physical properties and specific surface area were investigated by SEM, XRD and BET analyses. The Metal-SnO2 thick films were fabricated by screen-printing method onto Al2O3 substrates with platinum electrodes. The sensing characteristics were investigated by measuring the electrical resistance of each sensor in a test box as a function of gas concentration. This was then used to detect trimethylamine, dimethylamine and ammonia vapors within the concentration range of 100-1000 ppm. The gas sensing properties of metal-SnO2 mixed thick films depended on the content and variety of metal. It was found that sensitivity and selectivity of the sensing materials with 1wt.% Pd and 10wt.% TiO2 to TMA gas at the optimum operating temperature of 250 °C showed the best result.

A-7: P35 **Inorganic Mesoporous Membrane for PEMFC**
T. KUANCHAITRAKUL, H. MANUSPIYA, Chulalongkorn University, Bangkok, Thailand

Inorganic Mesoporous Membrane is a new alternative to improve high-temperature fuel cell performance in Proton Exchange Membrane Fuel cell (PEMFC) to substitute Nafion. Nafion which is the membrane commonly used in PEMFC has some limitations, especially the cost and the loss of proton conductivity at temperature above 80 °C, resulting in the decrease of cell performance. Therefore, total inorganic mesoporous membranes are developed to replace Nafion because they possess high porosity and specific surface areas, resulting in high proton conductivity. In this study, antimony-modified titania and antimony/niobium-modified titania ceramic membranes have been prepared via sol-gel technique. The various contents of antimony, 0 to 5 wt%, and niobium are incorporated into titania in order to improve the porous surface condition of ceramic membranes. The sols were casted into membranes at room temperature and the dry xerogels heated about 400-600 °C to achieve the ceramic membranes. The physical and electrical properties of these membranes were investigated. Moreover, ceramic membranes were also tested to evaluate the potential use as electrolyte in PEMFC at high temperature by using impedance spectroscopy, gas permeability and fuel cell test station.

A-7: P36 **Multifunctional Complex Materials with Nanometric Structure and Controlled Characteristics for Special Destination**
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The aims of the paper consists in the development of complex multifunction materials with nanometric structure for special use (civil - heavy duty electrical contacts, and/or military - hard core of small and medium calibre ammunition) with the aid of integrated and flexible technologies for industrial applications. The paper presents briefly some aspects regarding the present stage in production of homogenous mixtures of W-Ni-Cu powders system for manufacturing the materials made of heavy alloys type. Experimental results are presented in producing homogenous mixtures of W-Ni-Cu powders system by mechanical alloying. Elemental powder mixtures of 95 W-3.5%Ni-1.5%Cu were mechanically alloyed with a low-speed rotating drum attritor, without protective atmosphere or lubricant. The milling time was 100 hours. Powder samples were taken every 20 hours during the 100 hour milling time for qualitative and quantitative evaluation by X-ray diffraction. The influence of the technological parameters on structural, physical and mechanical characteristics of the materials thus obtained are also presented.

A-7: P38 **A New Synthesis Route to Prepare Polyaniline (PANI) Nanotubes Containing Magnetic Nanoparticles**
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Polymer-inorganic composites with an organized structure provide a new functional hybrid between organic and inorganic materials, among these, the preparation of PANI with ferromagnetic properties and nanostructures of PANI have been studied. We report a straightforward synthetic route to obtain polyaniline nanotubes containing magnetite. The nanoparticles of Fe3O4 were obtained adding a solution of NaOH to a FeSO4 suspension this mixture was left under ultrasound after that a precipitate Fe3O4 nanoparticles were obtained.The particle average size calculated from the broading of the XRD peaks using the Debey-Scherrer equation was 25-30nm.To these nanoparticles, an aniline solution was added, and was left to interage with UV radiation for 2h with stirring at room temperature, as the polymerization starts the suspension turned into a dark green and magnetic composite.The images of SEM indicate that the composite possesses similar morphology the one of nanotubes, with average diameters of 100nm could still be observed that in the surface of these nanotubes a great amount of agglomerates exists due to magnetic characteristic of the particles of present Fe3O4 in the middle.Nevertheless, we obtained a new and simple method to synthesize PANI nanotubes containing magnetic nanoparticles.

A-7: P39 **Investigation of Metal Effect on Gas-sensing Properties of Nanostructured Films Based on Novel Polyphthalocyanines**
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Novel synthesized polyphthalocyanines (PPc), containing Zn, Cu, Mn, Fe were investigated. The conductivity of the films, their resistance-temperature relationship, sensor properties relative to gases as well as effect of the metal content and the conditions of film formation on their characteristics were taken into account for developing PPc based sensors. The substances were synthesized by polycyclotetramerization of tetranitrile of pyromellitic acid in bulk and in polar solvents at 180-300 °C for 5-30 hours in the presence of 0-5 mol% carbamide. The nanostructured films of PPc were deposited on interdigitated test structures. 10-100 nm thick films were deposited by two methods: vacuum thermal evaporation and the Langmuir - Blodgett method. To stabilize properties the film was annealed in air at 100-250 °C. The investigations were carried out under sensor thermal stabilization conditions in the range 50 - 250 °C at the same humidity. Sensitivity of the films to different gases, such as NH3, NOx, H2S, O2 was investigated. It was found, that PPc of Cu has high sensitivity to NO2 micro concentrations (level 10ppb) and H2S (level 10ppb). The sensitivity increases with growth of Cu content in the substance. Comprehensive studies of polyphthalocyanine films proved their active behavior in the presence of many gases in air; in this situation the metal content and film deposition conditions play an important role in sensing properties.

A-7: P40 **Nanostructured Films Based on Polyoxometalates for Chemical Gas Sensors**
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The construction, fabrication technology and metrological characteristics of chemical gas sensors based on nanostructured nonorganic oxide films activated by different admixtures have been studied. The method of hydrolythic polycondensation from tetraetoxysilane solutions was used for forming such films. Polyoxometalates are attractive in view of their particular properties. Heteropolyanions and especially their metal-substituted derivatives have high stability of most of their redox states, and possibility of multiple electron transfer. The introduction of various polyoxometalates into SiOx films results in selective and high sensitive sensors for NH3, N2H2. The films were deposited on structures with metal interdigital electrodes. Sensors were manufactured on microelectronic planar technology. The thickness of the SiOx layers

was 0,2-0,3 µm. It was established that films have highly developed surface with nanoscale pores. Characteristics sensors based on the nanostructured SiOx films, containing polyoxometalates Dawson type as activating admixture were investigated. The sensitivity threshold of sensors based on SiOx/ Ce2P2Mo18O62 to NH3 is 0,1-0,5 ppm, the range of measurement concentration - 0,1-100 ppm, response time - 15-30 s. The sensitivity threshold of sensors based on SiOx/ Co3P2W6Mo12O62 to N2H2 is 0,5-1,0 ppm, the range of measurement concentration - 0,5-100 ppm, response time - 15-30 s.

A-7: P41 **First Molecular Conductors with Cobalt Bis(dicarbollide) Anion and its Derivatives**

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Just a few conducting radical cation salts containing metallacarborane anions have been described so far[1, 2]. No radical cation salt derived from the cobalt bis(dicarbollide) anion [3,3'-Co(1,2-C2B9H11)2]- or its halogen derivatives was reported. First molecular conductors with cobalt bis(dicarbollide) anion and its iodine and bromine derivatives were synthesized and investigated[3, 4]: (TMTSF)2[3,3'-Co(1,2-C2B9H11)2] (1), (TTF)[3,3'-Co(1,2-C2B9H11)2] (2), (ET)[3,3'-Co(1,2-C2B9H11)2] (3), (ET)2[3,3'-Co(1,2-C2B9H11)2] (4), (ET)2[8-I-3,3'-Co(1,2-C2B9H10)(1',2'-C2B9H11)] (5), (BMDT)[3,3'-Co(1,2-C2B9H11)2] (6), (ET)2[3,3'-Co(8-Br-1,2-C2B9H10)2] (1), (BMDT)4[3,3'-Co(8-Br-1,2-C2B9H10)2] (4), and ET[3,3'-Co(8-BrC2B9H10)2] (2). Salt (1) is a semiconductor with activation energy Ea = 0.03 eV, conductivity S(293) = 15 Ohm-1cm-1, that is the maximum value of conductivity for all metallacarborane radical cation salts studied before[1,2].

[1]*J.M. Forward et al, J. Organomet. Chem., 1994, 467, 207;* [2]*Y.K. Yan et al, Chem. Comm., 1995, 997;* [3]*O.N. Kazheva et al, J. Organomet. Chem., 2006, 691, 4225;* [4]*O.N. Kazheva et al, J. Organomet. Chem., 2007, in press*

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A-7: P42 **Modulation of the Metallic Oxide Properties Through Techniques of Soft Chemistry for Several Applications**

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Metallic oxides are widely used in the industry; these are object of intensive research due to the versatility of their applications and to the possibility of modulating their properties by appropriate processing. In this paper, the technique of soft chemistry is shown as an option to obtain metallic oxide films for use into optoelectronic devices. This work emphasizes the importance of applying simple techniques of deposit to the industrial scale with very good results at lower cost.

A-8: P44 **The Mechanical Behaviour of Silicon Diaphragm for Micromachined Capacitive Pressure Sensor**

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Single crystal silicon diaphragms are widely used as pressure sensitive elements in micromachined pressure sensors. When designing such a sensor it is usual to assume that the silicon is an isotropic material, with its properties defined by the orientation of the silicon wafer. However, the mechanical properties of single crystal silicon are orthotropic, and this has an important effect on the behaviour of silicon diaphragms. In this work, analytical solutions for the small deflection of orthotropic silicon circular diaphragms orientated against the (100) and (110) planes are presented. The assumption that the diaphragm is isotropic leads to an over-estimation of the deflection with the applied pressure. The effect of this discrepancy on the accuracy of a capacitance based pressure sensor has also been considered. All cases have been validated using FEA and the results are in good agreement. Therefore, it can be concluded that when a silicon diaphragm is used in a MEMS sensor, the orthotropic properties should be taken into account for accuracy.

A-8: P45 **GaAs Resonant and Non Resonant Micro-sensors: Design and Simulations**

C.R. TELLIER, Femto-st Institute, Besançon, France; S. DURAND, LAUM, Le Mans, France

The GaAs crystal has advantages for sensor applications due to piezoresistance effects of P-GaAs, to piezoelectric properties of insulating GaAs and to possible wet micromachining of GaAs crystal. Recently few GaAs sensors were developed on (100) and (110) wafers. This work focuses on design and simulation of resonant and non resonant GaAs sensors integrated on wafers with new (hk0) and (hhl) orientations. Emphasis is placed on specific mechanical structures (membranes, cantilevers and beams). Study concentrates firstly on the piezoresistive detection of active normal or shear stresses. Depending on the nature of stresses two types of detector configuration are retained to sense stresses: full bridge configuration with gauges (normal stresses) or four-terminal element (shear stress). A simulator PIEZOSIM is achieved to determine GaAs orientations that give the best sensitivities. Then the self elaborated simulator TENSOSIM is used to derive final 3D shapes of micromachined structures. New designs of masks are defined to optimize structures shapes. FEM simulations furnish stress mappings and evaluations of the influence of structure shape on the frequency of resonant sensors. This combination of three simulations successfully opens up new (hk0) and (hhl) GaAs sensors applications.

A-8: P46 **Thin Film YBCO Pixels for MMW Detector**

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This research addresses the fabrication of crack-free 40nm thin film YBa2Cu3O7 (YBCO) pixel structures based on high temperature superconductor (HTSC) microbolometers for highly sensitive thermal detectors that can be miniaturized for affordable passive millimeter-wave (MMW) imaging. A completely dry etch process is described for suspended transition edge bolometers by removing (releasing) the silicon substrate underneath a 3 micrometer wide pixel using either gaseous xenon difluoride (XeF2) or plasma sulfurhexafluoride (SF6) chemical reaction. This is an improvement over conventional selective wet chemical etching techniques that are both harsh on the YBCO and require additional complex alignment steps to the substrate material leading to very poor device yields and performance. Issues relating to material roughness, etch redeposition, and silicon undercutting will be analyzed and methodologies to overcome/minimize such problems will be explained in detail.

A-8: P47 **Micromask Generation for Polymer Morphology Control: Nanohair Fabrication for Synthetic Dry Adhesives**

D. SAMEOTO, C. MENON, YASONG LI, Simon Fraser University, Burnaby, BC, Canada

Since early this decade, investigations into how geckos achieve their remarkable adhesive properties, have determined that multi-scale compliant systems can allow geckos to attach to nearly any surface through Van der Waals forces. Microscopic hairs on the bottom of gecko feet can make intimate contact over large areas, and allows relatively weak Van der Waals forces to produce significant adhesion on the macroscale. Over the past five years, microfabrication technology has been used to replicate these multi-scale compliant mechanisms, using silicon or polymers to reproduce microscale rods or cantilevers to produce what is known as a dry adhesive. What is more difficult is creating the nanoscale compliant systems that create most contact areas in gecko feet. This work examines how a well known problem in reactive ion etching processes, RIE “grass” can be used to great effect to alter surface morphology on the nanoscale for nearly any polymer. Identical etching parameters in the presence of different elements, like gold or aluminum, can result in radically different surface morphologies and material behaviors, potentially allowing both adhesive and non-adhesive areas to be formed in a single material. This technique is potentially the easiest and fastest way to produce nano-compliant systems for use with dry adhesives.

A-8: P49 **Wet Etching of Si and GaAs Micro-arrays: Experimental and Theoretical Shapes**

T. LEBLOIS, Institute FEMTO-ST, Besançon cedex, France

Si and GaAs are very suitable materials to fabricate mechanical devices by wet micromachining. Emphasis is placed on the micromachining of micro-arrays constituted by very small mesa and holes. A lot of applications occur in biological field such as cellular separators, lab on chip for molecules of micrometric size. The micromachining of various Si and GaAs substrates is performed in KOH and H2SO4:8H2O2:H2O etchants respectively at room temperature. The mask is composed of several arrays with circular, square and ellipsoidal micrometric patterns. Square patterns aligned along two directions are used to investigate

how concave and convexe undercuts are affected by direction. Different etched shapes which are examined using SEM are obtained according to the crystal and the wafers orientation. Small holes must be limited by facets associated with the most pronounced maxima in the dissolution slowness. On the contrary, mesa are associated with pronounced minima. The self elaborated simulator TENSOSIM based on a kinetic and tensorial model of the anisotropic etching is used to predict shapes of microstructures. The database composed of dissolution constants determined from experiments was adjusted by an iterative procedure. A comparison between experiments and simulation is presented.

Special Session A-9
Recent Development in Electrical Writable Organic Memory Devices

A-9: P52 **Fabrication and Characterisation of MIS Organic Memory Devices**
M.F. MABROOK, D. KOLB, C. PEARSON, D.A. ZEZE, M.C. PETTY, University of Durham, Durham, UK

There is a current upsurge in research on devices with nanoparticles embedded in dielectrics. Such structures can operate as memories with high speed, high density, low voltage and low cost. Here, we report on hybrid gold nanoparticle-based metal-insulator-semiconductor (MIS) memory devices combining silicon technology and organic thin film deposition. The nanoparticles are deposited using a self-assembly technique at room temperature onto a 4.5 nm thermal silicon oxide layer. A 40 nm thin film of pentacene (deposited by flash thermal evaporation), polymethylmethacrylate (spin coated) and cadmium arachidate (deposited using the Langmuir-Blodgett technique) are used as insulators. Distinct capacitance-voltage (C-V) hysteresis is observed with a memory window that increases linearly with increasing voltage programming range. Clockwise and anticlockwise hysteresis in devices based on p-type and n-type silicon, respectively are observed, indicating that charges are injected from the top electrode to the nanoparticles rather than tunnelling through the thin SiO2 layer. However, thermal growth of SiO2 at a temperature below 800 °C resulted in a hysteresis in the opposite direction. The detailed electrical behaviour of the MIS devices will be discussed.

A-9: P53 **Gold Nanoparticle Based Electrically Rewritable Polymer Memory Devices**
D.C. PRIME, S. PAUL, De Montfort University, Leicester, UK

In recent years there has been a growing interest in the field of organic electronics as low cost, easily processible alternatives to silicon and other inorganic semiconductors. So far there have been successful implementations of devices such as organic field effect transistors (OFETs), organic solar cells and organic light emitting diodes (OLEDs). In the field of non-volatile polymer memory devices (PMDs) there has been considerably less research conducted[1]. Among the most promising PMDs to date are devices consisting of an admixture of organic polymer, nanoparticles, and small organic molecules deposited between top and bottom metal electrodes to form a crossbar structure[2, 3]. PMDs based on active layers containing gold nanoparticles with 8-hydroxyquinoline (8HQ) will be presented, showing the devices' electrical characteristics and memory performance attributes.

