Paper ID: 324

Oviduct -Mimetic DEP Chip for oocyte Manipulation and Embryo formation to enhance the probability of natural fertilization
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Abstract - In recent years, the biochip by MEMS technology has been developed. The biochip has the advantages of biocompatibility, precision, low-cost, disposable, and easy to produce etc. MEMS technology widely used in cell detection or position a single-cell level, including the mechanical, optical electromagnetic and electronic fields. This study proposal, imitate the oviduct that can effectively position the oocyte by dielectrophoresis microchannel chip technology. The biochip increases the opportunity of sperm in the natural fertilization of the collision, and directly replaces the traditional microinjection.

The in vitro fertilization (IVF) is an important technique in biological and clinical studies. We propose the imitation oviduct microfluidic system to perform IVF on a chip. Imitation of IVF, the oocyte was positioned through the dielectrophoresis (DEP) force in the microchannel, and then collided with the pre-treatment of sperms driven by syringe pump to form the embryo, the purpose of natural fertilization on the chip. The collision frequency between the cells plays the success key role of the IVF. Therefore to position oocyte in the microchannel and flow motile sperms to make more collision would be very important for the formation of health embryo. The numerical simulation software, CFDRC, was used to reveal the position of high and low electric field distribution in microchannel. The position of oocyte and the sperm collide oocyte were successfully achieved to enhance the probability of natural fertilization when the 10 Vpp and 1 MHz frequency were applied.
Tri-Functional Nanoparticles with Strong SERS for Biosensing
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2. Department of Engineering and System Science, National Tsing Hua University, Taiwan
3. Research Center for Applied Sciences, Academia Sinica, Taiwan

Abstract - We reports an approach to fabricate dual-faced polystyrene beads (DFPSBs) with tri-functions of tumor cells recognition, drug delivery, and real-time Raman sensing. One-step oxygen-plasma treatment process was used to etch commercially available fluorescent polystyrene beads into a corrugated upper hemisphere and simultaneously change the entire surface with carboxylic groups. After depositing gold onto the corrugated hemisphere for surface enhanced Raman scattering (SERS) while leaving the other smooth and clean hemisphere for fluorescence detection, the DFPSBs are formed with dual-surfaces of plasmonic gold semishells on the top and fluorescent carboxylated polystyrene at the bottom. Sulfo-NHS-SS-biotin disulfide linkers and anti-CD44 antibodies can be modified and added onto the top gold surfaces and the bottom carboxyl groups through Au-S and peptide bonds, respectively. Then, the surface-modified AuFNM suspension can be employed to target overexpressive glycoproteins (CD44) on the surfaces of cancer cells and release their loads via the cleavage of disulfide bonds in the cytoplasm environment. These anti-CD44-modified DFPSBs exhibit a 12-fold cancer targeting ability on HeLa cells when compared to a normal chondrocyte cell.

Preclinical Evaluation of Targeted Nanodiamond Drug Delivery
Edward Kai-Hua Chow
Cancer Science Institute National University of Singapore

Abstract - Our lab and others have demonstrated that Nanodiamonds (NDs) have the potential to be an ideal drug delivery platform because of a number of unique characteristics. This was particular clear in our studies which demonstrated that ND-doxorubicin (NDX) drug complexes could enhance the efficacy of chemotherapy in chemoresistant breast cancer and liver cancer mouse models while lowering the toxic effects of these drugs. While this work represents a promising initial step towards the utilization of NDs in cancer therapy, targeted therapy against specific forms and subtypes of cancer is becoming an important method of treatment as we move towards a more personalized medical future. A focus of our lab is the determination if cancer-targeting ND-drug complexes can improve treatment efficacy and lower drug toxicity compared to standard non-targeted methods of treatment. In accomplishing this, we have analyzed the use of targeted ND-drug delivery complexes in a number of different mouse models of cancer, targeting the most tumorigenic tumor cells and aggressive forms of cancer. In determining the potential for targeted drug delivery, characterization of ND-drug complexes as well as evaluation of functional metrics were performed to determine if targeted drug delivery by NDs is a reasonable approach to cancer therapy. This work represents a first-step in the demonstration of the potential for use of NDs in a personalized medical future.
Multimodal Diamond Platforms for Imaging and Therapy

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Division of Oral Biology and Medicine, Division of Advanced Prosthodontics, Biomaterials, and Hospital Dentistry, The Jane and Jerry Weintraub Center for Reconstructive Biotechnology UCLA School of Dentistry

Abstract - Nanodiamond (ND) surfaces possess faceted architectures that mediate improvements to drug delivery such as enhanced cancer treatment efficacy and safety [1]. More specifically, NDs can prevent early anthracycline elution, resulting in markedly decreased side effects in vivo, while gradually sustained elution and increased retention results in increased therapeutic activity [2]. Their surface electrostatic properties have mediated among the highest per-gadolinium magnetic resonance imaging (MRI) contrast efficiencies ever reported compared to all clinical and nanoparticle agents. NDs can also be functionalized with a broad array of therapeutics such as small molecules, proteins, antibodies, and DNA/siRNA for applications in cancer treatment, cardiovascular medicine, wound healing, and beyond. Towards the continued translational development of diamond-based nanomedicine platforms, recent work pertaining to the in vivo validation of ND-based treatment of drug-resistant tumors, and synthesis of multi-modal targeted ND complexes will be discussed.

Photovoltaic materials and solar cells based on semiconducting carbon nanotube photoabsorbers

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Department of Materials Science and Engineering, University of Wisconsin, Madison, USA

Abstract - We are investigating carbon nanotubes as the light-absorbing semiconductors of photovoltaic solar cells and photodetectors.[1-3] The use of nanotubes as light-harvesting materials is motivated by nanotubes’ built-in long-range crystallinity and tight sp2-bonding network that give rise to exceptional charge and energy transport characteristics, strong light absorption tunable throughout the visible and near-infrared spectra, and outstanding stability in air.

Here, we show that photogenerated charges and excitons can be efficiently harvested from photoexcited nanotubes by interfacing them with more electronegative electron accepting semiconductors in either bi-layered or blended donor / acceptor heterojunction composites. Specifically, we show that semiconducting nanotubes of diameter < 1 nm and bandgap > 1 eV form a type-II heterojunction with C_{60} fullerenes and C_{60} derivatives with energy offsets sufficient to drive electron transfer from the optically excited nanotubes to C_{60}, with an internal quantum efficiency (QE) for exciton dissociation and charge transfer > 75%. Thus, we have identified the nanotube / C_{60} materials pair as a promising basis for future nanotube-based light harvesting devices.

The performance of nanotube / C_{60} heterojunction photovoltaic devices is highly dependent on the morphology and nanostructure of the intermixing between the two materials. Excitons photogenerated in nanotubes must rapidly diffuse and reach the C_{60} phase, during their 10 ps lifetime, if they are to be dissociated into charge. We show that this diffusion can occur over short distances of ~ 5 nm via slow inter-nanotube hopping and potentially over much longer distances via more rapid intra-nanotube diffusion. Efficient devices must implement nanotube photoabsorber-based materials in consideration of these length-scales.

As a proof-of-principal, we have realized devices with a peak external QE > 20% across 1000 – 1365 nm and a monochromatic power conversion efficiency of 7% at 1050 nm. Our results show that AM1.5G photovoltaic power conversion efficiency > 10% should be possible with future optimization of materials synthesis, namely improved control over (a) the nanotube bandgap distribution and (b) nanostructure and morphology.

**Seeing Through a Li-ion Nanobattery: Lessons from In-Situ Electron Microscopy**

Reza Shahbazian-Yassar  
Michigan Technological University, USA

**Abstract** - Nanostructured anode materials have received considerable attention in energy storage devices due to the enhanced electrochemical reactions at the surface and their unique electrical and mechanical properties. Silicon and titanate nanostructures are promising anode materials because of their energy capacity and safer performance for Li-ion batteries. This presentation focuses on the in-situ observation of lithiation and delithiation in Si nanorods and TiO$_2$ nanotubes. The electrochemical testing of these low dimensional structures were conducted inside a transmission electron microscope equipped with a novel in-situ electrical probing holder. The intercalation of Li-ions in Si nanorods was monitored during charging and the fracture of nanorods was quantified in terms of size. In addition, the intercalation of crystalline anatase and amorphous TiO$_2$ was studied and their fracture events were monitored in real time.

