SYMPOSIUM J
Micro- and Nanosystems—Materials and Devices
March 28 - April 1, 2005

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* Invited paper
Micro- and nanofabrication techniques are increasingly employed in the development of biosensors, fundamental biological studies, and tissue engineering. This broad field of research, which is quickly expanding, is commonly referred to as bioMEMS. In this tutorial, the basic fabrication techniques commonly used in bioMEMS will be reviewed, promising devices highlighted, and the development and processing of new materials for sensor and tissue engineering applications described.

The tutorial will begin with an overview of the fabrication technologies typically used in the construction of bioMEMS. While this will include a brief summary of traditional technologies, such as surface and bulk micromachining, an emphasis will be placed on methods for fabricating polymer microsystems and patterning cellular materials. The second section of the tutorial will highlight work in the area of devices. Numerous biosensors and systems have been developed for a range of applications from protein and DNA detection to drug delivery. Several promising devices will be discussed in terms of their application, operating principle, and fabrication process. The final section of the symposium will cover the development and selection of materials for bioMEMS. This section will provide an overview of the important characteristics of materials for applications in this area and will review recent efforts aimed at developing materials for sensor and tissue engineering applications.

Instructors:
Nashid Hashir, Purdue University
David A. LeVan, Yale University
Kevin Turner, Massachusetts Institute of Technology

SESSION J1: Metrology and Materials Characterization

Chair: Somuri Prasad
Monday Beforenoon, March 28, 2005
Room 2003 (Moscone West)

1:30 PM J1.1

Microstructural characterization of Microelectromechanical systems (MEMS) devices is a challenging task. Here, the samples are often too small to handle using conventional metallographic sample preparation techniques. In recent years, focused ion beam (FIB) has become a novel tool for preparing samples for electron microscopy. The ability of the FIB to produce samples from specific regions of a specimen, including those from microscopic regions of a test specimen or a device, is well suited for MEMS characterization. Electron backscatter diffraction (EBSD) is an ideal technique for linking microstructure and crystallographic texture. In this study, we have successfully applied FIB microscopy to prepare samples for TEM and EBSD analyses from MEMS devices and materials to develop a better understanding of device reliability. Many MEMS devices have relied on silicon, silicon oxides and nitrides as structural load-bearing members. There is an increasing need to use more conventional and damage-tolerant materials such as nickel or other metals in MEMS applications and there is a need to understand the mechanical limits and reliability of metallic MEMS devices. Currently, one path to produce metallic MEMS devices is through theelectrodeposition of metals into deep x-ray lithography formed molds. This process is called LIGA after the German acronym for Lithographie, Galvaniformung, Abformung. This paper gives an overview of our current efforts on the application of FIB microscopy and EBSD techniques to characterize both silicon and metallic MEMS materials. We shall present two specific examples of our ongoing efforts to understand the role of fatigue and wear in MEMS materials using these two novel techniques.

2:00 PM J1.2
Electrical Characteristics of 1T/1R RRAM Device using ZrOx. Hyejung Choi, Dongsoo Lee, Yunik Son and Hyunsoong Hwang; Department of Materials Science and Engineering, Gwangan Institute of Science and Technology, Gwangju, South Korea.

RRAM (Resistance Random Access Memory) is considered as new candidate for future memory device. The principle of RRAM is switching using the resistance difference. The resistance is changed by voltage sweep or voltage pulse and this phenomena is reported for many thin films such as chalcogenide glasses, PCM0, NiO and etc. Resistance switching mechanism is also studied for different models like defect filament model, charge trap model, and interface model. For most cases they have a MIS structure as substrate-thin film electrode. In this study, we report on the fabrication of 1T/1R RRAM using non-stoichiometric zirconium oxide (ZrOx) and its electrical characteristics. 1T/1R RRAM structure has one resistor on the source part of the MOSFET, which can control drain current. Its advantage is amplification of voltage. ZrOx is deposited in source part of MOSFET by RF reactive magnetron sputter at atmosphere of oxygen and argon mixture and annealed in oxygen condition. The 5μm and 0.3μm MOSFET is used and silicon oxide is used as gate oxide. Positive DC voltage sweep and voltage pulse is used as switching method. Reset voltage and set voltage is 1.0–1.2V and 1.4–2.8V. At pulse switching, pulse time is 100ns and this time is in reverse proportion to voltage. There is a order of magnitude difference of drain current and low resistance state. They showed good characteristics at retention and cyclic test. ZrOx RRAM has low cost compared to others, low power due to nonvolatile memory and high current ratio at 1T/1R structure.

2:15 PM J1.3
Modification of Deposition Process of Piezoelectric Polycrystalline Film by Hydrogen Peroxide. Akiko Endo1, Norimichi Kawaista1, Shinich Takeuchi1, Mutsuo Ishikawa2 and Minoru Kurousawa2; 1Department of Biomedical Engineering, Toh University of Yokohama, Yokohama, Japan; 2Tokyo Institute of Technology University, Yokohama, Japan.

We deposited ferroelectric poly-crystals with perovskite structure on the titanium substrate processed using hydrothermal method, and have tried to develop ultrasonic probes using the ferroelectric poly-crystalline films which was deposited on the titanium substrate. The chemical cleaning process is employed as the cleaning of the titanium substrate before deposition in the conventional hydrothermal method. However, impurities or contaminations were removed from the surface of the substrate with the chemical cleaning process. This process can not control the roughness and chemical condition on the surface of titanium substrate. Therefore, it is important for suppression of the differences between individual elements to form poly-crystal nuclei with high quality stably. The surfaces of the titanium substrates with anticorrosion were corroded as pretreatment with hydrogen peroxide solution. The surfaces of the deposited PZT polycrystalline films with thickness of 10μm-50μm, the density and Young’s modulus were increased to about 250% by pretreatment. The standard deviation of the deposited PZT films with and without pretreatment were observed with SEM and compared. We could obtain the excellent quality deposited PZT polycrystal films without pinhole on the titanium substrate with pre-treatment using hydrogen peroxide solution. When crystal structure was measured by XRD, the peaks of high diffraction intensity corresponding to PZT were observed on the PZT polycrystal films deposited on the titanium substrates with pre-treatment. It confirmed that the good polycrystal nuclei was formed. When the composition ratios between Zr and Ti were measured on the deposited PZT films with EDS, these results were independent on the titanium substrates with and without pretreatment. Thickness of the deposited PZT films on the substrate with the pre-treatment was about 65% of thickness of those without pretreatment. The density and Young’s modulus were increased to about 30%, and the piezoelectric constant d31 was increased to about 200% by pre-treatment. The standard deviation of the thickness of deposited PZT film was suppressed to about 40%, and that of the density was about 50% by the pre-treatment. Consequently, we confirmed the validity of pre-treatment of titanium substrate using hydrogen peroxide solution.

2:30 PM J1.4
Micromirror Arrays for High Temperature Operation. Mahmoud Ebad Almari1 and A. Bruno Frazier; Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia.

This paper describes the design, modeling, fabrication, testing and the associated electronics for electroplated electostatic torsion

Electrodeposition through thick resist such as polymethylmethacrylate (PMMA) or SU8 has enabled the fabrication of metallic high aspect ratio microstructures. The most commonly deposited metal for this purpose is nickel, usually electroplated from a sulfamate electrolyte. When the deposition is employed to perform a mechanical function (such as in the case of an actuator, for example), the mechanical properties of the electrodeposited nickel are of interest. For example, the material may need to possess a certain yield strength for the device to function properly, or the modulus must be known to design for a desired elastic response. In order to obtain the required mechanical properties, the grain size and texture of the electrodeposited must be controlled. In this presentation, the various electrolys parameters that may be used to influence deposit structure and properties will be considered. The grain size of electroplated nickel is often refined by codepositing other elements, such as Fe, Co, or Mn. These approaches for depositing high strength Ni alloys will be compared and contrasted with emphasis on the unique challenges posed by electrodeposition into deep, high aspect ratio cavities. The texture, unique for each alloy, will be presented as well as the through-thickness and across-wafer uniformity of the deposited material will be discussed. Other, often unintended, electrolyte parameters (such as pH, temperature, and breakdown voltage) that may affect grain size and texture will be presented, along with understood aspects of thickness and growth process, resulting in deposits with unacceptable morphologies despite the presence of other intentionally added species that would otherwise lead to a desired result. Finally, the application of low-friction coatings on electroformed microdevices will be considered. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Anchoring of Organic Molecules on Cu(001) Surface through S-Headgroup, Patrizia Monachesi 1, Letizia Chiodo 2, Fabio Bussolotti 3, Maria Grazia Betti 4 and Carlo Mariani 5; 1Dipartimento di Fisica, Universita' dell'Aquila and INFN, L'Aquila, Italy; 2Dipartimento di Fisica, Universita' di Roma "Tor Vergata" and INFN, Roma, Italy; 3Dipartimento di Fisica, Universita' di Modena and INFN CRPS-S3, Modena, Italy; 4Dipartimento di Fisica, Universita' di Roma "La Sapienza" and INFN CRS-SOFI, Roma, Italy.

An important topic of molecular electronics is the functional characterization of self-assembled monolayers of organic molecules, on the nanometric scale, grown on traditional materials, like noble metals. Recent experiments [C. Mariani et al, Phys. Rev. B 66, 115407 (2002)] of angular resolved high-resolution UV photoelectron spectroscopy (AR-HRUPS) involving the aromatic molecule CyH2N(OS on the Cu(001) surface have focused on the formation of dispersive molecule-substrate electronic states. Theoretical calculations performed 'ab initio' in the Density Functional Theory [P. Monachesi et al, Phys. Rev. B 69, 165404 (2004)] have well reproduced the spectral density of the S-metal electronic states, allowing for the assignment of the structures observed experimentally. Recent AR-HRUPS measurements [F. Bussolotti et al, Surf. Sci. 2004, in press] yield yield density of states and dispersion of the electronic states of the S-metal, like the headgroup is again functionally devoted to the chemisorption of the whole molecule. Here we focus on the adsorption on Cu(001) of CH3H2NOS and CH3S. The surface reconstruction is different in the two cases and it depends critically, in the adsorption of the Lewis basic headgroup, on the adsorption temperature. The observed reconstructions are p(2x2) (S/Cu(001), CH3H2NOS, CH3S at low coverage and room temperature), c(2x2) (CH3S at low coverage and low temperature), and p(2x2) (CH3H2S at high coverage and room temperature). The interface we theoretically model is formed by the S overlayer and the Cu subsurface layer. The S-Cu hybrids are reproduced quantitatively by present theoretical calculations performed 'ab initio' in the Density Functional Theory. In particular, we reproduce quantitatively the width of the dispersion of the S-Cu hybrids and the fingerprint of the bonding states in the DOS for the p(2x2) and c(2x2) reconstructions. In conclusion, we have characterized experimentally and theoretically conditions.
the electronic properties of the Si/Cu interface in two molecule-metal systems and shown that the S-headgroup realizes the anchoring of these molecules to the Cu(001) surface.

4:15 PM PM 15.3

In-Situ Pretreatment Approach for Surface Deterioration Allievation in MEMS Switches and Relays

Arthur Pan1, Xu Wang1, Jamie Meeks2, Steve Durbin2 and Jim Zheng3; 1Electrical and Computer Engineering, FAMU-FSU College of Engineering, Tallahassee, Florida; 2MacDermid Institute for Advanced Materials and Nanotechnology, University of Canterbury, Christchurch, New Zealand.

Forgoing to silicon-based device construction, manufacturers typically discard wafer layers utilizing thermal desorption as the favored means over ion bombardment and chemical etching due to simplicity, usage ease, and minimal contamination. However, as the thermally driven chemical reaction necessary for oxide reduction proceeds, the wafer surface rapidly deteriorates requiring the necessity for homeopropulsive growth of micro-meter thick buffer layers to restore surface integrity. This customary procedure is undesirable due to the time and material utilized and furthermore without the assurance of eliminating stacking faults. Thus, it is highly beneficial to develop a method to frustrate the chemical reaction from etching the wafer surface, with such secondary goals as expedient implementation, readily integratable into existing systems, and financially beneficial. Within this article, a novel in-situ method is proposed as a modification of thermal desorption utilizing pretreatment which can be applied to systems subject to material deposition, substrate heating, and creation of non-oxidizing environments where, for example, contact bouncing the transient asperity analysis and in-situ reflective high-energy electron diffraction for crystalline information during the modified thermal desorption progression. Experimental results utilizing pretreatment durations under 60 seconds indicate a significant reduction in surface roughness of 75%, from an average value of 2.20 nm to 0.56 nm, while resulting in crystalline surfaces indicative of suitability for further epitaxial growth. Furthermore, results yield indirect information regarding initial chemical composition of the native oxide as well as insight into thermal desorption surface kinetics.

4:30 PM PM 16.4

Interface Phenomena in MEMS Switches and Relays

Lior Kogut and Kyriakos Koniovopoulos; Department of Mechanical Engineering, University of California at Berkeley, Berkeley, California.

Microelectromechanical systems (MEMS) technology has the potential to replace traditional solid-state devices, in response to demands for broader operating temperature range, higher breakdown voltage, and much higher off-state resistance. Interest in MEMS switches and relays has subsequently increased in the enhancement of the switching performance with radio-frequency (RF) signals. However, various complex interface phenomena often limit the performance and lifetime of microswitches and microrelays. Therefore, the development of reliable, high-performance MEMS switches and relays requires a comprehensive understanding of the dependence of the functionality and longevity of these microdevices on interface behavior controlled by different mechanisms that depend on the material properties, applied voltage, and operation environment. One of the principal objectives of this study was to provide a critical appraisal of the role of various interface phenomena on the stable operation and long-term use of MEMS switches and relays. Emphasis is given on the dependence of pull-in voltage on surface topology, enhancement of the electric field at surface asperities and its effect on trapped charges, electrical breakdown across micrograins and its role on surface erosion and microdevice failure due to permanent adhesion (stiction), limitations in switching frequency range and microscale longevity due to contact bouncing, electrical contact resistance, and implications of power dissipation at the contact interface in thermal softening and/or microwelding of the interacting surfaces. The analysis of the various interface phenomena is accompanied by a description of the operation modes of RF microswitches and ohmic microrelays. In view of the importance of surface topography in surface interaction, special MEMS switches and relays with tailored topography of top and bottom surfaces are discussed, in conjunction with a scale-invariant method based on fractal geometry, appropriate for unbiased surface topography description. Surface topography effects on the capacitance of closing-gap MEMS microswitches, and the transition to a macroscopic, continuous, liquid-like state when the surface are assumed to be smooth. For example, when surface topography is taken into consideration, intense electric fields are produced at surface asperities, and the enhanced electric field can be two orders of magnitude higher than the smooth-surface electric field. An excess electric field may increase the density of trapped charges through charge injection or electrical breakdown of the gap between the electrodes, hence increasing the likelihood for formation of the microswitch. Surface topography, mechanical properties, and adhesion forces influence contact bouncing. This degrades the microdevice performance by increasing the transition time between the instant that the control voltage is applied and the instant that the signal is allowed to flow without interruption.

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8:45 AM J3.2
Layer-by-Layer Metallic and Ceramic Photonic Crystals Fabricated by Soft Lithography for Optical Regime. Jae-Hwang Lee1, Chang-Hwan Kim1, Yong-Sung Kim1,2, Ji-Young Kang1,2, Wai Leung1,2, Ruan Biewangi1,2, Chia-Hwan Oh1,2, Kristen Constantini1,2, and Kai-Xing Hu1,2,3. 1Department of Physics and Astronomy, Iowa State University, Ames, Iowa; 2Department of Material Science and Engineering, Iowa State University, Ames, Iowa; 3Ames Laboratory DOE, Ames, Iowa; 4Department of Physics, Hanyang University, Seoul, South Korea.

We present fabrication methods and optical data of 3D metallic and dielectric photonic crystals. The fabrication methods are based on soft lithographic techniques that include layer-by-layer template fabrication, structure alignment and ceramic infiltration. These methods can be easily extendable for introduction of defects in 3D photonic crystals. With these techniques, freestanding metallic crystals and titania crystals on a silicon substrate have been fabricated. Since the crystals have systematical spatial deviations in their structures, structure-dependent optical properties were investigated in a single sample using an infrared spectral imaging. We also examined the effect of alignment errors on the optical signature in the 3D photonic crystals fabricated by these methods. The tolerance of alignment for both metallic and dielectric 3D photonic crystals will also be discussed.

9:00 AM J3.3
Temperature and Solution pH Effects on Cohesive and Adhesive Fracture of Silica/Adhesive/Polyimide Thin Film Systems. Louis Y. Wang and Reinhold H. Dauskardt; Materials Science and Engineering, Stanford University, Stanford, California.

Epoxy resins blended with silica coupling agents are widely used as adhesives between passivated substrates and polyimide films. Although such adhesive layers have high fracture toughness with fracture energies in excess of 500 J/m2, the silica/adhesive interface and the adhesive itself may be susceptible to environment assisted fracture. In this study, the effects of temperature and pH on the adhesive and cohesive fracture behavior of silica/adhesive/polyimide thin layered structures are examined under different loading mode mixities typical for a range of microelectronic device packages. The relationship between the debond growth rate (da/dt) and the applied strain energy release rate (G) in mode I was evaluated using fracture mechanics techniques. As expected, the thin film system exhibited higher crack growth rates with increasing temperature due to faster crack tip reaction kinetics. In addition, at higher temperature, the debond path moved from the adhesive to the silica/adhesive interface. Similar behavior was also apparent for very low crack growth rates approaching the fracture toughness in mode I.

9:15 AM J3.4
Detection of Residual Stress in Silicon Carbide MEMS by μ-Raman Spectroscopy. John C. Zingarelli1, Michael Marciniak1, and Jason R. Foley2,3, 1Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson AFB, Ohio; 2Materials Science and Engineering, Stanford University, Stanford, California; 3Layered Materials Laboratory, Stanford University, Stanford, California.

Micro-(μ)-Raman spectroscopy is used to measure residual stress in two silicon carbide (SiC) poly-types: single-crystal, hexagonally symmetric 6H-SiC, and polycrystalline, cubic 3C-SiC thin films deposited on Si substrates. Both are used in micro-electro-mechanical systems (MEMS) devices. The 6H-SiC structures are back-etched by reactive ion etching to form a 220-μm thick, single-crystal 6H-SiC wafer (p-type, 7 Ω·cm, 3.5-degree off-axis) to form a 50-μm thick diaphragm. A Wheatstone bridge, patterned of piezoresistive elements, is formed across the membrane from a 5-μm, 6H-SiC (n-type, 5×10^{17} cm^{-2}) to the silicon substrate; the output of the bridge is proportional to the flexure of the MEMS diaphragm. For these samples, the μ-Raman spectroscopy is performed using a Renishaw InVia Raman spectrometer with an argon-ion excitation source (λ = 514.5 nm, 785 mW, 24.1 eV/photon) and an approximate 1-μm2 spot size through the 90x objective. By employing an incorporated piezoelectric stage with submicron positioning capabilities along with the Raman spectral acquisition, spatial scans are performed to reveal areas in the MEMS structures that contain residual stress. Shifts in the transverse optical (TO) Stokes peaks of up to 2 cm^{-1} along the edge of the piezoresistive diaphragm identify the significant material strain induced by the MEMS fabrication process.

The phonon deformation potential in both SiC poly-types is measured to quantify the material stress as a function of the shift in the Raman peak position. The line center of the TO Stokes peak is determined by applying a uniform stress to the sample using a four-point strain fixture and monitoring the applied stress using a strain gauge, while the μ-Raman spectrum is being measured. A spectral analysis code tracks the shift of the Raman peak position with respect to the line center of the Rayleigh peak to account for any thermal drift of the spectrometer during the time of the area scan. 3C-SiC films, with thicknesses ranging from 1.5-6 μm and deposited by CVD on (100) Si substrates, are also investigated to determine their residual stress via their Raman spectral characteristics. An ultraviolet excitation source (λ = 325 nm, hv = 3.82 eV) is determined to be more effective for the detection of Raman shifts in these thin films than the 514.5 nm source, since the SiC absorption coefficient at 325 nm is 3660 cm^{-1} at 300 K and 3600 cm^{-1} at 514 nm, while that at 514 nm is less than 100 cm^{-1} (dependent on doping level). In addition, the Si substrate is less Raman active at 325-nm excitation, leading to a lower relative amplitude than that at 514.5 nm and increasing the signal-to-noise ratio (SNR) of the SiC Raman spectrum. Since SNR is also increased by increasing absorption length, the thicker films of the 3C-SiC are preferable for measuring Raman spectra. The phonon deformation potential of thin-film 3C-SiC is determined using the same method described for the bulk 6H-SiC samples.

9:30 AM J3.5
The Electrical Contact Resistance and Adhesion of Intermixed Metal Thin Films for Use in MEMS Contact Switches. Daniel J. Dickrell, Michael T. Dugger, Paul T. Vianen and Ron S. Goeke; Sandia National Laboratory, Albuquerque, New Mexico.

The performance and reliability of MEMS Ohmic contact switches is strongly influenced by the material properties of the interface. Contact material selection is an important decision in the device design process that affects electrical resistance and surface adhesion. These attributes are of particular concern, since the functional degradation of electrical contact MEMS devices is often dependent on electrical contact resistance and adhesion. Traditional MEMS electrical contact materials, most often noble metals like gold and platinum, have shown to be moderately compatible at satisfying the electrical resistance requirements of MEMS switches but are often highly adherent and proficient adsorbents of contaminants, which negatively affects device performance. A proposed method to reduce the adhesion and maintaining acceptable electrical conductivity is to form multiple layer contact metal films in situ by controlled annealing and diffusion processes. The goal of this controlled diffusion process is to tailor the surface properties of an electrical MEMS contact in order to address as many degradation mechanisms as possible. AuGe and AuCu intermixed thin-film systems were identified as potential candidates for new MEMS electrical contact materials. Direct contact testing at typical MEMS device applied force and electrical loads were conducted for both noble metal and intermixed thin film material pairs in a nano-indentation apparatus. Electrical contact resistance and adhesive pull-off force measurements were recorded during cyclic surface contact for all materials. Current-voltage sweeps were also performed to assess the Ohmic nature of the contacts. Relative contaminant adsorption ability and electrical resistance were further studied for noble metal and intermixed thin films was also determined by surface analytical techniques. All results are discussed in terms of the needs for MEMS electrical contacts and how the new films satisfy those needs in comparison to traditional contact materials.

9:45 AM J3.6
Strain Sensitivity in Conductor-Modified Polymers. Eun Hwangsook1, Yunan Zhao1, Vanessa B. Chial1, Kevin Chan1, Kenneth Wu1,2, and Beth L. Pruitt1,2; 1Mechanical Engineering, Stanford University, Stanford, California; 2Materials Science and Engineering, Stanford University, Stanford, California.

This study evaluates the mechanical and electrical properties of conductor-modified polymers. Specifically, it addresses 2 types of polydimethylsiloxane (PDMS) modified for conductivity: PDMS coated with gold film and PDMS coated with graphite-based ink. Direct contact testing at typical MEMS device applied force and electrical loads were conducted for both noble metal and intermixed thin film material pairs in a nano-indentation apparatus. Electrical contact resistance and adhesive pull-off force measurements were recorded during cyclic surface contact for all materials. Current-voltage sweeps were also performed to assess the Ohmic nature of the contacts. Relative contaminant adsorption ability and electrical resistance were further studied for noble metal and intermixed thin films was also determined by surface analytical techniques. All results are discussed in terms of the needs for MEMS electrical contacts and how the new films satisfy those needs in comparison to traditional contact materials.
a gage length of 20mm. 2 types of composites with conductive films were fabricated. Gold-modified samples were coated with a 5mm chromic acid anodized data in the 100nm layer of gold. Graphite-modified samples were sputtered with Creative Materials, Inc.’s 123-27 Electrically Conductive Silicone Ink and dried. Testing Samples were loaded in uniaxial tension on an MTS Bionix 200 tensile tester. We modified the tensile tester to monitor electrical resistance in addition to stress and strain, to obtain data on “piezoresistance” and gauge factor. Resistance data were collected with a Keithley 487 Picoammeter and logged in LabVIEW. Results Particularly in the gold-modified composite with reported strain at 100% are possible with a sustained resistance signal. A clear, linear trend up to 65% strain dominates its resistance vs. strain plot. Resistance rises more sharply above 65% strain, losing linearity. The conduction path breaks at 100% strain and the substrate yields shortly thereafter. In hysteresis plots of 5% strain-relaxation cycles, stress fluctuates ±10% from its baseline vs. strain. Resistance fluctuates ±1.8% from its baseline vs. strain. The sample exhibits a gauge factor of 4.2. In the case of gold, strain above the ultimate strain of 100% is possible. In contrast, the TiN film exhibits a clear hysteresis loop (1.5%), Hsu and Saff, FNAS, 27 April 2004) are not achieved. At high strains the gold film itself fractures, breaking electrical continuity. These findings are not in line with another study reporting finite resistance up to 25% strain in gadolinium diffused Pileni (Lacour et al., APL, 14 April 2003). According to Lacour, the mechanism that allows extension beyond the ultimate strain of freestanding gold is unfolding of residual stress from evaporation in the gold film. Thin film geometry forms anisotropic ripples in the gold, which unfold at high strain; however, the blanket film geometry tested in our work to date does not induce the same buckling. Work on replicating these results will continue in the coming months, employing shadow masks to generate conduction paths of different geometries.

SESSION J4: Tribology
Chair: Mihriz Ozkan
Tuesday Morning, March 28, 2005
Room 205 (Moscone West)
10:30 AM *J4.1
Surface and Materials Issues for High Reliability MEMS.
Roya Maboudian, Chemical Engineering, UC Berkeley, Berkeley, California.

This presentation will consist of two parts. In the first part, the tribological issues in MEMS are discussed. Despite much progress in surface micromachining technology, adhesion, friction and wear (fracture toughness), self-mated contacts typically exhibit high coefficients of friction (COF=0.6-1.0), unacceptable wear and debris generation during sliding contact. In a number of microsystems applications such as gear trains, comb drives and transmission linkages, tribological (friction and wear) considerations, particularly sliding contacts amongst sidewalls, is of paramount importance. With the increasing number of MEMS fabricated in single crystal silicon, to fabricate thicker resist electroforming processes, there exists a need for the development of materials that are capable of withstanding the mechanical forces involved in sliding contact and wear. These materials are expected to not only last the life of the microsystem, but also extend its sensitivity and reliability. In the second part of the presentation we will review a number of thin film technologies that have been fabricated and tested at Sandia National Laboratories for MEMS applications.

11:00 AM J4.2
Characterization of Ti/TiN and TiN Conductive Layers for High Temperature MEMS Devices. Peter Lange1, Birger Ohlen2, Sebastian Puls3 and Joerg Syre4; 1MST, FtG-BST, Itzehoe, Germany; 2Fh-Weeskue, Heide, Germany.

New thin film conductive layers for heating and sensing in MEMS devices operated at high temperatures are reported. In applications such as thermometric and anemometric flow sensors, thermopiles and gas sensors the resistors have to withstand temperatures of several hundreds degree of Celsius. Thereby degradation effects have to be prevented, otherwise the external/internal signal conditioning circuit could not work properly. Ti and TiN thin films are state of the art technology in MOS devices as diffusion barrier between Si and Al or Cu. Because of this proven compatibility with front end MOS technology we have investigated these films for the application as heating/cooling and resistors layers in microsystems. The Ti films were either covered with thin TiN layers for the protection against interdiffusion/oxidation effects. These layers are deposited on a membrane (SiO2/SiN4) of 1 micron thickness in a reactive sputtering process. After structuring the film the resistor lines are meandered with lines and spaces of 5 micrometers. Subsequent a passivation layer of 1 micron thickness is deposited. The response to elevated temperatures, the temperature coefficient (TC), the resistivity and the crystallographic structure were examined. The achieved temperature was calculated using the TC value. In addition temperature measurements were carried out by thermography. The Ti/TiN thin film consists of a sandwich of 25nm Ti, 650 nm Ti and 50nm TiN. The TC of this stack was measured with 3800 ppm/K. This value agrees well with reported data of 3800 ppm/K. The resistivity was measured via sheet resistance with 4 micro Ohm cm and fits also to the reported data of 5 micro Ohm cm. The structure is a polycrystalline hexagonal closed packed alpha-phase with grain sizes of 0.2 to 0.5 micron. So far these properties of thin film TiN reveal no significant difference from those of bulk Ti. The temperature stability of the resistivity exceeds 380C. Above this point a distinct degradation of the resistivity (hysteresis) could be observed. The TC of a TiN layer with 500 nm thickness was measured with 750 ppm/K (fig. 5) and is reported for the first time. The resistivity was measured with an 115 micro Ohm cm and fits also to the reported data of 3800 ppm/K. Temperature stressing was possible until 600C, at higher temperatures a degradation in the passivation layers occurred. Up to this point no hysteresis was observed. Overall these two materials show excellent characteristics and are compatible with CMOS technology and can easily be converted from standard processes. If a high TC is desired the Ti/TiN stack can be selected for temperatures of max T=380C. This is useful for sensor systems related to temperature measurement or for use in moderate heat environments. For heating purpose only, the material of choice is the pure Titaniumnitride layers since it withstands temperatures of at least 600C without material degradation.