[1]J.C. Scott, "Is There an Immortal Memory?" Science, 304, 62-63, (2004); [2]S. Paul, A. Kanwal, M. Chhowalla. "Memory Effect in Thin Films of Insulating Polymer and C60 Nanocomposites" Nanotechnology, 17, 145-151, (2006); [3]D. Prime and S. Paul, "Making Plastic Remember: Electrically Rewritable Polymer Memory Devices" in Mater. Res. Soc. Symp. Proc., 0997-I03-01, (2007)

A-9: P54 **Electrically Re-writable Non-volatile Memory Device - Using a Blend of Sea Salt and Polymer**
I. SALAORU, S. PAUL, De Montfort University, Leicester, UK

Intensive research is currently underway to exploit the highly interesting properties of nano-sized particles and organic molecules for optical, electronic and other applications. Recently, it has been shown that nano-sized particles and small molecules can be used in polymer matrices to realize memory devices[1-4]. Such memory devices are simple to fabricate via the spin on technique. This work presents an attempt to use sea salt, embedded in polyvinyl acetate in the making of the memory devices. A polymer blend of polyvinyl acetate and sodium chloride (NaCl) was prepared in methanol and spin coated onto a glass substrate marked with thin Al tracks and a top contact was evaporated on to the blend after drying - this resulted in a metal-organic-metal (MOM) structure. The current-voltage characteristic and the write-read-erase cycles of the MOM structures were measured in a screened sample chamber in the dark and at room temperatures using a PC-driven pico-ammeter (HP4140B). The I-V behaviour of MOM devices shows that the devices can be switched from a low conductivity state to a high conductivity state - this property can be exploited to store data bits. The possible charging mechanism, based on the electric dipole formation, is also presented in this work.

A-9: P55 **Effect of Varying Memory Device Architectures on the Electrical Properties of P(VDF/TrFE) (72/28) Copolymer Thin Film**
CHANG WOO CHOI, Korea High Tech Textile Research Institute (KOTERI), Gyeonggi-do, South Korea; A. ANAND PRABU, SUN YOON, KAP JIN KIM, Kyung Hee University, Gyeonggi-do, South Korea

PVDF and its copolymers were widely reported for their possible applications in electrically re-writable organic memory devices. In this work, we report the electrical characteristics of P(VDF/TrFE)(72/28) copolymer thin films as a function of varying device structures (MFM, MFIS, OFET) for use in non-volatile RAM devices with special emphasis on enhanced electrical stability and faster R/W/E capability. For MFM architecture, scanning probe microscopy (SPM) based technique was effectively used to confirm the changes in dipole moments along the applied field direction and the resultant change in amplitude or phase image for '1 or 0' state. C-V curve for MFIS type with SiO2 on p-type Si wafer when applied with cyclic bias voltage showed shifting to the negative side, whereas PVP layer used instead of SiO2 prevented this shifting phenomenon towards negative value so that the data written can be distinguished even at 0V state. OFET architecture using pentacene as an active material was also evaluated by reading the ratio of current (Ion/Ioff) between S/D electrodes. The results are reported in detail here.

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Focused Session A-10
State-of-the-art Research and Application of SMAs Technologies

A-10.1: P57 **Magnetic Properties and Microstructures of Rapidly Solidified FePd Alloy Ribbons**
YOICHI KISHI, ZENJIRO YAJIMA, Kanazawa Institute of Technology, Japan; TEIKO OKAZAKI, YASUBUMI FURUYA, Hirosaki University, Japan; M. WUTTIG, University of Maryland, USA

It is well known that FePd alloys are effective as a magneto-thermoelastic actuator material, because they have large magnetostriction and shape memory effect. In order to use the alloys for a micro-actuator, magnetic properties and microstructures have been examined as for rapidly solidified Fe-29.6 at% Pd alloy ribbons. The ribbons exhibit a large magnetostriction of 0.001 (0.1%) at room temperature and good shape memory effect. The value of the ribbons is 10 times as large as that of a polycrystalline bulk. Columnar grains, whose width is about 10 micro-m, are observed in the cross sectional SEM images. Relief effects corresponding to the formation of martensite variants are observed on the grains. X-ray diffraction profile at room temperature shows that FCT martensitic phase and FCC austenitic phase coexist in the ribbon. Dense striations are observed in the TEM bright field images of FCT martensite plates. Selected area electron diffraction patterns and TEM dark field images revealed the striations to be thin twins.

A-10.1: P59 **Influence of Substrate Temperature on Texture for TiNi Sputtered Films**

NORIAKI IKENAGA, YOICHI KISHI, ZENJIROYAJIMA, NORIYUKI SAKUDO, Kanazawa Institute of Technology, Hakusan, Ishikawa, Japan

It is especially important to evaluate the anisotropy of transformation strain in shape memory alloy films, which are caused by texture. Because such films can be used for fabricating two-dimensional microactuators in MEMS. In this paper, microstructures of TiNi sputtered films are examined. The films of 1 micro-m thickness are sputtered on Si(001) substrates by an RF and DC magnetron multi-sputtering system with four separate confocal sources and a substrate heating system. A pure Ti and Ni targets of 50 mm in diameter are used. The films routinely sputtered at ambient temperature are amorphous. However, several conditions determined by combining sputtering parameters such as source voltage and distance between confocal region and substrate, sometimes result in producing crystalline films. The films which are sputtered at 773K are crystallized during sputtering. X-ray powder diffraction and pole figure measurements reveal that these films are oriented with {110}B2 parallel or incline of 45 degree to the substrate.

A-10.2: P60 **Shape Recovery and ε Martensite to Austenite Transformation in a Fe29Mn7Si5Cr Shape Memory Alloy**

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The shape memory behavior of a laboratory processed Fe29Mn7Si5Cr alloy has been investigated in this work. The martensitic transformation and the corresponding changes in the microstructure have been characterized by means of light optical microscopy and X-ray diffraction methods. Transformation temperatures were determined by a set of dilatometry tests on undeformed and deformed samples. The shape recovery was quantified by means of dilatometry experiments on compressed samples where a secondary shape recovery stage was observed. High-temperature X-ray diffraction measurements were carried out in an attempt to characterize the secondary shape recovery effect in a highly strained alloy. Several possibilities to explain the secondary recovery effect were discussed in the light of the previous investigations and the current experimental data.

A-10.2: P62 **The Influence of Thermomechanical Treatment on Transformation Temperatures of Cu-Al-Ni Shape Memory Alloys**

A.A.M. TADEU, C.R.V. ANA, J.G.L. SEVERINO, M.G. RODINEI, Federal University of Paraíba, Joao Pessoa, Paraíba, Brazil

The applications of shape memory alloys are dependent of their transformation temperatures and hysteresis value. In this work the effects of the homogenization treatment and hot rolling on the transformation temperatures of Cu-Al-Ni alloys were studied based on differential scanning calorimetry analyses. It was observed that for as-cast condition the Ms and As temperatures increase slightly with heating and cooling cycles. However, for as-hot rolled alloys the characteristics transformations temperatures increase as much as 20K. It was concluded that the stabilization process appears to be mainly due to the short order atomic rearrangements in the martensitic state.

A-10.2: P63 **Pseudoelasticity of Cu-13.8Al-Ni Alloys Containing V and Nb**

M.G. RODINEI, C.R.V. ANA, J.G.L. SEVERINO, A.A.M. TADEU, Federal University of Paraíba, Joao Pessoa, Paraíba, Brazil

Polycrystalline copper-based shape memory alloys are of particular interest because of their low cost and good shape memory effect. However, the absence of a pronounced pseudoelasticity effect restricts the number of potential applications. In this work, the influence of Nb and V on the microstructure and the mechanical properties was investigated. CuAlNi alloys containing small amount of V and Nb were prepared by induction furnace under inert atmosphere. The samples were solution treated at 850 °C and quenched into cold water. The tensile tests were performed at temperatures slightly inferior to Ms and superior to Af, to investigate the pseudoelasticity. The addition of Nb and V promotes the formation of precipitates which act as grain size refiner and improve the mechanical properties. After inducing strains of 2%, 4% and 6% at temperatures higher than Af and unloading the total recoverable strain was measured to be of the order of 3%.

A-10.2: P64 **Multi-stage Martensitic Transformations in Ti - 50.0 at.% Ni Alloy Induced by Thermal Cycles**

S. BELYAEV, N. RESNINA, Saint-Petersburg State University, Saint-Petersburg, Russia

Usually a multi-stage martensitic transformation is observed in Ni-rich TiNi alloys after the heat treatment at 350 °C ÷ 500 °C. It is due to the internal stresses created by precipitated Ni4Ti3 particles. In the present work it was found the multi-stage martensitic transformation to appear in Ti - 50.0 at % Ni alloy after the thermal cycles through the temperature range of the phase transitions. An annealed sample undergoing one-stage phase transition was subjected to thermal cycles in DSC apparatus. The results showed that three-stage forward martensitic transformation observed after the 13 thermal cycle were due to the B2 → R, B2 → B19' and R → B19' phase transitions. It is evident that the multi-stage martensitic transformation is due to the generation of the defect structure during the phase hardening (structure fatigue). It was found that the B19' phase obtained from the B2 phase underwent the reverse transformation at the higher temperatures than the B19' phase obtained from R phase. After the annealing of the cycled sample at 350 °C the transformation behavior was the same as in non-thermal cycled sample.

A-10.2: P65 **Dynamic and Static Displacements of Atoms in B2-phase of TiNi Alloy**

V.M. GUNDYREV, V.I. ZEL'DOVICH, Institute of Metal Physics, Ural Division of Russian Academy of Sciences, Ekaterinburg, Russia

In Ref. 1 the root-mean-square displacements of Ni and Ti atoms in B2-phase in a single crystal of TiNi were found. It was shown, that the mean squares of displacements of Ni is more twice, than Ti. The purpose of this work is the separation of complete displacements of atoms into static and dynamic ones. The dynamic displacements squares depend linearly on absolute temperature in the researched interval of temperature. The factors of the linear dependence depend on Debye temperature. The first factor is found on the base of the already known complete displacements at two values of temperature[1]. The second factor is found by using the factors decomposition on Debye temperature as polynomes of the sixth degree. After calculation of dynamic displacements squares, the static displacements squares could be found as difference between the complete displacements and the dynamic ones. It was established, that the mean squares of dynamic displacements of Ni and Ti atoms are almost identical, but the mean squares of static displacements strongly differ. They are 4.7 times more for Ni, than Ti. Thus, the large value of complete atomic displacements in TiNi is caused by static displacements of Ni atoms.

[1]*V.M. Gundyrev, V.I. Zel'dovich. Mater. Sci. Eng. (2007) in press.*

A-10.3: P67 **On Functional Behavior of Strain-aged TiNi Alloy**

E.P. RYKLINA, S.D. PROKOSHKIN, A.A. CHERNAVINA, N.N. PEREVOSHCHIKOVA, Moscow Institute of Steel and Alloys, Moscow, Russia

The functional properties of shape memory alloys (critical temperatures, recovery strain, shape recovery rate, two-way shape memory effect - TWSME - magnitude, residual strain etc.) are determined by an alloy structure which is effectively regulated by thermomechanical treatment. At the same time, external training parameters strongly affect the final result as well. The main of them are as follows: strain and loading modes, loading temperature regime (phase state), load value, loading time, number of training cycles. Actual technical and medical SME articles are functioning on bending mode in most cases. Nevertheless, the influence of external training parameters under bending on properties was not systematically studied. The present work relates to study the combined influence of structure realized under various Low-Temperature Thermomechanical Treatment (LTMT) regimes, including isothermal annealing (strain aging), and external training parameters of bending on functional properties of Ti-50.7at.%Ni alloy. Variation of training parameters enables additional regulation of final functional properties. The obtained results can be used for development elements functioning in conditions of TWSME realization.

A-10.5: P71 **Fatigue Behavior of Ti-Ni Superelastic Component for Lumbago Prevent Apron**

KAZUHIRO KITAMURA, Nagano College of Technology, Nagano, Japan

The purpose of this study is to investigate fatigue characteristics of superelastic components for lumbago prevent apron. The component was made from five Ti-Ni superelastic wires of 1.8 mm in diameter and

400mm in length. The specimen was made by Daido Steel, Co., Ltd. The apron prevented lumbago by generating the power by superelastic components. Each three superelastic components were arranged right and left side of the apron. The transformation temperatures were measured by differential scanning calorimetry (DSC). From DSC measurement, this alloy showed the superelastic behavior at room temperature. The bending fatigue characteristics of superelastic components were investigated by fatigue tester. The maximum strain ration of bending fatigue test was about 1%. Fatigue lives of the superelastic components were about 10,000 times.

A-10.5: P72 **Generation and Advantages of Initial Tension in SMA Coil Spring**

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"Initial tension" is the force for tension springs to contract further in closed state. In case of tension springs of common metal, the initial tension can be provided by minus pitch winding. However, the initial tension cannot be given to SMA coils in the conventional method, since heat treatment for shape setting eliminates the tension generated by the minus pitch winding. The authors have invented a new way of supplying the initial tension to SMA coils by changing coil orientation after the shape setting treatment. The SMA coil with initial tension has some advantages over the conventional SMA coil springs. We introduce the merits of initial tension in SMA coil springs when their shape memory effect or superelasticity is applied.

Focused Session A-11

Smart Textiles

A-11.1: P73 **PVDF Nanoweb Touch Sensors Prepared Using the Electro-spinning Process for Smart Apparels Applications**

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Since PVDF film exhibits piezo- and pyroelectricity, it has been investigated for actuators, pressure and tactile sensors, and infrared sensors by many researchers. However, this film cannot be directly used as pressure sensors in textile fabrics due to very low beta-crystallinity without drawing process and very low degree of dipole orientation without subsequent poling. In this study, we focused our attentions on the electrospinning of PVDF/metal halide/DMAc/acetone solution in order to obtain PVDF nanowebs with high beta-crystallinity without further drawing and simultaneously relatively high degree of dipole orientation without poling. FT-IR analysis was made to evaluate the beta-crystallinity of the PVDF nanowebs and their piezoelectricity was estimated with the nanowebs adhered to a piezoelectric bimorph actuator using an oscilloscope interfaced with a voltage amplifier. Overall, the electrospun PVDF nanowebs exhibited good flexibility and vapor permeability, improved beta-crystallinity, and good tactile sensibility for smart apparel applications. The results are reported in detail here.

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A-11.1: P74 **A Novel Method to Produce Durable Water Repellent Cotton**

S. TRAGOONWICHIAN, N. YANUMET, Chulalongkorn University, Bangkok, Thailand; E.A. O'REAR, University of Oklahoma, Oklahoma, USA

Silane-coupling agents have been widely employed for surface modification. In this work, vinyltriethoxysilane (VTES), which is relatively inexpensive, was used to produce the water repellent cotton fabric. Ethoxy groups in VTES were firstly hydrolyzed to silanol groups which then formed hydrogen bonds with hydroxyl groups at cotton surface, after that the condensation reaction occurred. VTES reacted at one end with cotton and exposed the vinyl groups to the surface. Thus, the cotton surface became hydrophobic. The treated fabric was characterized by scanning electron microscopy (SEM) and Fourier transform infrared attenuated reflection spectroscopy (FTIR-ATR). The effect of VTES concentration on surface morphology and water contact angle were studied. The water contact angle values of the treated fabrics were more than 130 degree. The washing durability of the coating was also investigated.

A-11.1: P75 **Production of Flame Retardant Cotton Fabric by Thin Film Coating**

A. SIRIVIRIYANUN[1], E.A. O'REAR[2], N. YANUMET[1], [1]Chulalongkorn University, Bangkok, Thailand; [2]University of Oklahoma, Norman, Oklahoma, USA

Thin-film coating on cotton by the admicellar polymerization process was investigated. In this work, two types of quaternary ammonium cationic surfactants: dodecyltrimethylammonium bromide (DTAB), and hexadecyltrimethylammonium bromide (HTAB) were used in the admicellar polymerization of the acrylate monomer containing phosphorus on cotton fabric. The polymer film formed was characterized by IR (ATR) spectroscopy. The results show that the phosphorus containing polymer was successfully formed on the cotton fabric. The thermal stability of the treated cotton was investigated by thermogravimetric analyses. The results from TGA showed that the amount of char residue of the treated cotton using longer-chain surfactant (HTAB) is higher than using shorter-chain surfactant (DTAB). The longer the length of the hydrocarbon chain, the higher the amount of the phosphorus containing monomer adsolubilized into the adsorbed surfactant, hence the higher amount of coated film, leading to a higher char yield.