**Nanofabrication and Atomic-Scale Characterization of Complex Oxide Nanostructures**

Riad Alzgheir and Jeremiah T. Abiade  
University of Illinois at Chicago Laboratory for Oxide Research and Education, USA

**Abstract** - Complex oxides are seen as promising materials for various applications due to their chemical stability and the possibility of tuning their electrical properties by doping. Recently, several classes of oxides have been identified as candidate thermoelectrics for use in energy harvesting devices. For example, Nb-doped SrTiO$_3$ has a higher power factor ($S^2/\rho$) than state-of-the-art TE materials like bismuth telluride. However, the complex stoichiometries of doped oxides as well as high melting temperatures make many solution and vapor phase synthesis techniques unsuitable for preparation of nanostructures, which is necessary to take advantage of the recent advances in thermoelectrics research. For oxide thermoelectrics, the major challenge is reduction of the thermal conductivity to enhance the thermoelectric figure of merit, $ZT=(S^2 T)/\rho K$. Recent results on other TE materials have shown that thermal conductivity may be drastically reduced by reducing material dimensions to the nanoscale resulting in an increase in $ZT$. We are developing nanofabrication techniques for oxide TE materials to enhance $ZT$. Oxide nanostructures were fabricated on single crystalline substrates. Patterns were written into poly (methylmethacrylate) (PMMA) templates using electron beam lithography (EBL) followed by deposition of 20 atm% Nb-doped SrTiO$_3$ by pulsed laser deposition (PLD) and an annealing heat treatment. We then used high-resolution transmission electron microscopy (TEM) to study the morphology of the material. The TEM investigation includes dynamic imaging of nanostructure morphology during in-situ annealing. The combination of high-resolution EBL with PLD allows generation of nanoscale features with desired material composition.
Paper ID:

Akram BOUKAI

Abstract - Not available at the conference publication deadline.
Unexpected information transmission paths in a biosystem

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Abstract - An electromagnetic wave is usually strongly scattered in a complex biosystem made of a variety of soft materials with different shape, size, phase, density, dielectric constant and conductivity. The strong scattering processes are sometimes useful for precise imaging of the skin, bone, lung, or breast tumor in a biosystem. However, in a specially structured solid device or media, such as an optical fiber, an electromagnetic wave can travel for a long distance without much loss in scattering. In a living organism the information signals are known to be transmitted either by carriers of chemical molecules, or in the form of electric pulses. For the latter, the underlying mechanism is not fully clear, because a biosystem consists of no metallic wires and usually has a huge dc resistivity. We demonstrate here that the nature might have found a very effectively way for information transmission in the form of electromagnetic wave through special bio-structures, some of which are known in the micro- and nano-scales. The result will shed lights on understanding the working mechanism of electrical communication process among different parts of a biosystem, and it may lead to manmade neural devices for clinic and engineering applications.

Nanofluidic crystal: From theory, model, and fabrication to applications

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Abstract - Nanofluidics is a booming research topic which studies ion transportation in nanometer sized confined space. However, real application of nanofluidics faces serious challenges from difficulty in surface modification, complexity and costliness in manufacture. We have developed a novel nanofluidics scheme, named as nanofluidics crystal, to address the above issues by using nanoparticle crystal (NPC) as the basic functional nanostructure. Nanofluidics crystal is an ease-in-surface-modification, simple and cheap approach to establish a nanofluidic system, and thereby can be used to construct various biosensing and energy harvesting devices. Here, we theoretically analyzed the electrokinetics properties of the nanofluidics crystal and developed a simple electrical model for device design and optimization. Preliminary applications of nanofluidics crystal in biosensing and energy harvesting have been demonstrated. The experimental results indicated that nanofluidic crystal was capable of detecting thrombin with a sensitivity of 5 nM or generating power up to \(1.17 \pm 0.09 \text{nW}\).
Wireless Magnetic Resonance Energy Transfer System Based on High Q Flexible 3D MEMS Coils

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2. National Key Laboratory of Nano/Micro Fabrication Technology, Institute of Microelectronics, Peking University, Beijing, China

Abstract - As the energy transfer efficiency of four resonant coils is much higher than that of two coil inductive coupling system, a four coil magnetic resonant energy transfer system based on high Q flexible 3D MEMS coils is put forward in this lecture. A planar 3D flexible coil with magnetic core was gained by multi-layer plating technology on Polyimide (PI) substrate with great bio compatibility. Firstly, 10μm Polyimide (PI) was spin coated on the silicon wafer as the polymer substrate of the 3D coils. Then through thick glue photolithography, 10μm copper coil was electroplated on the wafer. The mold for the magnetic core is fabricated by the second lithography and 10μm FeNi soft magnetic core was electroplated. So far, the MEMS coil with FeNi magnetic core on the first layer was achieved. A layer of 10-12μm polyimide was spin coated on the substrate for insulating and self-flattening. The through via holes were etched on PI by RIE. As the same method mentioned before, the copper coils and FeNi soft magnetic core on the second layer could be fabricated. 3D flexible MEMS coils composed by two layer of planner spiral coil with magnetic core were obtained. 3D MEMS flexible coils were used as the secondary coil and load coil. The corresponding magnetic resonance energy transfer system was set up. The performace of the transmission efficiency was also characterized.

Micromaching-based Implantation Method for Fabrication of Carbon Nanotube Modified Electrodes

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National Key Laboratory of Science and Technology on Nano/Micro Fabrication Technology, Shanghai Jiao Tong University, China

Abstract - This paper reports a novel carbon nanotubes (CNTs) implantation method based on micromachining (IMM) for fabrication of CNT modified metal electrodes (CNTMME). Through the processes of IMM, CNTs with clear surface are vertically embedded in the flat metal substrate and reliable bonded with metal matrix. Good connections between CNTs and metal matrix increase electron transfer efficiency. As a result, these CNT modified metal electrode show good properties such as low turn-on field in field emission test and higher oxidation peak and more stability in electrochemical test. In addition, this implantation method can be integrated with micromachining. It is believed that this method may be helpful to CNTMMEs wide application for industry.
Paper ID: 316

**Self-Assembling Multifunctional Nano-Composites with Arbitrary Shapes and Functions**

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Bio/Nano Technology Laboratory, Institute for Nanoscience & Engineering, University of Arkansas, Fayetteville, Arkansas, USA

Abstract - Self-assembly of various nanoparticles (NPs) into nanostructures with designed arbitrary shapes and functions has much promise for advanced materials and devices. However, the difficulty is to control the assembly process in order for the designed structure to be constructed with minimum unwanted products and artifacts. This lecture will present the fundamental challenges to self-organization of NP nano-architectures with specific shape and function, and discuss some strategies to realize the control and functionality necessary to overcome the challenges. Specifically, it will consider the experimental realization of NP building blocks with DNA in defined numbers and geometric configurations, and methods for implementing multifunctional nanostructure selfassembly that couples structure to function of the nanoassembly. It will also discuss the future directions for research in the field and their promise in applications, including medical theranostics, drug delivery, electronic and photonic devices, etc. The work presented in this lecture was supported in part by the National Science Foundation (ECCS-1128660 and 1137948) and Arkansas Biosciences Institute.