11:15 AM J4.3
Exchange Spring Type Magnet Realized in FePt/Fe Multilayers Deposited by Magnetron Sputtering. Yousung Gu, Dayong Zhang, Zhen Ji and Yue Zhang; Department of Material Physics and Chemistry, University of Science and Technology in Beijing, Beijing, Beijing, China.

FePt/Fe multilayers have been deposited on Si substrates by magnetron sputtering and post annealing. Series of FePt/Fe multilayers with different layer thicknesses have been prepared and annealed at different temperatures and durations. The prepared multilayers have been characterized by x-ray diffraction(XRD), scanning electron microscope(SEM) and vibrating sample magnetometer(VSM). In [FePt(4nm)/Fe(50nm)]10 multilayers, after annealing at 560C for 1 hour, samples with tFe<4nm transformed from fcc to tetragonal ordered phases, while those with thick Fe layers remain as fcc phases. However, after annealing at 600C, all the samples (1min≤tFe≤5min) transformed into tetragonal ordered phases. However, the degree of order decreases as Fe layer thickness increased. The lattice constant a decreases with Fe layer thickness increases, while c does not change very much. After annealing at 500C, the samples with thick Fe layers (tFe≥4nm) remain as fcc phase and a, c value are the same. However, all those values are smaller than those of bulk value, indicating that the FePt phase is Fe rich. The grain sizes of samples annealed at 500C are less than 70nm and are less dependent of Fe layer thickness. The grain sizes of samples annealed at 600C increase as Fe layer thickness increase and reach 76nm for Fe layers deposited for 1 minute and 86nm for single layer. Magnetic measurements show that for samples annealed at 500C and 600C, the coercivities decrease and the saturated magnetizations increase as Fe layer thickness increase. Therefore, there are peaks in magnetic energy product (BxH)max at tFe=9 min, 17 MG Oe for the samples annealed at 600C. Searching the wider range for the best layer thickness show that for samples annealed at 500C, FePt(8nm)/Fe(44nm) shows the highest (BxH)max=14.9kG, 47fMs=12.6kGs, Hc=5.81kOe. and (BxH)max=15.2MG Oe. Quick annealing (10 minutes) experiments show fine grain size and close coupling between soft and hard magnetic phase. The decrease rate of Fe layer thickness is much slow than conventional annealing. Grain growth is small is quick annealing while fcc to tetragonal transformation is realized. The use of Ag underlayer is to inhibit Si diffusion and raise saturation magnetization. Results on FePt/Fe multilayers with Ag buffer layers show similar magnetic behavior but fine grain size. The small magnetization value (less than FePt bulk value) is not related to Si impurities.

11:30 AM J4.4

Microelectromechanical systems (MEMS) fabricated by LIGA utilize electro deposited metals and alloys. Although many of these metals and alloys meet structural requirements (e.g. strength, modulus, and fracture toughness), self-mated contacts typically exhibit high coefficients of friction (COF=0.6-1.0), unacceptable wear and debris generation during sliding contact. In a number of microsystems applications such as gear trains, comb drives and transmission linkages, tribological (friction and wear) considerations, particularly sliding contact amongst sidewalls, is of paramount importance. With the increasing number of MEMS fabricated in single crystal silicon, to fabricate thicker resist electroforming processes, there exists a need for the...
Wear is a potential failure mode in microelectromechanical systems (MEMS). The presence of wear particles is potentially catastrophic for applications where debris may inhibit electrical contact or motion. Therefore, it is necessary to understand the initiation of wear processes in MEMS in hopes of prolonging life. Since silicon is the workhorse material for MEMS fabrication, these materials are not trivial, because of the difficulties in patterning and deposition of materials and for the rapid access to different nanometer-sized materials and structures, both structural and electrically, being more resistive than metallic Pt metal, are being developed and, in some cases, are relatively well controlled. Nonetheless, the extraction of the electronic parameters of the individual materials or structures is not trivial, because of the difficulties in patterning electrical connections between electron beams and the measuring systems. Focused Ion Beam (FIB) is a powerful technique to coat the LIGA NiMn alloy parts with tungsten disulfide (WS2) solid lubricant films by using WF6 and H2S gas precursors in a viscous flow reactor at 300°C. A new catalytic process for fabrication of Pt contacts attached to the substrate in a conventional FBAR configuration. The reflection coefficients, S11, of the single port devices were measured and the resonators displayed a series and parallel frequency pair with a quality factor of 200 and an electromechanical coupling factor of 4.0%. At 1.432 GHz. The Smith chart plot was also smooth in the UHF regime exhibiting no spurious frequencies. Solidly clamped resonators were also tested and all failed to exhibit a frequency pair. ...
discussed as a function of the chemical composition and surface state of the material to be contacted and of the thermal treatment of the contacts. This work has been partially supported by the EU through the project NANOS4 of the VI FPM.

2:00 PM J5.3
Surface States of the Wurtzite Type Nanowires.
Natalia Malkova and Cun-Zheng Ning; NASA Ames Research Center, Moffett Field, California.

We study the surface states at the lateral facets of the wurtzite type nanowires. As particular example we consider nanowires with the same symmetry for all the lateral facets. Our approach is based on the transfer matrix technique within the semi-empirical tight-binding approximation. We calculate the surface states at \( \Gamma \), \( \Sigma \) and \( (0001) \) surfaces of the semi-infinite crystal first. Then using the cyclic boundary conditions, depending on the radius of the nanowire, we find the quantized spectrum for the surface states in question. We present a detailed analysis of the surface states of AlN wurtzite nanowires with the 1100 and 1210 lateral surfaces. The dangling bonds are shown to give a set of the states inside the band gap of the semiconductors studied. The orbital character and decay length of the states are calculated. We analyze the symmetry of the quantized states and possible optical dipole transitions between them.

2:15 PM J5.4
Mechanical Integrity of Polymer/Inorganic Interfaces for Micro and Nano Systems. Bree M. Sharratt* and Reinhold H. Dauskardt*; Aeronautics and Astronautics, Stanford University, Stanford, California.

The mechanical integrity of polymer/inorganic interfaces is of considerable technological importance for a range of micro- and nanosystems. For example, both MEMS and NEMS are hermetically sealed and bonded to substrates using thin polymer layers. Physical and chemical sensors also incorporate thin polymer layers both in the sensor structure and in the packages. The functional reliability of such structures during processing and in service depends critically on the integrity of the polymer interfaces. Even though interfacial debonding associated with thermomechanical fatigue, vibrational loading and moisture attack are of constant important, a fundamental understanding of the debonding mechanisms and their relationship to interfacial chemistry, environmental factors and loading parameters is lacking. We address these issues using a technologically relevant bisphenol F polymer layer bonded by weak secondary bonding to SiN\(_x\), passivated silicon substrates. We present evidence of a significant mechanical fatigue effect, which translates to dramatic reductions in predicted device lifetimes. More importantly, however, we show that anomalous threshold behavior develops under both monotonic and cyclic fatigue loading conditions, resulting in debond growth rates that are almost independent of the applied loads. This surprising behavior is probed in depth for the reliability of devices that incorporate thin polymer layers. We discuss the mechanisms associated with the debonding phenomena in terms of the interfacial chemistry, and the effects of moisture and applied loads. By comparing device lifetime predictions for interfaces that exhibit analogous threshold behavior to those that have well-defined debond growth thresholds, we reveal the dramatic impact of weak secondary bonding on device reliability. Significant implications arise for micro and nanosystems that incorporate thin polymer films.

2:30 PM J5.5
Through-Wafer Polysilicon Interconnect Fabrication with In-Situ Boron Doping. Jeroen Langen, Kimmo Heutlinen, Panu Peeko, Tapani Vehmas and Hannu Luoto; Microelectronics, VTT Information Technology, Espoo, Finland.

Bulk micromachining technology can be used to produce conducting through-wafer polysilicon interconnects, i.e., polysilicon via plugs. This paper presents the process fabrication steps of polysilicon via plugs with in-situ boron doped polysilicon material in order to develop fast one-step doping process, without additional diffusion. The via holes can be processed by high-aspect ratio silicon etching to substrates using thin polymer layers. Physical and chemical sensors also incorporate thin polymer layers both in the sensor structure and in the packages. The functional reliability of such structures during processing and in service depends critically on the integrity of the polymer interfaces. Even though interfacial debonding associated with thermomechanical fatigue, vibrational loading and moisture attack are of constant important, a fundamental understanding of the debonding mechanisms and their relationship to interfacial chemistry, environmental factors and loading parameters is lacking. We address these issues using a technologically relevant bisphenol F polymer layer bonded by weak secondary bonding to SiN\(_x\), passivated silicon substrates. We present evidence of a significant mechanical fatigue effect, which translates to dramatic reductions in predicted device lifetimes. More importantly, however, we show that anomalous threshold behavior develops under both monotonic and cyclic fatigue loading conditions, resulting in debond growth rates that are almost independent of the applied loads. This surprising behavior is probed in depth for the reliability of devices that incorporate thin polymer layers. We discuss the mechanisms associated with the debonding phenomena in terms of the interfacial chemistry, and the effects of moisture and applied loads. By comparing device lifetime predictions for interfaces that exhibit analogous threshold behavior to those that have well-defined debond growth thresholds, we reveal the dramatic impact of weak secondary bonding on device reliability. Significant implications arise for micro and nanosystems that incorporate thin polymer films.

2:30 PM J5.6

Chemisorbed monolayers are employed in silicon surface micromachined (SMM) and microelectromechanical systems (MEMS) to reduce the surface energy after removal of the sacrificial oxide layer and thereby prevent movable structures from adhering during manufacturing, handling or operation. These films also reduce static and dynamic friction between movable structures. Although these films nominally react with the surface to form a single monolayer, the degree to which they bond with the surface, and hence coverage, can be affected by the ability to generate a clean surface in high aspect ratio gaps between structures as well as on surfaces directly exposed to the cleaning and coating processes. Mechanical stress as well as exposure to other adsorbates, including water vapor, can affect the chemistry and structure of the films and change device operating characteristics. Surfaces examined using time-of-flight secondary ion mass spectroscopy (TOF-SIMS) reveal differences in coverage based on location, whether in an occluded region or a free surface. Coverage is depleted in narrow gaps compared to exposed surfaces. Coated surfaces have also been used in environments including a packaging process and controlled water vapor concentration at elevated temperature. The tribological behavior of the surfaces has been investigated using atomic force microscopy and specially constructed cantilever micrometers for measuring friction under MEMS operating conditions. Results show that contaminant adsorption can occur preferentially at locations of prior mechanical contact, and that this adsorption can increase the static friction coefficient between movable surfaces. In addition, exposure to water vapor is shown to result in an increase in adhesion and friction between coated surfaces even though the surfaces remain hydrophobic. The tribological behavior of MEMS interfaces will be discussed in terms of the composition of the surfactants determined by TOF-SIMS, large measurements, and the chemical stability of the monolayers.
measurements are a good tool to separate the thermal effect from electrical characterizations. By using a very small pulse width and relatively low temperatures, thermal effects can be minimized. The GaN/AlGaN HEMT structure was grown by metalorganic chemical vapor deposition (MOCVD) on a semi-insulating SiC substrate. It has a 165 nm AlGaN nucleation layer, a 1.3 μm thick GaN buffer, and a 20 nm undoped, non-polar, thick GaN channel. The undoped GaN buffer was grown with a 45° off-axis, single-crystal SiC wafer, and the high-purity GaN channel is free of nitrogen vacancies and dislocations. The GaN/AlGaN HEMT structure was fabricated with a four-step process consisting of (1) mesa isolation with a Cr-based RIE (reactive ion etch) or ICP (inductively coupled plasma) etch 2) a Ti/Al/Mo/Au (30/100/15/40 nm) ohmic contact alloyed at 995°C for 20 s using a repetitively pulsed laser to achieve the low-resistance ohmic contact, (3) a nitrogen diffusion process (for 0.25 μm gate length devices) and ebeam (for 0.25 μm gates) lithography, and 4) SiN passivation by PECVD (plasma-enhanced chemical vapor deposition). The source-drain spacing was 4.5 μm. Pulse testing was performed with a DIVA 9-2500 Series Switching Measurement System, with all devices measured from two fingers devices which have 1.0 μm (or 0.25 μm) gate length and 75 μm gate width for each finger. The output current from static measurements decreased as the drain to source bias voltage was increased, resulting in reduced saturated current values shown in the saturation current constant. Because a very small pulse width of 0.2 μs and 1 μs pulse period was used in the pulsed measurement, it is natural to assume that there is no self heating in pulsed I-V characteristics. Thus, current decreasing at high voltage in static measurement is believed to be mainly due to the self heating effect. The device junction temperature can be obtained by measuring this difference of two currents, with the current variation as a function of temperature, pulsed I-V characteristics were measured at several different ambient temperatures. A quite linear relation between the temperature and saturation current level was observed. As an example of this dependence, the junction temperatures were determined for representative devices under 20 V drain bias. Currents were measured at Vds=20V and Vgs=1 V, and the saturation current was quite constant up to Vgs=20V. The static current value at Vds=20V, Vgs=11 V was 30 μA for 1.0 μm gate length device and 125 μA for 0.25 μm gate length device. The device junction temperature can be calculated from the relation between temperature and saturation current and were found to be 90°C and 126°C for each device.

4:00 PM session 6.3
Lock-and-Key Effect in the Surface Diffusion of Large Organic Molecules Probed by STM: Roberto Otero Martin, Fernando Soato, Peter Thostrup, Sergio B. Legoas, Erik Laegsgaard, Douglas S. Galva0, Flen1ning Besenbacher;
1 Department of Physics and Astronomy, University of Aarhus, Aarhus, Denmark; 2Universidade Estadual de Can1pinas, Campinas, Brazil.

A nano-scale understanding of the complex dynamics of large molecules at surfaces is essential for the bottom-up design of molecular nanostructures. Although a large number of previous studies has discussed the formation of molecular assemblies in terms of the molecule-molecule and molecule-substrate interactions, thus addressing the thermodynamic aspects of molecular assemblies, very few studies have addressed the dynamical processes that a large organic molecule can undergo when anchored on a solid surface. Here we address how the orientation and shape of large and complex organic molecules influence their dynamics (diffusivity). To this end, we have exploited the capability of the scanning tunneling microscope (STM) (i) to resolve the conformation and orientation of single individual molecules on the atomic scale, (ii) to manipulate the orientation of individual molecules by using the STM tip as a nano-scale tool to gently push molecules adsorbed on surfaces, and finally with the fast-scanning Aarhus STM (iii) to track the surface diffusivity of the different molecular configurations by acquiring STM movies at low temperatures. In this way, we will show that the diffusion coefficient of the complex organic molecule named the Violet Lander (VL, C108H104) on a Cu(110) surface can be changed by two orders of magnitude by purposefully manipulating the VL molecules, thereby modifying the molecular orientation with respect to the substrate. From an interfacial Molecular Dynamics simulations, we interpret the results within a lock-and-key model similar to the one driving the recognition between biomolecules: the molecule (key) is immobilized only when its orientation is such that the molecular shape fits the atomic lattice of the surface (lock); otherwise the molecule is highly mobile.

4:15 PM 6.4
Surface Chemistry and Electrical Properties of Germanium Nanowires: Dunwei Wang and Hongjie Dai; Stanford University, Stanford, California.

Germanium is of renewed interest due to its high carrier mobilities and small carrier and optical bandgap, especially as Si based device scaling is approaching its theoretical limits. Lack of a stable native oxide has been a challenge that hindered the research progress on germanium-based devices. We report systematic studies of the surface effects on the electrical properties of single crystalline Ge nanowires synthesized at temperatures below 300°C via a chemical vapor deposition method. Complementary p and n-type field effect transistors (FETs) were then fabricated on the developed Ge nanowires, and their performance was evaluated. X-ray photoelectron spectroscopy (XPS) revealed opposite band-bending and distinctive oxidation processes. It was found that p-type Ge nanowires trend to occur at lower than n-type Ge nanowires FETs. A simple cleaning method was developed and it was integrated with high dielectric material and low temperature after depositing air stable transistors based on Ge nanowires. It also sheds lights on the understanding of nanowire electrical properties in general.

4:30 PM 6.5
Measurement of Faradaic Current in AFM Nano-oxidation of Semiconductor and its Dependence on Surface Conditions: Naofumi Funakoshi, Tatsomo Yamada, Yasushi Takemura, and Jun-ichi Shiraishi;
1 Electrical & Computer Eng., Yokohama National University, Yokohama, Japan; 2Electrical & Electronic Eng., Tokyo University of Agriculture and Technology, Tokyo, Japan.

Nanofabrication technique using an atomic force microscope (AFM) has attracted much interest. The AFM-based nanolithography is a promising approach for fabricating electronic devices with nanometer-scale well-defined structures. Here, a quantitative study on the Faradaic nano-oxidation is described. It is well known that the AFM and scanning tunneling microscope can be used to selectively oxidize the surface of various materials. The reaction mechanism of this nano-oxidation is considered to be an electrochemical reaction between the film materials and water absorbed on or transferred to the surface. The size of the fabricated nano-oxide depends on the applied voltage to the conductive cantilever, which can be explained by introducing the threshold electric field for promoting the oxidation [1]. The volume of the oxide can be theoretically calculated by integrating the reaction current, called Faradaic current specifically in this case, with time. Recently, it was reported that the current was successfully measured and that the volume of the fabricated oxide agreed with the integrated current value [2]. On the other hand, we have noticed the waveforms of the current-time sweeps, which strongly depend on surface conditions of the films. As for the surfaces covered with oxides, i.e. Si substrate with native oxide and metal surface capped with thin oxide layer, almost constant current was detected from the beginning of blasing the cantilever. The over-current was observed immediately after applying the voltage in the oxidation of the surfaces with the less or without oxides. These results agree with previously reported discussion [3] that the residual oxide on the surface acts as a nucleation of the anodic reaction and that it promotes the initial oxidation. The mechanism and quantitative analysis of the AFM-based nano-oxidation are discussed in this presentation.

4:45 PM 6.6
Electrostatic (Plasmon) Resonances in Metallic and Semiconductor Nanoparticles and Their Applications: Issak Myeroyzey and Zhenyu Zhang; Electrical & Computer Engineering, University of Maryland, College Park, Maryland.

It is known that small dielectric objects can exhibit resonant behavior at certain frequencies for which the object permittivity is negative and the free-space wavelength is large in comparison with object dimensions [1]. This phenomenon usually occurs at nanoscale and at optical frequencies where the above two conditions can be simultaneously satisfied. These resonances are electrically well known and they result in powerful localized sources of light, which may find applications in nano-lithography, nanophotonics, surface-enhanced Raman scattering, biosensors, and optical data storage. These resonances are often a consequence of the surface effects on nanowire bulk properties was derived and it in1plied that the surface would play an ilnportant role as nanowires are sn1all. Our approach is to use the AFM-based nanolithography to study the surface and nanowire bulk properties and to develop a new technique for direct calculation of the electronic waveforms of the current-titne sweeps, which strongly depend on surface conditions of the films. As for the surfaces covered with oxides, i.e. Si substrate with native oxide and metal surface capped with thin oxide layer, almost constant current was detected from the beginning of blasing the cantilever. The over-current was observed immediately after applying the voltage in the oxidation of the surfaces with the less or without oxides. These results agree with previously reported discussion [3] that the residual oxide on the surface acts as a nucleation of the anodic reaction and that it promotes the initial oxidation. The mechanism and quantitative analysis of the AFM-based nano-oxidation arc discussed in this presentation. [1] Takemura et al., JAP 93, 7346 (2003). [2] Kuramochi et al., Nanotechnology 15, 297 (2004). [3] Takemura et al., Nanotechnology 15, 5956 (2004).
resonance values of permittivity, and hence the resonance frequencies, can be directly (i.e. without laborious probing) found by computing the eigenvalues of a specific boundary integral equation. Once the resonance permittivity is known, the resonance frequency can be obtained by invoking appropriate dispersion relations. This approach also reveals the unique physical property of plasmon resonances: resonance frequencies depend on dielectric object shapes, but they are scale invariant with respect to object dimensions, provided that they remain appreciably smaller than the free-space wavelength. It turns out that the integral operator in the integral equation is compact, and hence the plasmon spectrum is discrete. The properties of this spectrum have been studied along with the excitation conditions for plasmon resonances. A novel algorithm and robust codes have been developed to solve the corresponding eigenvalue problem. This algorithm and codes have been tested for spherical particles where exact analytical solutions are available (Mie theory). Our computations have also reproduced (with sufficient accuracy) the experimental results for gold nano-rings recently published in [2].

Different wafer bonding approaches are currently used in the MEMS industry. For example, Direct Bonding (DB) processes require a high temperature annealing which is not always suitable for the devices, a high interest is focused on low temperature processes. Plasma activated wafer bonding is a surface activation method which results in decreasing the process temperature. By applying a plasma treatment to the wafers prior to bonding, the surface chemistry can be tailored in order to obtain a high bond strength for low temperature thermal annealing. In the past decade some research groups reported results on plasma activated wafer bonding. The experimental setup was built usually on plasma etching equipment (barrel-type reactors or RIE tools). Most of the experiments on plasma activated wafer bonding were using plasma activation process followed by a deloined water rinse or even an RCA cleaning prior to bonding. The use of a rinse step between surface activation and bonding steps was justified for particle removal and improving the bond strength. Some water rinsing was developed specifically for plasma activated wafer bonding. For direct wafer bonding the surface quality is of very high importance, therefore this process chamber was designed to prevent any potential surface damaging effect during the plasma exposure. Another important aspect considered during process development was the need of numerous MEMS applications for a completely dry process. As wet processes can not be applied for substrates containing metals, etched features or mechanically fragile structures, dry processes are required. This paper introduces a new low temperature plasma activated wafer bonding process. The process is optimized for a maximum temperature of 400°C and does not require any wet process prior to bonding step. Experimental results of plasma activated wafer bonding applications will be presented as an alternative to standard high temperature wafer bonding processes.

SESSION J7: New Materials and Fabrication
Methodology Chair: David Le Van
Tuesday Evening, March 29, 2005
Golden Gate C1/C2/C3 (Marriott)

7:00 PM J7.1 Low Temperature MEMS Manufacturing Processes: Plasma Activated Wafer Bonding. Viorel Dragoi, Shari Farrens and Paul Lindner; Technology, EV Group, Scharding, Austria.

Initially driven by the automotive applications, MEMS development is now driven mainly by portable consumer products. The new MEMS applications raise important challenges to the existing manufacturing technologies and lead to the development of new technologies in order to fulfill the new demands. Some applications require special conditions, as long term high vacuum encapsulation, low temperature processing and wafer level packaging. Wafer bonding became a key technology in various processes related to MEMS devices manufacturing. Plasma activated bonding is a very important step for both the technological and also the commercial point of view: for some types of devices the cost of the package account for ~70% of the total cost of the device. Considering this aspect, wafer level packaging becomes very important for high volume manufacturing. In this respect, wafer bonding becomes a crucial technology as far as it enables not only 3D structure building but also wafer level packaging. Different wafer bonding approaches are currently used in the MEMS manufacturing industry. Because of their high thermal processing requirements, the Direct Bonding (DB) processes require a high temperature annealing which is not always suitable for the devices, a high interest is focused on low temperature processes (maximum temperature of 400°C). Plasma activated bonding is a surface activation method which results in decreasing the process temperature. By applying a plasma treatment to the wafers prior to bonding, the surface chemistry can be tailored in order to obtain a high bond strength for low temperature thermal annealing. In the past decade some research groups reported results on plasma activated wafer bonding. The experimental setup was built usually on plasma etching equipment (barrel-type reactors or RIE tools). Most of the experiments on plasma activated wafer bonding were using plasma activation process followed by a deloined water rinse or even an RCA cleaning prior to bonding. The use of a rinse step between surface activation and bonding steps was justified for particle removal and improving the bond strength. Some water rinsing was developed specifically for plasma activated wafer bonding. For direct wafer bonding the surface quality is of very high importance, therefore this process chamber was designed to prevent any potential surface damaging effect during the plasma exposure. Another important aspect considered during process development was the need of numerous MEMS applications for a completely dry process. As wet processes can not be applied for substrates containing metals, etched features or mechanically fragile structures, dry processes are required. This paper introduces a new low temperature plasma activated wafer bonding process. The process is optimized for a maximum temperature of 400°C and does not require any wet process prior to bonding step. Experimental results of plasma activated wafer bonding applications will be presented as an alternative to standard high temperature wafer bonding processes.

7:15 PM J7.2 Spontaneous Growth of Nickel Silicide Nanowires and Formation of Self-Assembled Nanobridges by the Metal Induced Growth Method. Joondong Kim1, Wayne A. Anderson1 and Young-Joo Song2; 1 Electrical Engineering, University at Buffalo, Buffalo, New York; 2 High-Speed SoC, Electronics and Telecommunications Research Institute, Daejeon, Yuseong-gu, South Korea.

Nickel silicide nanowires (NWs) have been grown on n-type (1 0 0) and p-type (1 1 1) Si wafers and self-assembled nanobridges (NBs) have been formed in a trench Si wafer by Metal Induced Growth (MIG). Ni as a catalyst was first thermally evaporated on SiO2-coated Si wafers. Si was then sputtered on the Ni layer by a D.C. magnetron at substrate temperature of 400°C. To form NBs, a metal sputtering system was used to make trenches in a Si wafer at a chamber pressure of 130 mTorr and power of 450 W. A 250 nm - SiO2etch mask was thermally grown on a cleaned p-type (1 1 1) Si wafer at 1000°C. The trenches of the sample was then processed in a D.C. magnetron sputtering system after Ni evaporation on a SiO2-coated Si wafer similar to the NW growth process. The NWs have diameters of 20 ~ 80 nm, length of 1~10 μm and surface coverage of about 35/10-12 m2. NBs were formed by a trench as long as 300 μm. Self-assembly behavior of Ni nanowires in the promising 1 dimensional building blocks in nanoscale connections and nanoelectronic applications. The MIG NWs and NBs satisfy the need of self and direct assembled bottom-up fabrication concepts.

7:30 PM J7.3 Size-Dependent Electronic Structures of ZnO Nanowires. Juan Wang, Xi Fo An and Quan Li; Physics, The Chinese University of Hong Kong, Hong Kong, Hong Kong.

Recently one-dimensional (1D) nanomaterials have arisen much interest due to their dimensional effects and the size related novel properties, which may lead to potential applications in these nanodevices. Fundamental understanding of the electronic structure of these 1D nanomaterials is therefore of great importance in order to investigate the feasibility of using them as building blocks for the nanoelectronic devices. In this study, two different types of ZnO nanowires (circular vs. hexagon cross section) have been explored by the increased surface to volume ratio when the diameter of the nanowire decreases. Interestingly, we observed that the peak corresponding to the interband transition from O 2s to the conduction band splits into two peaks only in the nanowires with circular cross section at small diameter, which is attributed to the presence of oxygen dangling bonds on their rough surfaces. Such splitting coincides with a red shift of the bulk plasmon peak, which can be explained by the coupling between the interband transition and the plasmon resonance. The experimental results strongly suggested that with careful control of the growth conditions (resulting in ZnO nanowires with hexagon cross section), the interband transition (conduction band to valence band) can occur in the nanowires with 20 nm diameter are of high electronic quality, which can serve as effective building blocks for optoelectronic nanodevices.

7:45 PM J7.4 Combination of Soft Lithographic and Nonlithographic Methods of Nanofabrication for High-Tc Superconductor Systems. Sungwook Kim and John McDevitt; University of Texas at Austin, Austin, Texas.