A-11.2: P76 **Contributions Regarding Convergent Systems of Monitoring Mobile Personalized Information**

E. CARPUS, A. DOROGAN, R. SCARLAT, INCDTP, Bucharest, Romania; M. IGNAT, INCDIE-CA, Bucharest, Romania; G. ONOSE; UMF, Bucharest, Romania

Change is the only constant in dynamic world of today. A shift in the consumer's values intervened: instead of wishing for the finest natural materials, people look at beauty through engineering, the innovative design and the smart aspect of products. Thus, there is a critical need of integrating the basic technologies of electronics, sensors, computers and communications into textiles so that these could be developed into the infrastructure of smart, interactive information, in order to facilitate the mobile personalized information processing. One domain having an outstanding application potential for smart textiles is the medical one (clinical monitoring, scanning, prophylaxis, treatment). At present, the main tendencies include: parameters and sensors; transducers; specific technologies; the modelling of the smart apparel system; information conveying and processing; information rendering. The paper presents aspects referring to accomplishing a convergent system with textile elements, and has usage in monitoring certain biophysical signals.

Focused Session A-12

A joint Session with Symposium E

Artificial Muscle Actuators Using Electroactive Polymers

A-12.1: P77 **Elastomeric Conductor-insulator Composite as Improved Actuator Material**

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In the field of electroactive polymers (EAP), dielectric elastomer actuators (DEA) attract more and more attention due to their outstanding performance, particularly their large strains[1]. Unfortunately, DEA suffer from a high actuation voltage (kV range), which hinders their broad application. Especially the use as implantable prosthetic device demands an activation voltage below 30V. Decreasing the film thickness and

increasing the dielectric constant (k) of the insulating elastomer lowers the activation voltage for a given pressure[2, 3]. Blending of electrically conductive fillers into the elastomer matrix turns out to be a promising approach to enhance k of the resulting composites. We prepared composites from thermoset or thermoplastic silicone elastomers and filled them with polyaniline (PANI) and metal powder (e.g. Al, Ag), respectively. The influence of the fillers onto mechanical, dielectric and electromechanical properties of the composites will be discussed. First measurements of silicone/PANI blends show a thousandfold increase in k and an electromechanical strain of roughly 10%.

[1]Pelrine et al, Science, 287 (2000), 836ff; [2]Pelrine et al, Sens. & Act. A, 64 (1998), 77ff; [3]Zhang et al, Adv. Eng. Mat., 5 (2005), 361ff

A-12.1: P78 **A Co-axial Dielectric Elastomer Actuator**

G. KOFOD, H. STOYANOV, R. GERHARD, University of Potsdam, Potsdam, Germany

Dielectric elastomer actuators based on Maxwell-stress induced deformation, are considered for many potential applications where high actuation strain and high energy density are required. They usually rely on a planar actuator configuration, however, a string-like actuator would be less bulky, and more versatile for several applications. In this paper, a co-axial dielectric elastomer actuator that produces relatively high actuation strain (10%) is presented. The actuator is manufactured through alternating dip-coating steps with insulating and conductive thin layers. A soluble thermoplastic block-copolymer, SEBS(poly-(styrene-ethylene-butylene-styrene), is used for the dielectric layers as well as for the host material of the compliant electrodes. Electrical conductivity of the electrodes is achieved by incorporation of conductive carbon-black particles in the elastomer matrix. Actuators with a single and with multiple active layers (up to three) have been successfully demonstrated. This geometry is advantageous in that it is compact and can be bundled easily, and should therefore be practical in applications such as “artificial muscles”.

A-12.1: P79 **A Closer Look at the Polyacrylamide Microfibers for Natural-Like Artificial Muscle Fabrication**

M. BASSIL, M. EL TAHCHI, J. DAVENAS, Lebanese University, Lebanon, and Université Claude Bernard - Lyon I, Villeurbanne, France

Polyacrylamide gels suits better the artificial muscle fabrication despite their response time which stays low compared to natural human muscle. This main problem is due to their bulky form where the diffusion of ions takes a long time compared to the microsecond scale in human muscle. Thus a successful artificial muscle will need to replicate the small scales of the muscle fibers that can achieve fast response. First, we developed a three-dimensional (3D) polyacrylamide hydrogel structure with a swelling ratio of 1000, corresponding to a linear ratio of 10. Most recently, a fabrication technique for the fabrication of polyacrylamide gel fibers with micrometric diameter, 1D structure, aiming to converting isotropic swelling into a directional one, has been developed in our group. The response of these fibers to different physiological stimuli present in the human body, such as pH and ionic forces, are presented and compared to natural muscle fibers. This study shows that a system formed by microfibers of polyacrylamide gel working in parallel will enhance both: - The response time, provided that their surface area to volume ratios are high enough to reduce solvent diffusion times; - The tensile strength, by having a large number of small elements acting in parallel, hence approaching the physical and physiological properties of the human muscle. One further step is needed, which is the study of possible coupling between natural nervous system and our human-like artificial muscle.

SYMPOSIUM B
SMART OPTICS

B-1.1: P81 **Electrochromic Nickel Oxide-based Thin Films Deposited by Chemical Bath**

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Nickel oxide-based thin films were deposited on ITO-coated glass substrates by the chemical bath deposition method. The synthesis, based on the decomposition of urea in an aqueous nickel nitrate solution, promotes the deposition of nickel hydroxide in the turbostratic alpha (II) phase. Low and high urea concentrations were used. The electrochromic behavior of the films was tested after thermal annealing in air at temperatures of 250 and 300 °C for 30 min. Using cyclic voltammetry, chronoamperometry and in-situ single wavelength transmittance the cycle life, response time, and coulometric efficiency of the films were evaluated. For films annealed at 250 °C the bleached-colored cycling is between the nickel hydroxide and beta (III) NiOOH phases. By their side, films annealed at 300 °C are comprised by a nickel hydroxide-NiO (II) mixture and the colored phase are nickel oxide (III) and/or beta (III) NiOOH depending on urea concentration in solution. The gamma (III) NiOOH phase was clearly identified in over-colored films. Phase identification was performed by x-ray diffraction, Raman scattering and infrared reflectance. It is shown that the films can exhibit high optical contrast and good reversibility depending on the processing conditions and electrical potential applied.

B-1.1: P82 **WO3 Thin Films Active in the Infrared Region**

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Among electrochromic materials, WO3 remains by far the most studied. However, on the contrary to the visible region and despite a growing demand for active materials in the 2 to 15 µm domain, its properties in the IR region are still poorly addressed. WO3 thin films were grown using two different techniques, namely the Pulsed Laser Deposition and the Radio Frequence Sputtering. The variation of various growth conditions, including the temperature substrate and the chamber pressure, shows a strong correlation between the optical properties and the film structure, thickness, composition and morphology. Contrast in reflectance between the inserted HxWO3 and deinserted WO3 states as high as 73% in MW band was demonstrated for 350 nm WO3 films. The latter were RF sputtered on Au substrate at ambient temperature in 6 Pa of oxygen pressure. In this presentation, the relationship between the film optical response and its structure, morphology and composition will be discussed using techniques such as High Resolution Transmission Microscopy, Rutherford Back Scattering, X-ray Reflectometry, X-ray Photoelectron Spectroscopy. Finally, the potential of WO3 thin films for “IR Camouflage” applications will be demonstrated using IR cameras, following the evolution of the apparent temperature and of the deduced emissivity.

B-1.1: P83 **Acidochromic and Solvatochromic Fluorophores**

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As part of our interest in donor/acceptor-substituted pi-conjugated oligomers, we use pyridine-type hetarenes as electron-deficient rings in oligo(phenylenevinylene)s. A quadrupolar arrangement of electron donors and acceptors results in chromophores with a solvent-depending fluorescence, bathochromic shift and reduced efficiency correlate with increasing polarity. Due to the basic sites, the electronic spectra of these dyes are sensitive to hydrogen bridging. Protonation alters both, absorption and emission spectra. These interactions of the pi-systems with electric dipoles (solvatochromism) and protons (acidochromism) can differ greatly, in the ground state as well as in the excited state. The position of the basic centre relative to the conjugated system is controlling the impact of dipoles and, even more pronounced, of protons on the electronic spectra. Depending on the relative basicities, multiple changes in the electronic spectra result from increasing concentration or pKA of the acid.These dyes are interesting for sensor technology, as different ways of interaction with the environment result in two different molecular answers (absorption/fluorescence). Due to their quadrupolar electronic structure, these aza-OPVs are also attractive as two-photon absorbing chromophores.

B-1.2: P84 **Differences in Nonlinear Mesoscopical Magnetic Interactions between Achiral and Chiral Nitroxyl Radical Liquid crystals**

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Here we show the first observation of unique intermolecular mesoscopical-magnetic interactions only in the liquid crystalline (LC) state of all-organic radical compounds 1, which contain a polar and

chiral cyclic-nitroxide unit in the mesogen core and show achiral or chiral nematic (N or N*) phases at higher temperatures[1]. By the temperature-dependent magnetic susceptibility (Chi) measurement of racemic and enantiomerically enriched 1, we observed an anomalous increase in the Chi upon the crystal-to-LC phase transition, which cannot be explained in terms of the decrease in diamagnetic anisotropy. The Chi increase was larger in the N* phase than in the N phase. To observe the intermolecular magnetic interactions more directly, we examined how the respective N and N* phases of 1 behave by the action of magnetic fields. The LC grains on water were attracted by a weak permanent magnet, whereas the crystalline phases were almost paramagnetic and not responsive to the magnet. We observed that the LC grains moved faster in the N* phase than in the N phase. The difference in their motion turned out to correspond to the difference in above intermolecular magnetic interactions.

[1]Angew. Chem. Int. Ed. 2004, 43, 3677; Adv. Mater. 2006, 18, 477; Ferroelectrics 2006, 343, 119.

B-1.3: P85 **Study of Stimulated Luminescent Processes in Beta Irradiated SrAl2O4: Eu2+, Dy3+**

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Afterglow (AG), thermoluminescence (TL) and optically stimulated luminescence (OSL) emissions in SrAl2O4:Eu2+, Dy3+ are related to 4f65d1 —> 4f7 electronic transitions of the Eu2+ ions. We observed that the AG, also referred as long persistent luminescence (LPL), had at least two well-defined processes; one fast decay component of about 0-40s , followed for a slow decay component from 40 to 3600 s. The TL glow curves depicted two peaks at 382 and 431 K, respectively. The annealing curve of LPL indicated that the lower temperature TL peak at 382 K correlates with the maximum 323 K band, and it pointed to a common origin of the LPL and TL. The photo-stimulation with appropriate wavelength (875 nm, 40 mW/cm2) causes the release of trapped charge carriers and radiative recombination with opposite charge centers or defects, also. We have found that the main contribution for OSL came from the low temperature localized trapping states (around RT and 340 K). The OSL was observed up to near 435 K, but the thermoluminescence (TL) was detected up to around 500 K. Our experimental results have demonstrated the participation of charge carriers trapped in shallow or low temperature localized states in the optically and thermally stimulated processes.

B-1.3: P86 **Optical and Structural Characterization of Erbium-doped Ion-implanted Tellurite Glasses for Active Integrated Optical Devices**

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Erbium-doped tellurite glasses show great potential for the fabrication of high-performance integrated optical amplifiers and lasers, thanks to their unique properties in terms of bandwidth and rare earth solubility. As a first step towards the development of smart multi-functional integrated optical circuits, the fabrication of multimode channel waveguides in a sodium-tungsten-tellurite glass, by using nitrogen ions implantation, has been recently demonstrated[1]. The effects of the ion implantation process, however, have not been fully clarified, and a deeper investigation would be necessary in order to optimize the process and to truly exploit the glass useful characteristic. We therefore report here the results of a broad optical, topographic, and structural characterization of tellurite samples irradiated with various doses of nitrogen ions, while keeping constant the beam energy at 1.5 MeV. Characterization techniques have included absorption and luminescence spectroscopy, modal (dark-line) spectroscopy, surface profilometry, scanning electron microscopy, cathodoluminescence spectroscopy and EDX analysis.

[1]S. Berneschi et al, Ion beam irradiated channel waveguides in Er3+-doped tellurite glass, APPLIED PHYSICS LETTERS 90, 121136, 2007.

B-1.3: P88 **Lanthanide-organic Frameworks: Structure, Spectroscopy Studies**

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Lanthanides-organic frameworks (LOFs) can be efficiently used as Light-Conversion Molecular Devices. In this context several multifunctional ligands have been explored, amongst which the aromatics policarboxylates are of particular interest due to their chemical stability and photophysical properties. In this work we report a detailed photophysical study of the properties of the three new LOFs, [Ln2(MELL)(H2O)4(H3O+)2] (Ln= Eu3+ and Gd3+; MELL= Mellitate). Each lanthanide is coordinated with four distinct -COO- groups¬ ¬, being two as bis(monodentade), while, remaining display a tetrakis(bidentade). The coordination sphere environment is completed with three water molecules, forming distorted tricapped trigonal prism. This high connectivity between metal and mellitate anions ensures formation of the interesting 3-D supramolecular structures. The ligand triplet was localized at 24,154 cm-1 via [Gd2(MELL)(H2O)4(H3O+)2] phosphorescence at 77K. The Eu3+ compound shows red emission upon excitation at 310nm. However, the short lifetime (0.34 ms) and low quantum yield (8.00%) presented by sample can be associated to the energy transference occur via 5D2 to Eu3+ and the non-radiative decay channels due to vibronic coupling with the two water molecules and hydronium ion coordinated.

B-1.5: P91 **Raman Scattering on Quadrupolar Vibrational Modes of Spherical Nanoparticles**

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The light to vibration coupling coefficients for Raman scattering on the quadrupolar (l=2) vibrational modes of spherical nanoparticles are calculated for varius materials inside a silica matrix. The calculated coefficients are discussed and compared to the coefficients for Raman scattering on the symmetrical (l=0) modes. The Raman spectra for scattering on Ge, HfO2, CdSSe and TiO2 particles are calculated and compared to experimental results. The application Raman spectroscopy for the determination of the size distribution of nanoparticles embedded in matrix is also discussed.

B-2.1: P93 **Characterization of Brightness of ZnS Electroluminescent Device with Dielectric Materials of SOG or TEOS**

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Spin on glass (SOG) and Tetraethyl orthosilicate (TEOS) as a dielectric material were applied for inorganic powder type electroluminescent (EL) device. The spin coating method was used for the SOG layer or TEOS layer formation and phosphor layer formation. The phosphor layer was composed of ZnS:Cu,Cl powders and organic binder. The brightness of powder EL has been measured.

B-2.1: P95 **Humidity Influence on Gas-sensing Characteristics of Ammonia Sensor Films**

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A particular place among optical methods is occupied by chemical sensors based on optical fiber and thin films of substances which change their optical features under effect of the environment. When light conductors are combined with thin films they can be used for gas and humidity sensors as optical features of these thin films are effected by parameters of environment. An ammonia refractometric sensor has been developed on U-shaped cylindrical waveguide with the 4-[4-(Dimethylamino)phenylazo]benzenesulfonic acid sodium salt (Methyl Orange) immobilized within Nafion® film. The sensor works bases on the dependence of light loss from the environment refraction index. Thin film was deposited on the outside surface of the waveguide to increase the sensitivity and selectivity of the ammonia determination in the air. The thickness of the films is in the range 100-150 nm. The sensor is placed in a flow-through measuring cell and represents a cylindrical optical waveguide made of silicon. A specially designed microprocessor unit was used to take measurements. Signal change

speed is limited by the mass transfer processes in the surface and in the volume of the film. The humidity adsorption on the film surface accelerates the rate of adsorption-desorption and transfer of the ammonia molecules on the surface of the film, but practically does not affect diffusion speed in the film volume. The humidity change influences both signal value and dynamic parameters of the sensor.

SYMPOSIUM C

EMBODING INTELLIGENCE IN STRUCTURES AND INTEGRATED SYSTEMS

C-1: P97 **A Self-sensing Method for IPMC Actuator**
BYUNG-GEUN KO, HYOK-CHON KWON, SONGJUN LEE, Hanyang University, South Korea

This paper describes a novel method of self-sensing Ion-conductive Polymer Metal Composite (IPMC) actuator. Unlike the previous self-sensing technique, the proposed principle is based on the electric charge of the IPMC itself, which is correlated with its curvature. At the normal state, IPMC is electrically charged, and the amount varies according to the status of IPMC. While it is operated as an actuator, it also gives position information in the form of the electric charge amount, which is utilized for fast and accurate position control. In order to get the bending status of the actuator, the instantaneous voltage of IPMC is measured during the open state for input signal. The uncomplicated system is constructed to verify if the developed method is effective for the self-sensing actuator and evaluated by the experimental basis. The way to actuate the IPMC for self-sensing is an assigning discrete signal as an input, and it is also evaluated experimentally. The study also represents relatively simple structure for both actuation and sensing, which is very important factor to be implemented as a controller circuit for various applications.