Paper ID: 318

**Understanding the Design of Self-Assembled Nanostructures by Mapping to Ising Models**

Russell Deaton
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Abstract - Self-assembly is a process of construction through specific, localized interactions among component parts that results in spatially organized structures. The term has been applied to self-assembled monolayer, aggregation phenomena, assembly of inorganic materials on a surface, as well as DNA computing and its descendants. Likewise, though not realized in any practical, largescale way yet, self-assembly has the promise to revolutionize material science with a bottom-up approach that structures materials on a molecular scale to achieve desired properties. Experimental self-assembly is a stochastic physical process with potential for disorder from kinetic traps, mismatching of tiles, and other defects. Usually the desired assembly is one state among many possible imperfect states. In order to design and quantify the reliability of self-assembly for manufacturing processes, some characterization of the probability of the desired assembly is necessary. The quantity that is required is the partition function of the system. In addition, the complexity of calculating the partition function is an important metric for the feasibility of design. In this lecture, situations in which the partition function of the self-assembly is efficiently computed are investigated by examining a mapping of tile assembly to Ising spin glasses. This mapping produces a graph, whose planarity is an indication of the complexity of the self-assembly. This work was supported by the National Science Foundation “EAGER: Self-Assembly of Complex Systems” (CCF-1049719).
Nanochannel System for DNA Analysis
Taylor Busch and Steve Tung
Department of Mechanical Engineering, University of Arkansas, USA

Abstract - DNA sequencing is becoming increasingly important as a diagnostic tool in biomedical testing. The present lecture will discuss the application of nanofluidic systems to achieve DNA sequencing in a more rapid and cost-effective manner than the current commercially available techniques. This breakthrough is made possible by minimizing the sample preprocessing time and sensing the DNA bases directly in a nanochannel system equipped with embedded nanoelectrodes. The nanochannel system is fabricated by combining MEMS based microfabrication techniques and AFM nanolithography. Using the system, single-stranded DNAs are translocated through the nanochannel electrically while their electronic signatures are measured by the nanoelectrodes positioned along the channel. The present lecture will describe the fabrication method of the nanochannel system in details and demonstrate the test results of the translocating DNAs. Possibilities for applying the nanochannel system to characterize other biomolecules of similar scales will also be discussed.

Slippery Liquid-Infused Porous Surfaces (SLIPS): A New Class of Repellent Material for Energy and Biomedical Applications
Tak-Sing Wong1,2
1. Wyss Institute for Biologically Inspired Engineering, Harvard University, USA
2. Department of Mechanical and Nuclear Engineering, The Pennsylvania State University, USA

Abstract - Creating a robust synthetic surface that repels various liquids would have broad technological implications for areas ranging from biomedical devices to fuel transport to architecture but has proven to be extremely challenging. Cutting-edge development of liquid-repellent surfaces is inspired by the lotus effect, where liquid droplets are supported by surface textures on a composite solid/air interface that enables them to roll off easily. Despite over a decade of intense research, these surfaces are, however, still plagued with problems that restrict their practical applications: they show limited oleophobicity with high contact angle hysteresis; fail under pressure and upon any physical damage; and cannot self-heal. To address these challenges, I will discuss about the recent development of a novel repellent material that is inspired by the Nepenthes pitcher plants (Wong et al., Nature 2011). In particular, this material, which is termed as Slippery Liquid-Infused Porous Surfaces (SLIPS), outperforms its natural counterparts and state-of-the-art synthetic surfaces in its capability to repel various simple and complex liquids (water, crude oil, and blood); maintain low contact angle hysteresis (<2.5 °C); restore liquid-repellency after physical damage rapidly (within 0.1-1s); resist ice adhesion and bacterial bio-fouling; and function at high pressures (up to ~676 atm). Perspectives on how this nature-inspired material may impact future applications in energy and biomedicine will be discussed.
Silica Nanorattle and Gold Nanoshell on Silica Nanorattle for Cancer Therapy

Fangqiong Tang, Linlin Li, Tianlong Liu, Dong Chen, Huiyu Liu and Longfei Tan
Laboratory of Controllable Preparation and Application of Nanomaterials, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing, P. R. China.

Abstract - In the past decade, mesoporous silica nanoparticles (MSNs) with their tailored mesoporous structure and high surface area have attracted more and more attention for their potential biomedical applications. With a facile and scalable method to synthesize a special silica nanorattle with mesoporous and hollow structure, we designed a series of drug delivery systems for cancer targeted therapy. Furthermore, an “all in one” multifunctional gold nanoshell on silica nanorattle has also been designed for combinational therapy with the ability of tumor targeting, chemotherapy and thermotherapy, as well as tumor imaging. These platforms have potentials to be developed for future clinical application for cancer diagnosis and therapy.
A Novel Biophysical Property-based Circulating Tumor Cell Capture System toward Cancer Diagnosis

Minseok S. Kim¹, Jinhoon Kim¹, Wonho Lee¹, Goo-Eun Jung², June-Young Lee¹, Sanghyun Baek¹, Jin-Mi Oh¹, Hun Joo Lee¹, Sang-Joon Cho², Soo Suk Lee¹ and Jeong-Gun Lee¹
1. Samsung Advanced Institute of Technology (SAIT), Korea
2. Park Systems Corporation

Abstract - Circulating tumor cells (CTCs), which exists exceedingly rare population in blood, have been spotlighted in cancer diagnostics and stable as well as reliable isolation method is of importance toward credible personalized therapy. Unfortunately, few studies have been reported to simultaneously realize high recovery rate, purity and cell compatibility in CTC isolation technology. In this paper, we introduce a novel CTC isolation method using selective size amplification for target cells and multi-obstacle structure (MOS) filters. Polymer microbeads conjugated with anti-epithelial cell adhesion molecule (EpCAM) were used to selectively amplify the CTC size and the size of cancer cells was clearly discriminated with white blood cells (WBCs). In selection of microbead size, 3 µm microbeads were optimal not only in clear size discrimination between WBCs and breast cancer cells (MCF-7) but also in coverage of microbeads for cells. The MOS filter was designed to improve both recovery rate and cell compatibility and fabricated by Silicon-on-Glass (SOG) technology. Simulation result showed that the cells captured at multi-obstacle structure displayed 22% reduction in moving force compared to those at single-obstacle filter. Our approach, CTC size amplification with microbeads and then microfluidic filtration, exhibited stable cell capture via size amplification and the effect of cell deformation hindrance. Therefore, the enrichment platform satisfying stability, high recovery rate and purity is expected to contribute sensitive and credible clinical validations of CTC studies and implementation of robust CTC technology.

Fabrication and Testing of ISFET Based pH Sensor for Microliter Scale Solution Targets

Zhuxin Dong¹, Uchechukwu Wejinya¹, John Vaughan¹ and Alan Albrecht²
1. University of Arkansas, USA
2. University of Wisconsin – Madison, USA

Abstract - In recent years, there has been an increasing interest in the monitoring and controlling of pH. It has become an important aspect of many industrial wastewater and water quality treatment processes. At the same time, the demand for smaller electronic devices used for various industrial, commercial, and research applications has greatly increased. In this paper, we propose a fabrication method of Ion-Sensitive Field Effect Transistor (ISFET) using MEMS techniques for pH sensing application. The novelty of this device lies in the detection of target solution with volumes in the sub-micro liter range. This achievement has the potential to satisfy the research demands in various areas including chemistry, biology and medicine. Nanomaterials, such as Carbon Nanotubes (CNTs) with excellent electrical, mechanical, and thermal properties can be incorporated to these small ISFET devices through certain nano techniques including Atomic Force Microscopy (AFM) based surface nanomachining and Dielectrophoresis (DEP). With proper electrical packaging, our ISFET chip has been able to detect the pH values of 2.5 µl solutions. The results reveal a linearity of pH measurement with a corresponding sensitivity of 10.7 mV/pH.
Abstract - We present a successful inkjet printing capability for solar electrodes with line widths below 100 \( \mu \)m. A rheologically tailored conductive silver nano-ink was created to meet the rheological requirement of industrial printheads (XAAR 1001). The jetting optimization for the printhead was done using a desktop R&D inkjet printer from PiXDRO (OTB Solar). Printer-integrated software allowed the optimization of droplet formation and droplet stability during the jetting process. Typical printing parameters such as greyscale, DPI variation, substrate heating, etc., were optimized to achieve high print quality. However, initial printing results showed poor line definition and inhomogeneous film thickness. To overcome this, we developed a multiple pass printing process that results in excellent line definition. We also performed statistical analysis to correlate the droplet size with printed feature size. The minimum feature size of \(~15 \mu m\) was achieved by jetting \(~6 \text{ pl}\) droplets. After printing, the films were sintered thermally to achieve metallization. Detailed TGA study showed that complete metallization was achieved at temperature \(400^\circ\)C. Adhesion tests performed using an ASTM standard tape test on printed pattern showed less than 5% of delamination or flaking. Finally, test prototypes of solar front electrodes were printed successfully on ITO and silicon substrates.