In order to fabricate the nano-electronic device of High-Tc superconductors, especially organic molecule/superconductor devices, it is critical to develop the reliable lithographic methods and the interface control methods. Self-assembled nanolayers etching methods and thermal annealing methods were developed to control the interface and recrystallize the structures of high-Tc superconductor nano-devices. The current state of the suitable methods for the fabrication of cuprate superconductor/conductive polymer nano-devices will be described as well as experiment results that could probe the proximity effects at such nanocomposites.

8:00 PM J7.5 Electrical and Optical Properties of Self-Assembled, Ordered Gold Nanocrystal/Silica Thin Films Prepared by Sol-Gel Processing. Kai Yang1, Hongyou Fan2, Sinla La Fontaine1, Daniel M. Boye2, Kevin J. Malloy1, Jeffrey C. Brinker2 and Thomas W. Sigmon2; 1 Center for High Technology Materials, University of New Mexico, Albuquerque, New Mexico; 2 Ceramic Processing and Inorganic Materials Department, Advanced Materials Laboratory, Sandia National Laboratories, Albuquerque, New Mexico; 3 Self-Assembled Materials Department, Advanced Materials Laboratory, Sandia National Laboratories, Albuquerque, New Mexico; 4 Department of Chemical and Nuclear Engineering, University of New Mexico.
The result is consistent with the measured loss value of the polymer microresonators. Combining the effective refractive index and Q determined above, the material loss of Efron and Crystal Cast, two previously un-characterized polymers, has been determined in the present work.

8:45 PM J8.2
Peculiarities of X-ray Beam Formation for Nanoscale Size Range.
Igor Konstantinovich Egorov and Evgeny Egorov: Analytical, Institute of Microelectronics Technology, Chernogolovka, Moscow District, Russian Federation.

Generation and formation of X-ray beams with nanoscale characteristics is not simple task owing to difficulties of direct influence on high energy photon fluxes and appearing of diffraction satellites at using of nanosize slit-cut systems. Application of the planar X-ray waveguide-resonators removes these problems. This device forms X-ray beams with width 10-200 nm without diffraction satellites and divergence of 0.1° and smaller [1]. Moreover, the waveguide-resonator condenses the radiation and transports it almost without attenuation. Planar X-ray waveguide-resonator (PXWR) represents the narrow extended slit formed by two planar polished dielectric plates (reflectors) located parallel to one another with small distance between them. The distance is defined by thickness of metallic strips deposited on edges of one reflector. Such geometry promotes to appearing of uniform X-ray standing wave interference field in all space of the slit when the slit width falls into the specific size interval. It's upper limit is defined by the magnitude of the characteristic length of radiation, transported by slit, and for metallic characteristic radiation generated by X-ray tube (at using of different anodes), it is varied from 90 to 200 nm. The lower edge is connected with the material density of waveguide-resonator reflectors. Usually, it is about 10-20 nm. The radiation transport condition of the uniform interference field of X-ray standing wave is the new mechanism of the radiation propagation differed, in principle, from the mechanism of it's multiple total reflection. The waveguide-resonance mechanism is characterized by arising of the interference field not only in the slit space but also in volumes of reflectors. But in the reflector volumes the field has the dropping characteristic. In the result, the reflector volumes are excited at the first total reflection of the flux and next reflections occur without energy losses, and we have the super-stream type propagation.

Moreover, the diffraction effect for any slit size can be appear for PXWR inlet only. The PXWR emergent beam is formed together by slit extended areas and areas of reflector butt-ends, and it can be characterized by diffraction effects. Some attention will be spared to discussion of the waveguide-resonator practical application for X-ray diffractometry and fluorescence spectrometry. Directions of waveguide-resonator technique development will be discussed briefly.

process that takes advantage on the different filtering properties due to the different light penetration depth at different wavelengths inside the a-Si:H and a-SiC:H absorbers. We have successfully tested different SFM methods in order to detect and characterize the materials and mechanical properties that govern the performance of these devices. The application of Scanning Force Microscopy (SFM) methods for the measurement of acoustic vibrations in RF resonators does not only allow the measurement of the magnitude and phase of the desired acoustic modes with sub-nanometer-scale sensitivity, but also provides valuable information about the excitation of spurious resonant modes around the main resonance frequency as well as parasitic modes excited together with the desired resonant mode at the main resonance frequency. The excitation of these undesired modes prevents an ideal frequency response of the resonators and it also represents an important source of energy dissipation and Q-factor limitation for its applications in wireless communication systems as filters, duplexers, etc. Our work is focused on the development of SFM methods for the measurement of both out-of-plane and in-plane acoustic vibrations in RF resonant t. Film bulk Acoustic Resonators (FBARs) are based on the excitation of bulk acoustic waves in a piezoelectric thin film (typically AlN or ZnO), and are becoming extensively used in wireless communications due to their high sensitivity, small size, high quality and good power handling capabilities. Our results show that SFM methods allow an extensive acoustic characterization of these resonators, including vibration amplitude mapping, decomposition of vibration images into acoustic modes, mode shape reconstruction and identification of the different channels of energy dissipation such as thermal expansion or the excitation of undesired short wavelength Lamb wave modes. On the other hand, Silicon based resonators represent the most promising strategy for the CMOS integration of RF MEMS devices. These resonators are driven by the electrostatic excitation of bulk acoustic modes which imply in-plane vibrations of the resonating structure. We have successfully tested different SFM methods in order to detect and image in-plane acoustic waves using nanometer and micrometer range imaging. We have also tested SFM methods for the measurement of the mechanical stress induced changes in the periodicity of the photonic crystal, to consequently produce tunability much greater than that achievable by electro-optic materials such as liquid crystal. To demonstrate the concept, we theoretically investigate the reflection in the flexible PC structure made of a triangular array of Si pillars embedded in a polyimide film. At a normalized frequency of \( \omega / 2 \pi c = 0.36 \), the equifrequency surface (EFS) was highly anisotropic with a 5° fan angle, resulting in a gain in optical reflection in the range of 4% to 5% from the reflection angle reaches -70 degrees for an incident angle as small as 5 degrees. As the structure is mechanically stretched, the EFS becomes significantly flattened, dramatically reducing the reflection angles. When stretched by 1%, the curvature of the EFS is reversed and the flexible PC begins to exhibit positive refraction. This enables dynamic beam steering over a range as wide as 75 degrees. We have also demonstrated tunable focusing with sub-wavelength resolution by the negative refracting PC structure. For experimental demonstration, we fabricated the flexible PC structures on Si-on-insulator substrates. The test structure was comprised of a 10x100 matrix of Si pillars embedded in a polyimide thin film. The surfaces were released for mechanical tuning by etching the underlying SiO2 layer. SEM confirmed the precision fabrication of Si pillars with diameters ranging 400nm to 2.5µm and aspect ratio of 1:1. For optical characterization, we co-fabricated a Si ridge waveguide through which 1550 or 1310nm laser beam was delivered to the flexible PC. The PC's refractive properties were then measured directly by imaging the light scattered out of the device or the light transmitted through the device. Our test structure was designed to exhibit nearly isotropic negative refraction at 1550nm. The experiments clearly showed the anticipated negative refraction in which the incident beam was refracted back to the side it was incident. To our knowledge, this is the first experimental demonstration of negative refraction in a Si-based photonic crystal structure. We have also successfully fabricated metallic and Si comb drive actuators with sub-micron feature sizes. We are currently working on integrating the actuators with the flexible PC for experimental demonstration of dynamic tunability, which will be
presented at the conference. This new concept of tunable PC allows real-time, dynamic control of photonic band structure, thereby greatly expanding the utility of PCs and enabling novel advanced nanophotonic systems.

SESSION J9: Micro- and Nanofluidics
Chair: Cengiz S. Ozkan
Wednesday Morning, March 30, 2005
Room 2003 (Moscone West)

8:30 AM J9.1
CMOS Compatible Integrated Silicon Dioxide Microfluidic Tunnels for Fluidic Sample Delivery to Nanometer Scale

Using the cutting edge semiconductor technology it is possible to make very small sensors for very fast sensing of chemicals. However, the fluidic sample is needed to be delivered to the sensor from the off-chip sources and is needed to be taken out. In order to interface an external plumbing system with the on chip sensors, on chip microfluidic tunnels are needed to bring the sample from one end of the chip into the microfluidic sensors. Chemical sensors which use electrical detection schemes need to be electrically isolated from the microfluidic tunnels carrying the sample into the small openings of the sensors. The dimensions of the microfluidic tunnels need to be large enough to allow necessary throughput. Most of the CMOS based sensors and CMOS circuitry integrated with sensors have materials, process and temperature constraints for back-end of the line fluidic integration. We have developed a low temperature, CMOS compatible back end of the line process for making silicon dioxide microfluidic tunnels for sample delivery to CMOS based chemical sensors. Fabrication process of these tunnels involve removal of sacrificial photoresist, allow arbitrary tunnel widths with the use of the pillars and the maximum process temperature is 135 °C. The semicircular shaped of the fabricated tunnels are supported by pillars separated by 8 µm. These microfluidic tunnels are compatible with cleaning steps involving strong base or acid solutions and can withstand and anneal steps at higher temperatures. In the fabrication process 1.2 µm photoresist is filled into lithographically defined shallow trenches of 0.3 µm in leading to the sensors and patterned by photolithography using the same mask and image reversal with ammonia bake. In order to increase structural strength and increased flow rate in the tunnels, the top surface of the photoresist filling is rounded using isotropic oxygen plasma in a spin coated chamber. Wafers are then baked at 135 °C in order to prevent outgasing of the photoresist during the subsequent steps. The bake step slightly reshapes the photoresist to properly fill into the trench, eliminating possible problems due to misalignment in the lithography steps and stops the continuity of the tunnels into the nanofluidic sensors. After this step a thin 0.25 m shell of SiO 2 is sputtered on the wafer followed by a 120 °C PECD SiO 2 deposition of 1 µm thickness. The sputtered SiO 2 shell prevents both the reflow of the resist and SiO 2 deposition between the pillars and the liquid of the sensors during the PECD deposition. Irrigation holes are opened and the sacrificial photoresist is dissolved using acetone. It is possible to fabricate multiple levels of microfluidic tunnels one over another to implement complicated chemical sensor and mixer networks by simply repeating the process steps after the irrigation holes are sealed. We will show the use of this technique for on chip fluidic delivery.

8:45 AM J9.2
Microfluidic Platform for the Generation of Polymer Particles, Zuzanna Cygan, Kathryn L. Beers and Eric J. Amis; Polymers Division, National Institute of Standards and Technology, Gaithersburg, Maryland.

We demonstrate a microfluidic platform for the synthesis of polymer particles of controlled size and composition. Rapid prototyping photolithography of a silicone-based resin was used to fabricate microfluidic devices stable to organic solvents and monomers. Monodisperse droplets of monomer suspended in a water/surfactant matrix were formed and photopolymerized on chip to generate crosslinked polymer particles. In-line Raman spectroscopy was used to monitor extent of conversion and particle composition. Particles were isolated and shape and size were characterized by optical image analysis.

9:00 AM J9.3
Development of a Microfluidic Rheometer for Measuring the Complex Modulus of Complex Fluids, Jai Patnath and Kathryn Beers; Polymers Division, NIST, Gaithersburg, Maryland.

The measurement of the rheology of complex fluids at the micro-scale is an important scientific and technical challenge in the evolving field of microfluidics. As part of the Polymers Division program to integrate synthesis of model polymers and the characterization of their physical chemistry and rheology on a lab-on-a-chip platform, we present results of our work on the development of a microfluidic rheometer based on the well-established metrology principle of magnetic particle rheometry. We are inspired by ideas from the bio-rheology field, with which we face a common experimental challenge: the availability of extremely small quantities (sub-microliters) of fluid samples. We will discuss the design and fabrication of the instrument, and present results of oscillatory and steady shear rheometry on diverse fluids, including standards of known viscosities and a plethora of complex fluids.

9:15 AM J9.4
Novel Microfluidic Reactors for the Synthesis of Unconventional Materials, Kyung M. Choi; Abraham P. Lee and Kenneth J. Shea; Department of Chemistry, University of California-Irvine, Irvine, California.

Microsystem technology offers us numerous active devices by fabricating small features on a variety of substrates to satisfy a set of our demands in miniaturization. Since we have been seeking precision microdevices with enhanced performance at small scale, here we introduced a 'microfluidic approach' for the synthesis of new materials, which hitherto have been possible for micrometric synthetic approach. The use of microreactors for synthetic chemistry offers a number of potential advantages over existing chemical technology. Chemical reactions run in microfluidic devices have high thermal and mass transfer rates with an opportunity to use more aggressive reaction conditions allowing for improved product yield. The overall goal is to carry out all operations normally performed in a chemical laboratory including synthesis, processing, purification and analysis on one microfluidic device efficiently and economically using minute amounts of solvents and reagents. For example, we demonstrated here a microfluidic synthesis of functional molecularly imprinted polymer (MIPs) particles by using a novel microfluidic reactor to produce 'monoclonal MIPs particles', which offer only high affinity binding sites to achieve high performance molecular recognition function in chemical or bio-detective technology. We also synthesized nano-sized semiconductor particles by continuous, dynamic fusion method using a specially designed microfluidic reactor.

9:30 AM J9.5
High Resolution Parallel Microfluidic Arrays, Yu Xiang and David A. LaVan; Mechanical Engineering, Yale University, New Haven, Connecticut.

We describe a simple parallel microfluidic system that can produce an array of mixtures of 4 input compounds. A PDMS prototype device that is capable of producing 10^4 blends of 4 individual input compounds (named A, B, C and D) was designed, fabricated and tested. The prototype is composed of two micro-mixers and a 100x100 array of micro-mixer, a mixer array of size 1 mm, generates and mix 10 dilutions of compound A (or C) with 10 dilutions of compound B (or D), respectively, to deliver the 10^4 mixture combinations in separate outlet microchannels. The 10^4 array is generated by crossing the two sets of channels coming out of the two mixers, fabricated in two different layers. At every crossing, the channels are separated by a composite separator comprising a membrane, a microwell, and a second membrane. The fluidic networks have been carefully designed such that the flow rates are the same at all the outlets. The finest features of the prototype system are 50 micrometers wide. The devices described have broad potential in high-throughput synthesis of polymers along with drug-screening.

9:45 AM J9.6
Glancing Angle Deposition Thin Film Microstructures for Microfluidic Applications, Gregory K. Kielland, Martin O. Jensen and Michael J. Brett; Electrical and Computer Engineering, University of Alberta, Edmonton, Alberta, Canada.

Micro and nanometre-scale structures promise to be of great importance in the advancement of biotechnology. Recent studies have demonstrated the capabilities of these structures as artificial separation matrices for microfluidic devices. In comparison to conventional gels which have random pore size distribution, nano-fabricated artificial MIPs have highly controlled and measurable porosity which make them easier to integrate with devices that sort, separate and analyze molecules based on size or mechanical properties. Most of the previous methods for fabricating artificial micro and nanometre-scale fluidic structures have involved...
lithography approach and etching processes.[1] As a result, most of the materials used to nanofabricate artificial fluidic structures has been on glass and selected semiconductors limited to standard microfabrication technology. This however limits the experimentation of artificial gels made of materials that would interact with individual molecules at nanoscale-scale. In this work, we describe a new glancing angle deposition (GLAD) technique for fabricating three-dimensional artificial gels in a wide variety of materials with potential use in microfluidic analysis. Traditional GLAD technique involves physical vapour deposition of thin films onto substrates oriented at high angles to micro- and nanoparticles, competing mechanisms namely, self-shadowing and limited adatom diffusion dominate the film growth process.[2] The new GLAD method decouples the direction of incoming flux with the direction of film growth and this allows us to engineer the porosity of the film microstructures.[3] The fabricated microstructured were characterized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). A digital camera with a short focal distance was used to record flow through the fabricated artificial gel. Results show that the new GLAD method may be used to fabricate the entire microfluidic device as a monolithic unit which is an advantage. Observation of pressure driven flow through the fabricated high density microdumb arrays indicate the feasibility of microfluidic analysis using devices made with the new GLAD method. References 1. J. Han, H. G. Craighead, Science 288, 1026 (2000). 2. K. Robbie, M.J. Brett, U.S. Pat. 5,896,204. (1999). 3. M. O. Jensen, M. J. Brett, Appl. Phys. A. In Press (2004)

SESSION J10: Drug and Protein Delivery Chair: David La Van Wednesday Morning, March 30, 2005 Room 2003 (Moscone West)

10:30 AM J10.1 Novel Fluorescent Noble Metal Quantum Dots. Robert M. Dickson and Jie Zheng; Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, Georgia.

Highly fluorescent, water-soluble, several-atom gold and silver quantum dots have been created in dendritic and peptide matrices. These quantum dots behave as multi-electron artificial atoms with size-tunable, multi-colour, resonant transitions between states of well-defined angular momenta. Correlation of Au nanocluster size with transition energy is well-fit by the simple relation, EΦ/A1/3, indicating protoplasmonic fluorescence arising from intraband transitions of free electrons (the jellium model). These conduction electron transitions are the low number limit of the plasmon-the collective dipole oscillations occurring when a continuous density of states is reached.Photon auto-focusing experiments further indicate that single electron transitions instead of collective oscillations are responsible for the size-dependent emission. Providing the missing link between atomic and nanoparticle behavior in noble metals, these highly fluorescent, water-soluble noble metal quantum dots offer complementary transitions of energy size scaling at smaller dimensions than do semiconductor quantum dots. The unique, discrete excitation and emission coupled with facile creation in aqueous solution open new opportunities for noble metal quantum dots as biological labels, energy transfer pairs, and other light emitting sources in nanoscale optoelectronics. References: 1. Zheng, J.; Zhang C.W., Dickson, R.M. Physical Review Letters, 2004, 93, 077402. 2. Zheng, J.; Petty, J. T.; Dickson, R. M.; J. Amer. Chem. Soc., 2003,125, 7780-7781. 3. Zheng, J.; Dickson, R. M.; J. Amer. Chem. Soc.,2002 124, 13092-13093

10:45 AM J10.2 Nano and Micro-Assembly of Devices, Milind Ozkan, University of California, Riverside, Riverside, California.

Heterogeneous integration of devices made of different materials than the mother substrate requires creative ways of integration. In this presentation, a bio-assembly of both micro- and nano-size particles using linkers such as DNA, PNA and viruses will be discussed. Micro scale objects (polymer micro-spheres) and inorganic devices (silk micro-dioxide discs) are assembled on silicon substrate for using DNA linkers. Similarly, single walled carbon nanotubes, CdSe quantum dots are assembled via PNA and viruses as linkers. Assembly of these hybrid systems are analyzed by Scanning electron microscope, Transmission electron microscope and 4-Piperidinylphenylmethane infrared spectroscopy. Such hybrid systems offer controlled assembly of objects in the nano-scale for applications of electronics and bioengineering.

11:00 AM J10.3 High Density Chemical Delivery Arrays with Temporal and Spatial Control. Morgan Mager, Adam Freeman and Nicholas A. Melosh; Materials Science, Stanford University, Stanford, California.

Controlled delivery of chemical species into an aqueous system is an important component of drug research, molecular conformation studies and cell interrogation technology. To address the integration of biological systems with micro- or nano-scale devices, it is important to administer drugs, neurotransmitters, DNA fragments and other biomolecules exactly when and where they are needed. It would be useful to have a compact delivery system that is capable of operating in a number of local environments. We report the fabrication and testing of a system of electrically addressable nano-scale reservoirs that allows temporal control of seconds and spatial control of hundreds of nanometers. This system uses a vapour of a nanometer-sized reservoir and a diffusion barrier to the species inside. Through the application of an electric potential, this system could be electro-transported through the membrane and into the surrounding environment. Since it can be fashioned in a massively parallel array of independently controllable reservoirs, this technology has potential applications for directed cell growth.

11:15 AM J10.4 Electromagnetic Transport of Rigid and Soft Molecules in 2D and 3D Nanofluidic Geometries. Shenggiong Wang, Xin Hu and Ly James Lee; Chemical and Biomolecular Engineering, Ohio State University, Columbus, Ohio.

Sacrificial templates imprinting (STI) is introduced and applied to the fabrication of polymer nanonozze arrays. Nanonozzes with uniform conical fluidic channels can provide two important flow patterns: converging and diverging flow. Electric field enhanced transport is studied in both fluid patterns with rigid nanorings and aromatic DNA molecules. Since the analytes always carry negative charges, both electrophoresis (EP) and electroosmosis (EOF) play important roles. The geometry of those nanonozzes create velocity gradient along the radius of taper regions. Therefore, the diverging flow showed self clean function while converging flow easily clogged for rigid colloidal nanoparticle transport. But for flexible polymers (i.e., DNA), converging flow can moderately stretch the DNA chain to achieve easy passage. In equilibrium size of molecules much larger than the channel size. With the increase of analyte size, hindered transport became apparent until completely block the channel when the channel size closer to the analyte size. To directly observe the conformations of DNA, 3D nanofluidic geometries are fabricated by e-beam Lithography (EBL), followed by soft embossing. The motion of DNA is studied in electokinetic flow with different solutions, considering the effects of channel geometry and internal surface properties of nanochannels. Both steady state and dynamics of DNA conformation are investigated. To compare with experimental results, molecular model is employed to simulate DNA deformations in some cases. All of these findings are relevant in designing gene delivery strategies, and nanofluidic systems for biochemical analysis.

11:30 AM J10.5 Luminescence Enhancement and Inhibition Properties of Core-Silica Silica Fluorescent Nanoparticles. Carl Poitras1, Michal Lipson1, Andrew Burns2 and Ulrich Wiessner2; 1Electrical and Computer Engineering, Cornell University, Ithaca, New York; 2Materials Science and Engineering, Cornell University, Ithaca, New York.

We present results on lifetime, photoluminescence enhancement and inhibition of bright and photostable silica fluorescent nanoparticles. These nanoparticles, come is a liquid solution. They are produced by encapsulating tetramethylrhodamine isothiocyanate (TRITC) fluorophores into a silica shell. These emitters have a brightness that is of the same order of magnitude as quantum dots, and their colloidal form enables their incorporation into optical structures for providing optoelectronic properties to passive devices such as oxides. Here we control the emission properties of the nanoparticles by incorporating them into light confining microcavities. The photoluminescence of the nanoparticles studied is centered at about 570 nm with a FWHM of 39 nm at room temperature under optical excitation at 496.5 nm. Other fluorophores can also be used in order to obtain different luminescence spectra. The photoluminescence properties of the nanoparticles were controlled in 1D by a microcavity formed by distributed Bragg reflectors (DBRs). The microcavity is formed by sputtering layers of SiO2 and TiO2. The cavity mode of the structure exhibits a relatively high Q of 110. The confinement of light in the 3D structure was achieved by varying the effective cavity thickness along the sample. Due to the light confinement in the cavity we observe a strong photoluminescence enhancement and inhibition of the nanoparticles. We also observe a strong directional response to the in-plane confinement. With conjugation chemistry that is well developed for silica, the silica-clad nanoparticles embedded in microcavities opens the door to a variety of applications ranging from biosensing to displays.
Efficient Atomization Using MHz MEMS-Based Integrated Ultrasonic Nozzles. 1 T. A. C. Tsai, Yue L. Song2,1, Yuan P. Chou1, J. H. Cheng1 and Chen S. Tsai1,2; 1Chemical Engineering, California State University, Long Beach, Long Beach, California; 2Physics, National Taiwan University, Taipei, Taiwan; 3Electrical Engineering and Computer Science, University of California, Irvine, California; 4Mechanical Engineering, National Taiwan University, Taipei, Taiwan; 5Electrooptical Engineering, National Taiwan University, Taipei, Taiwan.

At the 2003 MRS Fall Meeting, we reported simulation and vibration characterization of 0.5 MHz silicon (Si) MEMS-based ultrasonic nozzles using a novel design of multiple Fourier horns. In this paper, we report for the FIRST time on successful atomization using such high frequencies in an integrated system for pumping and atomization. The MEMS-based integrated MHz ultrasonic nozzle is made of a piezoelectric drive section, a pump section, and a silicon-resonator with a central channel for liquid flow. The structure allows detection of the immobilization by fluorescence microscopy. For resonance frequency measurements the bridges are electrostatically actuated by applying both DC and AC voltage

allow detection of the immobilization by fluorescence microscopy. For resonance frequency measurements the bridges are electrostatically actuated by applying both DC and AC voltages between the bridge and the gate electrode. The resulting deflection is detected optically. Using fluorescence microscopy we have confirmed that the DNA molecules were immobilized specifically on the silicon dioxide on top of the microbridge available for DNA detection. Using fluorescence microscopy it was observed that the density of DNA immobilized in this process to be around 20% and is inversely proportional to the square of its length. Quality factors are of the order of 1000. DNA immobilization on the microbridge induces a resonance frequency shift. From previous experiments we have expected the density of DNA immobilized in this process to be around 30 pmol/cm². Observed shifts in resonance frequency around 2% are consistent with these results. Quantitative studies for the detection of DNA immobilization using silicon dioxide are also presented. In particular, the resonance frequency with the area of silicon dioxide on top of the microbridge available for DNA immobilization and also the effects of oligonucleotides with different length are studied. A model discussing this sensing method will also be presented.

SESSION J11: Actuators for BioMEMS

Chair: Somuri Prasad

Wednesday Afternoon, March 30, 2003

Room 2003 (Moscone West)

1:30 PM J11.1

Abstract Withdrawn

1:45 PM J11.2

Thin Film Silicon Microbridges for DNA Detection.

Teresa Adrega1, J. Gaspar1, F. Fixe2, V. Chu1, D. M. F. Pires2, and J. P. Conde1,2; 1INESC-MN, Lisbon, Portugal; 2Center of Biological and Chemical Engineering, Instituto Superior Tecnico, Lisbon, Portugal; 3Department of Chemical Engineering, Instituto Superior Tecnico, Lisbon, Portugal.

There has been growing interest in using microelectromechanical systems (MEMS) as biological sensors. Microresistors, in particular, have been proposed as sensors to detect and quantify the presence of specific compounds. Recently, thin-film silicon MEMS were developed in order to benefit from the advantages of thin-film technology. The use of low temperature processing (150°C) allows the use of substrates such as glass, plastic and stainless steel. In addition, thin-film MEMS are CMOS compatible enabling the monolithic integration of MEMS with its control electronics. This work presents a DNA sensor based on doped hydrogenated amorphous silicon (n-Si:H) fabricated on glass substrates. The sensor works by measuring the resonance frequency shift induced by specific oligonucleotide immobilization on a resonating microbridge. The sensor is fabricated using surface micromachining and consists of a n-Si:H/aluminum alloy microbridge with silicon dioxide patterned on the top. The silicon dioxide is a material suitable for DNA covalent binding after chemical functionalization by silanization. An aluminum gate underneath the bridge allows the electrostatic excitation of the bridge. The width of the microbridge is 18 microns, the air gap is 1 micron and the length ranges from 20 to 70 microns. The oligonucleotide molecules are labeled with fluorescein-5-isothiocyanate (FITC) on the NH₂ terminated end to
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Prior to the fabrication of the structural material. We have successfully demonstrated a latching for the SAW sensor and about 0.2 microliter/channel for the coating of the contacts we have demonstrated contact resistances as chemical vapor deposited tungsten films. However, in our process

The novel multi-layer photopolymer dry film and solution process also €lnl and/or viscous solution. Very high aspect-ratio 2- and generally severe out of plane stress problenls associated with blanket, structural materials based on microlasted tungsten. Micro-machining avoids the challenges of the micro-electronics, optics, MEMS, BioMEMS, and related industries, researchers look to next generation lithography. Here we describe a new MEMS process for fabricating metallic structures based on molded tungsten. Micro-molding avoids the generally severe out of plane stress problems associated with blistering, chemical vapor deposited tungsten films. However, in our process there remains a tensile stress associated with the mismatch in thermal expansion coefficient between the silicon substrate and the tungsten structural material. We have successfully demonstrated a latching relay which takes advantage of this high residual tensile stress. The device employs thermal actuation, however, since the state can be latched, the average power usage of such a device can be small for applications where the state of the latch is changed infrequently. The novel actuator design, which takes advantage of the inherent nature of the released tungsten components can generate milli-Newton level forces and avoids problems associated with buckling which can limit the force exerted by the device. Without any noble metal coating of the contacts we have demonstrated contact resistances as low as couple of ohms. While the major structural component of the parts is tungsten, there is a thin layer of TiN inherent to the fabrication process that contacts surfaces of the electrodes. We believe that while this application is useful in its own right, it does not exploit the main potential advantage of this process, its compatibility with back end CMOS processing. The processes we have employed have been developed directly from the different processes used in traditional CMOS back-end-of-line metallization. This potentially would enable the straightforward addition of complex metallic MEMS structures onto completed CMOS circuits. Sandia is a multipurpose National laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

SESSION J12: Process and Device Modeling

Chair: Mark McNee

Wednesday Afternoon, March 30, 2005

Room 2003 (Moscone West)

3:30 PM J12.1

Helical Oligothiophenes As Spring-like Electromechanical Actuators. Aditya Almutani and Michael J. Marsella; Chemistry, University of California Riverside, Riverside, California.