C-1: P101 **Structure Formation and Strengthening of Hot Deformed Nitrogen-Containing Steels**
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Alloying of steels by nitrogen is mainly to increase strength, wear and corrosion resistances and to decrease other alloying elements content. Combined alloying by carbon and nitrogen allows widening the range of chemical compositions in which application of nitrogen steels is rational. The structural and phase transformations and the strengthening of nitrogen-containing steels resulting from alloying and thermo-mechanical treatment have been investigated using X-ray diffraction analysis, optical microscopy, hardness measurements and tensile testing. For the modeling of thermoplastic treatment processes, a DIL 805A/D dilatometer with a deformation capability and a Gleeble 3800 simulator were used. Rational concentrations of nitrogen or nitrogen plus carbon are determined by basic composition of an alloy, they are limited by processes of precipitation of excess phases during crystallization and their dissolution during heating stage of thermal or thermomechanical treatment. Combined alloying by carbon and nitrogen leads to significant complication of phase and structural transformations in steels, including hot deformation that were manifested in changes of strain-stress diagram parameters. Effectiveness of increasing of a hot deformation resistance under alloying by nitrogen and carbon depends on a basic composition of steel, C/N ratio and temperature-strain rate conditions of deformation.

C-2: P102 **Piezoelectric Sensor System for Structural Health Monitoring**
BYUNGSOO KIM, YONGRAE ROH, Kyungpook National University, Daegu, Korea

This paper presents the feasibility of a sensor system consisting of piezoelectric oscillator sensors to detect local damages and ultrasonic sensors to detect global damages in a structure. The oscillator sensor is composed of a feedback oscillator circuit and a piezoceramic lateral mode vibrator to be attached to a structure. Damage to the structure causes a change in the resonant frequency of the vibrator. The oscillator circuit instantly detects the frequency change and configures the damages. However, the response of the oscillator sensor is limited to the area around the sensor, thus local measurement. The ultrasonic sensor generates Lamb waves and the waves traveled over a long distance are received by another piezoceramic patch on the structure. The received wave form reflects all the defects encountered during the propagation, thus global measurement is possible. The two sensor types are combined as a sensor network, and its operation system is developed as a portable unit for practical applicability. Performance of the sensor system was verified with a sample aluminum plate where artificial cracks of different lengths and number were imposed in sequence. Performance of the sensor was quite promising, responding accurately and reliably to the crack configuration.

C-3: P103 **Modeling, Identification, and Semi-active Control of a Large-scale Magnetorheological Fluid Damper**
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During the last years great interest has been attracted by magneto-rheological (MR) dampers to be used in civil engineering structures as semi-active control devices for vibration mitigation due to external dynamic loads. These devices are highly nonlinear and thus accurate models of these devices are important for effective simulation and control system design. Two hysteretic models based on the normalized Bouc-Wen model and the Dahl model are proposed in this paper to compare their effectiveness in a large scale MR fluid damper. A methodology for identification is proposed, and the obtained models are tested and validated experimentally. A simple semi-active control law is used to test the effectiveness of the models for seismic protection of base-isolated buildings structures employing MR dampers under different earthquake excitations.

C-3: P106 **Edge to Thickness Ratio as a Predictor of Cured Shape and Load-deflection Characteristics in Cross-ply Asymmetric Composite Laminates**
P. GIDDINGS, C.R. BOWEN, H.A. KIM, University of Bath, Bath, UK

Bistable composite laminates are of interest to many investigators with potential applications highlighted within morphing aircraft. Analytical models of cross-ply bistable laminates have been developed and the behaviour of such laminates is now well understood. Potter and Weaver (2007) manufactured and tested small thin bistable composite structures, but in some applications larger laminates may be advantageous. The relationship between the behaviour of small thin samples and that of larger thicker samples is not currently well understood. Jun and Hong (1990) showed that edge-thickness ratio (ET) can be used to predict the behaviour of bistable composites and that the onset of bistability occurs at a constant ET value. According to the literature, little experimental validation of these predictions has been carried out to explore the behaviour of thicker bistable laminates of the [0n/90n]T family; it is also unclear if ET may be used to predict the load-deflection behaviour of these laminates. This paper aims to investigate the relation between ET and cured shape in bistable laminates and evaluate scaling effects in cured shape and load-deflection behaviour in laminates of equivalent ET. Preliminary data on actuation of such laminates for shape control will also be presented.

C-4: P107 **Wavelength Spectra of Fiber Optic Bragg Grating for Crack Opening**
IL-BUM KWON, GUOHUA JIN, NAM-KWON LEE, DAE-CHEOL SEO, KRISS, Daejeon, South Korea

Civil structures usually show signs of catastrophic failure as crack growth on their stress concentration region. In order to evaluate structural health status, crack growths should be monitored continuously. Fiber optic sensors are very applicable to monitor crack growth continuously because they have many advantages: electromagnetic immunity, chemical inert property, compactness, flexibility etc. In this study, the wavelength spectra of fiber optic Bragg gratings are investigated according to crack opening effects. On the experiments, the line-width of the wavelength spectrum of fiber optic Bragg grating is changed by increasing the crack opening. After all, it is confirmed that the crack growth can be monitored by showing the spectrum change of fiber optic Bragg grating.

C-5: P110 **Tunable Dielectric Resonator Antennas**
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Dielectric Resonator Antennas (DRA) offer some advantages over microstrip antennas including reduced size, wider bandwidth and higher power handling capability. Different radiation patterns can be achieved by exciting different modes of a DRA. The resonant frequency of the DRA depends on the dimensions, shape and dielectric constant of the antenna. Thus, the size of DRA principally defines the resonant frequency. There are many instances where tunability of antennas is required. This can be due to the need to counter environment variations or the ability to operate different protocols using different frequency bands. The present contribution investigates the feasibility of making a DRA with voltage-controlled tunability. To this end, the deformability of Electro-Active Polymer (EAP) can be deployed to change the resonant dimensions of the DRA. For a circular cylindrical DRA, the resonant frequency of a DRA quadratically depends on the radius-to-height ratio. The radius-to-height ratio depends quadratically on the applied voltage. The resonant frequency is thus very sensitive to the applied voltage and the high voltage requirements can be moderated for tunable EAPs.

SYMPOSIUM D

BIOMEDICAL APPLICATIONS OF SMART MATERIALS, NANOTECHNOLOGY AND MICRO / NANO ENGINEERING

D-1: P111 **Photoluminescence Response and Particle Size Control of CdSe Quantum Dots by Wet Chemical Synthesis for Biomedical Applications**
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The chalcogenide CdSe quantum dots (QDs) were obtained through a simple wet chemical synthesis route, which was performed by using cadmium oxide and selenium as precursors, hexadecylamine (HDA), tetradecylphosphine oxide (TDPO) and tri-n-octylphosphine oxide (TOPO) as complexing agents in tri-n-butylphosphine (TBP) solvent surrounded an air-tight sealed reactor with argon or nitrogen atmosphere. For in vivo medical applications, our study aims at reducing the size of QDs for easy penetrating through the biological membranes, ensuring stability in adequate pH conditions of biological fluids, and tailoring their surface in order to functionalize and/or develop strong interactions with specific biological components such as dye, drug or effecter grafting. The obtained CdSe nanoparticles were tested particle size analyzer, photoluminescence spectroscopy, FE-SEM, TEM, and XPS. The desired particle size and photoluminescence response of CdSe QDs can be achieved by adjusting molar ratios of HDA/TOPO and CdO/Se, and the synthesis temperature and time. Our results show that the obtained CdSe quantum dots are of average size of 1~10 nm with the particle size distribution less than +/-5%, which have stable PL response by being excited by light sources with different wavelengths (388~550 nm).

D-1: P112 **Dispersion and Biofunctionalization of Singlewall Carbon Nanotubes**
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Carbon Nanotubes potential application as a drug delivery system is perplexed by their hydrophobity and their natural tendency to aggregate in the bundles. Dispersion and solubility of Singlewall Carbon Nanotubes (SWCNT) in Phosphate Buffered Saline (PBS) solution via non covalent and covalent interactions was investigated, by using galactosyl-ß1-Sphyngosine (glycolipid precursor of cerebrosides, structured with an hydrophobic chain, an hydrophilic head and an amine group between them). Pristine SWCNTs were wrapped with GalactosylSphyngosine, whereas the carboxylic groups of the functionalized CNTs were activated in order to interact with aminic group of Galactosylsphyngosine and render the coating stronger. Samples dispersion was characterized by optical absorption spectroscopy (OAS). The comparison and efficiency of the dispersion stability for both systems will be presented. We exploited Raman Spectroscopy and atomic forced spectroscopy (AFM) to evaluate relative purity of the samples. The morphology of the samples were studied with high resolution transmission electron microscope (HR-TEM).

D-1: P113 **Interaction of Protein with Nanostructured Films of Phthalocyanines**
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The important aim for biomedical investigations is to extend the possibility of affinity interactions study. Magnesium tetra-tert-butyl-phthalocyanine (Pct-BuMg) and mercury phthalocyanine (PcHg) were used for investigations to determine metal nature influence on horseradish peroxidase immobilization. Palladium film was selected for test experiment. The characteristics changes of nanostructured phthalocyanines films which were deposited on the outside of U-shaped multimode cylindrical waveguide were studied. The films with 10-100 nm thickness were deposited by two methods: vacuum thermal evaporation and Langmuir - Blodgett method. The horseradish peroxidase immobilization on phthalocyanines films from fresh phosphate buffer solution was investigated. The absorption of light passing the U-shaped waveguide during the precipitation on its side protein molecules was measured. Protein sorption has taken place on both phthalocyanines films, but in different manner. Parameters of chemical sorption process got by mathematical processing showed kinetic dependences. Process of horseradish peroxidase precipitation on Pct-BuMg film is the same that on Pd. The sorption of protein molecules on PcHg occurs almost hundred times slowly than other materials. Obvious that protein selectively interacts with different phthalocyanines. This fact may be used for dividing proteins mixtures and their analyses.

D-3: P119 **Artificial Control of the Bacterial Cell-to-cell Communication with Autoinducer Recognition Gel**
NORIHIRO KATO, YU OZONOE, ERI UMEBAYASHI, TOMOHIRO MOROHOSHI, TSUKASA IKEDA, Utsunomiya University, Utsunomiya, Japan

We design a novel hydrogel that possesses high affinity to the bacterial signal molecules of the quorum sensing (QS), autoinducer. The QS is one of the bacterial cell-to-cell communication mechanisms that have been found in many gram-positive and -negative bacteria. The QS is cell density dependent and occasionally controls the expression of multiple virulence genes that cause serious infectious disease. In many gram-negative bacteria, several kinds of N-acylhomoserine lactones (AHLs) have been identified as autoinducers. Transcription of the QS-regulated gene can be activated when the AHL concentration increases to a threshold due to an increase of cell density. By reducing the local autoinducer concentration, the specific gene expression could be inhibitory controlled. In this research, we report the cyclodextrin (CD) immobilized hydrogel sheets that can easily trap AHLs due to the inclusion complex formation. Production amount of antibacterial agent prodigiosin derived from the QS-regulated genes was investigated with immersing the CD gel sheets during the cell growth of the opportunistic human pathogen Serratia sp. The CD gel sheets effectively reduced the prodigiosin production. The AHL-trapping method has high potential to intercept the bacterial cell-to-cell communication.

D-3: P120 **Ultrasonic Transducer for Fluid Microagitation Based on β-PVDF**
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Microfluidic technology is an important tool for analytical biochemistry applications. It enables the fabrication of the so called lab-on-a-chip. This technology offers inherent performance gains such as reduced sample size, shortened response time, and reduced costs. One of the main problems to overcome is to develop reliable and non-expensive systems allowing the proper mixing of fluids. To overcome long transit times due by diffusion and to enable high-efficient reactions it is necessary to induce the microfluidic die by a mechanism that accelerates the mixing and reaction, with no moving parts. This paper reports on the development of a fully-integrated disposable lab-on-a-chip for point of care testing and monitoring of biochemical parameters in biological fluids. The lab-on-a-chip is composed mainly by two dies: the fluid and the detection. The fluid die comprises three microfluidic cuvettes, containing the fluids into analysis, and a microagitation system

based on electroactive ß-PVDF. The detection die contains the photodetectors and the electronics for signal actuation and detection. The acoustic microagitation technique based on ß-PVDF allows the enhancement of the mixing and the reaction.

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D-3: P122 **Biodosimetry of Gamma-irradiated Human Blood**

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Biological dosimetry may be based in blood changes. The accounting of these early response biomarkers is used for assessing radiation doses. Most of dose-prediction models are based on blood lymphocyte counts after the exposure to gamma radiation. The depletion of lymphocytes is often used with a twofold aim: to design an effective radiotherapy with minimum exposure doses and to reduce the risk of the Graft-versus-Host-Disease (GVHD) in peripheral blood transfusion. In the latter, it is accomplished by eliminating the donor lymphocytes and avoiding, in this way, the rejecting processes. In this work, we have irradiated human blood with gamma rays (60Co) with doses ranging from 3.21 to 71.65 Gy. We used practical and low cost techniques for studying the ionizing radiation effect on the biological hematological tissue, such as, Giemsa dying, an impedance based counter cell and a flow citometry technique. Our results show that it is possible to establish a simple protocol for small clinical laboratories for evaluating and controlling the quality of irradiated blood for medical and radiation biodosimetry applications.

D-4: P123 **Fabrication of Ti Fiber Scaffold for Biomaterial Use**

SHUNSUKE SAITO, Y. OYAKEA, T. ASAOKA, Tokyo Denki University, Saitama, Japan

In the event of a significant injury, human bone must be repaired by artificial means. In the present study, we used titanium (Ti) to create a scaffold for cell renewal with an emphasis on strength. Because scaffolds for cell renewal require a microporous structure that enables supply of oxygen and nutrients, sintered Ti fiber was used. However, although titanium has a high fracture toughness, it does not bond to hydroxyapatite (HAp), the main component of bone, and thus requires addition of bioactivity. Following treatment by sodium hydroxide, titanium fibers were heated and immersed in simulated body fluid. Through this process, HAp was formed on the titanium surface to create a bioactive material with both a high strength and biocompatibility. Following approximately two weeks of immersion in simulated body fluid, HAp was formed such that it covered the surroundings of titanium fibers without any gaps. In addition, the fracture mode of HAp was analyzed by conducting mechanical tests, such as tensile strength and compression tests, on the titanium fibers on which HAp was formed. Furthermore, collagen coating was applied on the titanium surface, and the material was immersed in simulated body fluid to investigate and compare HAp formation.

D-4: P124 **Fabrication of α-TPC, HAp Functionally Graded Porous Beads**

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HAp (Hydroxyapatite) and α-TCP (alpha tribasic calcium phosphate) are non-toxic to human cells and, thus, have been studied for applications as biomaterials. HAp is a bioactive material that is not readily absorbed by the body; it offers both high strength and better tissue-adhesive properties than α-TCP. In contrast, α-TCP is highly bioabsorbable; it is quickly absorbed by the body, and, therefore, for example, disappears before bone is completely replaced. If porous beads could be fabricated that would take advantage of the useful properties of α-TCP and HAp, they could be used as excellent scaffolds for cultivating cells. In the present study, ceramic beads with α-TCP at the center were fabricated and coated with a functionally graded film of HAp. A scaffold based on this configuration would be expected to have the following characteristics: good cell adhesion; strong beads; and a rate of absorption into the body that would be easy to control. In addition, to accelerate the formation of porous structure, some acid solutions were used to dissolve the beads surface layer and to penetrate pores toward inside of the bead. HAp formation through hydrolytic reaction seemed to be promoted by these acid solutions.

D-4: P125 **Addition of Surface Function to Zirconia for Biomaterial Use**

NATSUMI KOIDE, K. SUZUKI, M. TSUDA, T. ASAOKA, Tokyo Denki University, Saitama, Japan

Due to the merits of zirconia ceramics such as high strength, toughness, and abrasion resistance, as well as chemical stability in vivo, yttria-stabilized tetragonal zirconia polycrystals are currently used in the femoral head of hip prostheses. However, this material has a limited range of use because it is a bioinert material that does not interact with bone tissue and thus does not easily integrate directly with bone. Therefore, addition of a material surface that enables the in vivo formation of a bonelike apatite layer that exhibits bioactivity and facilitates interactions and integration with bone tissue is desired. In addition, by developing a surface structure that enhances mechanical bonding, this material can be expected to be used as an alternative aggregate under load bearing conditions. In the present study, structural design of the material surface, addition of bioactivity using chemical treatment, confirmation of formation of the apatite layer using immersion in simulated body fluid, mechanical assessment, and wettability testing were conducted with the objective of controlling interactions between zirconia ceramics and the body.