Investigation of PVDF-TrFE Nanofibers for Energy Harvesting

Summary of PVDF-TrFE Nanofibers for Energy Harvesting

Suman Dey, Mohsen PuraHmad, Suman Sinha-Ray, Alexander L. Yarin and Mitra Dutta
University of Illinois at Chicago (UIC), USA

Abstract - We have investigated the copolymer polyvinylidene fluoride, (PVDF-trifluoroethylene) for energy harvesting. Polyvinylidene fluoride (PVDF) nanofibers were electrospun on indium tin oxide (ITO) coated plastic. The electrical response of nanofibers at different frequencies was investigated. The experimental results demonstrate that the duty cycle of electrical response pulses is increased as the frequency of vibration is increased. By using the fast Fourier transform (FFT) of the response pulses, the maximum power extracted has been calculated.
Developing Solar Cell Front Contacts Using an All Inkjet Printing Process Following the Selective Emitter Approach

Ravi Shankar, Ty Chen, Steve Liker, Charles Tamarin and Keith Whites
1. South Dakota School of Mines and Technology, USA
2. Trident Industrial Inkjet - An ITW Company

Abstract - We present an approach for complete inkjet printing of solar cell front contacts for the implementation of "selective emitter approach", which can help in solar cell efficiency improvement. The fabrication of optimized emitters that can allow the low recombination below the silver front contact is an important process in solar cell fabrication. This selective emitter approach presents a heavily doped layer beneath the electrode and lightly doped regions between the electrode grids. Selective opening of the anti reflection coating is needed to implement this combination of heavily and lightly doped regions. This was achieved using an inkjet approach by printing an etchant-dopant ink followed by the printing of a diffusion barrier using a dielectric ink. Using a Trident Jet256S industrial printhead we created etched pattern with etch width ~50 µm. Once this pattern was created, the metallic front contact grid was printed using a silver nano-ink on top of the etched regions. Inkjet printed silver front contact grid with line width ~75 µm was printed successfully.

Microcontact printing using flexible flat PDMS stamps with metal embedment

Ikjoo Byun, Jongho Park and Beomjoon Kim
1. The University of Tokyo, Japan
2. Nagoya University, Japan

Abstract - This paper reports a microcontact printing (μCP) using flexible flat polydimethylsiloxane (PDMS) stamps with metal embedment. In conventional μCP process, self-assembled monolayer (SAM) ink can be transferred by conformal contact between a structural PDMS stamp and a substrate. In our research we utilized that hexadecanethiol (HDT), one of SAM ink molecules for μCP, can be soaked to the PDMS, but not to the Cr layer. Based on this fact, the PDMS with Cr embedment was used as a stamp for μCP even though there is 'no structural tip' (i.e. flat) in PDMS stamps. The new stamps for μCP have no mechanical deformation of stamps' tip which is crucial problem of conventional PDMS stamps during μCP. Moreover, there are several advantages compared to other flat PDMS stamps, such as no limitation of lifetime and no contamination problem during fabrication process.
Thursday, October 18, 2012

**Keynote Talk 1**  Nanowire-Graphene Hybrid Nanostructures for Transistor and Display Applications (by Prof. Sanghyun Ju)

**Invited Session 5**  Cells-based Platform & Applications


**Invited Session 7**  MEMS/NEMS for Biomedical Applications

**Invited Session 8**  Graphene 1

**Invited Session 9**  NanoFabrication: Nano Electronics and Sensing

**Regular Session 3**  Nanomaterials and Devices Characterization I

**Regular Session 4**  Bio-micro-nano Systems

**Regular Session 5**  Nanomaterials and Devices Characterization II
Paper ID: 311
**A microplatform to study the combinatorial effects of fluid shear stress and electric field on dermal fibroblast migration**
Jennifer Shin, Sukhyun Song, Hana Han, Ung Hyun Ko and Jaemin Kim
Korea Advanced Institute of Science and Technology, Korea

**Abstract** - In the wound site, interstitial flow and endogenous electric field are inherently generated to promote migration of dermal fibroblasts and remodeling of extracellular matrix. To examine the combinatorial effects of fluid shear stress and direct current electric field (dcEF) on the migration of fibroblasts, a soft lithography based integrated microfluidic platform was developed. When each of these stimulations is applied separately, fibroblasts migrate downstream of fluid flow and toward anode. The simultaneous application of shear stress and dcEF in an antiparallel manner, mimicking the wounded situation, enhances the synergetic effects on the directional migration of fibroblasts. When these two cues are applied in a parallel manner by changing the direction of dcEF, the balance point between the opposite directions of mechanotaxis and electrotaxis is observed where the average net movement of the cells becomes zero. The roles of membrane receptors, cytoskeletal proteins, and small GTPase proteins are investigated to understand the underlying mechanism for electrotaxis and mechanotaxis of the coordinated migration dermal fibroblasts under the influence of multiples physical cues.

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Paper ID: 322
**Cell Microchip for the large scale screen of functional genes regulating cancer metastasis**
Hanshuo Zhang, Changhong Sun and YanZhen Ye
Peking University, P.R.China

**Abstract** - RNA interference (RNAi) technology was a recently discovered post-transcriptional approach of gene silencing, by which the inhibition of protein production would be accomplished through the blockage of mRNA translation or the mRNA cleavage. Given the fact that conventional migration studying approaches including Boyden chamber assays, in vitro scratch assay, microfluidic-based system, etc., were time-consuming and low efficient, here we developed a novel cell chip which integrates photolithography technology and RNAi technology and allows us to perform the high-throughput screening to identify genes regulating cancer cell migration, invasion and apoptosis. In this talk, we will introduce our recent results as well as our near future work.
Electron Non-Zone Effective Mass in Semiconductor 2-D Layers

Dimiter Alexandrov
Semiconductor Research Lab, Lakehead University, Canada

Abstract - An investigation of electron non-zone effective mass in 2-D layers of semiconductors GaN, InN and InGaN is presented. The study is made on basis of LCAO electron band structures of the 2-D layers using two cases – without interaction with external ions and with interaction with external positive hydrogen nuclei (H⁺). LCAO electron band structures of the first case are calculated for 2-D lattices of the above semiconductors. The existence of energy pockets is found in both the conduction and valence bands for InGaN. The electron band structures of the second case are calculated in the same way as for the first case in consideration of additional interactions of (H⁺) ions with the 2-D lattice. Energy pockets are found in both conduction and valence bands for all of the above semiconductors. Condition giving applicability of the electron zone-effective mass theory in the case of energy pockets is derived. Expression for electron non-zone effective mass is derived and numerical values of this mass are found for 2-D layers of the above semiconductors. Existence of heavy electrons is found.