Electromechanical actuation (EMA) is the conversion of electrical to mechanical energy. Conducting polymer EMAs (CP-EMAs) generate strains that exceed those of natural muscle with an order of magnitude. Materials capable of enabling the action of natural muscle have been proposed for use in a variety of applications, such as muscle augmentation, and prosthetics. During oxidation, traditional CP-EMAs expand and contract by intercalation of counter ions. This non-intrinsic, bulk process can be augmented by designing polymers with redox induced intrinsic dimensional changes. We reported that 2,3-linked sexithiophene (1) and 3,3'-diaryl-2,2'-bithiophene (2) reliably exhibit helical motifs in the solid-state. The concept of using helical compounds as a spring-like CP-EMA stems from our computed and theoretical predictions that delocalization of charge generated by a redox event will cause the S-C-S dihedral angle to decrease in order to maximize planar-overlap in non-neutral states. This action results in a compression of the oligothiophene spring, furthering opportunities for charge delocalization via face-to-face thiophene pi-orbital interactions. Compound 3 undergoes anodic electrochemical polymerization at the free terminal alpha-positions. The resulting poly(2) is electroactive, exhibiting both oxidation and reduction. The latter redox state is an order of magnitude more electrically conducting than the former, as determined by in-situ conductivity measurements (relative conductivity). Theoretically, in the oxidized state, the intrinsic length of the polymer remains constant (polythiophene axis), while its width (tetramer long helical axis) contracts. Real-time EMA measurements of bulk poly(2), show a 1.5% contraction, of the polymer film, prior to the critical point when inter-chain contraction typically dominates ion intercalation. This is comparatively an augmentation of the 0.5% contraction that poly(3-hexyl) thiophene exhibited, according to measurements at constant light-doping regime include lower voltage requirements and faster response times (given that the flux of counterions will be at a minimum). We have demonstrated 3,3'-(diaryl)2,2'-bithiophenes as well-defined and predictable helical actuators. We are currently implementing traditional bulk CP-EMA actuation with intrinsic molecular contraction analogous to compression and expansion of a spring. Current work will focus on manipulating the electrolyte solution/solid to increase the inter-chain contraction phenomena. Results to date will be presented.

3:45 PM J12.2

Hot Embossing Lithography: Release Layer Characterization by Chemical Force Microscopy. Neil S Cameron1, Arnaud Oul2,3, Helene Roberge1 and Teodor Versil2; 1IML, National Research Council Canada, Boucherville, Quebec, Canada; 2École Superieure D'Ingénieurs de Recherche en Matériaux, Dijon, France.

High cost, slow serial throughput and resolution issues often handicap traditional micro and nanofabrication techniques. To meet the challenges of the micro-electronics, optics, MEMS, BioMEMS, and related industries, researchers look to next generation lithography. Among the technologies being re-invented to this end is hot-embossing lithography (HEL), an example of nano-implant lithography (NIL). HEL facilitates the miniaturization of micromachined devices with several advantages: high resolution, low long-term cost, flexibility, near-perfect pattern replication, and minimum dimensions in the sub-10 nm range. HEL is promising for optical, biological and data-storage devices as well as for fabrication of integrated circuits. We have employed chemical force microscopy (CFM) to quantify interfacial effects for nano-implant lithography. In our crudest form, a textured, but raw wafer is pressed into a thermoplastic polymer
heated above its Tg. As the stamp progresses into the material, the displaced polymer is pushed into the bulk reservoir for relatively thick thin-film targets. Thus a characteristic tuning curve was obtained on a calcium dependent LeX-LeX recognition with model systems including the perfluoro surface described below for both the embossing stroke and for failure-free de-embossing. Wafers and SPM tips were first silanized with perfluoro- and alkyl-silanes, and model CTM experiments were performed to explore the effect of the various release layers on the embossing process. Contact angle measurements confirmed the chemical process (18.2 Ml/cm water on SAM) and tip/SAM adhesion forces underscored the importance of the perfluorosilane layer.

Recent studies [18] have shown that the use of these channels, we incorporated transducers, which allowed for pumping of fluids through a microfluidic channel. After the remaining between the stamp and the substrate can approach the tribological regime where surface effects from both the stamp and the substrate act on the highly confined fluid. A greater understanding of the surface interactions is thus required with model systems simulating the perfluoro surface described below both for the embossing stroke and for failure-free de-embossing. Wafers and SPM tips were first silanized with perfluoro- and alkyl-silanes, and model CTM experiments were performed to explore the effect of the various release layers on the embossing process. Contact angle measurements confirmed the chemical process (18.2 Ml/cm water on SAM) and tip/SAM adhesion forces underscored the importance of the perfluorosilane layer.

Stochastic Frequency Signature for Chemical Sensing via Noninvasive Neuronelectronic Interface, Congzi Simon Oszom and Mo Yang; Mechanical Engineering, University of California at Riverside, Riverside, California.

The detection of chemical agents is important in many areas including environmental pollutants, toxins, biological and chemical pollutants. As smart cells, with strong information encoding ability, neurons can be treated as independent transducer elements. A hybrid circuit of a semiconductor chip with dissociated neurons formed both sensors and transducers. A stochastic frequency signature was used to differentiate a mixture of chemical agents with effect on the opening of different ion channels. The frequency of spike trains revealed the concentration of the chemical agent, where the characteristic tuning curve revealed the identity. Fatigue experiments were performed to explore the refreshing ability and memory effects of neurons by cyclic and cascaded sensing. Neuronelectronic noses such as this should have wide potential applications, most notably in environmental and medical monitoring.

Carbohydrate-Carbohydrate Recognition Promotes Membrane Adhesion, Christine Goering, Eric Perez, Yongmin Zhang, and Pierre Sinaÿ; 1Laboratoire de Physique Statistique, Ecole Normale Superieure, Paris, France; 2Department de Chimie, Ecole Normale Superieure, Paris, France.

Recently, carbohydrate-carbohydrate recognition has emerged as a new type of interaction in cell adhesion processes. One of these carbohydrates, the LewisX determinant (LeX), has been shown to be involved in murine embryogenesis. Useful information has been obtained on a calcium dependent LeX-LeX recognition with model systems far from the native cellular context. However, nature imposes to the LeX several constraints which may turn out to be decisive for a possible LeX-LeX recognition in a cell environment. One of them is the orientation provided to the LeX through the ceramide (the LeX natural bearing lipid). Therefore the calcium mediated homotypic recognition between natural LeX molecules inserted in a membrane still needs to be proven. For this purpose, natural LeX bearing lipids were isolated in ghost vesicles whose adhesion energy was measured. In the experiments, the vesicles, in tight contact, mimic reasonably well the geometry of cells during the compaction stage of the embryo. The measurement of the calcium dependent LeX-LeX recognition between two LeX borne by these natural molecules, but also that ceramide favors recognition. Moreover the choice of a control molecule very alike the LeX has allowed to show the high level of sensitivity of the LeX-LeX bond to molecular structure.
to general research community. Nanosphere lithography (NSL) is an economical technique that applies large planar ordered arrays of nanometer-sized latex or silica spheres as lithography masks to fabricate sub-micron sized particle arrays. Though NSL has been reported to generate nanowells arrays by conventional reactive ion etching, high aspect ratio features are yet been demonstrated. Here we present an NSL process of the KOH etch followed by silicon and gallium arsenide nano-pillars with high density plasma etching. Oxygen plasma reactive ion etching and nanospheres of different sizes were used to tailor the pattern of "nanosphere resist" to control the size and separation of nanopillars. Effect of chemical species, ratio, frequency power, and substrate bias on etching rates of Si and GaAs and anisotropy of etched profile have been investigated by scanning electron microscopy. This work was performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

J13.2 Synthesis of BaCrO₄ Nano-Crystallites within Thermally Evaporated Sodium bis-2-ethylhexyl-sulfosuccinate and Stearic Acid Thin Films. Kasthuri Sinha¹, Debabrata Rautaray², and Murail Sastry³. ¹Department of Materials & Metallurgical Engineering, University of Nevada, Reno, Reno, Nevada; ²Department of Materials Chemistry, National Chemical Laboratory, Pune, Maharashtra, India.

The growth of barium chromate nano-crystallites occurs within thermally evaporated thin films of stearic acid and sodium bis-2-ethylhexyl-sulfosuccinate by a process of Ba₂⁺ ion entrapment followed by inner reaction with CrO₄²⁻ ions. Dense spherical assemblies of BaCrO₄ nano-crystallites of very uniform size (~50 nm) were obtained within the two different host matrices. The spherical assemblies were composed of smaller (ca. 5-10 nm) BaCrO₄ nanocrystals indicating that efficient size control over crystal size may be exercised by the matrix. Contact angle measurements of the BaCrO₄-stearic acid and BaCrO₄-sodium bis-2-ethylhexyl-sulfosuccinate films indicated that they were hydrophobic, shifting according to the possible role of hydrophobic interaction between the stearic acid and sodium bis-2-ethylhexyl-sulfosuccinate monolayer-covered BaCrO₄ crystals in the assembly process.

J13.3 Characterization of Benzocyclobutene and Chromium-gold Film Interface for Application in Silicon Micromachining. Nima Ghahrechichi¹, Ali Reza Modafe¹, Paolo Lozzero², Victor Michel³, Mariano Andrè³ and Reza Ghodsi¹,². ¹Electrical and Computer Engineering, University of Maryland, College Park, Maryland; ²The Institute for Syncnes Research, University of Maryland, College Park, Maryland; ³ITC-Irst Centro per la Ricerca Scientifica e Tecnologica, Trento, Italy.

We report the interface study of Benzocyclobutene (BCB) polymer and chromium-gold (Cr/Au) films with emphasis on adhesion improvement. Strong adhesion between BCB and Cr/Au layer enables the fabrication of deep anisotropically etched grooves in silicon using potassium hydroxide (KOH) in presence of BCB films. BCB is a polyurethane-based dielectric constant materials with low dielectric constant, enabling the fabrication of microelectromechanical devices with low parasitic loss. In order to protect the low-k film during the highly corrosive, long, high-temperature KOH etching process, Au is used as an etch mask and Cr as an adhesion layer to improve the adhesion of Au to the underlying BCB layer. Metal-BCB adhesion is the key parameter in this masking design. A fabrication process is developed for integration of 1µm-thick BCB and 200 µm-deep anisotropically etched grooves in silicon using KOH. Partial cure of BCB at 210 °C for 40 min with appropriate surface treatment (adhesion promoter) prior to metallization and full cure at 250 °C for one hour after metallization improves the adhesion dramatically. In order to understand the mechanism of the adhesion improvement, the interfaces between BCB and the Cr/Au layer were studied. Several samples were prepared with different film layers and processing parameters, i.e. cure temperature and surface treatment. Time of flight secondary ion mass spectroscopy (ToF-SIMS) was used to investigate the Cr diffusion into Au after Au deposition and cure at 250 °C for one hour. The quantitative results for Cr concentration at the gold film was obtained using Auger electron spectroscopy (AES). Using tabulated sensitivity factors, Cr concentration at the gold layer was estimated to be on average about 1 at. %. To investigate the lateral distribution of Cr inside the Au layer, high lateral resolution ToF-SIMS images was acquired. It was found that Cr diffusion (after curing) into Au layer is not homogeneous. Chromium-enriched grains of 2 µm or smaller were detected close to pure Au grains. Positive and negative ToF-SIMS images were performed on two samples and depth profiles of Si, SiO₂, Si₃N₄, and Si₃O₄, as well as, Si, SiO₂, CrC, Cr, CrO₂, and CrO₃ were obtained respectively. Adhesion improvement which is mainly due to cure management and use of adhesion promoter is assisted with (1) the diffusion of carbon from the polymer structure into the Cr layer, and (2) the chemical interaction of BCB/adhesion promoter and Cr at the interface mainly in the form of the oxidation of Cr. The integration of BCB/bond pads and the KOH etch process obtained the adhesion of metal etch mask to the BCB film, together with the study of the interfaces, allow us to use thick low-k BCB film for fabrication of microelectromechanical devices with low parasitic loss.

J13.4 Fabrication and Evaluation of Conducting Polymer Nanowire Heterostructures. Yevgeny Berdichevsky and Y.-H. Lo; Electrical and Computer Engineering Department, University of California, San Diego, La Jolla, California.

Conducting polymer nanostructures such as nanofibers and nanotubes have potential uses in a variety of applications including electronic, photonic and plasmonic devices and sensors. In this work, a method for fabricating polypyrrole and gold nanorod heterostructures is demonstrated. Template synthesis is used to alternatively electropolymerize gold and polypyrrole in the pores of alumina and polycarbonate membranes. Polypyrrole was electropolymerized in an aqueous solution containing sodium dodecylbenzenesulfonate (NaDBS), resulting in a polymer doped with DBS ions. Individual gold/polypyrrole nanorods are then isolated, and electrical connections are established lithographically. Nanorod conductivity and mechanical activity are then evaluated in various electrolyte environments to establish stability of these heterostructure nanorods for use as pH and biological sensors and as nanomotors.

J13.5 Composition Influence on the Properties of Titanium-Doped Gamma Iron Oxides Nanoparticles Prepared by Laser Pyrolysis. Ion Morjan¹, Rodica Alexandrescu¹, Florian Dumiitrean¹, Ion Sandu¹, Monica Scajoareanu¹, Lavinia Albu¹, Iuliana Soare¹, Ion Voicu¹, Bohumil David² and Victor Ciupium². ¹Laboratory of Laser Photochemistry, National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania; ²Institute of Material Physics, Brno, Czech Republic; ³Ovidius University, Constanta, Romania.

The aim of this work is the compositional and sensing characterization of titanium-doped gamma iron oxide nanojunctions, in order to obtain stable materials for gas sensing. The properties of nanostructured materials are determined by the size, morphology, and phase characteristics of nanoparticles. Particularly in the case of nano-compounds, these properties are strongly dependent on the synthesis conditions. Titanium-doped gamma iron oxide and iron/iron oxide composite nanopowders were synthesized by laser pyrolysis technique. This is a versatile method that allows for the preparation of a wide variety of nanosized bodies (with diameters ranging from a few nm to about 50 nm) by promoting laser-induced reactions in the gas phase. It is based on the resonance between the emission of a CO₂ laser line and the infrared absorption band of a gas (vapour) precursor. The reactant gases are heated by laser absorption in a small, well-confined irradiation volume, defined by the intersection of the laser beam with the inlet gas flow. Basically, sensitized iron pentacarbonyl- and titanium tetrachloride-based mixtures were used as gas-phase reactants. The compositional characterization of the obtained nanostructures is performed by means of different analytical methods (such as TEM, SAED, XRD, and Mössbauer spectroscopy). Introducing Zr in the Fe₂O₃ network in very small quantities (≤ 1%) seems to have little influence on the titanium-doped powder morphology (mean grain size: ~ 1.5 µm) due to the fact that titanium could simply penetrate the iron oxide network. First attempts to increase the Ti content of gamma-Fe₂O₃ oxides modified with Zr using laser pyrolysis seem to indicate the formation of metastable compounds (to pressure-temperature) and a shift of the reaction route towards chlorinated by-products. Electrical measurements were performed in the presence of some gases of interest in polluting area (C₂H₂), in breath analysis (ethanol) and in food control (ethylene).

J13.6 A Systematic Study of the Formation of Nano-Tips on Silicon Thin Films by Excimer Laser Irradiation. D. C. Georges¹, R. J. Baird¹, I. Avrutsky¹, G. Anner¹, G. Newsa² and N. Tokranova³; ¹Dept. of Electrical and Computer Engineering, Wayne State University, Detroit, Michigan; ²Dept. of Mechanical Engineering, Wayne State University, Detroit, Michigan; ³Institute for Materials, SUNY at Albany, Albany, New York.

Recently [1], we reported conditions for controllable, direct laser fabrication of sharp conical tips with heights of about one micrometer and apex radii of curvature of several tens of nanometers. An individual cone is formed when a single-crystal silicon film on an insulator substrate is irradiated in air environment with a single pulse from a KrF excimer laser, homogenized and shaped to a circular spot.
several microns in diameter. In this work, we present a systematic study of the formation of such tips as a function of the laser fluence, the film thickness, and the diameter of the irradiated spot. Atomic force microscopy and scanning electron microscopy were used to study the topography of the structures. Auger electron spectroscopy was used to follow any laser-induced chemical transformations. A simple mechanism of the formation of nanotips based on an extrapolation of the experimental results. The model also predicts the formation of two-dimensional pattern of nanotips. The model of disordered potential was used for numerical studies of the formation of sharp cones in the re-solidification process. The experiments confirm that the film thickness must be below the thermal diffusion length to observe the cone formation. We have also studied structures (nano-ridges) that resulted from irradiation with narrow lines (width of several microns) instead of circular spots.

Silicon nanotips are seen to be among the most promising materials for nanoelectronic devices. The model also predicts that the film thickness, and the diameter of the irradiated spot. Atomic force microscopy and scanning electron microscopy were used to study the formation of纳米-scale tips as a function of the laser fluence, the film thickness, and the diameter of the irradiated spot. Atomic force microscopy and scanning electron microscopy were used to study the topography of the structures. Auger electron spectroscopy was used to follow any laser-induced chemical transformations. A simple mechanism of the formation of nanotips based on an extrapolation of the experimental results. The model also predicts the formation of two-dimensional pattern of nanotips. The model of disordered potential was used for numerical studies of the formation of sharp cones in the re-solidification process. The experiments confirm that the film thickness must be below the thermal diffusion length to observe the cone formation. We have also studied structures (nano-ridges) that resulted from irradiation with narrow lines (width of several microns) instead of circular spots. [1] D.G. Georgiev, R.D. Baird, A. Vorobyev, Y. Auner, Y. Newas, Appl. Phys. Lett., 84 (2004) 4881.


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Carbon nanotubes (CNTs) conjugation with bio-molecules is a very exciting research area, which finds its application in various fields like pharmaceuticals, piezoelectronics, novel nanodevices, and many others. The bionanode under investigation here is Peptide Nucleic Acid (PNA). PNA is a nucleic acid analog in which the sugar phosphate backbone of natural nucleic acid has been replaced by a synthetic peptide backbone usually formed from N-(2-aminomethyl)glycine units, resulting in an achiral and uncharged mimic. Due to their unique yet highly functional structure they show a tremendous improvement in the properties with respect to their counterpart nucleic acids. PNA forms two highly stable structures with Watson-Crick complementary DNA, RNA or PNA oligomers. The uncharged backbone facilitates the synthesis of shorter PNA probes unlike the nucleic acids, which require longer probes to overcome their mutual repulsion. Sensitivity, specificity, faster and stronger hybridization are few of many other advantages that PNA offer. These better chemical, physical and biological properties of PNA make it a strong candidate for its application at the interface of biology and engineering. We are able to form a controlled CNT-PNA network with the help of PNA, which acted as a linker between them. Glutamate modified ends of PNA and predominantly end functionalized CNTs resulted in high yield of CNT-PNA-CNT conjugates. These conjugates are further characterized by SEM (Scanning Electron Microscope), TEM (Transmission Electron Microscope) & FTIR (Fourier Transform Infrared) Spectroscopy. Results indicate that these nanocomposites are thermally, electrically and physically very stable and have excellent self-assembly properties, which can be utilized for building more complex structures.


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Compounds of AIB5C6 group (Ag3SbS3, Tl2SbS3, Ag2AsS3 and others) are seen to be among the most promising materials for manufacturing detectors of ionizing radiation. [gams-Ray Detectors Based on Composite AIB5C6 Semiconductors, H. Khlyap, L. Panchenko, M. Andrukhiv, MRS Proceedings 792 (2004), R3.4.1]. Electric properties of these wide-gap semiconductors are almost unexplored. The abstract reports the first experimental results on electric field-induced effects observed in these nanoscale semiconductor structures under different temperatures. Thin films with thickness up to 800 nm were grown by means of laser deposition technology on KCl substrates at the room temperature. The time of deposition was from 300 to 1120 s. SEM studies of the film surface revealed inhomogeneous relief. The experiments carried out on the bulk material as well as on the thin films under applied electric field up to 700 V/cm showed current-field characteristics typical for multi-step tunneling of charge carriers. In order to clarify the carriers transport mechanism the thin films were used for numerical treatment of the experimental data obtained for the films. Results of the field-current characteristics of the bulk materials were analyzed and modeled according to the semiclassical theory of tunneling in solids.

J13.9 Etching Silicon through an Effective Nanomask: An Electrochemical way to Nanomachining, Stefano Borini, Andrea M. Rossi, Luca Boarino and Giampiero Amato; Nanotechnology and Microsystems, IEN Galileo Ferraris, Torino, Italy.

The fabrication of Nano-Electro-Mechanical Systems (NEMS) requires the ability of nanostructuring bulk materials in a controlled and flexible manner. Here we present a novel approach to silicon nanomachining, based on the electrochemical etching of such material through a patterned mask. Combining a porous silicon (PS) buffer layer with cross-linked poly(ethylene glycol) (PHEMA) mixture in a HF/TEOH mixture, but it becomes resistant to such a solution after cross-linking of the polymer. This can be achieved by high-dose electron irradiation in a Scanning Electron Microscope (SEM), obtaining a mask for the subsequent electrochemical etching. The electrochemical etching can be performed through the masking layer during the electrochemical process, time duration of such a mask is limited. We demonstrate that the presence of a highly porous silicon thin film lying under the resist is sufficient for an evident improvement of the masking power during the electrochemical process. A final PS removal in alkaline solution leads to the formation of silicon micro- and nanostructures in relief, such as microtips and nanomolds. Thus, we have at hand a simple silicon nanomachining process, where the nanofeatures written by the electron beam in the SEM are transferred to the bulk material through a short anodization step in aci solution. This may be an useful alternative method for fabricating nanodevice elements, such as nanofluidic channels or field emitter arrays.

J13.10 Characterisation of Thin Film Piezoelectric Materials by Differential Interferometric Techniques, Markys Cain and Mark Stewart; National Physical Laboratory, Teddington, United Kingdom.

Piezoelectric thin films are considered-emergent materials for integration within Micro Systems Technology (MST) or MEMS devices. The development of suitable measurement facilities to characterise the materials functional properties is complicated by the fact that the film is often attached to a substrate which acts to clamp the film thus affecting the system performance. This presentation will describe a differential interferometer system based on common path Janin optics and measurement lock-in techniques that is able to analyse the displacements of the thin film to sub-μm resolution.

J13.11 An Optical Diffraction Microphone with Active Grating Diaphragm, Kazuhiro Sunaga, Hideyuki Funaki and Yujio Naruse; Corporate Research & Development Center, Toshiba Corporation, Kawasaki, Kanagawa, Japan.

We have previously proposed a MEMS-based optical microphone with an innovative structure as a type of directional microphone that optically detects the vibration displacement of the grating diaphragm. This optical microphone replaces the displacement of the grating pattern on the photo detector with the magnitude of change in the optical intensity and detects the vibration changes in the diaphragm. This paper describes an advanced version of the MEMS optical microphone which realizes the frequency selection and phase detection. The diaphragm of the microphone is fabricated using 8-inch SOI. The diffraction grating is fabricated using the 0.25-μm CMOS process after circuit formation, and the grating diaphragm is finally released from the substrate. In this structure, the diaphragm is suspended by the elastic connectors and can be vibrated in the up and down direction defined as vertical direction of the diaphragm by releasing the acoustic wave. The diaphragm is formed in a 2-D diffraction grating (Diaphragm dimensions: 4mm square, Lattice cycle: 30um). This optical microphone detection using the diffraction spot without any optical components for concentration of the laser beam. This allows for construction of a simple and compact optical microphone system. The microphone system has a driving circuit with a commercially available voltage to which an arbitrary frequency signal is superposed on a fixed bias voltage based on the control signal transferred from the processor. The driving voltage Vp is applied across the cavity between the diaphragm and the substrate. The bias voltage Vp, the electrostatic force is established between the grating diaphragm and the substrate, and the diaphragm is pulled down to the substrate. Consequently, while the diaphragm is actively vibrated by the driving voltage Vp, a passive vibration of the diaphragm is almost not induced by the sound pressure with the active vibration in the diaphragm.
While the diaphragm is actively vibrating with the waveform of a fixed frequency f0, the corresponding frequency component of the acoustic vibration of the diaphragm. The intensified vibration is processed as the amplified electrical sound signal by the photo detector and the processor. Hence, the selected frequency amplification of sound signal can be realized. Additionally, the selected frequency amplification is possible by scanning the frequency f0. In addition to the selective frequency amplification, phase information of the sound can be obtained by changing the phase of the vibration of the diaphragm. The coupling strength between the sound wave and the diaphragm is a function of the phase difference of the two vibrations. The results of the verification experiments indicated that this active optical diffraction microphone could be used for filtering functions and detection of phase information. The details of the experiments and results will be reported at the meeting.

A Theoretical Model for the CO Adsorption Kinetics on Cu(110) by Reflectance Anisotropy Spectroscopy

Coatings of Substrates for Aeroplane and Aircraft at very low coverages, is characterized by a critical concentration (5%-10% HF), current density (100 mA/cm²) and bath temperature, even when the CO molecule on Cu by ascribing the RA peaks to the formation of metallic surfaces monitored by RAS. The results of the verification experiments show that CO adsorption affects profoundly the dynamics of the CO/Cu(110)-p(2 x 1) geometry through 'ab initio' electronic structure calculations, performed within the Density Functional Theory using a PPLMTO code. As observed by Sun et al [Phys. Rev. Lett. 90, 106104 (2003)] and in good agreement with previous results, the 2 eV peak in the reflectance anisotropy (RA) spectrum, ascribed to surface states transitions in clean Cu(110), is found to decrease strongly non linearly at low CO coverage. We recognize this evolution as the signature of the CO molecule on Cu by ascribing the RA peaks to the formation of electronic states peculiar of the modified interface as also observed in infrared studies. In contrast, the RA intensity of the CO molecule even when the CO molecule on Cu by ascribing the RA peaks to the formation of metallic surfaces monitored by RAS. We therefore propose CO/Cu as a prototype for further investigations on the adsorption kinetics on metallic surfaces monitored by RAS.

Fabrication of a Bimodal Ferromagnetic Nanosystem in an Etched Silicon Structure and its Magnetically and Magneto-Optically Behaviour

Due to the low cost production of an array of nanowires mesoporous silicon was used. Using proper doping densities of the wafer as well as proper and well tuned electrochemical parameters like electrolyte concentration (1 mol/liter), current density (100 mA/cm²), and bath temperature (20 degrees Celsius) the mesopores with a narrow distribution of the porodiameter in the range of 60 nm and a length between 10 micrometer and 30 micrometer are highly oriented. This selforganized porous system with a rather homogenous spatial distribution of the pores is appropriate to be loaded with a ferromagnetic material (e.g. Ni) in an electrochemical way to achieve a perpendicular magnetic nanocomposite system. The distribution of both, the pores diameters as well as the spatial distance of the pores can be figured out by FT-image processing. Under convenient loading conditions the magnetic system consists of nanowires as well as granules and shows a very interesting magnetic behaviour with a lot of potential applications. A high magnetic anisotropy with the easy axis perpendicular to the surface can be observed as well as an interesting bimodal behaviour showing two switching fields in magnetic hysteresis due to strong dipolar interaction of the needles. This twofold switching system with a steep slope at the switching fields of HSW1 = 0.05 T and HSW2 = 5.2 T is promising to be useable for magnetic field sensors with a steep characteristic especially in the field of few Tesla. For this purpose cooled curves with a broad splitting and the splitting point between 250 K and 300 K is an advantage for technical applications, like magnetic storage. Due to that long spin-relaxation lifetimes in silicon the needles could be used for spin-injection into the silicon matrix and therefore it is also an interesting system for spintronics. Beside the sample characterization with SEM, EDXS and AES all magnetically and magneto-optically investigations were carried out with a SQUID-magnetometer (H = 7 T, T = 1.7 K - 300 K) and an IR-spectrometer (especially Kerr-rotation measurements), respectively.