D-5: P129 **Prepation and Characterization of Highly Water Soluble Pharmaceutical Loaded PLA Microcapsules**

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Microencapsulation of highly water soluble pharmaceutical substances (solubility more than 1g/ml) especially if high drug loading is required (more than 50%) is a big challenge. Biodegradable polylactide as coating material and polyvinyl alcohol as surfactant were found suitable for this purpose. Method developed enables not only the microencapsulation of highly water soluble pharmaceuticals, but also to predict the properties of products obtained. Active substance was microencapsulated using slightly modified water-in-oil-in-water technique which involves dissolving of the drug in water and polymer in methylene chloride and forming an emulsion in water using a surfactant. Procedure of microencapsulation was followed by filtration and drying of product obtained. Microencapsulation technique developed allows to encapsulate highly water soluble pharmaceutical substance with drug load up to 45% and encapsulation efficiency of 65%. During the study the effect of such parameters as extraction media volume, extraction time, amount of organic solvent, concentration of emulsifier, active substance and polymer, amount of inner water phase, molecular weight and type of emulsifier on microencapsulation process and product properties was investigated.

D-5: P130 **Effect of Electric Field Strength on the Diffusion of Salicylic Acid Through Polyacrylamide Hydrogels**

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The release mechanisms and the diffusion coefficients of salicylic acid-loaded polyacrylamide hydrogels were investigated experimentally by using a modified Franz-diffusion cell at 37 °C to determine the effects of crosslinking ratio and electric field strength. A significant amount of salicylic acid is released within 48 hours from the hydrogels of various crosslinking ratios, with and without electric field. The release characteristic follows the Q vs. t1/2 linear relationship. Diffusion coefficient initially increases with increasing electric field strength and reaches the maximum value at electric field strength of 0.1 V; beyond that it decreases with electric field strength and becomes saturated at electric field strength of 5 V. The diffusion coefficient increases at low electric field strength (less 0.1 V) as a result of the electrophoresis of the salicylic acid, the expansion of pore size, and the induced pathway in pigskin. For electric field strength higher than 0.1 V, the decrease in the diffusion coefficient is due to the reduction of the polyacrylamide pore size. The diffusion coefficient obeys the scaling behavior D/Do = (drug size/pore size)m, with the scaling exponent m equal to 0.93 and 0.42 at electric fields of 0 and 0.1 V, respectively.

D-5: P132 **New Antibacterial, Antiadhesive Films Based on Layer by Layer Self Assemblies of Biodegradable PLGA/Chitosan Polymers Containing Modified Tetraetherlipids**

E. DAYYOUB, J. SITTERBERG, U. BAKOWSKY, Philipps University of Marburg, Marburg, Germany

Biofilm formation is one of the most well-known problems of the urethral catheters, leading to serious infections. A technique that can reduce the attachment of bacteria onto device surfaces and increase the

effectiveness of killing the bacteria on the device surfaces is of prime importance. Catheter´s surface modifying with films of both anti-adhesive and antibacterial substances is a potential method to avoid bacteria adhesion onto the surface and to raise the antibacterial activity. This project focus on the development and characterisation of ultrathin antibacterial and anti-adhesive films prepared by the layer by layer technology consisting of alternating layers of PLGA and Chitosan consisting modified Tetraetherlipids (TEL). The TEL are highly chemical stable in urethral environment and show resistance to hydrolytic, oxidative and other (bio)chemical attack. In addition the well-famous antibacterial combination of Chitosan-Silvers nanoparticles with a high antibacterial activity were used for a further modification. The physicochemical and biological properties of the supported films were examined by scanning force microscopy (AFM) and confocal laser scanning microscopy regarding their morphology, surface energy, blood serum and bacterial adhesion.

D-6: P134 **Estimate Biocompatibility and Injection-molding Processability of Ti-based Metallic Glasses for Dental Implant**
JEONG-JUNG OAK, H. KIMURA, A. INOUE, Tohoku University, Sendai, Japan

Recently, Ti-based metallic glasses aim at biomaterials with their high specific strength and superior corrosion resistance. Their high workability also shows a good performance for mass production under energy saving environment. In this study, we started investigation of the design of Ti-based metallic glasses with the restricted alloying elements for biocompatibility and characteristic evaluation of the optimized Ti-based metallic glasses with higher glass forming ability for dental implants. These Ti-based metallic glasses do not contain Al, V and Ni elements which are well known to be neurotoxic and cytotoxic for human body. Current medical reports of impracticability by these elements have been a hot issue in biomaterials science. Newly designed Ti-based metallic glasses exhibit good performances. Especially, the optimized Ti-based metallic glass has high corrosion resistance with better passivity in a wide passivation range in simulated body fluids at 310K. In addition, biocompatibility of Ti-based metallic glass was also evaluated by cell culture in vitro. Excellent biocompatibility of Ti-based metallic glass show high potentials to be applied as biomaterial because necrosis of osteoblast (SaOS2) was not detected in this study.

D-6: P135 **Bone Implant Failure Detection Through a Piezo-active Network**
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This study is related to the development of smart systems for Total Joint Arthroplasty. The most common complication in this area is the loosening of the prosthetic stem and cup. Loosening appears as relative motion between implant and bone, and is caused by failure of the implant to sustain cycling loading. It is important to develop a sensing system capable of analyzing the implant internal environment and detecting the first critical regions in real time. One further evolution would be the implementation of secondary functions to enhance bone growth, improving stability. In this work the development of a multifunctional solution able to be used as a biosensor and as an actuator based on the piezo-active properties of the materials used to fabricate the device is proposed. The diagnosis will be based on the measurements of different parameters related to dynamic and static loads. For each parameter different sensor types will be used, mainly based on the piezoelectric and piezoresistive effects. Moreover, bone growth around the implant will be stimulated by piezoelectric actuators distributed along the surface. This coating must also allow for good bone adhesion, by tailoring the porosity in order to enable cell invasion. Results on the first prototypes will be reported.

D-7: P136 **Treatment of Ingrown Nails Using Cu-Al-Mn New Shape Memory Alloy**
NOBUKO TABATA, Japanese Red Cross Sendai Hospital, Sendai, Japan; M. ISHIBASHI, Tohoku University, Sendai, Japan; T. SUETAKE, Suetake Dermatology Clinic, Sendai, Japan; T. OMORI, Y. SUTOU, R. KAINUMA, K. YAMAUCHI, K. ISHIDA, Tohoku University, Sendai, Japan

Ingrown toenails are one of the most common foot maladies, leading to significant pain in foot. The predisposing factors include wearing narrow-toed shoes and improperly trimming of nails. There are many varieties of treatments available for ingrown toenails such as cotton-wick insertion and nail matrix phonolization. Ingrown toenail correction using small plastic plate or superelastic wire is also a possible treatment. Recently, we have developed an ingrown nail correcting device made of Cu-Al-Mn shape memory alloy characterized by excellent cold-workability which is necessary for forming complicated shape of the device. The nail correction treatment using the new shape memory alloy were carried out in a total of 14 patients, 12 to 75 years old (5 male and 9 female patients). The treatment consists of clipping the device at the tip of ingrown toenails, keeping the curved nail straightened due to the recovery force of the superelastic shape memory alloy. Although this procedure was not effective for heavily curved toenails, a great success was produced in the mild case of ingrown toenails. It is suggested that this simple and low invasive technique be considered as a new method of the treatment for ingrown nails.

D-7: P137 **Enzyme Mediated Coupling of Protein-based Biomaterials onto Wool Fibres**
S. JUS[1, 2], G.M. GUEBITZ[2], V. KOKOL[1], [1]University of Maribor, Maribor, Slovenia; [2]Technical University of Graz, Graz, Austria

Chemical, physical-mechanical and biological properties of wool protein fibres, which are endowed with excellent biocompatibility, can be explored to develop innovative biomaterials for medical applications such as bioactive dressings. Tyrosinase is capable of oxidizing tyrosine residues in proteins to the corresponding quinones, which can further react with e.g. free sulfhydryl (thiol) and/or amino groups resulting in formation of tyrosine-cysteine and tyrosine-lysine crosslinks or phenol coupling. These characteristics are exploited to transfer specific properties to the wool fibres surfaces using protein-based bio-materials like collagen, elastin and gelatine. The enzyme mediated coupling reaction was examined by FT-IR, Raman and UV/VIS spectroscopy. The durability of the grafting was determined using FITC labelled collagen which was not removed from wool after severe washing. In addition, antimicrobial properties of wool fibres were successfully imparted due to the grafted collagen substrate.

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SYMPOSIUM E
MINING SMARTNESS FROM NATURE

E-1.1: P138 **Dosing Disorder: a Classification of the Visual Effects Developed by Weevils**
J.P. VIGNERON, V. WELCH, M. RASSART, University of Namur, Namur, Belgium

Photonic structures which appear on living organisms are not perfect. However, contrasting the usual engineer's feeling, these imperfections are not the result of unreliable fabrication processes, but qualities that are maintained throughout evolution at each generation in the species population. The family of weevils known as Curculionidae is exemplative: many of the species in this family are coloured by scales which contain a three-dimensional photonic crystal. However, these photonic structures are usually divided in domains, so that the contents of the scale is better described as a photonic polycrystal than a monocrystal : each grain in the polycrystal is cut from a highly ordered photonic crystal (short-range order), but the orientation of the different grains varies across the scale (long-range disorder). The size of the domains range from the full size of the scale (monocrystal) to the size of the photonic-crystal period in the grain (amorphous). The visual effect produced by structures with different coherence lengths include iridescence, metallic colour lacking iridescence, dull colours and whites. Examples of weevils which present this wide range of coherence lengths and visual effects will be presented and commented.

E-2.1: P139 **Effective Impregnation of SiO2 Sol-Gel Solution in Pine Wood and Following Gel Localization in Free Cell Volume**
J. LOCS, L. BERZINA-CIMDINA, D. LOCA, Riga Tech. University, Riga, Latvia; A. ZHURINSH, Latvian State Inst. of Wood Chemistry, Riga, Latvia

Advantage of the wood as structural material is durability of structure combined with low bulk density. Introduction of Si in the wood opens the possibility to obtain porous SiC ceramic during the high temperature treatment in inert atmosphere. Key problem in this field is the amount of Si (in our case SiO2) that should be uniformly introduced in the wood. Pine tree (Pinus silvestris) with shaped sample dimensions of 20 x 20 x 5mm (axial) was selected as raw material. Samples were dried and for some of samples resin extraction from sample were applied. SiO2 sol-gel solution was prepared using ethanol, tetraetoxysilane, distilled water and hydrochloric acid. Samples were impregnated under different vacuum and pressure conditions. Impregnation efficiency was calculated for impregnated samples and varies for different samples and impregnation conditions. Impregnation and drying procedures were repeated several times, to increase SiO2 amount introduced in the sample. SEM microphotograps of samples were taken and are showing the localization of SiO2 in wood. Repeating infiltration cycles several times, sample mass continues to grow. After three infiltration cycles sample weight increases enough for possibility to synthesize SiC.

E-2.1: P140 **Giant Neotropical Beetles Show the Way to Hygrochromes Materials**

M. RASSART, J.-P. VIGNERON, LPS (FUNDP), Namur, Belgium

The large beetle Dynastes hercules lichyi (South America) undergoes passive colour transformations, changing from khaki-green to deep black when the ambient humidity is increased. This communication focuses on the physical aspects of the colour change. The optical reflection factor of the cuticle of this beetle is described for various hygrometric levels. In parallel, scanning electron microscope nano-morphology investigations of the cuticle allowed to determine the structure of the hygro-adjustable colouring layers. The structure is essentially a wide-period Bragg multilayer which alternates chitin sheets and air layers. The khaki-green colouration is due to the second-order photonic gap which opens near 500 nm and the black appearance results from water infiltration through cracks in the thin wax layer covering the photonic structure. The colour change is explained by the attenuation of the refractive index contrast which permits the incident light to reach the deeper absorbing melanin substrate. This mechanism is confirmed by 3D transfer-matrices calculations. It is suggested that these natural structures can be synthesized with already known mesoporous materials. The resulting artificial hygrochromic surfaces could have a variety of uses in sensing or displaying applications.

E-2.1: P141 **Superhydrophobic Coating of Metals Under Ambient Conditions**

I.A. LARMOUR, S.E.J. BELL, G.C. SAUNDERS, Queen's University Belfast, Northern Ireland

The self-cleaning ability of many plants with superhydrophobic surfaces has encouraged researchers to produce synthetic mimics with high contact angles and low roll-off angles. Potential uses include medical device coatings, self-cleaning windows and marine anti fouling coatings. Most synthetic hydrophobic surfaces are based on silicon technology, which gives precise top-down structure control but is very limited in terms of geometry and size of objects that can be manufactured. Here a simple electroless Galvanic deposition method, performed at ambient temperature and pressure, is shown to allow large metallic objects of any shape to be made superhydrophobic. In this two stage process, the metal ions are first spontaneously reduced to form a double roughness metal over-layer of diffusion-limited aggregates. Secondly a wet immersion step adds the low energy surface modifier, a close-packed chemically bound thiol monolayer. This method can be applied on the laboratory scale, e.g. in preparing systems for digital microfluidics where reactions are carried out in discrete droplets. However, the simplicity of the method means that it is potentially much more far-reaching since it can also be used to prepare superhydrophobic coatings on an industrial scale.

E-3.2: P142 **Mining Smartness from the Hydraulic System of Spiders: a Bioinspired Actuator for Advanced Applications**

C. LIRA, University of Bristol, UK; C. MENON, K. KIANFAR, M. MANI, Simon Fraser University, Canada

Most animals and insects use opposing muscles, called flexors and extensors, to articulate the joints of their limbs. However, some spiders do not have extensors in some of their joints and use, instead, a simple and efficient miniaturized hydraulic system to extend their limbs. An actuator inspired by the hydraulic system of spiders, which can be embedded on smart structures, is proposed in this paper. Its design and characteristics are discussed and the effects of the geometrical parameters on its performance are investigated. The numerical analyses that have been performed to predict the behaviour of the actuator in different load conditions are presented. The experimental set-up used to validate the numerical analyses is described and experimental results are discussed. The manufacturing procedure used for the fabrication of the tested prototypes is presented and additional promising fabrication techniques are proposed. Different potential applications of the bioinspired actuator are identified and investigated in this paper.

E-4.2: P143 **Multi-UUVs Team Formation Control by a Behaviour-based Method with Fuzzy Logic Adapters**

YAN HOU, R. ALLEN, University of Southampton, Southampton, UK

A team of low-cost underwater vehicles could cover an area quickly, e.g. for pollution detection and clearance and benefit from the advantages of formation control, for example it can reduce the cost, increase the robustness and efficiency. In previous work, we have investigated behaviour-based rules with fuzzy logic controlled priority weights for multi-UUVs team cooperation. The goal of this paper is to justify whether the behaviour-based rules can control the formation of the team when considering the dynamic manoeuvring model of a single real vehicle. In the meantime, fuzzy logic controllers are applied to update the priority weights for behavioural rules according to different situations that the vehicles meet in real time. The particular behavioural rules are designed to position the vehicles within the specified formations. The geometric configuration of the circle and line formations and the relationship between the teammates in the formations are described. The cooperative mission scenarios with line and circle formation are simulated and the results prove that the approach can potentially help to maintain the cooperative vehicles in a specified formation.

E-4.2: P144 **An Underwater Biomimetic Jellyfish Robot by Using IPMC**

SEONG WON YEOM, I.K. OH, Chonnam National University, Gwang-ju, Republic of Korea

Up to now IPMC (Ionic Polymer Metal Composite) has been discussed by various researchers, because IPMC has many attractive merits such as large bending deformation, light weight, low driving voltage, and softness of material to realize the biomimetic locomotion. Application fields of the existing IPMC actuators are limited due to the flat shape as beam, which is also a serious weakness for such actuation material. In this paper, a new concept of IPMC actuator concerning intended initial deformation is addressed to overcome the weakness of flat IPMC actuator. To obtain intended initial deformation, heat treatment was applied. A biomimetic robot that imitates jellyfish was developed by using intended bending IPMC actuator. The imitating actuation signal to imitate the real locomotion of a jellyfish efficiently was also developed by using the LabVIEW 7.1. The bell diameter and the buoyancy of the biomimetic jellyfish robot under various imitating signal was detected by using two laser sensors (LK301) and a micro-Load cell (LVS-5GA) in real-time. Although there are still certain problems to be resolved in power system and buoyancy, the designed jellyfish robot may possibly be a promising intelligent system that can materialize the biomimetic motion underwater.