Mechanoregulation of Tissue Morphogenesis

Pak Kin Wong
Aerospace and Mechanical Engineering, Biomedical Engineering IDP & Bio5 Institute, University of Arizona, USA

Abstract - The fascinating capability of cellular self-organization (often referred as pattern formation) during tissue morphogenesis and regeneration is a central question in developmental biology, regenerative medicine, and complex systems. How do the cells of a tissue know how to organize into functional tissue structures that are much bigger than themselves? How the individual cells know what they are supposed to do without a central coordinator or a blueprint? Furthermore, relatively little is known about how multicellular systems interpret the mechanical cues in the microenvironment, such as global geometric guidance, local cell-cell interactions, and extracellular matrix properties, to collectively drive the morphogenetic process that creates complex tissue structures across multiple length scales. In this talk, I will discuss an engineering framework for investigating the mechanoregulation of tissue morphogenesis, such as the long-range alignment of myogenic progenitors during myogenesis and collective cell migration during wound healing.
"Mechanobio-Materials": Design of Elastically-Micropatterned Gels To Control Cell Mechanotaxis and Motility-Related Functions
S. Kidoaki¹, T. Kawano¹, H. Sakashita²
1. Institute for Materials Chemistry and Engineering, Kyushu University, Japan
2. Graduate School of Engineering, Kyushu University, Japan

Abstract - Cell functions are known to be regulated not only by the biochemical or physiological conditions of extracellular milieu but also by the mechanical conditions of substrate surface or extracellular matrix. The detailed understandings for the cellular responses induced by such mechanical field or mechanical stimuli, and its application for systematic design of mechanical field of cell culture substrate are expected to establish solid basis for constructing high-functional cell manipulation materials. To develop such biomaterials that manipulate cell mechanobiology, we focus on the control of mechanical taxis of cell movement, mechanotaxis, by the micropatterned elastic gels. The potential application of the systematic design of micromechanical field of elastic substrate for cell functional regulation is discussed.
MEMS Devices for Delivery of Nucleic Acid-Based Drugs
Kazunori Shimizu
Graduate School of Pharmaceutical Sciences, Kyoto University, JAPAN

Abstract - In this talk, I will discuss our recent progress on development of MEMS devices for drug delivery systems (DDS) of nucleic acid-based drugs. Nucleic acids such as plasmid DNA, small interference RNA (siRNA) and so on, act as drug for controlling gene expression or protein synthesis. The use of DDS is required to deliver nucleic acids within cells in target tissues. We focused on the tissue pressure-mediated transfection method which is a simple, safe, and easy in vivo DDS for nucleic acid-based drugs. It is performed by applying direct pressure to a target tissue after intravenous injection of naked nucleic acids in mice. To innovate this method, we have applied MEMS devices. The development of an implantable device for pre-clinical study\(^1\), the use of a suction device for minimally invasive treatment\(^2\), and the development of a cell-stretch device for elucidating the mechanisms\(^3\) will be discussed.


3D Membrane Microchannel and Nano-fibrous Capsule for Regenerative Medicine
Masashi Ikeuchi
Research Center for Advanced Science and Technology, The University of Tokyo, Japan

Abstract - Recently, cell culture in three dimensional conditions has been thoroughly investigated to regenerate thick tissues or organs in vitro for transplantation. Although various types of 3D culture materials and methods have been developed, there remains a common challenge of circulation in the thick tissue cultured in vitro. To overcome this issue, herein, we propose a new culture device composed of membrane microchannels and nano-fibrous microcapsules. The membrane microchannel was fabricated with a thin film of biocompatible collagen and formed a capillary-like network by micro-molding process. The nano-fibrous micro capsule was composed of a biodegradable polymer and formed by phase separation incorporated electrospray process. By stacking the membrane microchannels and the nano-fibrous microcapsules, the novel cell culture device with sufficient internal circulation and high porosity for cell proliferation was realized.
Three-Dimensional Bio-Microsystems using High-Aspect-Ratio-Microstructures
Yoshiaki Ukita¹, Yuichi Utsumi², and Yuzuru Takamura¹
1. School of Materials Science, Japan Advanced Institute of Science and Technology, (JAIST), Japan
2. Laboratory of Advanced Science and Technology for Industry(LASTI), University of Hyogo, Japan

Abstract - Three-dimensional micro architectures are useful to realize highly-functionalized microsystems. In this talk, the various effects of these architectures for the enhancement of chemical and fluidic functions are reported. Bundle-like structures of capillaries with tens micron of diameter, made of poly-methylmethacrylate, poly-tetrafluoroethylene, and negative thick photoresist are applied for immobilization of antibodies for the immunoassay of analyte such as immunoglobulin G, nonylphenol, and poly-chrolinedibiphenil and high-throughput DNA trapping for extraction and purification. The development of automated three-dimensional system using centrifugal microfluidics is also introduced.

Material Characterizations of Negative Photoresist for Bio-MEMS Applications
Yoshikazu Hirai
University Of Tsukuba, Japan

Abstract - Biocompatible permeable membranes integrated with a microfluidic system, which allow the diffusion of biological molecules with certain molecular weight, are desirable in biomedical applications. Recently, the fabrication of nano-porous membrane structure by photoresist serving as a permeable membrane has been proposed by authors. However, high autofluorescence intensity of photoresist limits their application of bio-analytical applications. To decrease the autofluorescence of photoresists, the objective of this paper is to investigate the behaviors of fluorescence under continuous laser illumination. In addition, we report on a molecular level study of molecular diffusivity by employing a coarse-grained molecular dynamics (CGMD) simulation. The simulation results show that, with increasing the cross-linked ratio of photoresists, the diffusion coefficient of small molecules in photoresist have larger diffusion coefficient, and which suggests photoresist membrane can be used as permeable membranes with controllable permeability by varying photolithography parameters.
Artificial regulatory microenvironments (niche) for controlling cell function

Ken-ichiro Kamei
Institute for Integrated Cell-Material Sciences (WPI-iCeMS), Kyoto University, Japan

Abstract - Microenvironmental cues (i.e., soluble factors, extracellular matrices (ECMs) and cell-cell interactions) have critical roles for determining stem cell fates, such as self-renewal, differentiation, survival and apoptosis. Conventional macro-scale techniques can only provide limited controls of microenvironments over cells, therefore, there is a current lack of tools to perform accurate and effective procedures for regulating stem cells. To meet this urgent need, we propose to develop micro- and nanofabrication technologies in combination with material sciences to create artificial microenvironments for a better control of cell function, including human pluripotent stem cells (hPSCs).

In my presentation, I will present our researches on i) nanofibrous substrates as cellular scaffolds for hPSC defined culture system for long-term periods, and ii) evaluation of effects of nano/microfabrication materials on hPSC phenotypes and gene expressions towards applications in hPSC research.
Chemical Reactions Based on a Nanotransport Platform by Integrating Motor Proteins and Micro/nano Fabrications
Ryuji Yokokawa
Kyoto University, Japan

Abstract - One of our research directions is to use motor proteins in micro/nano structures and microfluidic systems to emerge a new function that could not be achieved by top-down technologies such as micro/nano fabrications. Here, I will present a molecular system in a nanotrack array to miniaturize conventional fluid-driven micro total analysis systems (MTAS) to molecular TAS (MTAS), where chemical reactions can be achieved at the molecular scale. Motor protein-based nanosystems, kinesin and dynein moving on microtubules, are utilized as a driving force for molecular transport, manipulation, and reaction. Although motors work in a well-organized manner in vivo, it is still challenging to reconstruct to a functional system using purified proteins in vitro. Focusing on methods for orienting polarities of microtubules, manipulation of individual microtubules and chemical reactions on a microtubule array will be presented. Such bio-hybrid systems with support of micro/nano fabrications will be a key factor toward functional nanosystems at the molecular scale.