Nanocomposite Thin Film Coatings for Ageing Aircraft Skins, Ramanan Asmatullah, Richard O. Cluss, Jeffrey B. Mecham and Sean G. Corcoran, FEORC, Virginia Tech, Blacksburg, Virginia.

The present study deals with nanocomposite thin film coating, analysis and application steps for the ageing aircraft skins. Several nanoparticles (100 nm) were incorporated into polymers, and then the obtained polymeric nanocomposites were characterized (2024-T3) by a nozzle sprayer at different thicknesses. The main purpose of nanoparticles in coating materials is to absorb/block unwanted ions/molecules (i.e., Cl−, OH−, H2O, etc.). An urethane top coat (approximately 1 mm) was also coated on some of initially coated surfaces. Several corrosion tests including electrochemical impedance spectroscopy (EIS) and salt spray were conducted on the prepared samples using 0.5 M NaCl solution. The corrosion test results showed that the Al coupons coated by nanoparticles and urethane top coat gave the excellent corrosion resistances (up to 109 m–cm2) against the corrosion attacks. As a result, it is assumed that the nanostructured coating system will allow military, private companies and government agencies to effectively protect the aircraft surfaces against corisions and flying objects.

Thermal Stability of Ir/TaN Electrode/Barrier on Thin Gate Oxide for MFMOs Structure Application

The Metal-Ferroelectric-Metal-Oxide-Silicon structure has a metal electrode directly on top of thin gate oxide. This structure can be used in NEMS and MEMS systems. The gate oxide used in our present MFMOs structure was a polycrystalline silicon dioxide. Ir was used as the bottom electrode and TaN was used as the barrier layer. It is important in this structure that TaN is stable and will not react with the gate oxide during the ferroelectric material deposition, annealing and subsequent processing which usually was performed at high temperature oxygen ambient. In this paper, TaN barriers with different deposition conditions have been deposited on 3 nm gate oxide. 150 nm Ir was deposited on the TaN barrier layer. Capacitors of Ir/TaN/gate SiO2/Si were defined by dry etching. Series RTP annealing were performed in oxygen from 500 to 650°C with different annealing times. The capacitors were also annealed in nitrogen ambient at 1000°C for 10s. CV and IV characteristics were measured before and after annealing. It shows that Ir/TaN/gate SiO2/Si structure is very stable during the above annealing processes. The consumption and further oxidation of the gate oxide is negligible and would depend on the deposition conditions of the TaN barrier layer. With optimized deposition conditions, a 22 nm TaN barrier layer can effectively prevent any iridium silicide formation and will not degrade the gate oxide during annealing processes. The interfaces between the TaN and gate SiO2 and Si substrate can be further improved by forming gas annealing. It demonstrated that Ir/TaN/gate SiO2/Si is a good candidate for MFMOs structure applications.

Conductive Nanocomposites Incorporating Polymer–Modified Carbon Black: Yaltencir Zucollete, Janashd Avyavan, Rinaldo Gregorio Jr. and Luisa H. C., Mattoso, DEFCM, University of Sao Paulo, Sao Carlos, SP, Brazil; Emory C., Pimole, California; DEMa, Federal University of Sao Carlos, Sao Carlos, SP, Brazil; EMBRAPA, Sao Carlos, SP, Brazil.

Conductive composites incorporating poly(vinylidene fluoride) PVDF or triblock copolymer poly(styrene–b–ethylene–co–butylene–b–styrene) SEBS and a novel conducting polymer-modified carbon black (CPMBC) additive were produced by melt processing. CPMBC additive comprises conductive nanoparticles via deposition of polyaniline or polypropylene on carbon black particles. The composites were produced in a high temperature mixer and then hot pressed in the form of homogeneous flexible films. Electrical conductivity in the order of 10−2 S/cm could be achieved with low contents of the conductive filler. The addition of CPMBC is advantageous to the melt processing of the composites reducing the melt viscosity in comparison to the addition of pure carbon black. It was shown that for the SEBS based composites, both strength at break and yield point decreases with the increment of the polyaniline content on CPMBC formulation. The conductivity is quite stable at high temperatures, even when the samples are exposed for long time at high temperatures. Thermogravimetric analyses (TGA) showed that the composites have an excellent thermal stability up to temperatures of about 330 °C, which is highly desirable during the melt processing. For PVDF-based nanocomposites, in particular, the incorporation of the nanocomposites made the achievement of PVDF- β phase in a one-step process, when the
nanocomposites are quenched from the melt.

J13.17 Spectroscopic Investigation of Ferromagnetic Co-doped TiO2. Jong-Pil Kim1, Chye Ryong Cho2, Mi-Sook Won3, Jong-Hee Yoon1, Kyung-Soo Hong1, Se-Young Jeong2 and Dong-Ho Kim3; 1Busan Branch, Korea Basic Science Institute, Busan, South Korea; 2School of nanochemistry, National University, Busan, South Korea; 3Department of Physics, Yeungnam University, Gyeongsan, South Korea.

Diluted magnetic semiconductors (DMS) have attracted considerable attention because of their potential for novel applications in the rapidly evolving area of spintronics. Recently, room-temperature ferromagnetism has been observed in some wide-bandgap host semiconductors such as GaN, ZnO, and TiO2. Among them, Co-doped TiO2, discovered by Matsumoto et al.[1], has been actively investigated due to properties like a high Tc over 400 K, excellent optical transmittance in the visible and near-infrared regions, and high n-type carrier density without intentional doping. Chatterjee et al.[2] reported improved properties like higher magnetic moments of 1.26 μB/Co atom and larger remanence when activated oxygen, such as oxygen plasma, was used during the film growth process. The oxidation state of cobalt in the film was +2 from both Co 2p core level photoemission and Co L-edge X-ray absorption analysis. Chambers claimed that the ferromagnetism originated from the electron-mediated exchange interaction between Co2+ cations that substitute for Ti4+ in the lattice, arguing against the formation of cobalt metallic nanoclusters. Recently, the occurrence of room-temperature ferromagnetic (FM) in Co-doped TiO2 anatase films grown by molecular beam epitaxy is reported. Co-doped TiO2 anatase, grown by pulsed laser deposition (PLD), has recently been demonstrated to be weakly FM and semiconductor for doping levels up to ~8 at.%, and temperatures of up to 400 K. To this end, we described the phase formation, ferromagnetic properties and interface effect of diluted magnetic semiconductor. The structural properties were analyzed by X-ray diffraction (XRD), scanning electron microscope (SEM) and transmission electron microscope (TEM) and the magnetic properties were measured with a Physical Property Measurement System (PPMS). The curve of Ti0.97Co0.03O2 in annealing temperature 450°C shows hysteresis loop with coercivity (Hc) of about 90 Oe and the saturation magnetic moment (Ms) of the magnetization saturation. The elemental distribution with depth of thin films is measured by Auger electron spectroscopy (AES) and chemical state of thin films measured by X-ray photoelectron spectroscopy (XPS). From AES depth profile, it was found that Ti and O concentration of Ti0.97Co0.03O2 thin film were nearly constant in the interlayer between surface and substrate. And, with increasing of Co doping, O concentration of films were decreased from surface. From the binding energy, the main peaks of Co 2p3/2 and shoulders may be indicated oxidation state of Co and shifter of main peaks may be due to CoTiO3 phase. This work was supported by the Korean Research Foundation Grant (KRF-2002-070-C00333). [1] Y. Matsumoto, et al. Science 291, 854 (2001). [2] S. A. Chambers et al. Appl. Phys. Lett. 79, 2467 (2001).

J13.18 Embedded Piezoresistive Microcantilever Sensors: Materials for Sensing Chemical and Biological Analytes. Timothy L. Porter, William Delinger, Randy Dillingham and Robert Günter; Physics, Northern Arizona University, Flagstaff, Arizona.

Embedded piezoresistive microcantilever array (EPMA) sensors combine many of the positive features of coated-cantilever sensor designs and standard chemiresistor sensors. In the EPMA sensor design, a tiny microcantilever of approximately 200 microns in length is embedded or encapsulated in a sensing material. This sensing material may be polymeric, functionalized polymeric, biological, or a composite material combining a polymer with biological molecules. Depending on the sensing material, analyte molecules may bind to the polymer matrix and partition into the interfacial layer, or cooperate themselves to form the material layer. This chemical action results in a tiny change in the physical properties of the sensing material, which in turn results in a tiny strain or deformation. Strains of only a few Angstroms may be measured. The piezoresistive cantilever strain is measured as a change in resistance; a simple multimeter or bridge circuit is sufficient to record this change. These EPMA sensors are very simple, and require only simple electronics to operate. They are also very robust, as the cantilever/sensing material form a single, rigid unit. We will discuss materials and composite materials to be used as the active elements in EPMA sensors. We have used polymeric materials, as well as biomolecule/polymer composite materials to sense a wide variety of analytes. These analytes include volatile organic compounds (VOC’s) in air or in liquids, and biological molecules in liquids and in aerosol. VOC’s detected include industrial compounds such as toluene, hexane, ethanol, and others, gases such as carbon monoxide, environmentally sensitive compounds such as carbon tetrachloride, MIB and TCE, and biological molecules such as vitamins (e.g. vitamin B12), single-strand DNA, and proteins including bovine serum albumin. Future work on new compound materials will also be discussed. These new materials, based on hydrogel matrices, will be used in applications such as biological sensing, hydration level sensing in living hosts, and poison gas sensing.


We have fabricated poly-Si/ Au nano-gap electrode pairs for characterizing and utilizing electrical properties of single molecules or nano-particles, using atomic-layer-deposited (ALD) Al2O3 as a sacrificial layer. In this process, a nano-gap is formed by removing a sacrificial ALD Al2O3 layer pre-formed between the poly-Si and Au electrode regions, where the gap-width is determined by the thickness of the ALD Al2O3 layer. As the ALD process is a layer-by-layer growth based on self-saturated surface reactions, the width of gaps can be controlled within the range of a few angstroms by varying the number of deposition cycles. Because no thermal or anodic oxidation process is needed for forming the sacrificial layer, we can freely choose the electrode materials suitable for the molecular species to be characterized. In addition, this method enables the massive formation of nanogaps in a single process very useful in fabricating integrated circuits of molecular electronic devices containing numerous nano-gap electrodes. Using this method, we successfully fabricated 10X10 arrays of poly-Si/Au nano-gap electrode pairs varying the gap-width in the range of 3-10 nm, and confirmed that they had good insulating properties in room temperature.

However, when functionalized Au nano-particles were trapped within the gap region, the current flow through the nano-gap electrodes increased significantly. It demonstrates that the nano-gap electrodes fabricated by the new process can actually be used for measuring the electrical properties of nano-sized molecular species.

J13.20 Comparison of Laterally Aligned InGaAs/ GaAs Quantum Dots Grown by MBE and ALE Techniques. Sung-Yool Choi; Electrical Engineering, University of California - Riverside, Riverside, California.

Two kinds of growth techniques, conventional molecular-beam epitaxy (MBE) and atomic layer epitaxy (ALE), have been introduced for formation of laterally aligned InGaAs quantum dot (QD) structures, and the QD profiles and their optical characteristics were investigated for comparison. In MBE-grown QDs, the order of alignment of QDs has been controlled by the number of stacks with growth interruption during the growth of AlAs QD layer. The length of alignment becomes longer with increase of the period of stacks as reported, and the QD chain with a length of ~1 um can be obtained from the 15-layer stacked sample in this study. The thickness of InGaAs QD and GaAs spacer layers are 7.5 monolayers (MLs) and 60 MLs, respectively, and the growth interruption for 10 sec for every 3 MLs is applied for the first 30 MLs. On the other hand, the laterally aligned QD chain similar to that grown by MBE can be achieved without stacking of QD layers only by controlling the coverage of QD layer (2.5-25 MLs) or the number of cycles of species. Dissimilarly to MBE-grown QD chain, ALE-grown one shows very strong photoluminescence (PL) emissions even at room temperature with a far-infrared carrier transfer behavior, and the above mentioned PL emission which is applicable to 1.3 or 1.5 um QD laser diode is realized at x = 0.5 and τ ~ 7.2 ms. The preferential alignment and the emission characteristics may be enhanced by a larger surface migration due to alternate source supply in ALE technique compared with conventional MBE. Comparative data between MBE- and ALE-grown QD chains will be presented together with the details. [1] Z. M. Wang, K. Holmes, Yu. I. Mazur, and G. J. Salomo, Appl. Phys. Lett. 84, 1931 (2004).

J13.21 Interpretation of the Phonon Frequency Shifts in ZnO Quantum Dots. Khan A. Alim, Vladimir A. Fonoberov and Alexander A. Balandin; Nano-Device Laboratory, Department of Electrical Engineering, University of California - Riverside, Riverside, California.

Nanostructures made of zinc oxide (ZnO), a wide-bandgap
semiconductor, have recently attracted a lot of attention due to their proposed applications in low-voltage and short-wavelength (368 nm) electronic-optical devices. The unique properties of GaN nanorods include high optical gain, gas sensors, and varistors. Raman spectroscopy presents a powerful tool for identifying specific materials in complex structures and for extracting useful information on properties of nanoscale objects. At the same time, the direction of Raman peak evolution from In2O3 is highly recommended. Phase and microstructure evolution was found to induce a large red shift of the phonon frequencies. It is calculated that the observed red shift of 14 l/cm corresponds to the local temperature of the quantum dot ensemble of about 700 degrees Celsius. The experimental results are in excellent agreement with the theory of the optical phonons in wurtzite nanocrystals developed by Fonoberov and Balandin. The theory predicts that the asymmetry of the wurtzite crystal lattice leads to the quantum dot shape-dependent splitting of the frequencies of polar optical phonons in a series of discrete frequencies. The obtained experimental and theoretical results allow one to unambiguously identify non-polar phonon peaks in the Raman spectrum of ZnO nanostructures. This research has been supported through DARPA - SRC MARCO Center on Functional Engineered Nano Architectonics (FENA) and NSF Award to A.A.B. [1] V. A. Fonoberov and A. A. Balandin, Phys. Rev. B 70, in print, December 15, 2004; ibid, cond-mat/0405881.

J13.22 SnO2 Doping Effect in In2O3(ZnO): Ceramics. Chang Seok Han1,2, Sejoon Lee1,2, Sun Jae Hwang1,2, Duck Nan Kim1,2. Recently, multicomponent oxide of ZnIn2O3 system has been found to have a low resistivity and a good average transmittance above 80% in the visible range. Researches on In2O3(ZnO): (indium zinc oxide; IZO) ceramics reported that the system is known to have various homologous compounds with different k values (k=3, 4, 5, 9, 11, 15, 15), and the electrical conductivity and carrier mobility greatly depend on the k values. It is also known that the solubility limit of Zn in In2O3 is very narrow which is close to 2 mol%. However, among the IZO composites, In2O3(ZnO):k (k=3) is known to have the best electrical and optical properties, and high electrical conductivity of IZO was reported when 30~40 mol% of Zn is contained. In these compositions where k=2~3, it was thought that the addition of Sn4+ could expand the solubility limits of Zn−k in IZO due to the charge compensation effect. In this study, therefore, Sn was added to In2O3(ZnO):k (k=2~3) for an expanded solubility limit of both Zn and Sn in In2O3(ZnO):k (k=2~3). In this case, since the cost of indium sources is very expensive, Sn was used as a substitute for indium in IZO is highly recommended. Phase and microstructure development and electrical characteristics of IZO as a function of Sn and Sn concentration were examined.

J13.25 Effects of e-Beam Annealing on Structural and Optical Properties of GaN Nanorods. Deuk Young Kim1,2, Chang Seok Han1,2, Sejoon Lee1,2, Sun Jae Hwang1,2, Duck Nam Kim1,2, Hye Sung Lee1,2, Doo Soo Kim1, Hongseung Ryu1, Jinhyung Cho2, Hwa-Mok Kim5 and Tho Won Kang2. GaN is the most promising wide-bandgap semiconductor for such potential applications as blue LEDs, blue LDs, and high-power electronic devices, because of its outstanding properties including a wide bandgap of 3.39 eV, high breakdown field of 5x10^9 Vcm^-1, and high saturation drift velocity of 2.7x10^7 cm/s. Recently, the synthesis of one-dimensional GaN nanostructures has been achieved by various techniques such as laser-ablation, chemical vapor deposition, catalytic reaction process, and it is well established that these one-dimensional GaN nanostructures enhance and modify their optical properties. Unfortunately, one-dimensional GaN nanostructures have a high defect density and surface and/or interfacial properties. Many researchers reported that the e-beam annealing process could change the chemical potential in surface or interface and that the ion-beam irradiation process might reduce the residual stress. In this study, the effect of e-beam annealing on structural and optical properties of GaN nanorods grown by HVPE has been investigated. GaN nanorods were directly grown on the c-α-2O2 substrates at 50°C without catalyst. In order to investigate the e-beam annealing on structural and optical properties of GaN nanorods, we performed e-beam annealing for 5 hours with applying the acceleration energy of 30 keV. For measurements of XRD, it was observed that the FWHM of e-beam-annealed GaN nanorods becomes narrower than that of as-grown GaN nanorods. The Bragg angle of e-beam-annealed GaN nanorods was slightly moved to the left-hand side. The peak position of the DCXD pattern was determined to be 17.27, which this value is very similar to that of GaN thin films having no significant strain. For CL measurements, the values of FWHM and intensities were significantly decreased and gradually increased with increasing the annealing time, respectively. Moreover, it was observed that the peak position of e-beam-annealed GaN nanorods was 3.30 eV, and this value is closer to that of GaN thin films without considerable strain. These results indicate that the improvement of crystallinity might be induced by relaxation of the compressive strain due to e-beam annealing. The results of Raman showed that the peaks of A1g (TO), E2g (TO), and E2g (high) modes were changed into narrower shapes and that the peak position of A1g (TO) mode was slightly shifted to higher-frequency region. These behaviors suggest that the decrease in boundaries and/or disorder of crystalline. Therefore, it is considered that the e-beam annealing process might lead to induce the enhancement of the crystallinity in the GaN nano-rod surface and interface resulting from the relaxation of the residual strains in GaN nano-rods.

SESSION J14: Materials and Devices

Chair: Rashid Bashir

Thursday, March 31, 2005
Room 2003 (Moscone West)

8:45 AM J14.1

A Novel Photo-patterning Method for PHFMA Hydrogels. Stephanie J. Bryant1, Kip D. Hauch1 and Buddy D. Ratner1,2. 1Bioengineering, University of Washington, Seattle, Washington; 2Chemical Engineering, University of Washington, Seattle, Washington.

Patterned hydrogel structures have potential application in a variety
uses of including microfluidic devices and tissue engineering scaffolds. In traditional photolithography of liquid phase solutions, the patterned material solution is dip-coated onto the bottom of the wafer. With the wafer held at a shallow angle, the solution will flow down and fill the channels of the micromold. This method has been used successfully to fabricate channels on the order of 10 μm deep.

However, these methods have limitations. They require specialized equipment and are time-consuming. Additionally, they are limited to the use of photoresist materials, which can be costly and environmentally unfriendly. Therefore, alternative approaches to fabricating microfluidic devices are being explored.

In recent years, the use of microfluidic devices has become increasingly common in various fields, including biology, medicine, and engineering. These devices are designed to mimic the environment of living organisms, allowing for the study of cellular behavior and biological processes. They are also used in drug development, diagnostic testing, and environmental monitoring.

In conclusion, the fabrication of microfluidic devices is a complex process that requires careful consideration of various factors. The use of alternative approaches to traditional methods, such as the one described in this paper, may help to improve the efficiency and effectiveness of these devices. Additionally, advancements in microfabrication technology are likely to continue to drive the development of more sophisticated and functional microfluidic devices in the future.

We have investigated the effect of donors and acceptors on the band structure of Ba$_0$Sr$_2$TiO$_3$ (BST) thin films prepared by a pulsed-laser deposition method. We have chosen Mg/Al and La as acceptor and donor dopants, respectively. Based on x-ray photoelectron spectroscopy (XPS) and ultraviolet-visible spectrophotometer (UVS) data, the Fermi level, valence-band edge and conduction-band edge are calculated for BST films in which Mg/Al and La dopants have been added. The Fermi level depends strongly on the oxygen vacancy concentration in thin films. Stress and grain size of thin films play a key role in determination of valence and conduction-band edges. The effects of dopants on the oxygen vacancy concentration, stress and grain size are detailedly discussed.

SESSION J15: MEMS and Photonics

Chair: Mihriz Ozkan

Thursday Morning, March 31, 2005
Room 2003 (Moscone West)

10:30 AM J15.1
Fabrication of GaN Photonic Crystal Membrane Cavities. Cedrik Moler,$^1$ Elaine D. Haberer,$^2$ Rajat Sharma,$^3$ Kevin Hennessey,$^1$ Kelly McGroder,$^1$ Ken Sakamura,$^1$ and Evelyn L. Hu.$^4$ $^1$California NanoSystems Institute, University of California, Santa Barbara, Santa Barbara, California; $^2$Materials Department, University of California, Santa Barbara, Santa Barbara, California.

Photonic Cavities such as microdisks, micropillars and photonic crystal cavities provide the possibility to confine light into distinct, well-defined modes. By coupling emission from active layers such as quantum wells or quantum dots to these modes, the emission properties can be greatly modified, e.g., by the Purcell effect. This has possible applications in low-threshold laser, quantum cryptography etc. To achieve efficient coupling, two figures of merit are of importance: the quality factor $Q$, namely the spectral linewidth of the mode, and the effective mode volume $V$, which determines the volume the mode is confined into. As the Purcell factor increases with $Q/V$, a high quality / small volume mode is necessary to achieve optimum coupling strength. Of all types of photonic resonators, photonic crystal defect cavities can provide the smallest mode volume while maintaining high (up to $Q>10^6$) demonstrated in GaAs) quality factors. An effective way of forming such a cavity is to form photonic cavity membrane structures in which the light is confined in-plane by the photonic crystal and confined in the vertical direction by the index difference between the membrane and surrounding regions. While the formation of an undercut membrane can be achieved by selective wet etches in many material systems, this is more difficult for GaN as this material system has no conventional wet etch. We have used bandgap-selective photoelectrochemical (PEC) etch to selectively undercut a sacrificial layer while maintaining the active layer underneath. Successful formation of photonic crystal membrane cavities, using a triangular lattice / H2 defect with lattice constants between $a=160\text{nm}$ and $a=200\text{nm}$, suitable for coupling to emitters in the range between $400\text{nm}$ and $520\text{nm}$. We will also analyze our device performance using FDTD simulations. Finally, we will discuss the impact of lattice constant on the mode spectrum of the H2 defect.

10:45 AM J15.2

Semiconductor quantum dots (QD) possess enormous potential as single photon sources, nano-lasers, and luminescent reporters for biological processes, to name a few. To realize the full potential for QDs, especially in nano-scale design and engineering, a fundamental understanding of their optical property at the single-molecule / single-particle level is critical. Since the initial discovery of “on” and “off” intermittent emission of individual QDs, considerable efforts have been made in characterizing the statistical properties of such behavior. These endeavors, however, are hampered by the inability to locate accurately the time instant at which the emission intensities change. Here we report a new study using the recently developed change-point detection method that allows the estimation of the statistical properties of underlying QD emission dynamics photon by photon. The number of emissive states (greater than 2) was determined. Inter-state transition kinetics and state-resolved luminescence lifetime were measured. Their implication in rational design of optical probes using QDs will be discussed.
The J-Ln1 and Arun laser is absorbed extensively on a fused silica substrate. Gate voltage can be used to control the nanochannel environment.

From impregnated thin-films to thicker substrate platforms, this process allows for freely deformable geometries to be generated on a metal-coated glass using the photolithographic process. Where the metal is etched away, the laser light is allowed to pass, transferring the pattern onto the substrate. Dedicated masks allow for flexibility and an automatic alignment can precisely position the mask within +/- 1.0 microns.

We demonstrate a nanofluidic transistor-a nanochannel with a gate electrode- that exploits this effect. The nanofluidic transistor can be used to control ionic as well as biomolecular concentrations and hence control their flow. This effect is similar to the metal-oxide-semiconductor field effect transistor (MOSFET). Further, surface-bound biomolecules and bio-reactions, such as antibody-antigen binding, will effectively control the electrical conductance of the nanochannels, enabling their use as a novel charge-sensitive biosensor. Nanochannels that were 30-40 nm thick and 1 μm wide were fabricated on a fused silica substrate. Gate electrodes were incorporated into different templates to create a nanofluidic transistor.

Microchannel Arrays in Borophosphosilicate Glass for Photonic Device and Optical Sensor Applications.

The fabrication of arrays of embedded microchannels on a silicon wafer and their integration with optical waveguides offer great potential for the realization of novel photonic devices and sensors. In this work, we present the fabrication of two-dimensional uniform arrays of microchannels with circular cross-sections of 250 μm in diameter in borophosphosilicate glass (BPSG) layers deposited by plasma-enhanced chemical vapor deposition (PECVD), and demonstrate the application of these structures in optical sensors. The microchannels are formed by depositing specific thicknesses of BPSG over periodic ridge/space templates etched into underlying silica layers using reactive ion etching (RIE). High temperature annealing results in refraction of the BPSG and formation of uniform voids between the template ridges. We demonstrate how the size, shape, and position of the microchannels relative to the ridge templates can be controlled through adjustment of the template geometry, the thickness of the deposited layers, and the annealing conditions. The use of different ridge templates to fabricate one-dimensional and two-dimensional arrays as well as novel interconnecting channel structures will be presented. The silica-on-silicon PECVD/RIE processing techniques used in this work offer the flexibility to engineer these microchannels in a number of different multilayer structures with tightly controlled physical and optical properties. By using the same BPSG material for the template and void forming layers, silica-air microstructures in a single matrix material can be formed. Alternatively, by patterning the templates in Ge-doped silica layers, optical waveguides aligned to close proximity to microfluidic channels are formed. The evanescent field of the light guided in the waveguides can then be used to access the optical properties of the fluid in the channels. Sensor and detector functionality will be demonstrated through absorption and fluorescence in the integrated structure, and the performance of a novel optical sensor sensitive to changes of refractive index in small volumes (< 1 x 10^-12 m3) of liquid will be presented.

Conducting or semiconducting conjugated polymers show significant change in their electrical properties after exposure to humidity. A number of different techniques such as electrochemical polymerization, chemical and electrochemical deposition and spin coating have been applied for the fabrication of polymer humidity sensors. In this paper we report layer-by-layer nano-assembly for fabrication of highly sensitive and fast response humidity sensors using conducting polymer polypyrrole (PPy). Spin coating was also used for fabrication of PPy humidity sensor for comparison. Layer-by-layer nano-assembly of poly(styrenesulfonate) (PSS), and PPy was done on glass substrate. PSS was used as polyanion, while PPy was used as polycation. Five alternating precursor layers of (poly(allylamine) (PAA)/PSS) were deposited before self-assembly of polymer sensing layers. A LbL self-assembled bilayer thickness was measured to be 2.3±0.1 nm. The change of electrical resistance in the sensing polymer was monitored when the sensing element was exposed to humidity. These LbL assembled nano-films produced a fast change in resistance when exposed to humidity. The change in resistance was monitored for humidity ranging from 50 % to 80%. The experimental results show 10% decrease in resistance for the LbL-based PPy and 8% resistance change for the spin coated PPy for every 5% increase in humidity. A comparison was made in terms of sensitivity and response time for the two different fabrication techniques. LbL-based sensors showed higher sensitivity and fast response than those from spin coating. The response time is tested to be 25 seconds for the LbL-based sensor, while it is around one minute for the spin coated sensors. The degradation was noted when the sensors were exposed to an environment for 7 days. LbL based humidity sensor showed less drift in sensor baseline resistance than that from spin coated humidity sensor. Such PPy humidity sensors can be used as disposable handheld humidity detectors due to low cost and easy fabrication.