E-4.3: P145 **Nano and Micromanipulators Based on Magnetic Bacterium**

M. IGNAT, G. ZARNESCU, National Institute of Electrical Engineering Researches-Advanced Researches, Bucharest, Romania

The paper presents a type of nano and micro manipulators which are based on the structure of a magnetic bacterium. Main interest is placed on the magnetic sensibility and flexibility of the the magnetosome chain of the magnetic bacterium. There are presented a theoretical study and analisys of the micromechanic circuit with elastic and damper elements, the micromagnetic circuit (with micromagnetic specific characteristics) and also the electromechanic analogy aspects of the magnetic bacterium. The authors propose some nano and micromanipulators based on the structure of the chain of magnetic bacterium which include the nano or micro magnetic particles. The calculation, electromechanical modeling and experimental of these nano or microstructures that work in the fluid medium are presented. There are evidenced the possible aspects on microrobotics and application field.

HOT POSTERS

A: HP01 **Spiropyran Modified Microfluidic Chip Channels for Photonically Controlled Sensor Array Detection of Metal Ions**

F. BENITO-LOPEZ, S. SCARMAGNANI, Z. WALSH, B. PAULL, M. MACKA, D. DIAMOND, Dublin City University, Dublin, Ireland

Microfluidic chips are particularly attractive for analytical purposes because they provide a convenient small platform for rapid analysis and detection.[1] Furthermore, spiropyrans dyes can be used as photonically controlled, self-indicating molecular recognition agents for the fabrication of sensors.[2] Here, we show how through integrating the beneficial characteristics of microfluidic devices and spiropyrans dyes, a simple and very innovative chip for on-line metal ion sensor array can be realised. The chip (4x3cm) consists of four independent 180 μm depth, polydimethylsiloxane (PDMS) channels. 1'-(3-Carboxypropyl)-3,3'-dimethyl-6-nitrospiro-[2H-1]-benzopyran-2,2'-indoline is covalently immobilised on the ozone plasma activated PDMS microchannel surfaces. Upon exposure to UV light, the transparent PDMS channels change to light purple colour because the spiropyran molecules of the surface undergo a heterocyclic ring cleavage that result in the formation of the highly conjugated merocyanine form. When stock solutions of several ion metals ($Ca2+$,$Zn2+$,$Hg2+$,$Cu2+$) are pumped independently through the four channels, different optical responses were observed for each metal.

[1]L. Basabe-Desmonts et al, Anal. Bioanal. Chem. (2008) 390:307-315
[2]R.J. Byrne et al, J. Mat. Chem. (2006) 16:1332-1337

A: HP02 **Properties of a Bending Sensor based on Galfenol Thin Film**

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$Fe_{83}Ga_{17}$ layers were sputtered on (20 x 2) mm² Si samples. The thickness was 1 μm on a bottom layer of 50 nm Ti. The intrinsic stress of the Galfenol layers averages about some 100 MPa. The texture of the Galfenol is a function of the underlying layer and has here a trend to (111) fiber texture. The stress σ and the coercive field strength H are in the rectangular sensor plane mainly oriented perpendicular to each other. The saturation magnetization is 1.45 T and the functions B(H) are quite linear between H_{max} = 1 Oe and 25 Oe. Therefore the relative permeability were calculated from the B(H) curve with H_{max} = 25 Oe. The absolute values of μ_r and the variation due to bending are a function of the texture and the film thickness. The $\Delta\mu_r$ of the investigated sensors are about 30 % for ε = 0,012%. On top of the Galfenol and a thin SiO_2 insulation layer a planar rectangular copper inductor was deposited galvanically. An unloaded resonance frequency of 5.73 MHz was measured. The sensor was glued on a (w x t x h = 10 x 2 x 100) mm³ titanium beam and bended by an external force applied at the beam end. The sensor worked properly without premagnetization. The electromechanical transducer model for a solenoid was developed.

A: HP03 **Dielectric and Piezoelectric Properties of PVDF/ZnO Flexible Composites**

C. DAGDEVIREN, M. GÜLLEROGLU, M. PAPILA, Sabanci University, Tuzla, Istanbul, Turkey

The focus of this study is to make flexible PVDF/ZnO fibrous composites and to investigate their dielectric and piezoelectric behavior. ZnO fibrous network are first produced by sintering of the precursor PVA/Zinc Acetate electrospun fiber mats. Composite making will then include dipping the ZnO fibrous mat into PVDF/DMF solution followed by hot-pres melt-casting. SEM images of these nanocomposites will be taken in order to see how fibrous network is affected during casting. PVDF/ZnO composite films will be characterized for dielectric properties by scanning a range of frequency and temperature. The dielectric measurements are performed by Hewlett Packard 4192A LF Impedance Analyzer. The results will be compared with data of pure PVDF films. Through-the-thickness piezoelectric properties of the PVDF/ZnO composite will also be investigated using MTI 2100 high resolution photonic displacement sensor.

A: HP04 **New Synthetic Inorganic Nanotubes For Innovative Technological Applications**

I.G. LESCI, I. FOLTRAN, E. FORESTI, G. FRACASSO, N. ROVERI, T. ZUCCHERI, University of Bologna, Bologna, Italy

Stoichiometric chrysotile tubular nanocrystals have been synthesized as possible starting materials for applications toward the nanotechnology science. Chrysotile nanocrystals have been synthesized under controlled hydrothermal conditions and have been characterized by chemical, morphological, structural, spectroscopic and microcalorimetric analyses. They show a constant “cylinder in cylinder” morphology constituted by two or three concentric subunits. Each single nanocrystal has a tubular shape of about 49 ± 1 nm in outer maximum diameter and a hollow core of about 7 ± 1 nm. Structural investigation carried out on the X-ray powder pattern allowed to improve the structural model proposed for chrysotile mineral samples. Synthetic chrysotile crystallizes in the monoclinic Cc space group with a = 0.5340(1) nm, b = 0.9241(1) nm, c = 1.4689(2) nm, δ = 93.66(3)°. Recently, mineral chrysotile appears as a very suitable for nanowires preparation, filling the inner nanometer-sized cavity of their densely packed bundles of multiwall hollow tubular fibers with a proper material. With the aim at preparing the first synthetic inorganic nanowires, stoichiometric synthetic chrysotile nanotubes have been partially filled with metals and semiconductors synthesized nanoparticles by capillarity effect at room temperature and pressure using a suitable organic solvent.

A: HP05 **A joint Empa-ETHZ Initiative for Analysis and Development of Compliant Systems**

L.F. CAMPANILE, A. HASSE, M. SAUTER, Empa, Dübendorf, Switzerland; E. MAZZA, ETHZ, Switzerland

Compliant systems are a peculiar class of mechanical systems designed to produce controllable large deformations by exploiting structural flexibility. They can be seen as a blend between structures and traditional mechanisms. Compared to conventional kinematics, compliant systems offer large advantages including absence of wear and backlash, reduced noise, absence of particle release, easier maintenance and manufacturing, better scalability and accuracy. Even if compliant solutions are state of the art in small-scale, precision equipment, they are strongly underrepresented in other application fields, mainly due to their inherent complexity in analysis and design. In order to contribute to closing this gap, a joint research group was build at Empa (Swiss Federal Laboratories for Materials Testing and Research) and ETHZ (Swiss Federal Institute of Technology Zurich). In close collaboration with industrial partners, the group is investigating and developing compliant solutions for products of several industrial sectors (e.g. surgery instrumentation, sport articles, eye glasses and prostheses). Some representative examples are shown in the poster.

A: HP06 **Natural-Fiber-Reinforced Polymer Composites in Automotive Applications**

A.R. CARAMITU, V. NICOLAE, L. AVADANEI, S. COTESCU, M. POPESCU NICUSOR, I. PAUNA, M. BADITA, G. ANGHELACHE, V. LAZAR, I. ION, INCDIE ICPE - CA, Bucuresti, Romania

The application of natural fibre reinforced plastics today is a nationally and internationally fast growing market with high yearly growth rates. The production processes of injection molding and extrusion technique are seen as a market of the future, especially for small and medium-size suppliers for the automobile-, building- and furniture industry. Wood- or natural fibre reinforced plastics offer -because of their special properties- a multitude of economical, technical and ecological advantages as compared to the conventionally reinforced or filled plastics as well as compared to wood. Wood reinforced PP is used as a substitute material in construction of buildings because it allows great freedom in design and resists weathering and splintering. For quite a number of years natural fibre reinforced materials have been in use in the automobile industry in mass production because of their light weight as well as their acoustical damping qualities. Besides wood fibres, flax, hemp and jute, other exotic fibres are used in combination with thermosets or thermoplastic matrix materials. The influence of additives, for instance

coloring agents, stabilizers, coupling agents, processing aids, on the physical and mechanical values are tested in cooperation with the raw material manufacturers. The paper studies the effect of the properties characteristic to the wood fibres in the properties of the polypropylene got by compounding.

A: HP07 **Preparation and Characterisation of Dense TiO_2 Ceramics**

A. PAVLOVA, L. BERZINA-CIMDINA, J. LOCS, D. LOCA, Riga Technical University, Riga, Latvia; J. BOSSERT, Fr. Schiller University Jena, Jena, Germany

Today scientists have focused their attention on new specific TiO_2 properties, which result from oxygen and titanium ratio in ceramic. Recently such TiO_2 applications as implantable biomaterials in medicine and photocatalysts in purification of waste water become very significant. High temperature vacuum treated titanium oxide ceramics become biologically active and decrease microbiological water pollution when used as electrodes in electrochemical water treatment. In most of these cases highly dense ceramics are requested. TiO_2 low-temperature modification anatase, TiO_2 high-temperature modification rutile and anatase transformed to rutile on the site in lab was used during the investigation. Different additives were used to improve particle packing and increase green density of pressed pellets as well as following sinter density. During the investigation it was found that green density of the samples depends not only on powder characteristics such as particle size distribution, grain size, mineralogical composition of raw material, quantity and nature of additives used in mass preparation procedure but also on kind and magnitude of compaction, temperature increase and holding time during the calcinations as well as sintering conditions.

A: HP08 **Thiophene Containing Polyaromatic Hydrocarbons**

C.J. MARTIN, S.D. PERERA, S.M. DRAPER, Trinity College Dublin, Dublin, Ireland

In this poster we detail recent investigations into the formation of new sulfur-based polyaromatic hydrocarbons. These form an extension to our previous work on a new class of polyaromatic, nitrogen-containing compounds, the “N-Heterosuperbenzenes”. Through modification of our developed synthetic strategy[1] we have successfully incorporated thiophene rings into the periphery of the polyphenyl precursors and studied their influence on key chemical modifications such as dehydrogenation, carbon-carbon bond formation and polymerisation. Building on the work of Tovar[2] and McCullough[3] we show the unique consequences of steric bulk in the polyphenylene precursor; and examine how changes in the dehydrogenation conditions alter the aromaticity of the final products. Strategies to control the polymerisation and dimerisation reactions of the precursors have been developed. Investigations into the photochemical and electrochemical properties of the precursors and the new fused aromatics will be presented along with their possible application in metal coordination complexes and molecular switching devices.

[1]*S.M. Draper et al, Journal of the American Chemical Society 2004, 126, 8694-8701;* [2]*R.D. McCullough, Advanced Materials 1998, 10 (2), 93-116;* [3]*J.D. Tovar et al*

A: HP09 **Controlling the Mechanical Response of Cellular Structures by Using Magnetic Field**

L. SORRENTINO, M. AURILIA, S. IANNACE, IMCB-CNR, Portici, Napoli, Italy

Polymeric foams with different concentrations of Fe particles were prepared. The effects of magnetic field (MF) during the foaming process was analyzed. Mechanical properties and cell morphology of samples foamed with and without the application of the MF were compared. As revealed by optical and electronic scanning microscopy the magnetic field induced an alignment of Fe particles. According to the compressive mechanical tests the foams produced showed an enhancement of the properties with the increase of particles concentration. The comparison of samples produced by using high weight content of Fe particles (up to 30wt%) showed that the mechanical response in the magnetic field was enhanced by the particle alignment, while at lower Fe content the contribute of the particles alignment was not evident. The development of cellular structures produced by applying a magnetic field during the foaming process allows the design of anisotropic structures with cell morphology and mechanical properties tailored for specific applications.

A: HP10 **MHz Oscillations and Switching in Polyaniline Nanocomposite Nanofibrils**

J.J. LANGER, S. GOLCZAK, L. SOJKA, K. LANGER, A. Mickiewicz University at Poznan, Srem, Poland

Switching effect in polyaniline is known since the middle of nineteen-seventies[1], but it is still a mysterious behavior[2, 3]. We have examined polyaniline nanocomposites formed as micro- and nanofibrils randomly oriented. Polyaniline nanoparticles were encapsulated and ordered along the main axis of micro- and nanofibrils. Following observations of instabilities in the electrical current and switching in polyaniline[1, 2], we performed experiments with nanostrucutred material aiming in analysis of signals recorded with the digital oscilloscope. Above a threshold voltage, we found generation of MHz frequency oscillations (about 5 MHz) with a specific sawtooth wave time profile, typical for a relaxation oscillator. Taking into account a dynamic negative resistance, the behavior is related to Gunn effect. A high increase in the electrical current and the sawtooth time profile of oscillations seem to be owing to fast switching between low-conducting and highly-conducting state in the nanostructured polyaniline[2].

[1]*J.J. Langer, Solid State Communications, 26 (1978) 839;* [2]*H.X. He, X.L. Li, and N.J. Tao, L.A. Nagahara, I. Amlani, and R. Tsui, PHYSICAL REVIEW B 68, 045302 (2003);* [3]*Kwanghee Lee, Shinuk Cho, Sung Heum Park, A.J. Heeger, Chan-Woo Lee and Suck-Hyun Lee, Nature 441, 65-68 (2006)*

A: HP11 **Tailored Magnetic Nano Particles on Carbon Nitride Nanotubes**

JUNG WOO LEE, YOON JEONG CHOI, KYUNG MIN CHOI, YEOB LEE, SAJI AUGUSTINE, RAVINDRANATH VISWAN, JEUNG KU KANG, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea

Nano-sized particles (NPs) are attracting 0-D materials for their enhanced novel properties in electrical, optical, and magnetic applications comparing to their bulk states. In addition, unique characteristics of carbon nanotubes (CNTs) as 1-D materials have led to interdisciplinary investigations. Furthermore, the CNTs have been used as a support material for the dispersion and stabilization of metal and semiconductor NPs for their large chemically active surface and thermal stability. On that account, the hybridization of NPs and CNTs brought about synergistic effects in catalysis, sensors, hydrogen storage, and nano-electronics both in experimental and theoretical ways. We present decorating magnetic NPs directly on the CNNTs using liquid polyol processes. The CNNTs were used as grown state without any further surface treatment for the fabrication of magnetic NPs. The type, size and dispersion of NPs show the tailored magnetic properties. The resulting superpara-magnetic NPs-CNNTs hybrid materials are promising in sensor, biomaterial, drug delivery and composite applications.

A: HP12 **Synthesis and Characterization of Porous Carbon Nitride Spheres**

SE YUN KIM[1, 2], WON HYUK SUH[1], JUNG HOON CHOI[2], JEUNG KU KANG[2], GALEN D. STUCKY[1], [1]University of California, Santa Barbara, CA, USA; [2]KAIST, Daejeon, Republic of Korea

Carbon nitride materials having nanopores (<1 nm) could advance various fields such as gas separator and gas storage media. Since there is an energy barrier for the molecule penetration through the nanopores (<1 nm), a selective gas would be entered into the pore at a specific condition which makes it possible to separate one gas with others or store a gas. Here we report microporous carbon nitride spheres (CNS) which have the maximum surface area of 995.3 m2/g. Melamine-Formaldehyde resin is used as the source of carbon and nitrogen. Most of the pores in CNS have diameters in the range of 6 to 8 Å which could give a penetration energy barrier to a certain molecule. In addition, the maximum hydrogen storage capacity of the carbon nitride spheres is 1.9 wt% under 77 K and 1 atm.

A: HP13 **Mocvd Deposition of Vanadium Oxide Films with a Novel Vanadium (III) Precursor**

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Vanadium forms several oxides with a wide variety of properties and technological applications in the field of catalysis, solid state batteries, electrochromic devices and infrared modulators. The ability of vanadium atoms to possess multiple oxidation states and the facile conversion

between oxides of different stoichiometry makes the synthesis of pure vanadium oxide phases difficult. Vanadium pentaoxide (V_2O_5) and vanadium dioxide (VO_2) are the two main oxide phases and several chemical and physical methods have been used to obtain such oxides: among vapour phase techniques CVD offers the opportunity of metal oxide films with good quality and uniformity. In the CVD deposition of vanadium oxide VO_x films the usual precursors are vanadium chlorides like VCl_4 and $VOCl_3$[1], vanadium alkoxide like $VO(O^iPr)_3$[2] and vanadium b-diketonates like $VO(acac)_2$,[3] which are commercial products. However since the use of vanadium chlorides may imply technological problems and in a recent study it has been evidenced that the use of b-diketonate derivatives like $VO(acac)_2$ determined a substantially higher carbon contamination of the VO_x films with respect to vanadium alkoxides like $[VO(O^iPr)_3]$[4] in our research of new suitable CVD precursors for the deposition of vanadium oxide VO_x films we focused our attention on vanadium alkoxides and in particular on the vanadium (III) alkoxide $V(ODiMe)_3$, DiMeO = $(O(CMe_2)CH_2OMe)$. This complex is characterized by an appreciable volatility (55 °C/1.5 Torr)[5] and it contains vanadium (III) whose oxidation can be carried out under control using appropriate deposition conditions. Unfortunately no synthetic detail was reported what prompted us to set up a preparation method. Hence in this paper we report the synthesis and characterization of $V(ODiMe)_3$, its successful use as MOCVD precursor for the deposition of pure VO_2 and V_2O_5 films and their characterization by means of Rutheford Back Scattering (RBS), X-Ray Diffraction (XRD) and IR spectroscopy.