MEMS Energy Harvesters of Piezoelectric Thin Films
Isaku Kanno
Kobe University, Japan

Abstract - Piezoelectric MEMS energy harvesters have attracted attention as self-powered distributed sensor nodes. We have developed piezoelectric MEMS energy harvesters composed of PZT thin films and evaluated their power-generation performance. In order to improve the toughness of the MEMS harvesters, we prepared unimorph cantilevers of PZT thin films on the thin metal cantilevers instead of brittle Si. Piezoelectric PZT thin films were directly deposited on the cantilever-shaped stainless steel or titanium by rf-magnetron sputtering. Metal-based piezoelectric MEMS energy harvesters enable not only stable power generation but also high energy density due to the flexibility of thin metal cantilevers. We also fabricated energy harvesters composed of lead-free piezoelectric thin films of (K,Na)NbO₃ (KNN) and demonstrated high power generation performance compatible to the PZT films.
NEMS meets Bio-sensing: there’re plenty of things to do in the middle

Beomjoon Kim
CIRMM, Institute of Industrial Science, The University of Tokyo, Japan

Abstract - Our research goals are to build nanosystems and fabricate nanoscale devices, in particular for bio-sensing in singular level, through both bottom-up and top-down approaches. We focus on interdisciplinary research about local “bottom-up” surface modification using functional self-assembled monolayers and “top-down” approaches for micro/nano patterning technologies. We demonstrate that a single DNA molecule could be driven in the nanofluidic device by electrophoresis, in which the linear stretching and electrophoretic migration of a DNA polymer molecule could be observed at a single molecule level. Finally, we investigate length-dependent mobility of chromosome-sized DNA in nanofluidic channel and successfully separate different lengths of DNA under simultaneous action of electric field as well as pressure gradient. The uniformly charged polymer such as DNA molecule moves with length-independent mobility in the electric field because the friction force is proportional to DNA contour length as well as the electrostatic force. This size-independent migration prevents separation in free buffer solution, and thus the sieving matrix such as agarose gels should be used. However, the DNAs above a critical length (typically ~20,000 basepairs) show the length-independent electrophoretical mobility even in sieving matrix, because the long DNA molecule becomes highly-oriented along the direction of electric field in the gels. Therefore, the pulsed field gel electrophoresis (PFGC) is generally used for the long DNA separation, which is typically oneday process. To achieve the size-dependent behavior of the long DNAs, a novel concept, the electrophoresis under pressure gradient, is proposed. As a result, the different two kinds of DNA show the length-dependent behavior, where YOYO-1 stained λ-DNA (48.5 kbp) and T4-DNA (166kbp) were used as the standard of long DNA molecules.
Spatially Controlled Self-Assembly of Nanoparticles in Microfluidic Channels

Eunpyo Choi¹, Hyung-kwan Chang¹, Chae young Lim¹, Kilsung Kwon¹, Taesung Kim², Daejoong Kim¹, and Jungyul Park¹

1. Department of Mechanical Engineering, Sogang University, Seoul, Korea
2. School of Mechanical and Advanced Materials Engineering, Ulsan National Institute of Science and Technology, Ulsan, Korea

Abstract - We report a novel method for in-situ geometrically controlled self-assembly of colloidal crystals within microchannel using properly adjusting capillary pressure and evaporation. We demonstrated two applications using the integrated microfluidic system. First, a direct sea water desalination using the ion concentration polarization (ICP) is demonstrated. Second, a robust microfluidic platform for stable generation of multiple chemical gradients is proposed. Except the presented applications, the microchannels integrated with the assembled nanoparticles have great potentials in various applications, such as separation, accumulation, and analysis of biomolecules and optofluidic system.

Ashutosh TIWARI

Abstract - Not available at the conference publication deadline.
The Role of Substrate for Transport in Graphene

D. K. Ferry
School of Electrical, Computer and Energy Engineering, Arizona State University, USA

Abstract - We study the mobility and high field velocity in graphene placed upon various substrates, such as BN, SiC, or SiO2. The transport is subject to the intrinsic phonons in graphene, as well as flexural modes, but it is the remote polar modes from the substrate and impurities sited between the substrate layer and the graphene that dominate the mobility and velocity.

INVESTIGATIONS OF ANALOG/RF PERFORMANCE FOR UNDERLAP GRAPHENE NANO-RIBBON FIELD EFFECT TRANSISTOR (GNRFET)

Muhammad Shah Alam, Abdul Barik and G. A. Armstrong
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Abstract - GNRFET with 10% doping of potassium (K) in source/drain and channel regions with width $W=2$ and 5 nm has been synthesized. On-to-off current ratio ($I_{on}/I_{off}$) and sub-threshold swing ($S$) with $W=2$ nm have been found to be $\sim 10^7$ and $\sim 20\text{mV/dec}$, respectively. Intrinsic speed ($f_s$) and voltage gain $A_V$ have been calculated as $\sim 12 \text{ THz}$ and 20, respectively (at low bias of gate-to-source voltage $V_{gs}=0.1 \text{ V}$ and drain-to-source voltage $V_{ds}=0.1 \text{ V}$), for single gate configuration. However, with double gate $A_V$ becomes $\sim 2.5$ times higher, but $f_s$ reduces by $\sim 20\%$. Furthermore, the device follows a square-law, which would greatly suppress odd-order harmonics and improve dynamic range in designing of low power communication system. Using a new figure-of-merit ($FOM$) involving $A_V$, $f_s$, dynamic power ($P_{\text{dyn}}$) and off state leakage power ($P_{\text{off}}$) consumption, it has been found that GNRFET gives significant advantage compared to carbon nanotubes (CNT) FET having similar dimension. The on current $I_{on}$ and $f_s$ compare very favorably with both current ITRS Road Map specifications and available experimental results for GNR FET.
Large Photocurrents in Single Layer Graphene Thin Films: Towards Graphene Based Low Cost Solar Cells
James Loomis, Peng Xu, Hanwen Yuan and Balaji Panchapakesan
University of Louisville, USA

Abstract - This paper reports large photocurrents in air-assisted depositions of single layer graphene (derived from reduced single layer graphene oxide) upon illumination with near-infrared (NIR) light. NIR-induced charge carrier generation and subsequent separation at the metal–graphene interface resulted in photocurrent generation. Varying bias voltages were applied to test samples and allowed for evaluating photoresponses in either diffusion- or drift-dominated regions. In the diffusion-dominated region, position-dependent effects of photoconductivity were demonstrated. The photocurrent exhibited increase when the positive electrode was illuminated, decrease when the negative electrode was illuminated, and negligible response when the area between the electrodes was illuminated. At a 100 μV bias voltage, a percent change in current from ~150% (40 mW NIR) to ~1800% (335 mW NIR) is reported. Such large photocurrent responses result from built-in electric fields and optically generated temperature gradients (maximum NIR-induced temperature rise ~70 °C). The percent photocurrent change was observed to depend on both annealing temperature and NIR power, but not resistance value. In the drift-dominated realm, a Gaussian photocurrent profile was obtained, signaling drift of charge carriers with increase in localized electric field, akin to the classic Haynes–Shockley experiment. A minority carrier mobility value of \( \mu \approx 700 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1} \) is reported. The simple low cost graphene devices presented in this paper were fabricated without lithographic processing and are ideal candidates for assorted infrared imaging applications. Finally, the applications of graphene based devices for low cost solar cells and our latest results on the use of single layer graphene for low cost solar cells will be presented.

The new accelerometer technology based the graphene magneticresistance device
Huang Tiantian
Zhejiang University, P.R.China

Abstract - Magnetic suspended system is increasingly common used in sensors to achieve high sensitivity and accuracy because of no physical connection, but it is difficult to suspend objects by magnetic field. However, by using superparamagnetic materials as suspended body, magnetic suspended system will be very simple, and this kind of suspended body will be under well control of magnetic field. To endow composites superparamagnetism, a good method is to add nanoparticles into polymer, because nanoparticles have many special characteristics. Superparamagnetic films had been prepared by dispersing magnetite nanoparticles into polyimide (PI). Some researchers also prepared superparamagnetism PI/nano-ferric oxide films by chemical synthesis and sol-gel process. However, superparamagnetic films were unsatisfied with the conditions of utilizing in magnetic suspended system. In this letter, we prepared a kind of suitable bulk composite. We focused on prepared magnetite nanoparticles by co-precipitation method, then directly dispersing them into BMI, finally prepared a kind of superparamagnetic bulk composite.
The Nano-scale Resistive Memory Effect of Graphene Oxide