A metal-insulator-semiconductor (MIS) type sensor, utilizing a Pd-Cr or Pd-Ni / AIN/n-Si(111) structure are being developed to measure hydrogen in the atmosphere. The Capacitance-Voltage (CV) curve would shift in the presence of hydrogen. At a constant capacitance, the voltage shift is a function of hydrogen concentration. The alloy gates were deposited in a magnetron sputtering chamber and the AIN was grown using Plasma Source Molecular Beam Epitaxy (PSMBE). Samples with Cr concentration from 4-10% and Ni from 4- 20% were fabricated. Addition of Cr and Ni would suppress the phase transition of palladium and provide a more stable film, as revealed by X-ray Photoelectron Spectroscopy (XPS). Surface segregations of Cr and Ni were found. Furthermore, in Pd-Cr alloy, Cr was oxidized on the outer surface while Pd was oxidized in the metal/insulator interface. However, no similar result was shown in the Pd-Ni alloy film. The work function of the Pd was different depends on the concentration of Cr and Ni. The effect of this difference on the sensor performance is still being studied. Several operating parameters including temperature, flow rate and ac signal frequency were investigated, the larger response could be obtained with measurements made at a low temperature and with a low ac signal frequency.
These observations strongly support the formation of molecule-nanoparticle network. The three-terminal measurements for the conjugated molecule were performed on 1 μm wide gate 

It will guide applications of gold metallic nanoparticles in biological probes. We report here for the first time that p-type gate effects were clearly observed for conjugated oligo-phenylidendithiol molecules incorporated in a nanoparticle array. While most of previous works utilized some forms of nanogap for single-molecule connections, our molecule-nanoparticle network was formed by a macroscopic network of inter-connected metal-molecule-metal junctions between μ-sized channel regions. This structure is an excellent example of making it possible to study intra-molecular transport and charge transfer reliably, and results. The network consists of a densely packed gold nanoparticle monolayer array and dithiol linker molecules that chemically bridge pairs of nearest-neighbor nanoparticles. The particle array was prepared over a conductive glass substrate by modified Langmuir-Budgett method and transferred, without damaging the array quality, to an insulating substrate with interdigitated metal electrode patterns on it. The array was submerged in a solution of linker molecules and subsequently rinsed well in a water bath. The substrate has a particular angle-of-incidence of the optical probe beam that is used. This situation cases where this approximation is insufficient and a wavelength-dependent function must be employed. In these cases, considerable advantages accrue from being able to combine SE, BPR, and Broad-Band (BB), near-normal incidence spectrophotometry into the same measurement. A number of examples are supplied of p-C films characterized by these techniques, both singly as well as components of more complex hard-mak filmstack structures. Three-sigma reproducibility results achieved for t, n, and k at 193 nm on single ~5000 nm wide blade is of the order of 0.7 A, 0.020, and 0.001, respectively.
caps and manipulation of nanoparticles, we have demonstrated nanoscale assembly of inorganic carbon nanotubes and quantum dots with engineered viruses to produce a new array of hybrid structures. Network assembly has been achieved between a mutant insect Flock-House Virus (FHV-A205K) and single-walled carbon nanotubes (SWCNTs), and Plant Cowpea Mosaic Virus (CPMV) and quantum dots (QDs) through carbodiimide coupling chemistry. FTIR confirmed covalent amide linkages between each heterostructure, and SEM studies visualized large-scale network assembly. Fluorescence microscopy visualized how quantum dots were incorporated into carbon nanotube networks. To control quality of starting material, SWCNTs were separated by length using centrifugal fractionation to isolate a more monodisperse sample. Water-soluble quantum dots were prepared by functionalizing them with a carboxylic acid. Such a hybrid system can be employed to fabricate novel biofilms with tunable pore sizes, 3-dimensional architecture for nanoelectronic device fabrication, a tool for biological probing, dynamic epitope expression systems, and drug delivery applications.

J18.2 Abstract Withdrawn


We report on the progress of the development of a reconfigurable MEMS-based photonic crystal waveguide device. The realization of this device requires overcoming a number of processing challenges, and the complexity of fabricating a three-dimensional MEMS device is compounded with the nanometer scale features of the photonic crystal. The fabrication challenges were compounded by fabricating the fabrication process, which includes e-beam lithography and various dry and wet etch techniques. The interdependence of the fabrication steps and how it affects the overall device will be examined. These devices can be a basic building block in optoelectronic integrated circuits, which can be used in a number of military applications such as signal processing for communications, radar, sensors, and imaging.


Functional nanocomposites based on magnetic nanoparticles are becoming very popular in many fields finding applications in medicine and nanosystems. However, relatively few works have explored the use of chitosan in magnetic composites. We have developed a novel nanocomposite based on Fe3O4 nanoparticles embedded in a chitosan (CHCOOH) matrix. The magnetic nanoparticles were prepared by coprecipitation from a FeCl3 and FeCl2 in NaOH solution of an iron-organometallic gas. Both TEM and XPS measurements were performed in order to visualize the structure of the nanoparticles and to study the iron incorporation in the polymer matrix by the use of different soft-chemistry methods. The characterization of the nanocomposite was performed by TEM, OM, XRD, FTIR, TGA, DSC and APM. The possible applications of this composite in nanosystems is discussed.

J18.5 Negative Transverse Magnetoresistance Effect in Bismuth Nanowires. Dmytro Vasylievich Gitsu1, Tito E. Huber2, Leonid Alexandrovich Komolko1,3 and Albina Alexandrovna Nikolaeva1,3. 1Institute of Applied Physics, Chisinau, Moldova; 2Department of Chemistry, Howard University, Washington, Washington; 3International Laboratory of High Magnetic Fields and Low Temperatures, Wroclaw, Poland.

In Bi nanowires with diameters d<100nm for the first time the negative magnetoresistance effect at H1.11 at T=1.6-4.2K is found. Glass covered single crystal Bi wires of strictly cylindrical form with d=100±50 nm were obtained by the liquid phase casting by the Ulltovskiy-Tailor method. Orientation of the samples of all the diameters was the same: the wire axis made up an angle of ~20° with the bisection axis C2 in the bisection-trigonal plane. The diameter was controlled with the help of SEM and APM microscopes. It was found that with the wire diameter d decreasing the minimum on the TM shifted into the region of strong magnetic fields and its depth increased. Investigation of temperature and thickness dependences of the TMR allows us to conclude that two special points on the temperature (minimum of the negative polarity and the point of intersection with the axis x (RHL) = 0) are connected to both size effect determined by the ratio d=RCF=FC/(R_L), where the Larmor radius) and size quantization effect: ω = 2πh/2md^2. In the first case this gives a possibility to estimate the Fermi pulse of the carriers in the direction of the LLL, and in the second - the size quantization value.

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J18.6 Towards Novel Light-Activated Shape Memory Polymer: Thermomechanical Properties of Photo-responsive Polymers. Emily Snyder and TM Hung Tong; Cornerstone Research Group, Inc., Dayton, Ohio.

The basic principle for the operation of a thermally stimulated shape memory polymer (SMP) is the inelastic change in elastic modulus above the glass transition temperature (Tg). This change from glassy modulus to rubbery modulus allows the material to be deformed above the Tg and retain the deformed shape when cooled below the Tg. The material will recover its original shape when heated above the Tg again. However, thermal activation is not the only possibility for a polymer to exhibit this shape memory effect or change of modulus. In this report, the results of an alternative approach to SMP activation are discussed. It is well known that the Tg of a thermosetting polymer is proportional to its crosslinking density. It is possible for the crosslinking density of a room temperature elastomer to be modified through photo-crosslinking special photo-reactive monomer groups incorporated into the material system in order to increase its Tg. Correspondingly, the modulus will be increased from the rubbery state to the glassy state. As a result, the material is transformed from an elastomer to a rigid glassy photoset, depending on the crosslinking density before exposure and the crosslinking density after exposure. This process is reversible by irradiation with a different wavelength, thus making it possible to produce light-activated SMP materials that could be deformed at room temperature, held deformed during exposure of the material using one wavelength, and recovered to the original shape by irradiation with a different wavelength. In this work, monomers which contain photo-crosslinkable groups in addition to the primary polymerizable groups were synthesized. These monomers were formulated and cured with other monomers to form photo-responsive polymers. The mechanical properties of these materials, the kinetics, and the reversibility of the photo-activated shape memory effect were studied to demonstrate the effectiveness of using photo-irradiation to effect change of modulus (and thus shape memory effect).


Polymer films with embedded metal nanoparticles are nanoscale materials of great interest due to their special structural, optical and electrical properties [1]. The possibility to tailor these properties by changing preparation parameters makes them promising materials for new applications, especially in optics and electronics. Combining metal nanoparticles in 2D or 3D arrays gives rise to materials with optical spectrum that will depend upon the nature of the metal, the size and the shape of the particle, the interparticle distance. Moreover, the electronic structure of these materials is an important issue: as the size of metallic particles is reduced down to the nanometre range, the electronic structure will change from metallic (continuous energy bands) to free atom-like (discrete energy levels). These effects are still not well characterized and thus a good comprehension of the phenomena that occur can help in the development of applications such as nanoscale electronics. In this work we use plasma technology to create the nanostructured materials. Both gold and iron nanoparticles embedded in polymer matrix are studied. Transmission electron microscopy (TEM) measurements were performed in order to visualize the structural change and X-ray photoelectron spectroscopy to analyse their electronic structure change. Gold incorporation in the polymer matrix was achieved by alternating evaporation of the metal and plasma polymerization of styrene in an inductive coupled rf (13.56 MHz) glow discharge. TEM showed changes in the shape and size of particles when varying deposition parameters (rate and time of evaporation, polymerization parameters). It was possible to control the mean diameter of the particles from 1.5nm to 5nm. At large concentration, the gold islands begin to coalesce and form clusters with elongated-shapes. The binding energy shift and width of the Au 4f line were studied by XPS with the aim to understand initial and final states effects in the photoemission process [2], that were intrinsically influenced by the size of the clusters. The iron incorporation in the polymer matrix was obtained by simultaneously plasma polymerization of styrene and of a solution of an iron-organometallic gas. Both TEM and XPS measurements were performed on this material and the possibility to estimate the Fermi pulse of the carriers in the direction of the LLL, and in the second - the size quantization value.

Electrode materials and their surface topography influence the quality of neural interfaces between electrodes and neural tissue are very important in chronic in vivo stimulation/recording. In order to study the effect of the electrode material and its surface on neural interfaces, we cultured neurons on thin films of biocompatible materials such as platinum, and iridium oxide. We used both flat film surfaces and laser micro-structured ones. The laser micro-structuring consisted of creating regular arrays of micro-bumps with height of about 1 μm and diameter of 2-3 microns. Recently, we found conditions for fabrication of such micro-bumps on platinum and iridium thin films on borosilicate glass substrate (Pyrex 7740) by mask-projection irradiation with single nano-second pulses from a KrF excimer laser (λ = 248 nm). To obtain micro-bump-structured films of iridium oxide, we deposited iridium oxide films on laser micro-structured iridium films using a pulsed DC reactive sputtering technique. Several types of iridium oxide films were studied including amorphous (reactively sputtered at low sub atmospheric pressure) and polycrystalline (quenched at 300°C), and electrochemically activated iridium metal films. Cortical neurons isolated from rat embryo brains were cultured on these thin film surfaces. Cells were more than 98% viable as determined by trypan blue exclusion test. Poly-DL-β-Tryptophan coated surfaces and micro-bumps were used as positive controls for cell growth and plastic surfaces served the purpose of negative controls. Regular optical and fluorescent microscopy techniques were used to image the cells after they were cultured. To differentiate between live and dead cells a viability test with fluorescein diacetate (FDA) and propidium iodide was carried out. Also, immunocytochemistry analysis of neuron cells was performed using antibody for neuron-specific enolase (NSE) staining. A qualitative and quantitative comparison was carried out between the different types of modified electrode surfaces to study the neuronal growth in order to explore the feasibility of micro-bumps as stimulating/recording neural interfaces. Electrical stimulation/recording experiments will be carried out on the best performing thin film electrodes by using a multi-electrode array setup.


There is considerable interest in measuring and using electron spins, e.g. in quantum computing, magnetic resonance, and magnetic data storage. High spatial resolution is especially useful, which can be provided by the combination of magnetic-resonance imaging and atomic-force microscopy (AFM/MRI). Although sensitivity to a single spin has recently been achieved [1] there is benefit in developing probes that could be used in conventional atomic force microscopes to measure high-frequency magnetic-resonance (MR) effects. Toward this goal, we have fabricated a novel cantilever probe capable of measuring very small MR signals. The cantilevers have integrated conductive loop probes at their ends to act as sensors capable of high-spatial-resolution measurement of magnetic fields. Our new probe design is comprised of a ~3/4 gold loop (variously with diameters of 6, 12, and 40 μm), and a 3/4 gold loop (variously with diameters of 2-3 μm, and 6, 12, and 18 μm) placed in the center of the loop, at the maximum of its field, a feature that is important because the signal-to-noise ratio in MRFM is directly proportional to the length of the loop. We have an experimental advantage for our sensor by sensing localized microwave resonance in yttrium iron garnet (YIG), a ferrimagnetic microwave resonator. Previous probes show spatially localized resonance detection, but are unshielded and thus susceptible to noise and induced fields in the feed lines. Our probes show higher sensitivity due to the shielding and more complete loop. The μm-level spatial resolution in magnetic detection of our probe also has great potential for non-invasive examination of the currents in integrated circuits and magnetic thin films in recording heads. 1. D. Rugar, R. Budakian, H. J. Mamin & B. W. Chui, Single Spin Detection by Magnetic Resonance Force Microscopy, Nature 2004, Vol. 430, p. 329


Modification of the surface properties in microfluidic channels may be achieved through in situ growth of multivalled carbon nanotubes (CNT) by plasma enhanced chemical vapour deposition (PECVD). By disturbing the electrical-field we can control the inclination angle between the channel floor and the CNTs. Microfluidic channels with inclined nanotubes may be used as channels with anisotropic flow resistance (valves), for filters, or for direction and routing of DNA. The growth direction of CNTs follows the direction of the electric field present in the plasma sheet. Recent works indicate that this is caused by the catalyst particle at the tip of the CNT [1,2]. Conductive substrate holders with special geometry allow us to distort the electrical field locally. By designing the substrate holder appropriately, the CNT forests can be grown inclined with respect to the surface, with an angle depending on the distance from the field emission feature. This is important to avoid experimental observations. We fabricated microfluid channels on Si wafers by conventional photolithography and KOH etch using SiO2 as an etch mask. Since KOH mainly etches the (100) plane, the resulting channels had flat floors with rounded sidewalls. A growth step was used to deposit (by evaporation) the catalyst material just inside the KOH etched channels. The CNTs were synthesised in a PECVD system at a 5 mbar pressure and 650 °C with a discharge voltage of ~600 V, using acetylene as carbon feed gas. A-co flow of ammonia was used to avoid formation of amorphous carbon. The elastic response of the CNTs depends strongly on the length and diameter, which can be controlled experimentally by growth time and catalyst ratio. Multivalled CNTs have a Young modulus of order 1 TPa, but PECVD-grown nanotubes have more defects, and can be expected to be softer. Assuming CNTs with Young modulus of 0.1 TPa, diameter of 50 nm and lengths between 1 and 5 mm, the force required to deflect the nanotubes 10% of its length is of order 0.1 nN to 0.005 nN. Given a drag coefficient of 3 for the nanotubes, and a viscosity of 1 mN/m2 for water, deflecting the CNTs require fluid velocities between 50 to 0.5 mm/s. We suggest that flexible and inclined CNTs may, given certain conditions, bend down due to fluid flow in one direction and rise up for fluid flow in the opposite direction. Even moderate variation of length and diameter allows the flexibility of the CNTs to be matched to a large range of different flow conditions. 1. M. F. Seabaugh, Micro and Nanotechnology, Technical University of Denmark, Bldg 345 east, DK 2800 Kongens Lyngby, Denmark; 2ECE, Wayne State University, Detroit, Michigan; 3Dept. of Engineering, University of Cambridge, Cambridge, United Kingdom.

Characterization and Processing of Vanadium Dioxide Thin Films for Advanced Optical and Electrical Switching Devices. Mohamed Soltani, Luc Stafford, Mohamad Chaker, Joelie Margot, INRS-Energie, Matériaux et Télécommunications, Varennes, Quebec, Canada; 2 Département de Physique, Université de Montréal, Montréal, Quebec, Canada.

Vanadium oxide compounds (V2O3, V2O5, VO13, etc.) present an interesting phase transition, undergoing a transition from a semiconducting monoclinic phase at low temperature to a metallic tetragonal phase at higher temperature. This change is accompanied by an important modification of electrical resistivity, optical transmittance, and reflectance in the infrared region. Among these oxides, VO2 is the most interesting because its transition temperature Ti lies close to room temperature (Ti=68 deg. C). Thin films made of VO2 are thus very promising for various technological applications such as infrared uncooled bolometers, variable attenuators, optical, and holographic storage systems, fiber-optical switching devices, ultrafast switching, and smart radiator devices for spacecraft.

However, the integration of VO2 thin films into specific devices requires optimizing simultaneously the semiconductor-to-metal phase transition and the patterning process. In this context, single phase VO2 layers have been deposited on quartz substrates by means of a reactive pulsed-laser-deposition technique. In this work, the potential...
of VO2 thin films for the fabrication of advanced optical and electrical switching devices is examined. In the first part, we investigate the optical and electrical switching properties of undoped, W-doped, and Ti-W co-doped VO2 thin films as a function of temperature using infrared transmittance and electrical resistivity measurements. Our results show that while the transmittance in the metallic state is not affected by W- or Ti-W co-doping, the transmittance in the semiconductor state is significantly affected by these dopants. These results can be understood from the increase or the decrease of the carrier density, whether the material is mainly acceptor-doped (Ti) or donor-doped (W). A closer analysis of the infrared transmittance and resistivity measurements also shows a hysteresis of about 5 deg. C for both undoped and W-doped VO2 films, such hysteresis being suppressed for Ti-W co-doped VO2. In the second part, the patterning characteristics of VO2 thin films are performed using a magnetized high-density plasma in a pure argon atmosphere (sputter-etching). At low argon pressure (i.e., below 1 mTorr), highly anisotropic features are obtained with high etch rate and good selectivity over photoresist. As pressure increases, the redeposition rate of sputtered species is enhanced due to collisions with neutrals in the plasma sheath. This is found to significantly alter the profile vertically and thus the etching quality. Finally, our capability to control both the semiconductor-to-metal phase transition and the patterning process of VO2 thin films clearly indicates the strong potential of VO2 films for functional switching devices applications.

J18.12 Effect of Substrate Materials on the Electrical Behavior of Pd/AIn/Semiconductor Based Hydrogen Sensors. Md Habibur Rahman1, L. Zhang2, Ibrahim A. A. Hamouda3, E. F. McEneny2, L. D. Niek3, K. Y. S. Ng4, R. L. Baird5, G. W. Aumer6 and G. Neman7;1Chemical Engineering and Materials Science, Wayne State University, Detroit, Michigan; 2Department of Electrical and Computer Engineering, Wayne State University, Detroit, Michigan; 3Department of Mechanical Engineering, Wayne State University, Detroit, Michigan; 4Department of Physics and Astronomy, Wayne State University, Detroit, Michigan.

Pd/AIn/Semiconductor based devices were fabricated by a combination of plasma source molecular beam epitaxy (PSMBE) and magnetron sputtering techniques. Four different semiconductor substrates consisting of on- and off-axis 6H-SiC, on-axis 3C-SiC, and Si(111) were used for fabricating the devices. All of these substrates are n-type, where the net carrier concentration at room temperature was ~5x10^18 cm^-2 for all types of SiC and ~2x10^15 cm^-2 for Si(111). A typical device consisted of 60 nm of AIn deposited onto the semiconductor by PSMBE, then a circular 1 mm diameter, 150 nm thick Pd dot was deposited onto the AIn by magnetron sputtering as catalytic electrode. Pt and Al film of 150 nm thickness were deposited onto the back side of the SiC and Si based devices respectively to form the back contact. Details on the fabrication process and some experimental results from Pd/AIn/6H-SiC based devices are presented in our earlier work [1-2]. The electrical behavior of SiC based devices at the onset of a rectification diode, where a MIS-like behavior is observed with the use of AIn as the conducting layer was also presented. The device on 6H-SiC shows an apparent barrier height of ~1.5 eV whereas the device on 3C-SiC shows 0.8 eV in the absence of hydrogen. Result shows that the device made with thicker Al on the same type of SiC has higher series resistance. For a forward current of 3 mA the required applied voltage is 1.6 V larger for the 90 nm thick AIn device than for the device made with 25 nm Al layer, both on off-axis 6H-SiC. A comparison between the simulated and experimental I-V curves will also be presented. References: 1. F. Serina et al. Appl. Phys. Lett. 79, 3350-3352 (2001). 2. M. H. Rahman et al. Mat. Res. Soc. Symp. J. Vol: 815 (2004). 3. L. Rimi et al. Mat. Res. Soc. Symp. J. Vol: 815, (2004). 4. E. F. McEneny et al. J. Appl. Phys. Vol 93, pg 5757 (2003).

J18.13 Surface and Microscopic Study of ZnO Nanoparticles. Ung-Dat Chen1, 2, Vinay Kumar Rangari2, Leon J. Morrison1, 2, Vijaya Kumar Rangari3, Libeg Bargmann2, 4, 5 and Kalyan Kumar Das1, 2, 3, 4, 5; 1Department of Electrical Engineering, Tuskegee University, Tuskegee, Alabama; 2Department of Physics, University of Idaho, Moscow, Idaho; 3Center of Advanced Materials, Tuskegee University, Moscow, Alabama.

Zinc oxide, is a direct wide bandgap (3.37 eV) semiconductor with a high chemical and physical stability, is of interest for potential applications in the fabrication of high-energy and high-speed optoelectronic devices. In this paper, we report the synthesis of ZnO nanoparticles by sonochemical and microwave techniques. Synthesized particles were characterized by photoluminescence (PL) study, scanning and transmission electron microscopy (SEM and TEM) and X-ray diffraction. A preliminary study of electrical conductivity was also performed using current - voltage (I-V) measurements employing photochromically doped electrodes. For an electrical conductivity synthesis 1g of zinc(II)acetate dihydrate was dissolved in a mixture of 12.5 mL of N,N-dimethylformamide (DMF) and 112.5 mL of deionized water. This reaction mixture was irradiated with a high-intensity ultraviolet horn (20kHz, 100 W/cm²) at room temperature for 3 hr. For microwave synthesis the reaction mixture was placed a microwave oven and allowed to boil for 22 min. The synthesized product obtained was washed with doubly distilled water and dried for 3hr. Samples for SEM examination photoluminescence (PL) were prepared from a suspension of the product in absolute ethanol. Nanoparticles deposited on a Cu grid was used for TEM studies. XRD measurements were carried for the dried sample. It was observed that the diffraction peaks of the sample match that of Joint Committee for Powder Diffraction Standards, JCPDS 36-1451. Gold contact pads, photolithographically fabricated on a spin-on-oxide coated quartz substrate using a transfer length pattern mask, were used for electrical characterization of the nanoparticles. The quartz substrate with the fabricated Au TLM pattern was spin-coated (3000 rpm) with the ZnO suspension. Spin coating and drying was repeated thirty-five times. Current - voltage measurements were then performed using an HP4156A, Semiconductor Parameter Analyzer. The SEM images indicated the presence of ZnO nanoparticles ~160nm in diameter and also some agglomeration of particles was observed. Transmission electron microscopy, however, indicated the presence of platelets of ~ 20 nm x 100 nm in dimension. The ultraviolet PL study showed a strong intensity and a significant blue shift relative to the PL of the bulk. Shifts up to 170 meV were observed and attributed to a confinement effect. From nonresonant calculations the calculated potential well size corresponding to the observed shift was found to be ~ 4 nm. Additionally the linewidth of the PL of the nanoclusters was found to be ~ 154 meV which is much broader in comparison to the bulk value of ~ 38 meV. The large linewidths observed for the clusters will be discussed in terms of the size distribution and impurity broadening. The I-V measurements indicated a highly resistive nature of the nanoparticles. It was speculated that carrier transport was obtained through chains of nanoparticles bridging the gap separating the electrodes.


One approach to the formation of nanostructures is by fabricating them using a direct writing method. Focused Ion Beam (FIB) etching, with ion beam diameters on the order of 10 nm, is a promising technique for this nanofabrication work. In this technique, interactions have been characterized for various materials, including single crystal Si and GaAs, polycrystalline Au, semiconductors, and amorphous glass. For all materials, arrays of square holes were etched using 10 or 100 pA 30keV Ga ion beam as a function of dwell time per feature. The depth of the features initially scales with dwell time. However, as the etching time increases, the apparent depth of the features etching in the crystalline and polycrystalline material decreases due to redeposition of the sputtered material. In addition, excess material is deposited around the feature, resulting in a lip around the hole. In the case of the single crystal material only, the redeposited material occupies the lowest energy close-packed planes, thus altering the geometry of the features. Only in semicrystalline polycrystaline and amorphous glass does the redeposition not occur in the same manner. We have used FIB patterning to direct the self assembly of compound semiconductor quantum dots and the sedimentation of colloidal crystals. Furthermore, this technique can be used to pattern a single-walled carbon nanotube-polymer composite in order to confine the attachment and growth of neuronal cells in selected areas.

J18.15 Low Dose Ionizing Radiation Detection using Luminescent Polymers. Rodrigo Fernando Biaschi1, 2, J. Borin3, E. A. B. Silva3, P. Nicolotti1, T. Guillard Neto1 and C. F. O. Graeff3; 1Departamento de Física e Ciência dos Materiais, Universidade de São Paulo, São Carlos, São Paulo, Brazil; 2Departamento de Sistemas Eletrónicos, Escola Politecnica da Universidade de São Paulo, São Paulo, São Paulo, Brazil; 3Departamento de Física e Matemática, Universidade de São Paulo, Bihemira Preto, Sao Paulo, Brazil.

In this work we present a novel application of luminescent polymers as active material for dosimeters. The effect of gamma radiation on the optical properties of MEH-PPV, or the
poly(2-methoxy-5-(2-ethylhexoxy)-p-phenylenevinylene) is studied. The samples were irradiated at room temperature with different doses from 0 Gy to 152 Gy using a 60 Co gamma ray source. For thin films, significant changes in the UV-Visible spectra were only observed at high doses (>1 kGy). However, in solution, shifts in absorption peaks are observed at low doses (<10 Gy), linearly dependent on dose. The shifts are explained by conjugation reduction due to photo-oxidation processes. Our results indicate that MEHPPV solution can be used as a dosimeter adequate for medical applications. This work was sponsored by Fapesp and MCT/IMPP from Brazil.

J18.16
Synthesis, Cathodoluminescence and Photoluminescence of ZnO Nanowires. Arrangalo Khan 1* and Martin F. Kordesch 2; 1Physics and Astronomy, Ohio University, Athens, Ohio; 2CMSS, Ohio University, Athens, Ohio.

Single crystal ZnO nanowires, nanorods and nanoflakes of size 5-200 nm in diameter are grown by thermal evaporation method in tube furnace. Two sets of deposition of ZnO powder and graphite mixture with controlled temperature and gas flow of Argon over Si(100) and Al2O3 with out any metal on its surface. Molybdenum grids were also used for as a substrate in order to use it in TEM. The furnace tube temperature is ramped between 1000-1150 degree C and substrate temperature 400-500 degree C. Photoluminescence of the nanowires reveals that a blue shift occurred in the emission spectrum of ultra small nanowires compared to the bulk ZnO nanowires having dimension of ~200 nm.