[1]M.N. Field, I.P. Parkin J. Mater. Chem. 2000, 10, 1863; [2]H. Groult, K. Le Van, A. Mantoux, L. Perrigaud, P. Doppelt, J. Power Sources 2007, 174, 312; [3]M.B. Sahana, M.S. Dharmaprakash, S.A. Shivashankar, J. Mater. Chem. 2002, 12, 333; [4]S. Mathur, T. Ruegamer, I. Grobelsek, Chem. Vap. Deposition 2007, 13, 42; [5]W.A. Herrmann, N.W. Huber, O. Runte, Angew. Chem. Int. Ed. Engl. 1995, 34, 2187

A: HP14 **Novel Topological Materials Based on the Self-assembling Properties of Polyrotaxanes**

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A polyrotaxane (PR) molecule is a pearl necklace which consists in the stable supramolecular assembly of macrocycles (a-cyclodextrins, a-CDs) along a template polymer chain (polyethylene oxide, PEO). Concentrated PR solutions in dimethyl sulfoxide (DMSO) exhibit a physical gelation when cooled down from 45 °C to room temperature. This phenomenon is thermo-reversible and due to the formation of weaker interactions not only between a-CDs but as well between naked PEO segments, i.e. the ethylene oxide units of the PEO chains which are not covered by a-CDs: - We demonstrate using Small Angle Neutron Scattering measurements that organized a-CD nanocylinders are formed through intra- and inter-molecular hydrogen bonds between a-CDs. Using an appropriate fitting, we show that these nanocylinders, independently of the number a-CDs threaded onto a PEO chain, result from the assembly of roughly 61 rod-like segments, the rod-like segments consisting in 6-7 weakly stacked a-CDs along a PEO chain; - Moreover we prove using Wide Angle X-ray Scattering measurements that crystallites of naked PEO segments are obtained, PEO being in bad solvent conditions in DMSO at room temperature. The a-CD nanocylinders will be chemically cross-linked to fix in situ their geometry and form nanoscale fillers.

A: HP15 **pH-switchable Supramolecular "Sliding" Gels Based on Polyrotaxanes of Poly(ethyleneimine-b-ethylene Oxide-b-ethyleneimine) Block Copolymer and Cyclodextrin: Synthesis and Swelling Behaviour**

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A new type of pH-switchable supramolecular "sliding" gel has been synthesized.[1] It is based on polyrotaxanes of poly(ethyleneimine-b-ethylene glycol-b-ethyleneimine), (PEI-b-PEG-b-PEI) block copolymer and a-cyclodextrin (a-CD). In the case of polyrotaxane having block copolymer as template chain, it has been demonstrated in the literature that sliding motion of CDs can be activated by changing conditions such as pH, temperature or solvent condition.[2, 3] In this work, we extend this concept to supramolecular sliding gels where the sliding motions of the CD crosslink points are switched under an external field (pH). A series of three dimensional supramolecular networks with different crosslinker amounts was obtained by inter-molecular reaction between a-CDs belonging to two different polyrotaxanes via 1, 1'-carbonyldiimidazole. The pH studies showed higher gel equilibrium swelling at acidic than at basic medium. This behaviour has been explained by the ionization of EI units leading to the sliding motions of a-CDs from PEI to medium PEG block.

[1]K. Karaky, C. Brochon, G. Schlatter, and G. Hadziioannou, Soft Matter (accepted); [2]A. Harada, Acc. Chem. Res., 2001, 34, 456; [3]D. Whang, K.M. Park, J. Heo, and K. Kim, J. Am. Chem.Soc. 1998, 120, 4899

A: HP16 **Multifunctional Wear and Corrosion Resistant Decorative Nanostructured Carbon-base Coatings**

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Multifunctional wear and corrosion resistant decorative nanostructured carbon-base coatings were prepared by PACVD (Plasma Assisted Chemical Vapour Deposition) method on steel substrates. As the multifunctional coating the carbon-base, particularly DLC (Diamond-Like Carbon) nanolayer, was chosen. For the deposition of adherent DLC coating on steel substrate a very thin Si-O-C interlayer was applied in some cases. Deposition of DLC coating and Si-O-C interlayer was performed using dc plasma without additional heating and with the HMDSO (hexamethyldisiloxane) and methane as precursors. During coating growth with increasing of thickness of DLC nanolayer the colour of nanolayer is changed. Whole spectrum of attractive colours is obtained, what is possible to use to decorative purposes. Effect of film thickness on colour is following: The reference specimen (bare stainless steel) has a bright metallic sheen. In the order of increasing thickness, the DLC films produced by PACVD have colours as follows: dark violet at ~75 nm; medium blue at ~130 nm; golden light at ~170 nm; deep rose pink at ~240 nm; golden brown at ~320 nm; and soot black at ~1200 nm. Decorative coatings must be adherent and hard for good wear resistance. Adhesion was tested by scratchtester and microhardness was determined by nanoindentation. The microhardness data were thickness-dependent, influenced by substrate. The highest measured value was 23 GPa. Tribology of the coatings was assessed by wet friction tests.

A: HP17 **Magnetic Properties of Ultrafine Non-interacting γ-Fe_2O_3 Nanoparticles Dispersed in a Silica Matrix**

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γ-Fe_2O_3/SiO_2 nanocomposite containing 15% in weight of maghemite has been synthesized by the sol-gel method. TEM studies shows that the estimated average particle size of spherical nanoparticles is around 3 nm with narrow size distribution, whereas SAED confirmes the formation of the maghemite phase. The magnetic properties investigations by DC magnetization and AC susceptibility measurements indicates behavior typical of superparamagnetic system, such as existence and frequency dependence of blocking temperature, irreversibility of ZFC and FC curves, and emergence of magnetic hysteresis below blocking temperature $T_B = 8K$. The ZFC-FC curves stay separated up to the irreversibility temperature $T_{irr} = 25$ K. Below T_B the curves split significantly: the ZFC magnetization sharply decreases while the FC magnetization steadily rises. The shift of the magnetic hysteresis loop after field cooling were also observed thus revealing exchange anisotropy effects due to the exchange coupling between the particle core and surface (exchange bias). The quantitative analysis of the DC magnetic data indicates that system consists of an ultrafine single-domain nanoparticles with narrow size distribution, whereas AC data points to the non-interacting system.

A-10: HP01 **Shape Memory Behavior in Some (Ti,Zr,Hf)50(Ni,Cu)50 Alloys Elaborated by Glass Devitrification (Ribbons)**

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A series of multielementary AB-type shape memory alloys, quaternary (Ti,Hf)50(Ni,Cu)50 and quinary (Ti,Zr,Hf)50(Ni,Cu)50, have been produced by means of the melt-spinning (ribbons), twin-roll casting (strips) and injection casting (bars) techniques. The glass forming ability

(GFA) has been investigated by means of calorimetric studies (DSC, DTA), microscopic observations (TEM/SAD, SEM, XRD, optical microscopy) and deformation tests (bending, tension). The glass transition (Tg) and crystallization (Tx) temperatures with the corresponding supercooled liquid window $\Delta T = Tx - Tg$ have been determined for the mentioned rapid solidification techniques. GFA is found to be strongly dependent on specific ratio between the constituent alloying elements, with effective element A containing mixture of the early transition elements A=(Ti,Zr,Hf) and effective element B containing mixture of the late transition elements B=(Ni,Cu), respectively. We report a choice of the alloy composition, which is amorphous after fast cooling and recovers a reversible B2↔B19↔B19' martensitic transformation sequence and demonstrates shape memory and superelastic properties (up to MS~400 K, AF~450 K in the bulk material versus MS~250 K, AF~350 K in the ribbon and strip states) after an adequate thermal treatment.

A-11: HP01 **Electrical Conductive Composite-filaments**

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During the last years, worldwide, researchers have focused their attention on the area of textiles with electrical functions. The reason for such interest in this field is due to the potential to develop textiles that could sense, react and adjust in a controllable way to environmental conditions or stimuli. Nowadays, the execution of these functions is realized through microelectronic devices and electrical wiring that are integrated in textile structures. Alternatives routes are needed to make truly wearable electronic textiles. The objective of the work is to develop conductive yarns to be used as electrical wiring in e-textiles with the typical mechanical properties of a textile yarn. To accomplish this, conductive polymer composites based on polymers typically used in the textile industry (Polypropylene) with electrical conductive fillers (carbon black, carbon fibres, carbon nanotubes) will be developed and studied. The novelty of this work resides in creating oriented filaments using traditional fiber processing technique together with a specially designed drafting machine. This poster will present the analysis performed to evaluate the impact of the fillers and composite-filaments concentration and orientation on electrical conductivity. Furthermore, mechanical properties and characterization of the composite-filament morphology will be also investigated to discern the structure-property relationship of the different compounds.

A-11: HP02 **Molecular Encapsulation of Textiles**

B. VONCINA, S. KRESEVIC VRAS, V. VIVOD, D. JAUSOVEC, University of Maribor, Maribor, Slovenia

In textiles, the major interest in microencapsulation is currently in the application of durable fragrances, phase-change materials, antimicrobial agents, and drug delivery systems. Encapsulation can be divided into two groups: microencapsulation and molecular encapsulation. Microencapsulation is described as a process of enclosing the micron-size particles of solids or droplets of liquids or gasses within an inert shell which, in turns, isolates and protects them from the external environment. Molecular encapsulation involves all intermolecular interactions where no covalent bonds are established between the interacting species. The majority of these interactions are of the host-guest type. The cyclodextrins (CD) are the most important from among all potential hosts, they have a ring structure, which allows them to act as hosts and form inclusion compounds with various small molecules. Such complexes can be formed in solution, in the solid state, as well as when cylodextrins are linked to a textile surface where they can act as permanent or temporary hosts to those small molecules that provide certain desirable attributes such as fragrance and antimicrobial activity. In our research we have grafted beta-cyclodextrin (b-CD) onto various textile materials using a polyfunctional reagent 1,2,3,4-butanetetra-carboxylic acid (BTCA). We prepare nano-encapsulated textile materials with increased adsorption capacity and with delayed release of active compounds.

A-11: HP03 **Functional Properties of Electroless Silver Plated Cotton Fabric via Low-temperature Plasma Pre-treatment**

S.Q. JIANG, X.M. TAO, C.W.M. YUEN, C.W. KAN, L. ZHANG, P.S.R. CHOI, The Hong Kong Polytechnic University, Hong Kong, China

Silver-plated textiles have exhibited their specific features not only on functional properties but also on decorative effects. In this study, the effects of silver-plating on the properties of cotton fabric were investigated. Silver plating technique was applied on cotton fabric to improve its functional properties. Silver plating was conducted in this research with the aid of oxygen and argon low-temperature plasma (LTP) pre-treatment on the cotton fabric to manipulate the thickness of the coating. The silver-plated cotton fabric was characterized in terms of its mechanical and functional properties. The micro-roughness formed on the cotton fabric after the LTP pre-treatment facilitated the silver particles depositing on the surface of cotton fabric. It has been observed that the thickness and weight of silver-coated cotton fabric had been increased significantly, which was attributed to the surface modification of the cotton fabric due to the LTP pretreatment. As a result, the anti-bacterial and anti-UV properties of the silver-plated cotton fabric and the water repellent ability of the cotton fabric were improved after the silver-plating process. In addition, the tensile strength of the fabric was enhanced.

A-12: HP01 **Ionic Polymer-Metal Composite Actuator Behaviour in Two Novel Configurations**

M. KHAZRAVI, A. DEHGHANI, University of Leeds, Leeds, UK

IPMCs are one of the most promising smart actuators to replace traditional actuators for some specific applications particularly in the micro-nano scales. IPMC actuator's shape and configuration have a dramatic effect on the actuation parameters. While the behaviour of IPMCs as a single fixed end strip actuator (cantilever) has been widely studied since the early 80's, its behaviour in other configurations is relatively unknown. This paper presents work carried out in order to reconfigure these actuators for some new applications. The first configuration is when both ends of an IPMC actuator strip are fully constrained, in both the actuator plane and the normal direction. In this case the displacement and force measurements at the mid point of the strip are presented. The results of a series of experiments show the behaviour of the actuator in this configuration and using these results some models have been proposed. The second configuration is when only one end of the strip is fixed and the other end is constrained in the normal direction with respect to the plane of the actuator strip. A series of experiments were also carried out to explore the IPMC actuator behaviour in terms of maximum displacement and force generated in this configuration. The behaviour of the IPMC actuator in these two configurations is also investigated by studying the internal stresses in the IPMC structure.

B: HP01 **Accurate, Fully Vectorial Computer Model of the Acousto-optical Bragg Diffraction**

G. MIHAJLIK, P. MAÁK, A. BARÓCSI, P. RICHTER, Budapest University of Technology and Economics, Budapest, Hungary

We present a novel numerical model that simulates the anisotropic Bragg diffraction in optically uniaxial acousto-optic devices. We use a nonparaxial vectorial beam propagation method, adapted to optically inhomogeneous medium and non cylindrical symmetric field distribution. We exploit the assumptions that the field is monochromatic and that the deviation of the dielectric tensor due to the photoelastic effect is small related to the average value. The principal idea of our solving method is that we solve the wave equation along a properly selected spatial direction e.g. the bisetrix of the angle formed by zero and first diffracted orders. Since the refractive index inhomogeneity caused by the acoustic wave is relatively small, we can consider it as a perturbation and iterate to the exact solution. The accuracy depends on the relative step size of the vectorial BPM. The results converge rapidly to fulfill energy conservation (up to 10^{-3} with less than hour computational time). We show that the calculated angles, the space dependent intensity and polarization variations of the diffracted beams agree accurately with those predicted by theory and experiment, under Bragg diffraction condition, in various acousto-optic configurations.

B: HP02 **Experimental and Theoretical Examination of the Phase Transfer from the Acoustic to Optical Waves during Strong Anisotropic Bragg Diffraction in Acousto-optic Devices**

M. VERESS, P. MAÁK, P. RICHTER, Budapest University of Technology and Economics, Budapest, Hungary

A wide variety of signal processing applications requires control of the phase of the optical waves diffracted within acousto-optic interaction. The optical phase may be directly controlled with the acoustic phase, but limitations occur in the case of commonly used AO devices, based on strong anisotropic AO interaction. This problem is of particular importance e.g. in optical filters used to compensate the nonlinear frequency dependent phase components of ultrashort pulses, to

eliminate pulse lengthening and distortion. In our study we present measurement and theoretical calculation of the phase shift of a laser beam diffracted in an AO deflector. The optical phase is a function of the acoustic and optical frequency and of the relative spatial positions of the interacting beams. We measured the phase shift with a heterodyne setup, where we measured the phase of the heterodyne signal relative to a fixed reference. We found that the phase shift introduced by the AO crystal is linear with the sound frequency, its gradient is of 10-20rad/MHz and depends mainly on the optical beam's distance from the transducer. We show that this phase shift can be derived theoretically from the momentum matching condition that must be fulfilled at each optical and acoustic frequency pair.

B: HP03 **Development of Cavity Mirror Enhanced Raman Spectroscopy (CMERS)**

TOSHIHIRO ONA, SHUICHI MURAKAMI, Kyushu University, Fukuoka, Japan

Environmental condition analysis becomes increasingly important because of both national security and health care. It demands a high sensitive, rapid and easy on-site technique. However, the conventional analysis requires tedious sampling, target compound concentration and mass analysis. Surface enhanced Raman spectroscopy is a novel method to analyze low concentration of aqueous solution using nano-fabricated plasmonic metal structures. However, the sensitivity is limited to ppb-level without using a microscope and is not enough for bulk samples in environmental condition analysis. Here we show cavity mirror enhanced Raman spectroscopy (CMERS) suitable for ppt-level analysis for aqueous solution. It comprises of several nano-fabricated plasmonic metal structures on glass plates perpendicular to laser beam with mm-level spaces, which transparent laser beam partially. By CMERS, we achieved significant enhancements of over 200,000 times compared to normal Raman spectroscopy and over 100 times to SERS in case of pyridine. We successfully applied this new method to dioxins, pesticides, heavy metal, and uric acid solutions. CMERS requires only conventional Raman spectrometer towards on-site high sensitive and rapid environmental condition analysis.