H. Q. Wei¹, P. Zhou¹, L. H. Wang¹, Q. Q. Sun¹, D. W. Zhang¹, X. B. Wang²

1. ASIC & System State Key Lab, School of Microelectronics, Fudan University, Shanghai, China
2. Hubei University, China

Abstract - We demonstrate that graphene oxide (GO) can be reversibly reduced and oxidized by applying bias voltages in nano-scale by the nano-tip of conductive atomic force microscopy (CAFM) system. The low resistance state (LRS) when reduced and a high resistance state (HRS) when oxidized can be achieved under the opposite applied bias direction. The LRS (around 10 KΩ) and HRS (around 40 MΩ) were stable for more than 103 s, and no obvious degradation was observed during the tests. Threshold voltages for reduction and oxidation, which can be considered as the set and reset voltages are separately around -6.5 V and +7 V. Raman spectroscopy and X-ray photoelectron spectroscopy (XPS) are performed to confirm this resistive memory switching behaviors. It is showed that the hydrogen (H+) ions dissociated from the water meniscus formed between the tip and GO in air at room temperature plays an essential role in the resistive memory switching.
Paper ID: 333

**Automated Surface Nanomachining for Nano-Bio Applications Using Atomic Force Microscopy**

Uche Wejinya  
Department of Mechanical Engineering, University of Arkansas, USA

**Abstract** - Among current nanotechnology applications, the design and fabrication of nanochannels are one of the major challenges. To date, the methods for fabricating nanochannels have included bulk nanomachining and wafer-bonding, surface nanomachining, buried channel technology and nanoimprint lithography. Although nanoimprint lithography can fabricate 2-dimensional nanochannels, these channels are all fabricated by complex processing methods that require sophisticated masking and etching. Thus, a means by which nanochannels are able to be fabricated without complex processing and reach nano scale level in 3-dimension becomes necessary. This presentation will address recent progress in AFM-based precision nanomachining on bare silicon surfaces. The results show that this technique can be applied in the fabrication of CNT-based Ion Sensitive Field Effect Transistor (ISFET) structure, where relatively large nanochannels on the silicon substrate are required. These systems have the potential for significant impact in a broad array of application including and not limited to biosensor, nanofluidics and drug testing.

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Paper ID: 334

**Inter-layer Graphene Nanostructure for Chemical Sensing**

Wen Li, Fubo Rao, Haider Al-Mumen, Zheng Fan and Lixin Dong  
Electrical & Computer Engineering, Michigan State University, USA

**Abstract** - This talk covers the development of an inter-layer graphene sensing structure and its applications for chemical vapor detection. Few layer graphene (FLGs) consists of stacked layers of carbon sheets with their inter-layer spacing of sub-nanometer (~0.335 nm), possessing inherent inter-sheet transduction effects such as electron tunneling, doping, and edge effects. Such effects can be exposed by selective patterning ohmic contacts on different stacked graphene sheets. This inter-layer graphene structure can potentially be utilized as a sensing element for measuring molecule adsorption/desorption, force/displacement, pressure, or surface tension. The design, fabrication and characterization of the proposed inter-layer graphene sensors are introduced in this talk. An oxygen plasma etching (OPE) technique is developed to engineer the number of layers of graphene layer, enabling fast and controllable fabrication of FLGs exfoliation. Results from chemical sensing experiments are shown to validate improved sensitivity of the inter-layer graphene sensors as compared to the conventional intra-layer sensors.
Carbon-Based Transistor and Inverter using Graphene-On-Boron-Nitride (GOBON) Material System
Edwin Kim
Ramtron International Corporation, USA

Abstract - Graphene-channel field-effect transistor (GFET) is an emerging element for future-generation nanoscale electronics and sensor applications thanks to the high carrier mobility. For large-scale carbon-based electronics, 2D graphene sheet assembled by chemical vapor deposition (CVD) process is preferred in contrast to the exfoliated method. The comparison of electrical characteristics between the GFET devices on hexagonal boron nitride (hBN) and on standard thermal SiO2 indicates that transconductance (gm) and effective carrier mobility (μeff) are much improved owing to the lattice-matching, dangling-bond-free hBN substrate. This makes hBN an attractive material for future wafer-scale integration of the CVD graphene-based circuits. In addition, logic inverter based on graphene-on-boron nitride material system was demonstrated as the basic building block of graphene electronics. The inverter was composed of two adjacent GFETs. The prototype of logic inverter was implemented on a single sheet of CVD-assembled monolayer graphene using the unique ambipolar conduction behavior of 2D nanoscale carbon system. This talk highlights recent progress in demonstrating GFET and logic inverter made by transferred CVD graphene on hBN.

Fabrication Nano Devices using Nanocarbon Materials
King Wai Chiu Lai
City University of Hong Kong, China

Abstract - Low-dimensional materials, such as carbon nanotubes, graphene and nanowires, are attractive building blocks for high-performance nanoscale electronic, photonic and mechanical devices. These materials behave quite differently from conventional materials, which offer superior quantum optical, electrical and mechanical effects. Making low-dimensional material based functional nano devices is one of the most challenging frontiers of manufacturing. In this talk, the speaker will present the development of robust nanomanufacturing technology for effective fabrication, assembly, packaging and testing of nanoscale devices with various low-dimensional materials. The applications of these nanodevices to photovoltaic cells, nanosensors and electronics will also be presented. Nanomanufacturing refers to a series of tools and processes to build nanoscale structures and devices using nanomaterials. In particular, the new tools will be discussed in this talk include nano robots for assembly, and micro plasma fabrication system for nano fabrications. The integrations of the above tools and processes have provided effective and efficient nanomanufacturing systems for fabrication of the next generation of nanoscale optical sensors and electronic devices. The examples of manufacturing nano photovoltaic devices and electronic devices using the integrated nanomanufacturing systems will also be presented.
**Fabrication and Characterization of Vertical Silicon Nanopillar Schottky Diodes**

Nishant Chandra, Adam C. Overvig, Clarence J. Tracy and Stephen M. Goodnick
Arizona State University, USA

**Abstract** - The authors report fabrication of vertical Schottky diodes using sub-100nm diameter n-type doped Silicon nanopillars. The nanopillars were fabricated using a top-down approach employing the Bosch process. Square-shaped islands of Silicon dioxide patterned using electron beam lithography and deposited by thermal evaporation acted as hard masks for vertical inductively coupled plasma (ICP) etching. Once formed, the nanopillars were conformally covered in a blanket layer of SiO2 and their tips were exposed using Chemical-Mechanical Polishing. Nickel contacts were patterned and deposited on them using DC magnetron sputtering and were annealed to form Nickel silicide forming Schottky diodes with barrier heights between 0.6 and 0.7 eV. We have thus established a low temperature process (no thermal oxide required) for constructing vertical Silicon Schottky diodes with approximately circular cross-sections of diameters from 40nm to 100nm. The ION to IOFF ratio was at least 104. We also observed non-ideal current-voltage characteristics that differentiate these nanoscale diodes from planar Schottky diodes.

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**Graphene for Metal-semiconductor Ohmic Contacts**

Kyung-Eun Byun, Seongjun Park, Heejun Yang, Hyun-Jong Chung, Hyun Jae Song, Jaeho Lee, David H. Seo, Jinseong Heo, Dongwook Lee, Hyeon Jin Shin and Yun Sung Woo
Samsung Advanced Institute of Technology (SAIT), Korea

**Abstract** - One of the key components of modern device structures is the metal-semiconductor (MS) contact with low symmetric contact resistance. We report on a MS contact structure utilizing graphene insertion. In this strategy, graphene reduces or even eliminates in ideal conditions, the Fermi-level pinning at a MS junction. Since the metal, Ni, deposited on graphene reduced the work function of graphene, the doped graphene was able to lower the Schottky barrier at the MS junction. The Schottky barrier height of metal-graphene-Si (MGS) junction was obtained from temperature dependent I-V characteristics. We confirmed that the graphene doped with Ni reduced the Schottky barrier height from 0.67 eV to 0.20 eV in wafer scale test. We also demonstrated the formation of an ideal MGS Ohmic contact via conductive atomic force microscopy. The contact resistance of the ideal MGS was less than 1.0 x 10-6 Ohm cm^2 with low doped Si (10^15cm^-3). The resistance is comparable to that of a current device contact with highly doped Si. Since it only requires the insertion of a single layer of graphene, this method can be directly applied to the current Si technology to reduce the contact resistance at MS junctions.
In situ Electrical Resistivity Measurement of Self Assembled Cu3Si Nanowires on Si(111)

Poh-Keong Ng1, Jian-Yih Cheng2, Brandon Fisher3 and Carmen Lilley2
1. Department of Electrical and Computer Engineering, University of Illinois at Chicago, USA
2. Department of Mechanical and Industrial Engineering, University of Illinois at Chicago, USA
3. Center for Nanoscale Material, Argonne National Laboratory, USA

Abstract - Self assembled Copper-Silicide nanowires were fabricated on a 600°C annealed Si(111) substrate by electron beam evaporation technique. In situ scanning electron microscopy images of self-assembled Copper-Silicide nanowires and nanoislands were obtained. In situ four point probe electrical resistivity measurements were performed on Copper-Silicide nanowires using Pt-Ir probes. The cross section geometry of a nanowire was studied by transmission electron microscopy technique, which was prepared using a focused ion beam technique. The composition of the nanowire was analyzed with x-ray energy dispersive technique and determined its phase to be Cu3Si. In situ electrical resistivity measurements were performed on two Cu-Si nanowires. The electrical resistivity of one of the nanowire was obtained as ~63 μΩ·cm.