J18.17

A device with nanometric resolution in space and millisecond resolution in time, intended for neural electrophysiological imaging and prosthetic applications, was designed, fabricated and tested in vitro. An array of equi-spaced multiple gold electrodes was deposited on an insulating silicon dioxide substrate by means of lift-off lithography followed by subsequent chemical vapor deposition (CVD), oxidation, and CVD nitridation. A second lithography step followed by plasma etching on selected portions of the substrate, was used to open the tips of the electrodes to designated electronic recording loci. This process assured electrical insulation of the channels leading to the electrodes. In addition, a composite consisting of multi-walled, carbon nanotubes was designed with conductivity in the range 200-500 [Ω·m]-1 (1.23), and was positioned in intimate contact with the multiple electrode array. The nanotubes were grown on silicon dioxide substrates using a different CVD method (4) and, subsequently, infiltrated with in situ polymerized polymethylmethacrylate to achieve electrical insulation between adjacent nanotube bundles. During this process, methyl metacrylate monomers were reacted with acryloisobutylmonitrile and decane thiol to achieve in situ polymerization activated by ultrasound (5). This novel device can be deployed as an interface between mammalian cells and underlying integrated circuits during electrophysiological in vitro studies. Acknowledgement This work was supported by grants from Philips USA and the National Science Foundation and Engineering Initiative of the National Science Foundation under NSF Award No. DMR-0117702. References 1. A. Cao, G. Meng, P.M. Ajayan (2004) Nanobelt-Templated Growth of Carbon Nanotube Rows. Adv. Mater. 16, 43-44. 2. A. Thess, R. Lee, P. Nikolaev, H. Dai, P. Petk, J. Robert, C. Xu, Y.H. Lee, S.G. Kim, A.G. Rinzler, D.T. Colbert, G. Scuseria, D. Tomance, J.E. Fisher, K.S. Smalley (1996) Crystalline Ropes of Metallic Carbon Nanotubes. Science 273, 483-487. 3. H. Dai, K. Li, J. Wang, C.M. Lieber (1996) Probing Electrical Transport in Nanomaterials: Conductivity of Individual Carbon Nanotubes. Science 272, 523-527. 4. L.M. Dell Acqua-Bellavitis, J.D. Ballard, P.M. Ajayan, R.W. Siegel (2004) Kinetics for the Synthesis of Carbon Nanotubes: A Study Based on In Situ Diffractography. Nano Letters 4, 1013-1020. 5. S. N. R. Harivarasan (2004) Novel approaches towards the development of architectures based on carbon nanotube and polymers. Ph.D. Thesis Rensselaer Polytechnic Institute, Troy, New York - USA.

J18.18
Anomalous Temperature Dependence of Fermi-Edge Singularity in Cathodoluminescence Spectra of Modulation-Doped AlGaAs/InGaAs/GaAs Heterostructures. K. Gopalakrishna Naik 1, K. S. R. Koteswara Rao 1, T. Srinivasan 1, R. Muralidharan 2 and S. K. Mehta 2; 1Indian Institute of Science, Bangalore, India; 2Solid State Physics Laboratory, Delhi, India.

The temperature and power dependence of Fermi-edge singularity in high-density two-dimensional electron gas, specific to pseudomorphic AlxGa1-xAs/InyGa1-yAs/GaAs heterostructures is studied by photoluminescence (PL). In all these structures, there are two prominent transitions E_11 and E_21 considered to be the result of heavy-hole recombination in the first and second electron sub-bands with that of first heavy-hole sub-band. Along with these transitions weak LO-phonon replica is also observed. The major contribution of this work is observation of Fermi-edge singularity (FES) and its behavior with excitation power. In all the samples, which were divided into two sets, FES is observed approximately 5-10 meV below the E_21 transition. At 4.2 K, FES appears as a lower energy shoulder to the E_21 transition. The PL intensity of all the three transitions E_11, FES and E_21 grows linearly even with two orders of change in excitation power. However, we observe anomalous behavior of FES with temperature. While PL intensity of E_11 and E_21 decreases with temperature, the FES initially grows, later decreases in intensity as the temperature is increased and disappears around 40K. Though it appears as a distinct peak at about 20 K, it has a maximum around 7 K in one set of samples and at 13 K in another set of samples. In this presentation, we will show experimental observations related to the above parameters and the plausible explanation.

J18.19
Separate Control of InAs Quantum Dot Density and Uniformity on GaAs (001). Zuoming Zhao and Ya-Hong Xie; Materials Science and Engineering, UCLA, Los Angeles, California.

InAs quantum dots were grown on GaAs (001) substrates via molecular beam epitaxy. Quantum dot density and uniformity are controlled separately by two-step growth. In this method, the wetting layer and nucleation are finished at low temperature to get the high density. Dot growth is finished at high temperature to achieve high uniformity. Atomic force microscopy shows both the increase of quantum dot density and the improvement of quantum dot uniformity. The dot density of 7x10^10 cm^-2 was achieved with first growth at 400 °C and then finishing dot growth at 530°C. Optical properties were characterized by low-temperature photoluminescence (PL). Improvement of PL confirms improvement of dot structure.

J18.20
A Combined Vapor and Electrochemical Deposition Approach to the Controlled Growth of Nanoscale Metal Dendritic Islands, Beaded Wires, and Continuous Wires. Cobey Cross, John C. Hemminger and Reginald M. Penner; Chemistry, University of California, Irvine, California.

Under conditions of careful control of the experimental parameters of substrate temperature and metal atom flux, conventional vapor deposition can be used to grow a variety of useful metal nanostructures. We use this approach to grow dendritic islands as well as beaded nanowires of gold on graphite substrates. Combining this approach with electrochemical deposition allows us to convert beaded nanowires into continuous nanowires (diameters as small as 20nm) that are many microns in length. Low flux vapor deposition of a gold/silicon layer amount sufficient to give a graphite substrate held at or near room temperature generates dendritic islands of gold. The islands are fairly monodispersed in lateral dimensions (~100nm across). If the graphite substrate is held at higher temperature (~500°C) "beaded wires" can be grown by decorating the graphite substrate in discrete steps. The "beaded wires" are composed of gold "dots" that are 10-20nm diameter. Once again the "beaded wires" consist of gold dots that are highly monodispersed. The "beaded wires" provide excellent nuclei for electrochemical growth of very narrow, long, continuous wires of gold on graphite, where the wires are several microns in length. Each of these classes of structures have potentially interesting uses. The dendritic islands of gold are of interest in studies of the catalytic properties of gold nanostructures. The theoretically expected one dimensional electronic structure and optical properties of linear chains of gold dots that are tens of nanometers in diameter spaced by 10nm are of interest and the long nanometer scale continuous wires of gold are under development for sensor applications.

J18.21
Composite Contacts in Microsystems: Fabrication of Metal-Nanostructured Titania Nanocomposites. Zuzzi Abu Samah 1, Marcus S. Ward 1, Ding Chong Song 2 and Noël C. MacDonald 1; 1Materials Department, University of California, Santa Barbara, California; 2Mechanical and Environmental Engineering, University of California, Santa Barbara, California.

Micro-Electro-Mechanical Systems (MEMS) switches possess the advantages of both solid-state devices such as being highly miniaturized, lightweight, consume relatively low power, and have short time response as well as those of conventional electromechanical relays, such as low leakage currents. More importantly, since fabrication of MEMS switches utilizes the Si-based CMOS infrastructure already in place, MEMS switches can be integrated into
devices and manufactured in large volume thus reducing costs. However, one critical issue associated with MEMS switches is the degradation of device performance due to wear. Ceramic matrix composites (CRMMC) have superior wear properties relative to its metal component alone. Hence it is desirable that CRMMC which are wear resistant and possessing high conductivity be integrated into MEMS switch applications. We recently developed a technique to form nanostructured titania (NST) into MEMS devices[1]. Here, we demonstrate the integration of patterned metal-NST nanocomposites as contacts in MEMS switches using NST as the ceramic matrix component. As a result, we have developed a process involving formation of patterned NST matrix composites contacts, we report a simple route for their integration into MEMS devices. These nanocomposites were developed using a simple process that is compatible with current CMOS process tool and material sets. The process involves formation of patterns of sponge-like NST matrix which is subsequently infiltrated with metal. In this contribution, we shall present results of NST infiltrated with gold. Since gold is detrimental to CMOS device characteristics, its deposition must be avoided and the process conducted in an inert environment. In the process developed, metal infiltration occurs by an electroless method and hence highly selective deposition of gold was achieved. Selective deposition is confirmed by results obtained using area X-ray Photoelectron Spectroscopy (XPS) as well as X-ray diffraction (XRD). In addition to the above techniques, we have characterized the Metal-NST nanocomposites using Focuss Ion Beam machining and high resolution SEM. Finally, we shall demonstrate the formation and integration of NST-metal nanocomposite contacts in a MEMS switch [1]. S. Zuruzi and N. C. MacDonald, "Facile Fabrication and Integration of Patterned Nanostructured Titania into Microsystems", Accepted for publication in Advanced Functional Materials.

J18.22 Nanindentation, Mechanical Property Measurements of ZnS Nanobelts. Xin Xu, Xiaodong Li, Xinnan Wang, Qihua Xiong and Peter Richards, School of Physics, Nanjing University of Science and Technology, Nanjing, China. ZnS nanobelts are basic building blocks for constructing micro-and nanosystems. The recently developed nanoindentor has the capability of measuring surface morphology at the nanoscale by scanning the sample surface with the same indenter tip, which is analogous to AFM contact mode. We have successfully performed nanoscale indentations directly on individual ZnS nanobelts using the nanoindentor. We used a pyramidal Berkovich nanoindentor tip both to image the ZnS nanobelts of interest and to indent them in-situ. The hardness and elastic modulus were obtained from the nanoindentation load-displacement curves. Posttest in-situ imaging of the indentation impressions together with the load-displacement curves offers a unique opportunity for studying indentation deformation behavior. We also broke individual ZnS nanobelts to assess their fracture toughness. Our preliminary results showed that it is possible to mechanically interrogate the ZnS nanobelts with the nanoindentor.

J18.23 Hydrogen-Mediated Ferromagnetism in ZnCoO, Se-Young Jeong, Seung-Joon Cho, Chul Hong Park and Hyun-Jin Lee; 2School of Nanoscience and Technology, Pusan National University, Busan, South Korea; 2Korea Basic Science Institute, Busan, Korea; 4Advanced Materials Research Laboratory, COMTECS Limited, Daegu, South Korea; 4Research Center for Dielectric and Advanced Matter Physics, Pusan National University, Busan, South Korea.

There is currently great interest in the physical properties of doped magnetic semiconductors (DMS) because of their potential use in spintronic devices where both electronic charge and spin degrees of freedom are important. Although many kinds of DMS exhibiting high-temperature ferromagnetism have been identified, the microscopic origin of their magnetic properties is still quite controversial in II-VI as well as III-V-based materials. Generally, ferromagnetic materials with doped magnetic systems has been explained by invoking carrier effects and a double exchange interaction. Recently a new mechanism was theoretically proposed for the ferromagnetism in ZnCoO induced by hydrogen[1]. Here, we show that ZnCoO samples have a tendency to become seriously contaminated by hydrogen and that a significantly enhanced ferromagnetism is possible through enrichment of the hydrogen content by exposure to hydrogen gas[2]. We assumed that the hydrogen contamination effect is cause of controversial results experiment reported and experimentally confirmed having reliable results that a strong ferromagnetic spin-spin interaction between Co atoms in a Co-dimer is induced by hydrogen. In this study, we have introduced an intrinsic properties of doped magnetic semiconductor using a magnetic circular dichroism. We discussed the relationship between the ferromagnetism and hydrogen contamination in ZnCoO system.


Various physical and chemical phenomena have been observed at and near the sliding contact. Typical physical phenomena are the emission of electrons ions and photons from wearing solid surfaces. In insulators and semiconductors, these processes are driven by interactions due to tribocharging. Electrons, positive ions and photons produced in the plasma are observed as triboemission particles. Nakayama et al recently discovered the triboemissions from metals[1]. The triboemissions is experimentally observed for the first time, for metals, electrons are emitted spontaneously at room temperature by a chemical interaction of the worn surface with the surrounding chemical species. This phenomenon is called chemi emission of electrons[2]. It has also been reported that thermally stimulated electron emission (TSEE) occurs at much lower temperature than that for thermal electron emission. This suggests that TSEE occurs at and near the sliding contact in addition to the triboemission and chemi emission by frictional temperature rise. The purpose of the present study is to investigate the TSEE characteristics from scratched metal surfaces. An apparatus to measure TSEE intensity in vacuum was constructed. Using the apparatus, TSEE characteristics were investigated for scratched metal surface of fourteen kinds of metals of Al, Ti, V, Cr, Fe, Co, Ni, Cu, Mo, W, Pt, Pd, Ag and Au. Their surfaces were scratched by a diamond stylus in an ambient room air atmosphere and in the vacuum chamber. Then the metal surface was thermally stimulated in a vacuum chamber at temperatures between 1.5 and 4.3 K/C in a residual gas pressure of 10^{-4} Pa. During the heating, a channeling type secondary electron multiplier detected electrons emitted from the scratched metal surface and I-T curves were obtained, where I is electron emission intensity and T is sample temperature. Generally, I-T curve showed that electrons are emitted at temperatures at a few tenths to hundreds degree C. TSEE disappeared in the second and further heating cycle of the same metal specimen for almost all metals except Cu and Ag. The integrated electron emission intensities for some temperature range depend on metal species. The emission mechanism is discussed from the point of view of chemical process of adsorbed molecules, structure change and the defects in the metals. Acknowledgment This study was supported by Grant-in-Aid through Ministry of Education, Culture, Sports, Science, and Technology.

J18.25 Correlating Thermoelectric Efficiency with Nanowire Diameter for Electrodeposited Bismuth Telluride Nanowire Arrays. Erik Menke and Reg Peuser; Chemistry, University of California, Irvine, Irvine, California.

Physicists have predicted that the thermoelectric figure-of-merit (ZT) for a given material will increase as the material dimension is reduced from 3D to 2D to 1D. However, there have been few experimental tests of these predictions because of the difficulties associated with synthesizing the nanowires and in making high quality measurements of ZT. We have devised a method for preparing arrays of very long n- and p-type Bi2Te3 nanowires with diameters ranging from 80 to 250 nm. These nanowires are prepared using electrochemical deposition on graphite and then transferred to the surface of an electrical and thermal insulator. High quality measurements of ZT are possible on these transferred nanowire arrays, and the results of these measurements will be reported in this presentation.


Piezoelectric materials convert mechanical energy to electrical energy under small deformation conditions. Bending conditions, for example, are often used in piezoelectric applications. However, the mechanical deformation is impervious to the electromechanical behavior of micromachined membrane performance. This paper discusses an analytical model devised to determine the microscale structure that minimizes residual stresses and outlines the implementation of two different designs: one for Al, the other for PZT films. The first design originates from intrinsic properties of doped magnetic semiconductor using a magnetic circular dichroism. We discussed the relationship between the ferromagnetism and hydrogen contamination in ZnCoO system.

membranes. The support structure consists of both tensile and compressive layers, and thus utilizing the analytical model a structure was determined the residual stress of the composite and increased the electromechanical coupling 35 times when the effective stress was lowered to 11 MPa. The boundary conditions of the membrane were also found to influence the electromechanical behavior. Changing the geometry of the electrode coverage increased the compliance of the structure by 25%. A simply supported structure releases some of the residual stress as opposed to a strictly clamped structure. Trenching around the membrane released the membrane from the sides of the structure, which decreased the residual stress further and thus increased the compliance by approximately 10%. A comparison of the electromechanical behavior for each of these structures will be discussed, showing a route towards increasing electromechanical coupling in PZT MEMS.

**J18.27**

**Electron Tunneling at Nano-Cross-Bar Junctions.**

Nicolaas Plochocka
d and Kyung-ah Son Division, Naval Air Warfare Center, China Lake, California; 2Jet Propulsion Laboratory, Pasadena, California.

Electron tunneling between nano-spaced electrodes is highly sensitive to the intervening medium. Slight changes in the chemical composition and structure of the channel can lead to significant changes in current flow. This current-media dependence can provide a transduction mechanism for detecting chemical analytes. To generate nano-spaced electrodes, cross-bar junctions comprised of 20-200 nm wide gold wires in parallel arrays were fabricated using a top-down nanofabrication approach. The vertical separation between overlapping and non-overlapping gold-metal-bridging germanium layers. The thickness of this germanium layer can be precisely controlled to provide a specific separation of 1-5 nm between the overlapping wires. Subsequent selective removal of the germanium with a hydrofluoric acid etch results in a wire cross-bar framework. Dissolution of this germanium layer can be monitored by the changes in the electrical properties of the junctions. Electron-tunneling measurements of the nano-junctions were measured with various organic solvents between the wire arrays.

**J18.28**

**Quantum Sizing of Power Electronics: A Trend Towards Miniaturized Power Electronics and Equipments.**


Human ability to manipulate atoms and molecules on quantum basis has generated a new dimension of physical structures for molecular scale transistors and devices. We will discuss about nanodimensional single electron transistor. This molecular device works as a switching element by controlling the electron tunneling for amplifying the current. The basic structure consists of two tunnel junctions isolated by a common insulator of nanodimensional length. One broader aspect of nano power electronics is that, it has got significant role in nanodimensional devices like tunneling diodes. They have got inherently fast tunneling rate, which makes them highly suitable for high-speed operation. A special type of tunneling diode is an interband tunneling diode (ITD), which is actually a p-n diode. The V-I characteristics of such diodes are governed by the tunneling barrier and tunneling process itself. Another special feature of these diodes is their negative differential-resistance characteristics. This special characteristic of such diodes makes them very useful in switching digital circuits. A special point of notice now in the area of nano power electronics, are the researches on Coulomb blockade circuits based on background charge fluctuations. For making large scale-integration of devices, electrostatic interactions among devices must be overcome, which makes the error tolerance for the Coulomb blockade devices possible. Among the tunneling devices, one very important device is resonant-tunneling device (RTD), which is actually categorized as the premier quantum transport devices. The fabrication techniques of such devices is scaled upon the level of power consumption, for which minimum current density at low level of voltage is made. Some of the significant uses of such devices are in Gigahertz optoelectronic-switching devices, logic-switching circuits operating at few GHz switching frequencies. There have enough research been made in the area of field effect transistors, especially, MOSFETs at micro and nano dimensions for the fabrication of many high speed switching devices. A very good example of such a FET device may be a double gate MOSFET, which is a great advancement in the area of silicon transistors. Among nanodevices, actuators are very useful for conversion of energy from one form to another. The working principles of such nanodevices are based on the charging principle of carbon nanotubes. The Faraday cup can be used to fabricate nanoscale silicon based power electronic structures of dimension less than 10nm. With technological advancement, as it is happening day by day towards miniaturization, many more MEMS and MEMS devices will be developed.

**J18.29**

In Search of Metallic Nanowires on Si(001), Indr P. Batra and Bikash C. Gupta; Department of Physics, University of Illinois at Chicago, Chicago, Illinois.

The study of metals on semiconductors dates back to the nineteenth century and has seen a vigorous recent revival due to tremendous interest in Nanotechnology. The scanning tunneling microscopy has enabled us to manipulate atoms, place them at will on different substrates to create and explore novel electronic properties [1]. The placement of metal atoms such as Al, Ga and In on Si (001) may lead to the formation of low-dimensionality structures, exhibiting significant new electronic and transport properties. Atomic scale structures themselves have proven to be valuable technological applications in developing atomic scale devices [2]. In particular, realization of one-dimensional metallic nanowire is of great importance as it may be used as a metallic interconnect in nanodevices. Free standing nanowires for a large variety of atoms, e.g., K, Al, Cu, Ni, Au and Si [3-4]. In general, free standing nanowires tend to be metallic but these nanowires in practice are to be supported. Silicon is the most widely used substrate for practical applications and the low index surfaces; Si (001) is the surface of choice. With the downward spiral toward nano devices, it is desirable to investigate the electronic properties at the lowest possible coversages. It is in this context that the study of metals like Al, Ga and In at sub-nanometer coverages on Si (001) take on the added importance. The interaction of metal nanowires with substrate can significanly alter the electronic properties, and not always in the desired direction [6-9]. Electronic structure calculations for the placement of metals like Al, Ga and In are performed for a patterned diphosphorogened Si (001)x1 in search of nanowires with metallic properties. The di-hydrogenated Si (001) is patterned by depassivating one row of Si atoms along the [1 -1 0] direction resulting in a wire cross-bar framework. Dissolution of this germanium layer can be monitored by the changes in the electrical properties of the junctions. Electron-tunneling measurements of the nano-junctions were measured with various organic solvents between the wire arrays.

**J18.30**

**Space Charge Limited Current in Porous Silicon with Traces of Nitrogen Dioxide.**

Stefano Borini, Andrea M. Rossi, Luca Boarino and Gianpiero Amato; Nanotechnology and Microsystems, IEN Galileo Ferraris, Torino, Italy.

Apart from the obvious sensor application, the discovery of the steep increase of electrical conductivity in Porous Silicon (PS) samples in contact with traces of Nitrogen Dioxide, NO2, has opened a new field of studying the electrical conduction processes in such a system from a completely new point of view. The system undergoes a change of conductivity of 5 orders of magnitude when exposed to few ppm of NO2, whereas the free charge concentration increases by more than 1 order of magnitude in the same concentration range. The increase of carrier mobility inside the nanowires can be considered as a possible effect occurring thanks to the interaction with NO2. The implication of this comes to be cleary. By means of the Space Charge Limited Current technique is possible to study the evolution of defects and trap states consequent to the interaction with NO2. The results clearly indicate that the changes of the Trap Fill Limit threshold to higher NO2 concentrations when NO2 is present. As a consequence, the ohmic region is more extended. From the theory of carrier injection in insulators it is then possible to infer that the charging status of shallow states in PS is modified by the interaction with NO2 molecules. The dramatic reduction of the charging status of shallow defects is then the dominant mechanism at the basis of the observed conductivity variation, more efficient that the simple free charge generation. Other “exotic” effects like the apparent conductivity reduction in this PS samples exposed to traces of NO2 can be also explained in this framework. In spite of the several intriguing effects and of the topological disorder of the system, the present work shows that the well-known theory of carrier injection in insulators helps us to shed light on the peculiar conductivity effects arising from NO2 interaction.

**J18.31**

**Novel Approach to Fabrication of Atomic-Scale Free-Standing Circular INP Membranes for MEMS Applications.**

Nicholas Prokopuk and Kyung-ah Son Division, Naval Air Warfare Center, China Lake, California; 2 Jet Propulsion Laboratory, Pasadena, California.

Hunlan ability to manipulate atonlS and molecules on quantunl basis has generated a new dimension of physical structures for molecular scale transistors and devices. We will discuss about nanodimensional single electron transistor. This molecular device works as a switching element by controlling the electron tunneling for amplifying the current. The basic structure consists of two tunnel junctions isolated by a common insulator of nanodimensional length. One broader aspect of nano power electronics is that, it has got significant role in nanodimensional devices like tunneling diodes. They have got inherently fast tunneling rate, which makes them highly suitable for high-speed operation. A special type of tunneling diode is an interband tunneling diode (ITD), which is actually a p-n diode. The V-I characteristics of such diodes are governed by the tunneling barrier and tunneling process itself. Another special feature of these diodes is their negative differential-resistance characteristics. This special characteristic of such diodes makes them very useful in switching digital circuits. A special point of notice now in the area of nano power electronics, are the researches on Coulomb blockade circuits based on background charge fluctuations. For making large scale-integration of devices, electrostatic interactions among devices must be overcome, which makes the error tolerance for the Coulomb blockade devices possible. Among the tunneling devices, one very important device is resonant-tunneling device (RTD), which is actually categorized as the premier quantum transport devices. The fabrication techniques of such devices is scaled upon the level of power consumption, for which minimum current density at low level of voltage is made. Some of the significant uses of such devices are in Gigahertz optoelectronic-switching devices, logic-switching circuits operating at few GHz switching frequencies. There have enough research been made in the area of field effect transistors, especially, MOSFETs at micro and nano dimensions for the fabrication of many high speed switching devices. A very good example of such a FET device may be a double gate MOSFET, which is a great advancement in the area of silicon transistors. Among nanodevices, actuators are very useful for conversion of energy from one form to another. The working principles of such nanodevices are based on the charging principle of carbon nanotubes. The Faraday cup can be used to fabricate nanoscale silicon based power electronic structures of dimension less than 10nm. With technological advancement, as it is happening day by day towards miniaturization, many more MEMS and MEMS devices will be developed.
Free standing diaphragms are an integral part of the vast array of modern microdevices, and their properties and manufacturing methods attract significant attention. One particular area of interest is the fabrication of ultra-thin membrane structures, due to the anticipated increase in sensitivity of the membrane for sensor applications with decreasing membrane thickness. Applications of devices with incorporated membranes include gas pressure or mass loading sensors. Surface and bulk micromachining techniques are often employed to build such structures. Traditionally Silicon is the most common platform for fabrication of MEMS devices and typical processing workflows involve chemical vapor deposition (CVD) of a sacrificial SiO$_2$ layer followed by a polysilicon layer. An obvious limitation of this technique is the inherent high residual stress in deposited polysilicon due to its high deposition temperature required in the CVD process. When films are released they often buckle and deform to relieve the stress, causing detrimental effects for the application of such devices. Similarly silicon-on-insulator (SOI) as a technique for ultra-thin membrane fabrication is limited by the minimum thicknesses of Si and SiO$_2$ layers that can be achieved and their uniformity. Moreover neither SOI nor any other Si based front side fabrication methods are capable of producing fully enclosed membranes and require via's for structure release by wet etching. Wafer bonding and back side etching techniques add another layer of complexity and cost. III-V semiconductors are a viable alternative material system, with superior processing characteristics in many respects. Extreme selectivity to wet chemical etching of various III-V compounds along with precisely controllable high quality heteroepitaxial layers grown by molecular beam epitaxy (MBE) allows for greater freedom in fabrication of free standing diaphragm structures than is ever attainable in Si based devices. Yet, surprisingly very few InP-based devices have been reported in the literature. We have developed a novel technique for fabrication of InP free standing circular membrane structures that are just 30 atomic rows thick and 1 to 10 μm in diameter utilizing exclusively front side processing. These are the thinnest (150 Å) and among the lightest (1.27×10$^{-10}$ kg) semiconductor membranes manufactured to date. The lateral dimensions of our membranes can be further reduced by incorporating e-beam lithography into our process workflow. The combination of light weight and the relatively large surface area of these membrane devices offers the unique advantage of straightforward instrumentation for detection of the small changes in dynamic mechanical properties caused by a sub monolayer coverage of the adsorbate species. We anticipate the fundamental limiting thickness of these devices to be comparable to that of the etch stop layers used in III-V materials, or approximately 50 Å.

**J18.32**

Functional Carbon Nanotube Substrates for Tissue Engineering Applications: Congrie Sinn Oriae and Yuan Zhang: Mechanical Engineering, University of California at Riverside, Riverside, California.

A combination of microolithography and chemical vapor deposition is used to engineer patterned vertical multwall carbon nanotube substrates. They are used to demonstrate the formation of directed neuronal networks. Multiple substrate geometries and nanotube heights were investigated to determine the most suitable combination for understanding the cell morphological changes. The interaction between the cell membrane and the nanotube substrate are visually characterized. The viability of the networks on the nanoscale substrates was observed.

**J18.33**


Electrowetting on dielectric (EWOD) has recently been implemented in MEMS applications for micro-pumps, liquid transportation, and biomedical devices. This principle has also been used for millimeter scale fluidics although large voltages are necessary. In this work, we study the implementation of EWOD to microscale fluidic optics using MEMS based technology. We investigate the scaling issues associated with two liquid systems (i.e. one liquid droplet, is immersed in another liquid) and the dynamic behavior of the interfacial tension. A change in contact angle and curvature of the micro-droplet is observed when voltage is applied between the liquid pool and an electrode underneath a dielectric layer deposited on top of the substrate. The measurement is obtained by optimizing the dielectric layer thickness and materials properties of the dielectric layer.

**J18.34**


GaAsSbN/GaAs single quantum well (SQW) growth and their properties are investigated. We have developed a novel technique for fabrication of InP free standing circular membrane structures grown on undoped GaAs substrates in an elemental solid source molecular beam epitaxy (MBE) system assisted with a RF plasma nitrogen source. A systematic study has been carried out to determine the influence of various growth conditions such as substrate temperature and various nitrogen pressures on the quality of the layers and optical properties of the structures. GaAsSb/GaAs and GaAsN/GaAs reference SQWs were also grown and characterized. The substrate temperature in the range of 450-470°C is found to be optimal. Opening the source shutters simultaneously resulted in sharper QW/barrier layer interface and more incorporation of N. SB incorporation into the QW layer is strongly influenced by substrate temperature, while source shutter opening sequence also plays a role in N incorporation. The dilute nitrogen was introduced in a range of nitrogen flux (1e-7 to 7e-7 torr) and various characterizations are performed with respect to the nitrogen concentration dependence.