B: HP04 **New Magnetron Sputtered Stainless Steel Nitride Cermet Solar Absorber Coatings**

REI-CHENG JUANG, YONG-JIN YE, SHIAU-WEI CHANG, WEN-CHIEN CHEN, Industrial Technology Research Institute, Hsinchu, Taiwan

This paper presents a new method for sputtering solar selective absorber coatings. Stainless steel/stainless steel nitride (SS/SS-N) cermet thin films were coated by RF magnetron reactive sputtering under varied nitrogen gas flow ratios. In the present study, a stainless steel material is used as one-target sputter to manufacture a solar selective absorber film having good solar absorptance of 0.91 and low thermal emittance of 0.06. The results show considerable and stable usefulness of the sputtering process due to the anti-oxidation and single target. Optical constants n and k have been determined by Spectroscopic Ellipsometry for cermet composite in a reactive gas flow from 0% to 50%. According to the different nitrogen content of the thin films, we use a different oscillator for the analysis. When the nitrogen gas flow achieved 10%, the sputtered films had a significant transformation from metal to cermet properties. At nitrogen gas flow above 17.5%, a dielectric anti-reflection layer is obtained. A solar absorptance of 0.92 was derived theoretically for a selective solar-absorbing three-layer, which shows that the experimental result agreed well with the theoretical prediction.

B: HP05 **Hybrid Electrochromic-liquid Crystal Materials for Applications in Electrooptical Devices**

A. VINUALES, C. POZO-GONZALO, J.A. POMPOSO, H. GRANDE, CIDETEC-Centre for Electrochem. Technologies, San Sebastian, Spain

The research in new hybrid electrochromic-liquid crystal materials which exhibit new electrooptic properties is an important breakthrough within the electroactive materials field. In the present work, two different strategies have been followed with the purpose of attaining hybrid electrochromic-liquid crystal polymers. The first one has consisted of the attachment of a mesogenic group to EDOT-MeOH monomer (mixture of 2,3-dihydrothieno[3,4-b][1,4]dioxin-2-yl and 3,4-dihydro-2H-thieno[3,4-b][1,4]dioxepin-3-ol) while the second strategy has been the electrochemical polymerisation of EDOT-MeOH and the EDOT derivatives bearing a mesogenic group, in a nematic or chiral nematic liquid crystal electrolyte. The polymers thus synthesized are expected to assume the texture of the liquid crystal media. The polymer films have been fully characterised in order to analyse the influence of the different reaction parameters on the final optical properties: transparency, optical contrast, cyclability and hybrid electrochromic-liquid crystal behaviour.

B: HP06 **Light-controlled Partitioning of Spiropyran between Polar and Non-polar Solvents**

C. BRACKEN, A. RADU, M. O'TOOLE, M. VASQUEZ, D. DIAMOND, Dublin City University, Dublin, Ireland

Photoswitchable compounds (i.e. spiropyran (SP) and spirooxazenes (SO)) are often studied as model cases for light-controlled sensing of heavy metals. They show metal ion binding abilities only upon irradiation with UV light that results with their transformation in so called merocyanine (MC) form. This complex with metal ions is effectively broken by illumination with green light. These systems have been utilized in light-controlled transport of heavy metals. Interestingly, there is limited number of studies of the transport of SP and SO. A light-induced change of aqueous solution composition without addition of any auxiliary chemicals or the change of temperature can open many new areas of application. We are particularly interested in utilizing of SPs and SOs as chaperones to enable light-driven transport of species of interest through phases of different polarity. In this work, we demonstrate initial work on understanding of partitioning of SP between non-polar solvents and water. Furthermore, we studied the influence of the presence of amino acid in the water layer on the transport of SP. All experiments were performed in in-house made cell that utilizes light emitting diodes (LEDs) as both light sources and detectors and allows simultaneous measurements in both phases.

C: HP01 **Embedding Intelligence for RTM Process Monitoring and Control**

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In the last decade liquid molding technologies have attracted increasing interest in the field of polymer composite manufacturing in general and it is one of the most studied topics in the aeronautical and naval sectors. A key factor in RTM processing is the development of the right flow front in order to ensure the right impregnation of the part. The flow front is affected by many parameters as: the resin pressure and velocity, the preform permeability, the mold shape, the injection and venting gate location etc. In order to overcome these difficulties we present in this work a technique to monitor and control resin flow front that can be easily adopted in VARTM or RTM light process. The technique consists in embedding linear capacitive sensors which provide the position of the moving flow front. The embedded capacitor consists of two parallel wires while the resin, between the wires, acts as a moving dielectric which changes the capacity values. Therefore the position of the resin is obtained from the measured capacity variation. In order to validate the proposed methodology the sensor has been characterized and the obtained characteristic curve showed a quasi-linear trend. Monitoring in parallel all the sensors it is possible to follow the flow front. An appropriate software system will be developed in order to visualize, on line, the resin movement. The shape of the resin front could be modified, if necessary, acting locally with controlled injectors.

C: HP02 **Electroactive Pressure Sensors for Smart Structures**

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A hardware-software interface for smart electroactive pressure sensors has been designed with the objective of providing a low power consumption and high performance impact monitoring system,integrated in the structure. The interface is specifically designed for its use with Ikerlan-Cidetec patented distributed pressure sensors, based on conductive polymers, used as electroactive materials on flexible plastic substrates. Their low cost and flexibility make them suitable for placing on large surfaces. The smart sensor integrates a microprocessor, a radio chip and a complete analog front end based on a period-modulated oscillator. The software developed implements new interface applications for this hardware in TinyOS. The response of the sensor, on both loading and unloading, to diferent impact energies first, and then to different probe stiffnes is presented. The behaviour of the sensor to impact is also compared to the response in static, and the different factors affecting the sensor response in both conditions are described. Comparing and contrasting the sensor signal with that of an impact pendulum shows that the sensor is suitable for measuring impact in both flexible and rigid structures.

C: HP03 **Linking the Impact Force History with Residual Mechanical Characteristics and Ndi - A Smart Way to Perform SHM in Composites**

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Structural integrity monitoring (SHM) is a continuously challenging subject, especially when composite structures, by nature prone to a wide range of damages during service life, are used in high tech applications. One of the most feared events is low velocity impact, with consequences that may become further serious when the impacted part is loaded in fatigue. Few authors made a link between the force history recorded during the event and the damage level occurred in the impacted area. The authors put in evidence a clear link in this matter in a variety of layered composite materials: GFRP, CFRP, sandwiches and hybrid composites (ARALL or GLARE type). The link was assessed by evaluating the residual mechanical performance and by nondestructive inspection (NDI) by ultrasonics, infrared thermography (IRT) and guided waves on the impacted samples, sometimes with a follow up when additional fatigue loading took place. As force history was recorded so far in laboratory conditions, another approach must be in view, which can fulfill, for increased reliability, recording of low velocity impact events and post-event NDI. The use of PZT and/or optical fibres is the most promising, due to relative low cost and noninvasive mounting on/in the composite. The possibility to achieve on-line SHM using such sensor architecture and appropriate software is immediate and gives another element of high interest to this issue.

D: HP01 **Development of Cell-based Quantitative Evaluation Method and Instrument on Personal Therapeutic Potential of Cancer Drugs for Apoptosis by High Precision Surface Plasmon Resonance Sensor**

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In vitro rapid and quantitative cell-based assay is demanded to verify the efficacy prediction of cancer drugs since a cancer patient may have unconventional aspects of tumor development. Here we show the rapid and non-label quantitative verifying method and instrument of apoptosis for cancer drugs by reaction analysis of living cancer cells cultured on a sensor chip with a newly developed high precision (50 ndeg s-1 average fluctuation) surface plasmon resonance (SPR) sensor. The time-course cell reaction as SPR signal change rate for 5 min from 35 min cell culture with a drug was significantly related to cell viability indicating apoptosis by caspase-3 assay. By the detection of fluorescence by specific probes, SPR signal was independent to cell membrane potential and cytosolic pH but dependent to the nano-order potential decrease in inner mitochondrial membrane potential. The results obtained are universally valid for various cancer drugs mediating apoptosis through different cell-signaling pathways even combined use by various pancreatic cancer cell lines. This system towards the application to evaluate personal therapeutic potentials of drugs including pharmaco-dynamic interactions using cancer cells from patients in clinical use.

D: HP02 **Fabrication of a Microfluidic Device for the Detection of a Specific Biomolecule**

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Mutation and aggregation of superoxide dismutase (SOD) are reported as one of the causes of amyotrophic lateral sclerosis (ALS). To detect SOD1 protein from the motor neuron, surface plasmon resonance (SPR) analysis was adopted due to its advantages in the in-situ biomolecular recognition by surface analysis without labeling. For the patterning of protein antigens at Au surface for use in SPR imaging experiments, microfluidic devices were fabricated with polydimethylsiloxane (PDMS) by replica molding method. They were designed for the solution to flow by capillary force only without using any additional pumping equipments or flow controllers. Performance of microfluidic devices was verified by the simple microfluidic experiments, and multiple protein-patterned sensor surfaces were constructed by using these microfluidic devices.

D: HP03 **Polysiloxane Coatings on Biomedical Micro Devices: Plasma Etching and Surface Modification**

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The mechanical and chemical properties of polysiloxanes make this polymers very attractive coating materials for implantable micro devices (e.g cochlear implants). The specific chemical structure of silicones makes their processing more difficult than that of other polymers. Silicone elastomers can be effectively etched in fluorine-based plasma. Nevertheless, there are some urgent challenges we are facing e.g. relatively low etch rate, etch profile and morphology control problems or presence of post-etch residues on the surface. We investigated the plasma processing of polysiloxane using fluorine-based chemistry ionized in RIE (Reactive Ion Etching) or ICP (Inductively Coupled Plasma) discharge. The effect of the temperature on polysiloxane etch rate and the resulting surface morphology was examined. XPS was employed to determine any chemical changes induced by plasma treatment. The cytotoxicity on a cell line was observed using CV and MTT assays in order to estimate suitability of plasma processed silicone elastomer for use in biomedical applications. The results highlighted the nature of polysiloxane plasma etching and revealed how the surface properties can change depending upon plasma treatment conditions.

D: HP04 **Thin Film Microsensor for Electrical and Optical Blood Diagnostics**

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Thin film microsensor (TFμS) consisted of interdigitated arrays of electrodes (IDAE) for electrical and optical monitoring of the aggregation phase of erythrocyte sedimentation has been developed. Planar TFμS is based on IDAE, Pt or transparent conductive ZnO:Al thin films sputtered on ceramic or glass substrates. It allows single or simultaneous measurements of electrical impedance (1 kHz÷1MHz) and optical reflectance/transmittance (320÷800 nm) of small blood drop applied on TFμS. Time monitoring of these parameters (in the first 300 sec) can distinguish between healthy and cancer state of blood and could serve as screening method for early diagnoses or for the simple long-term diagnostics after surgical operation.

D: HP05 **Supramolecular Analogues of Poly(N,N-dimethylacrylamide) Hydrogels**

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Several cross-linked poly(N-alkylacrylamides) form stable gels in water and are extensively used for biomedical applications. In these polymers the hydrophilic amide groups are held together covalently through the polymer backbone. Thus, we started from the hypothesis that if we are able to self-assemble short amides into supramolecular polymers we could obtain a hydrogel. We have synthesized N,N-dimethyl-3-mercaptopropanamide (DMMPA), starting from N,N-dimethylacrylamide and thioacetic acid. Then, a supramolecular hydrogel is formed by the addition of AgNO3 to a solution of DMMPA at room temperature. The silver(I) thiolate resulting from the reaction, with a molecular formula of Ag-SCH2CH2CONMe2, self-assembles into a supramolecular 3D network stabilized through Ag(I)-Ag(I) metallophilic interactions. This compound is able to gelate more than two hundred times its weight in water, without the need of cross-linking, and exhibits a thermoreversible sol/gel transition at around 50-55 ºC. The material is easy and cheap to produce, just by mixing its two components at room temperature. The biocidal properties of silver ions make these materials promising candidates for biomedical applications,

D: HP06 **Direct Detection of Spores and Vegetative Cells with Polyaniline Nanofibrils**

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Rapid detection of pathogenic bacteria is very important in health care and national defense. Three species of *Bacillus* (*Bacillus cereus*, *Bacillus subtilis and Bacillus megaterium)* were evaluated as potential surrogates for *Bacillus anthracis*. Nanobiodetectors based on polyaniline nanofibril networks have been designed and fabricated in our laboratory[1, 2]. Recently, the continuous flow nanobiodetector (CFNBD) was successfully tested on vegetative cells and spores. We found that CFNBD system is able to detect spores in the analyzed sample and even distinguish between the living vegetative cells and spores. The electrical response of nanobiodetector is proportional to the number of objects (spores or vegetative cells) in the sample analyzed. The results are

unique, very promising and important for food, cosmetics and drug production, medical applications, environmental monitoring and national defense (bio-alarm systems). The mechanism of detection, properties of the material used and possible applications of our detecting devices will be discussed.

[1]Langer, J.J., Langer, K., Polyaniline Nanobiodetector. Rev. Adv. Mater. Sci. (RAMS). 5 (2005), 434-436; [2]Langer, K., Barczynski, P, Baksalary, K., Filipiak, M., Golczak, S., Langer, J.J., A fast and sensitive continuous flow nanobiodetector based on polyaniline nanofibrils. Microchimica Acta 159 (2007), 201-206

D: HP07 **Development of Metal-based Biodegradable Material with High Strength and High Stiffness**

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Medical implants or devices have to fulfill different requirements depending on the biomedical demands. For atrial septal defects, the implanted device is not needed after overgrowing of the tissue. Our research is focused on developing strong, stiff and biodegradable metal based materials for an atrial septal defect closure device. Since metals are in the early stages of development as biodegradable materials, it is mandatory to determine and characterize the corrosion kinetics and corrosion products of the candidate materials in biological environments. In order to determine the degradation products and degradation rate, we have developed a corrosion cell in which the different metal based materials were subjected to various simulated body solutions. The corrosion products of the candidate materials were characterized by Raman spectroscopy and their morphology was observed by Scanning Electron Microscopy (SEM). The results allow us to select an appropriate material for further *in vivo* experiments.

D: HP08 **Functional Materials Based on Photoswitchable Ionogels**

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Functional materials based on photo-responsive polymers or gels have generated interest due to their ability to function as drug delivery systems[1], permeable membranes[2] and microactuators[3]. Light irradiation is a useful means of control because it can be applied instantaneously,with high resolution and without physical contact. Poly(N-isopropylacrylamide) (pNIPAAm), which is a well-known thermoresponsive polymer and a photochromic (spirobenzopyran) monomer were co-polymerized within an ionic liquid matrix yielding a functional ionogel. Ionic liquids (ILs) are organic salts in the liquid state under ambient conditions,and many show negligible volatility and non-flammability. Impregnating photo-responsive polymers with ILs offers certain advantages over aqueous media, for example, through the tailoring of chemical and physical properties of ILs (acid/ base character,viscosity etc.). Therefore, we can tune the characteristics of photoresponsive gels by changing the IL.Herein, we present the changes in physio-chemical,electrochemical and rheological properties of the ionogel when irradiated with light.

[1]Gong, C.; Adv. Funct. Mater. 2006, 16, 1759-1767; [2]Kameda, M.; J. Appl. Polym. Sci. 2003, 88, 2068-2072; [3]Sugiura, S.; Sens. Actuators, A 2007, A140, 176-184

E: HP01 **The Cuttlefish Buoyancy Tank: A One Dimensionally Ordered, Porous Calcium Carbonate Mesocrystal**

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Biological control of crystal texture is a widespread strategy for adapting crystal properties to function. An outstanding example is the porous calcium carbonate (aragonite polymorph) buoyancy tank (cuttlebone) of the cuttlefish (sepia officinalis). We performed optical microscope, SEM and X-ray diffraction experiments on cuttlebones to elucidate their structural and crystallographic details. Microscopy and SEM reveal an open structure of stacked aragonite lamellae (~15 μm thick), held apart by delicate pillars/walls of some 200-300 μm height. The lamellae in turn consist of sandwiches of layers of columnar crystal growth. One- and two-dimensional X-ray diffraction patterns show a unique fibre texture, with the aragonite c-axis being oriented parallel to the pillars and the columns in the lamellae, whereas the lateral orientation of the crystallites is random. Even the much harder protective outside layer, the dorsal shield, obeys the same fibre texture. Although columnar crystal growth within calcium carbonate layers is known from egg shells, the fact that their c-axis orientation combined with lateral orientational disorder is retained throughout the entire complicated porous structure seems to be unique to the cuttlebone, which could be a model for biomimetic constructions.