**J18.35**


Spontaneous and piezoelectric polarization in group III nitride semiconductors give rise to large sheet charge densities at heterointerfaces, which can be used to achieve desired device characteristics by engineering the band profile. A polarization barrier consisting of a 50 Å-thick undoped Aluminium Gallium Nitride layer between two undoped Gallium Nitride layers was fabricated using Molecular Beam Epitaxial growth and standard lithographic techniques. The undoped layer thicknesses are 300 nanometers and 20 nanometers. Highly doped n-type Gallium Nitride layers are used as terminating layers and for making ohmic contacts. Equi- and opposite charges at the two interfaces of the barrier layer result in a voltage drop of about 1.5 volts across it. This facilitates tunneling of electrons with high enough energy due to a large electric field of 3.2 MV/cm over a triangular barrier width of 1 Å, leading to a barrier at room temperature. The current voltage characteristics of the barrier show rectifying behavior due to the large leverage ratio for barrier lowering in the forward and reverse directions. The device turns on at around 1 volt of forward bias and the forward current is limited by space-charge limited current flow at large forward bias. The device undergoes impact ionization breakdown just above 25 volts of reverse bias. The ideality factors of these barriers are around 2 or higher due to the injection associated with the transition across these materials. This barrier can be placed in the channel layer of an Aluminium Gallium Nitride/ Gallium Nitride High Electron Mobility Transistor to block current flow paths far away from the interface between the barrier layer and the channel layer.

**J18.36**

Explosive Porous Silicon - A New Microsystem and its Potential Applications: Dominik Clemen, Joshua Keller and Dmitri Kovales; Physics Department, TUM, Munich, Garching.
Germany.

We present a highly explosive nanostructure based composite material. This self-confined and mechanically stable micro-system is based on solid oxidizer filled porous silicon (PSi) layers or micrograins. We demonstrate that due to the production method, a commonly used electrochemical or thermal etching method, the size-selective and the particle velocity can be controlled by the process parameters. The chemical and physical parameters of the reaction and the material itself are determined and are presented. We discuss the specifics of morphology of this composite explosive material and its long-term stabilization. The preparation of a microscaled mixture of fuel and oxidizer via filling of the nanopores is shown. Furthermore, the explosive efficiency of various PSi/oxidizer systems and the influence of interfaces on the explosive power are discussed. The reaction time was found to be faster than $10^{-6}$ s and the energy yield for a stoichiometric ratio of Si to oxidizer is at least 9.2 kJ/g. This yield is higher than that of other high explosives. The system can be ignited in different ways, thermally, optically and electrically. The electrical ignition fulfills the standard automotive requirements for air-bag initiation. Finally, we demonstrate a construction and behaviour of the first industrial prototype of air-bag initiator, based on this nano-composite system, and suggest further possible applications, particularly in orientation/propulsion systems and medicine.

**J18.37**

**Abstract Withdrawn**

**J18.38**

**Two Dimensional Biphasic Nanocables from a C$_{60}$ Based Acceptor-Bridge-Donor Dyad; S. Shankara Gopala and Archita Patnaik:** Chemistry, Indian Institute of Technology Madras, Chennai, Tamil Nadu, India.

Self assembly at different length scales offers rich possibility to construct nano-structured materials. Fullerene C$_{60}$ amphiphilic derivatives self-assemble at the nanometer scale leading to fullerene based optical and electronic devices. Thus, a fair understanding of molecular structure, design, intermolecular interactions, and thermodynamic conditions is necessary for successful self-assembly of such amphiphilic molecules. On basis of the above, a fullerene derivative with Acceptor-Bridge-Donor structure has been designed and synthesized. The redox active chromophore in the adduct showed increased absorption relative to pristine C$_{60}$ and the HOMO-LUMO gap was experimentally found to be 1.6 eV as against a theoretical gap maximum of 2.30 eV, obtained using LCAO approach with DFT/B3LYP(3-21G). The transmission electron microscopic images of the 2-D surface structure of the spread monolayers revealed the formation of uniform diameter (~200 nm) biphasic nanocables with distinct ridges comprising of fullerene molecules. Each subunit of the cable has a C$_{60}$ peripheral amorphous layer of ~30 nm in diameter, connecting these molecules through van der Waals interaction. The C$_{60}$ sandwiched region is indicative of hydrophobic alkyl chain network with distinct crystallinity which further self-organizes into a vesicular nanowires. Such material with directed structure in constricted dimensions are ideal materials for directional electron transport.

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**SESSION J19: Applied Micro- and Nanotechnology**

**Chair: Joseph Michael**

**Friday Morning, April 1, 2005**

**Room 2003 (Moscone West)**

**8:30 AM J19.1**

**A New Approach for Roughness Gradient Fabrication.**

Tobias P. Kienzler, Tanja K. Drobek and Nicholas D. Spencer; Surface Science, Federal Institute of Technology (ETH), Zurich, Switzerland.

Studies in medicine, biology and materials science can often benefit from experiments including surfaces that are capable of performing many tests as possible within a minimum time. Gradient surfaces allow systematic studies to be performed with a continuously varying surface parameter within a single experiment. One such parameter is the surface chemistry, and a number of methods have recently appeared for the fabrication of surface-chemistry gradients [1-3].

Another parameter that can also influence biological or materials science phenomena is the surface morphology. However, there are only very few reports of the fabrication of gradients in surface morphology [4]. We propose a new approach for the reproducible production of well-defined surface morphologies on a centimeter scale with topographical features in the micrometer and sub-micrometer range.

To obtain such a gradient we first sandblasted a piece of aluminum sheet with ceramic beads with a diameter range of 125-250 microns or 0-250 microns to create a homogeneous stochastic roughness. A subsequent chemical-polishing process the sample was immersed into a hot acid solution and then continuously withdrawn by means of a linear-motion drive. The polishing solution, depending on the residence time of the specific surface location, was smoothed into a roughness gradient with a small radius of curvature and thus led to the smoothing out of the surface topography. The gradients were characterized by means of scanning electron microscopy (SEM), laser profilometry and atomic force microscopy (AFM).

Calculations of the standardized Ra and RMS integral roughness values from data obtained with laser profilometry showed values of 2.3 and 3.4 microns, respectively for the rough end and 0.3 and 0.4 microns, respectively for the smooth end of the gradient. Following the gradient axis from rough to smooth, the Ra and RMS values were found to decrease monotonically. The surfaces were further investigated by applying fast Fourier transformation (FFT) wavelength-dependent roughness analysis approaches [5].

**8:45 AM J19.2**

**Small Particle Manipulation Using the Stick-Slip Effect.**

Michael Einig$^1$, Robert W. Carpick$^1$ and Mark A. Eriksson$^2$.

$^1$Engineering-Physics, University of Wisconsin - Madison, Madison WI, Wisconsin; $^2$Physics, University of Wisconsin - Madison, Madison, Wisconsin.

Recently there has been an increasing demand for methods enabling the manipulation (transport, positioning, separation, or removal) of micro- and nanoparticles. Examples of such techniques include particle transport and separation in microfluidic channels or by electrophoresis and particle manipulation using optical trapping, micromanipulators, or atomic force microprobes. Most of these techniques either manipulate particles one at a time or rely on the use of a carrier medium to transport or suspend the particles. In contrast, we present a simple method to transport a large number of micrometer sized particles in parallel without the need of a carrier medium. Piezoelectric shear plates are used to excite asymmetric shear waves which are coupled into a substrate. At the surface of the substrate, linear motion of particles is induced due to inertial forces on the particles and the stick-slip effect. This method is very versatile. We have successfully applied it to a range of particle sizes and materials as well as different substrate materials. The transport mechanism is size-selective and the particle velocity can be controlled by the waveform, amplitude, and frequency of the electrical drive signal used to excite the shear waves. A major advantage of this technique is the ease to investigate the tribological behavior of particles on surfaces. In this case, a symmetric waveform is applied to the piezo in order to detach the particles, which allows the probing of the static friction force between the particle and substrate. The frictional behavior of the particles was investigated for a range of chemically functionalized surfaces.

**9:00 AM J19.3**

**Critical Process Issues in the Fabrication of A Lateral, Self-Cleaning, MEMS Switch.**

Yong Shi$^1$ and Sang-Gook Kim$^1$.

$^1$Mechanical Engineering, Stevens Institute of Technology, Hoboken, New Jersey; $^2$Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.

A lateral contact MEMS switch was developed to address the needs for long life cycle, low contact resistance and low cost. The switch is unique in the periodic self-cleaning of particles at the contact, self-alignment of contact surfaces and the mechanical interlocking of the contact metal into the polymer switch structures. This paper will discuss the critical issues related to the fabrication of the switch and its near parallel metal sidewalls. The major issues for the lateral contact device fabrication include the creation of the vertical Au sidewall. Existing physical or chemical vapor deposition methods are found not suitable since the deposited metal is neither dense nor robust in the micro- and nanoparticles. Examples of such techniques include particle transport and separation in microfluidic channels or by electrophoresis and particle manipulation using optical trapping, micromanipulators, or atomic force microprobes. Most of these techniques either manipulate particles one at a time or rely on the use of a carrier medium to transport or suspend the particles. In contrast, we present a simple method to transport a large number of micrometer sized particles in parallel without the need of a carrier medium. Piezoelectric shear plates are used to excite asymmetric shear waves which are coupled into a substrate. At the surface of the substrate, linear motion of particles is induced due to inertial forces on the particles and the stick-slip effect. This method is very versatile. We have successfully applied it to a range of particle sizes and materials as well as different substrate materials. The transport mechanism is size-selective and the particle velocity can be controlled by the waveform, amplitude, and frequency of the electrical drive signal used to excite the shear waves. A major advantage of this technique is the ease to investigate the tribological behavior of particles on surfaces. In this case, a symmetric waveform is applied to the piezo in order to detach the particles, which allows the probing of the static friction force between the particle and substrate. The frictional behavior of the particles was investigated for a range of chemically functionalized surfaces.
temperature, current density carefully controlled. Bottom electrode cleanliness is one of the key parameters to deposit high quality metal on the electrode, especially into the corners of the 10 micro meter thick Si-8 beam structure. It has been observed that electroplating temperature control prevents mold de-bonding and under-plating. SEM pictures show that the undulated surfaces are created because the face of the evaporated layer is much smoother and denser than that by e-beam evaporation. The long lifetime test shows that the contact resistance has been maintained below 0.1 ohm over 10 billion cycles and is expected to maintain the resistance far beyond that. The fabricated switch shows that the self-cleaning works well and opens the possibility of direct contact MEMS switch for high power and low cost RF applications.

9:15 AM J10.4

Self-assembled semiconductor nanostructures such as quantum dots (QDs) have been under intense investigation during the last years due to their appealing electronic and optical properties. Unique physical properties have been observed in QD structures and device applications using QDs, such as lasers, detectors and memories have been explored. However, for novel QD devices, like single photon sources or transistor structures, it is desirable to control the lateral position of the QDs. To achieve this, nanoscale grid patterns can be used to laterally align the QDs. In this work, the self-organization of InAs quantum dots grown with molecular beam epitaxy (MBE) on pre-patterned GaAs substrates, using different methodologies and growth parameters was investigated. The investigated techniques for substrate pre-patternning include lithographic and non-lithographic methods. Among the non-lithographic methods, holographic lithography was studied because it provides an easy and efficient way to create nanosized patterns over large areas. For holographic lithography a He-Cd laser at a wavelength of 325nm was used as an ultraviolet (UV) light source. After coating the GaAs substrate with photocyst it was then exposed in a holographic apparatus twice, with the sample rotated 90° after the first exposure. The nanoscale grid patterns were then transferred onto the GaAs using wet chemical etching or reactive ion etching (RIE). Also a non-lithographic method - Focused Ion Beam (FIB) processing - was studied for its applicability to transfer nanosized patterns into the substrate for subsequent QD growth. FIB processing has the advantage that it offers the possibility to directly etch the patterns without the need of lithography. After preparing the substrates they were cleaned and inserted into the MBE-chamber and prepared for the growth. Different GaAs-based buffer layers were grown on the substrates, consequently covered with self assembled QDs. These dots are either embedded into GaAs or serve as surface dots for further investigations. Various thicknesses and sequences of buffer layers are used and covered with InAs QDs or stacks of QDs. The influence of the pattern size and height, the pattern definition, the etching technique, the preparation and the buffer sequence on dot quality and density are investigated. Furthermore the influence of different dot growth conditions on dot quality and density is examined. The dot density, lateral and size distribution of covered as well as surface grown QDs have been measured using atomic force microscopy (AFM) and photoluminescence (PL) measurements performed on the samples with and without patterns give further information on dot size and size distribution.

9:30 AM J10.5
Exploiting Nanoscale Structure to Tune Electrical Characteristics of Macroscopic Films. Al-Amin Dhari, Paul-Emile Trudeau and Yoshitomi Suganuma; University of Toronto, Toronto, Ontario, Canada.

Electrical measurements of nanostuctures represent a frontier in chemistry and physics. One of the driving forces in this field is the idea that control over local conductivities within a material offers a possibility to design rationally its averaged electrical properties. Using nanoparticle/molecular linkers as building blocks, we can generate composite films that can be very widely range of properties. In particular, by varying film parameters, we can drive a rapid percolation transition and an insulator-metal transition. The results point to a singificant potential to generate materials with designer properties.

9:45 AM J10.6
Advanced Applications of Anodised Aluminium Oxide Templates for Nanotechnology. Darren J. LeClere; Materials Science Centre, University of Manchester, Manchester, United Kingdom.

Anodised aluminium oxide films have been applied to the construction of various nanometre sized structures. The production of such structures requires either a "Two-Step" method or a minimal amount of embossing, with optical gratings or micro-machined Si templates, which allows for the alignment of the sharp nanopores. For other structures precise manipulation of the pore sizes throughout the entire anodising procedure must be maintained to modify the shapes that can be obtained. After removing the excess aluminium the anodised layer is partially etched away, depending on the desired outcome. The oxide films are then used in conjunction with evaporation and sputtering techniques, electro-chemical deposition or replication with polymers to produce arrays of structures with applications to various areas of nanotechnology at greatly reduced costs.
typically produce wires with six sphere strands, though wires with 4 to 7 strands have been observed. Both chiral and a chiral packings are also possible.

11:15 AM J20.4 The Performance of the Gate Electrode using Co Thin Films Selectively Deposited on SAMs Patterns for a-Si TFT. Heejung Yang1, Taewook Kwon1, Jeonggil Lee1, Myungno Sung2, Hyeonjung Shim1, Jiyoung Kim1 and Jaegab Lee1; 1School of Advanced Materials Engineering, Kookmin University, Seoul, South Korea; 2Department of Chemistry, Kookmin University, Seoul, South Korea.

We have successfully developed selective deposition of Co thin films using MOCVD coupled with Octadecyltrichlorosilane (OTS) micro-contact printing (μCP), which was used as gate electrodes in a-Si TFT. The developed process of Co gate electrodes selectively formed on SAMs patterns can replace the conventional TPT one, by eliminating the photolithography and etching steps. MOCVD Co shows excellent selectivity over OTS at the low temperature regime, in which the growth of Co films is surface limited with an activation energy of 0.8 eV. In addition, the as-deposited Co films reveal smooth surface (rms = 2 nm), and low resistivity of 12 µΩ·cm for 60 nm-thick Co. The process pressure is identified to be a critical factor to achieve selective deposition of Co films on OTS patterns. Finally, the TFT has been fabricated using the Co thin films selectively formed using MOCVD and micro-contact printing as gate electrode, and electrically characterized. The subthreshold slope value on/off current ratio are 0.88 V/decade and 8×106, respectively. The electron field-effect mobility at saturation is 0.35 cm2/Vs for Vd = 9V. It can be concluded that the newly developed process is suitable for a-Si TFT fabrication, and thus replacing the conventional one.

11:30 AM J20.5 Ink Dependence of Poly(dimethylsiloxane) Contamination in Micromcontact Printing.Rubin S. Huesken1, Harold J. W. Zandvliet2, David N. Reinhoudt2 and Bene Poelsema3; 1MESA+ Institute for Nanotechnology and department of Science and Technology, University of Twente, Enschede, Overijssel, Netherlands; 2Molecular and Bimolecular Engineering, Philips Research, Eindhoven, N. Brabant, Netherlands.

Self-assembled monolayers (SAMs), being well ordered molecular assemblies of extremely low thickness, allow the tuning of surface chemistry within the monolayer thickness of a substrate. SAMs, therefore, find application in a host of areas where (local) control of interfacial properties is desired. Micromcontact printing is a well-established, highly versatile technique for patterning SAMs, in which suitable molecules (ink) are transferred to a substrate upon intimate contact with a polymeric relief structure (stamp). Usually, due to its versatility, chemical inertness and mechanical properties, poly(dimethylsiloxane) (PDMS) is the polymer of choice. An inherent drawback of it, however, is its inclination to contaminate printed substrates with low molecular weight PDMS fragments. In this study it is shown, by a combination of lateral force microscopy (LFM), Fourier transform infrared spectroscopy (FT-IR) and X-ray induced Photoelectron Spectroscopy (XPS), that the severity of the PDMS induced contamination is highly dependent on the nature of the ink. Contrary to intuition, the contamination was found to be worst for the transfer of hydrophobic inks, when using hydrophobic PDMS as the ink transfer medium. The use of hydrophobic inks, on the one hand, were found to shield the substrate to a large extent from contamination. A possible mechanism and its implication on other ink/stamp/substrate systems is discussed.

SESSION J21: Nanomaterials Synthesis and Applications
Chair: Mark McNie
Friday Afternoon, April 1, 2005 Room 2003 (Moscone West)

1:30 PM J21.1 Surface Electronic States and Electrostatic Attractive Forces between Metals or Semiconductor and Tribocharged Polymeric Surfaces. Yoshihito Morimoto1, Masahiro Umeki1, Danke Suzuki1 and Keiji Nakayama2; 1Materials Science, Ibaraki University, Hitachi, Japan; 2Nanotechnology, AIST, Tsukuba, Japan.

Attractive force between the sheets of silicon and metals and polymer surfaces was measured and its relationship to the electronic nature of the silicon and metal surfaces has been investigated to clarify the interaction force involved. The attractive force was measured by an electronic balance. The direction of the attractive force between the sheets of silicon wafer and metals and polymers. The electronic nature of the silicon and metal surfaces was characterized by temperature programmed photoelectron emission (TPPE) technique developed by the authors [1]. The TPPE was measured as a function of incident light with wavelength from 300 to 170 nm. The TPPE characteristics are the amount of emitted photoelectrons (PS total count) and the photodetector threshold value. commercial silicon wafer and rolled nickel and titanium sheets were used. The silicon wafer used was as received, and the metal surfaces were prepared by three surface treatments: successive argon plasma cleaning, glancing angle evaporation of 20 and 5 micron grain size (T1), ultrasonic cleaning in acetone (T2) and heating oxidation in air at 837K for 1 h (T3). Polymers such as polystyrene foam (PS), polytetrafluoroethylene (PTFE), and polystyrene (PS) were used. Prior to use the polymer sheets were rubbed with a cellulose paper, and negatively charged. The attractive force increased progressively with decreasing distance. With silicon wafer the attractive force depended on the polymers, resulting in the decreasing order: PS > PTFE > Pt. With the metals for PS the attractive force for nickel was much greater than that for titanium. With both metals the attractive force for T1 was much greater than that for T2 and T3. The TPPE characteristics also depended strongly on the metals and the surface treatments. For the PE total count for nickel was greater than that for titanium, while the threshold value for nickel was smaller than that for titanium. With both metals the PE total count for T1 was greater than that for T2 and T3, and the threshold value for T1 was smaller than that for T2 and T3, resulting in that the PE total count decreased linearly with increasing threshold value. This means that the abraded metal sample has high ability to emit electrons from the surface compared with the metal samples cleaned in acetone and oxidized in air. Thus it is concluded that the attractive force between the metal and the polymer surfaces was well correlated with the electronic nature evaluated by the ability of the metal samples to emit electrons. Acknowledgement This work was supported by Grant-in-Aid through Ministry of Education, Culture, Sports, Science, and Technology.


1:45 PM J21.2 Chirality Characterization of Dispersed Single Wall Carbon Nanotubes. Min Namkung1, Philipp Williams2, Candia Mayweather3, Buzz Wincheski1, Cheol Park4 and Juan S. Namkung5; 1NASA LaRC, Hampton, Virginia; 2National Research Council, NASA LaRC, Hampton, Virginia; 3Department of Chemistry, Spelman College, Atlanta, Georgia; 4National Institute of Aerospace, Virginia; 5Naval Air Warfare Center, Patuxent River, Maryland.

Two surfactants in aqueous solutions are used in order to disperse a batch of HOPCO single wall carbon nanotubes (SWNTs). The surfactants used are sodium dodecylsulphene sulphonate (NaDDS) and sodium dodecyl sulphate (SDS); these surfactants, as well as a range of organic solvents, are utilized for their efficacy in dispersing SWNTs in solution. Raman scattering and optical absorption spectroscopy are used for the chirality characterization of the SWNTs. Three resonant breathing mode (RBM) peaks are identified by directly comparing the Raman spectra with the Kataura plot. The SWNT diameters are calculated from these resonant peak positions. Next, p (n, m) pairs, yielding the SWNT diameters within a few percent of that obtained from each resonant peak position, is established. Finally, the interband transition energies are calculated based on the tight binding energy expression for each list of (n, m) pairs thereby yielding the closest values to the corresponding optical absorption peak are selected. The results reveal (2, 10), (6, 7) and (2, 12) as the most probable chiralities of this particular batch of SWNTs. Directly relating the Raman scattering and optical absorption spectra, the present method is considered the simplest technique currently available.


Energetic neutral atom beam lithography/epitaxy (ENABLE), recently developed at LANL, is a versatile technique that permits both patterning of nanoscale features into polymer substrates and the low temperature growth of nitride and oxide thin films into the patterned features. ENABLE achieves the direct activation of surface chemical reactions by exposing substrates to a beam of atoms with energies between 5.5 and 5.6 eV. Polymer oxidation products may be anisotropically etched using a neutral beam of oxygen atoms, thereby avoiding problems inherent to other etching techniques related to different species and diffusivity effects. Directed low temperature growth of high quality thin films may then be achieved by exposing the patterned substrate to a concurrent flux of evaporated metal (Al, Ga, In etc.) that reacts with the energetic O- or N-atoms impinging upon the sample to form a metal or nitride films. Since the reaction is being activated by the kinetic energies of the
imposing atoms and not high substrate temperatures, film deposition at temperatures as low as ambient becomes feasible. As a result, nitride and oxide thin films are grown on previously etched polymeric templates that would otherwise decompose at high temperatures. Furthermore, the chemical stability of the deposited thin films allows protection and passivation of underlying surfaces and/or materials. Taking advantage of these properties we have used ENABLE to encapsulate active layers of nanocrystals into operational LEDs with extended lifetimes. The application of the ENABLE for producing photonic, MEMS and NEMS, microfluidic, and novel electronic devices will be discussed along with the latest results on nanoscale etching and device integration.

2:15 PM J21.4
TIN/GaN Metal/Semiconductor Multilayer Nanocomposites Grown by Reactive Pulsed Laser Deposition. Vijay Rawat¹ and Timothy Sande²,³; ¹School of Materials Engineering, Purdue University, West Lafayette, Indiana; ²Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana; ³Tick Nanotechnology Center, Purdue University, West Lafayette, Indiana.

Metal/semiconductor multilayers with nanoscale periods and tailored barrier heights are expected to exhibit novel thermal and electronic cross-plane transport properties. Theory suggests that metal/semiconductor multilayers with controlled interface roughness have the potential to yield solid-state thermionic energy conversion efficiencies that are substantially greater than those of conventional thermoelectric materials [1]. Potential applications include conversion of waste heat to electrical power in automobiles and direct thermal-to-electrical generators for naval vessels. In this study, TIN/GaN metal/semiconductor multilayers have been chosen for initial investigations of metal/semiconductor multilayer growth mechanisms. Nitriles have high melting points and excellent corrosion resistance. Furthermore, the properties (e.g., barrier height and thermal conductivity) of metallic and semiconducting layers and their interfaces can be tuned by alloying. TIN/GaN multilayers with periods ranging from 5 nm to 10 nm were grown by reactive pulsed laser deposition (PLD) using elemental metal targets at an ammonia pressure of 20mtooruont0 Si(100), MgO(100) and sapphire(0001) substrates. For growth on Si and MgO substrates, an epitaxial 40 nm thick TIN buffer layer was deposited prior to deposition of the multilayers. An epitaxial 40 nm GaN buffer layer was grown on sapphire substrates. For all substrates, layer thicknesses and periods investigated, high-resolution x-ray diffraction and cross-sectional transmission electron microscopy revealed (0001) texture for the GaN, and (111) texture for the TIN in the multilayers. Both TIN layers and GaN layers thicker than ~2nm appear to be continuous, with no evidence of agglomeration. Both phases are crystalline, with lateral grain sizes comparable to the layer thickness. These results suggest that epitaxy will not be necessary to fabricate pinhole free metal/semiconductor multilayers in the nitride system. Cross-plane electrical and thermal properties of these first metal/semiconductor multilayers will be reported. [1] "Improved Thermoelectric Power Factor in Metal-Based Superlattices", D. Vashistha and A. Shokoufi, Phys. Rev. Lett. 92, 106103(2004). This work was sponsored by ONR (MURI thermionic energy conversion center).

2:30 PM J21.5

Composite nanomaterials combine the properties of the individual components in a synergistic manner, resulting in functionally new materials that fill or create the need for new applications. Currently, magnetically responsive elastomeric materials (or magneto-rheological elastomers, MREs) are used largely in industrial applications and have not been explored for potential applications in nanoscience. Commercially available MREs are unsuitable for precision applications, largely due to the size and variation of the magnetic component. We have prepared improved magnetic elastomers through the homogeneous distribution of stabilized iron or iron oxide nanoparticles within a silicone elastomer matrix. These MREs are suitable for submicron scale templating applications, and exhibit strong magnetic response sufficient to allow actuation of templated structures by the application of oscillating magnetic fields. We will describe the preparation and characterization of the materials and the devices. In addition, we have measured the mechanical properties of the MREs. The magnetic properties of the material vary depending on the loading fraction of the magnetic nanoparticles. We will describe further applications of these materials in device fabrication.

2:45 PM J21.6
Zinc Powder Evaporation: an Efficient Way of Synthesizing a Wide Range of High Quality ZnO Nanostructures at Lower Temperature. Yue Zhang¹,², Jian He³, Yunhua Huang⁴, Yousong Gu³, Zhen Ji¹ and Cheng Zhou¹; ¹Department of Materials Physics, University of Science and Technology Beijing, Beijing, China; ²State Key Laboratory for Advanced Metals and Materials, University of Science and Technology Beijing, Beijing, China.

ZnO, recognized as one of the most promising oxide semiconductor materials because of its good optical, electrical, and piezoelectric properties, is probably the richest family of nanostructures among all materials. Among all the fabrication methods reported for ZnO, simple ZnO thermal evaporation is considered as the most efficient way in achieving a large range of ZnO nanostructures in spite of the demand of a high temperature more than 1300 degrees centigrade. To seek a lower temperature in achieving this, we applied ourselves to study synthesis of ZnO nanostructures by zinc powder evaporation. The experiments were carried out in a quartz tube (diameter 30 mm, length 90 cm) of a tubular furnace. The source materials were put in an alumina ceramics boat and a silicon substrate was placed above it. After the alumina ceramics boat was inserted into the center of the quartz tube, the processes of deposition were conducted under the desired temperature (550-700 degrees centigrade), evaporation time and flow rate of Ar/O2 gas mixture. Accordingly, a wide range of structures such as tetrapod-like nanorods, nanobelts, toothed nanobelts, nanowires, nanocables, a diverse group of nanoarrays and a diverse group of nanocombs have been fabricated successfully through this method. Meanwhile, XRD, SEM, TEM, HRTEM and EDS investigations were also performed on the products and revealed the products with qualities having wurtzite crystalline structure, clean surface and uniform nanoscale morphology respectively, which demonstrate that a wide range of high-quality ZnO nanostructures can also be achieved at lower temperature by our method. Except nanocables, these nanostructures were synthesized without a catalyst. The growth of these quasi one dimensional nanostructures was induced by the three types fastest growth directions<0 0 0 1>, <0 1 1 0> and <2 -1 -1 0> and VS (vapor-solid) mechanism. Interestingly, the nanocables, i.e. ZnO nanowires coated with amorphous silicon oxide layer, grow along a unique direction of [2 0 -2 1], which was first reported by us to our knowledge. The growth of nanocables was probably based on the eutectic alloy of Au-Si system, where Au served as a catalyst. To sum up, the way of zinc powder evaporation is efficient enough and promising to synthesize a large family of high-quality ZnO nanostructures in lower temperature.