Laser Assisted Atom Probe Tomography of III-Nitride Semiconductors and Zinc Oxide Nanostructures

Nabil Dawahre, Gang Shen, Paul Tolmer, Seungsin Margaret Kim and Patrick Kung
University of Alabama, USA

Abstract - Wide bandgap AlInGaN and ZnO semiconductors are important materials for optoelectronic and electronic devices. We present here the investigation of laser assisted atom probe tomography of lattice matched AlInN/GaN heterostructures and ZnO nanowires, which is able to yield 3D chemical mapping with atomic sensitivity and sub-nanometer spatial resolution, and correlate with other material optical and electrical characteristics.
Programming Optical States in VO2 film for IR phototherapy

Noraica Davila, Rafmag Cabrera and Nelson Sepulveda
Michigan State University, USA

Abstract - This work presents a new technology suitable for localized infrared (IR) phototherapy. Specified regions of a VO$_2$ thin film were programmed to different transmissivity values in the near IR. Such programming was done through photothermal actuation of the thin film, achieved by controlling the scanning of a red laser over its surface. The thermally-induced phase transition of the VO$_2$ thin film comes with an abrupt change in its transmittance, which (due to its hysteretic behavior) can be stored; allowing for the programming of optical memory states in the films. Several patterns were stored and read through a simple optical system. A single film can store one pattern at a time. The nature of this material allows for a relatively fast reconfiguration of the stored pattern. After a specific pattern was programmed on the film, an IR image was projected by illumination of the entire VO$_2$ film with an IR beam. The image was detected by a laser beam profiler (LBP). This pattern storage and projection technology proves promising in the development of applications for treatments of IR phototherapy.
Bandwidth Limitation of the Electrolytes for DNA Sequencing Using Nanopore Sensors

Kunsun Eom, Heejeong Jeong, Jeoyoung Shim, Taehan Jeon, Dongho Lee and Nam Huh
Samsung Electronics, Korea

Abstract - DNA sequencing using nanopore-based sensors attracts considerable interests because of the possibility of ultimate sensitivity of single-molecule resolution. Due to the fast DNA translocation speed on the order of microsecond, the sensor requires a wide bandwidth exceeding a megahertz. Such a high frequency signal transmits through the electrolyte and the sensor measures ionic current changes. The electrolyte is essential to dissolve DNA sample into the sensor. However, the bandwidth of the electrolyte has not been considered yet. This study presents the bandwidth limitation of the electrolyte and we believe it should be considered when using DNA sequencing method via high frequency signal detection through the electrolyte.

Micro-slit Filter for Separation of Circulating Tumor Cells with High Recovery and High Purity

Tae Seok Sim, Minseok S. Kim, Hui-Sung Moon, June-Young Lee, Jeong-Gun Lee, Hyoyoung Jeong, Yeon Jeong Kim, Hun Joo Lee, Sanghyun Baek, Jin-Mi Oh and Soo Suk Lee
Samsung Advanced Institute of Technology (SAIT), Korea

Abstract - We present a novel method for separating circulating tumor cells (CTCs) with high recovery and purity at the same time using a micro-slit filter chip and a fully automated fluidic system. Considering white blood cells (WBCs) as big as CTCs are also captured with CTCs during filtration, we amplified the size of CTCs specifically using microbeads (3 µm) coated with anti-epithelial cell adhesion molecule (anti-EpCAM) antibodies to increase size difference between WBCs and CTCs. The average diameter of MCF-7 cells was increased from 16.5 µm to 23.1 µm. A micro filter chip having an extremely high aspect ratio (AR=3488) rectangular slit was designed to prevent clogging which induces unwanted aggregation, capturing of other small blood cells and consequently decreasing purity. A fully automated fluid control system was implemented for the better reproducibility and the minimization of handling errors. The procedures from blood loading to staining before analysis were performed automatically. With the optimized condition, separation experiments using 5ml of normal whole blood spiked with 100 MCF-7 cells have demonstrated reduction of clogging, high recovery (91.1 %) and high purity (52.0 %) at the same time.
Molecular-Level Dengue Fever Diagnostics via a Combination of RT-LAMP and Paper-based Devices
Shih-Jie Lo¹, Shih-Chun Yang², Da-Jeng Yao¹, Jiann-Hwa Chen² and Chao-Min Cheng¹
1. Institute of Nanoengineering and Microsystems, National Tsing Hua University, Taiwan
2. Institute of Molecular Biology, National Chung Hsing University, Taichung 402, Taiwan

Abstract - This paper describes the development of an inexpensive, but robust and easy-to-use point-of-care diagnostic device that can be used for the detection of dengue fever at the molecular level (i.e., the detection of dengue virus via using a piece of paper). To date, the clinical diagnosis of dengue fever mainly relies on ELISA-based examinations for a specific antigen. However, the protein-based diagnostics is at the relatively late stage, and it is needed to develop a simple and low-cost diagnostic device for the detection of dengue fever at the early stage after the infection. Here, we have developed a procedure for monitoring dengue virus serotype 2 RNA (in the buffer system), including: i) amplifying the nucleic acids via RT-LAMP (reverse transcription loop-mediated isothermal amplification), and ii) examining the amplified products via a colorimetric assay in paper. We have demonstrated the ability to amplify dengue virus via RT-LAMP with the virus concentration of 60 PFU/mL; the current results indicated that this paper-based diagnostic device was capable of detecting the RT-LAMP products in the buffer system with the concentration of 300 ng/mL.

A Novel Microchip Filter for Rare Cells Separation
June-Young Lee, Hui-Sung Moon, Tae Seok Sim, Minseok S. Kim, Hyoyoung Jeong, Yeon Jeong Kim, Jeong-Gun Lee, Sanghyun Back, Jin-Mi Oh, Hun Joo Lee, Jae Chan Park, Nam Huh and Soo Suk Lee
Samsung Advanced Institute of Technology (SAIT), Korea

Abstract - This paper describes a novel microchip filter device incorporating slit arrays and 3-dimensional flow that can separate rare cells with high efficiency and throughput. The proposed device has several tens of times increased throughput, and has a unique pressure distribution along the filter pore, inducing target cells to be captured and gently lined up at the end of the slit in relatively low shear stress condition. With the enhanced capture yield and throughput, the proposed device can be used as an efficient rare-cell-analyzing tool for blood-based diagnostics.
SNP Detection based on Temperature-Controllable EWOD Digital Microfluidics System

Hsien-Hua Shen, Tsung-Yao Su, Hwan-You Chang and Da-Jeng Yao
NTHU, Taiwan

Abstract - This study based on the technique, “Electrowetting on Dielectric (EWOD),” with the micro-heaters designed in EWOD microfluidics system for temperature controlling in biomedical reaction. On this platform, magnetic beads (MBs) were used as carriers for single-nucleotide polymorphism (SNP) detection. In human genome, SNPs are responsible for the variations between individuals. The genome of a person comprise specific SNP could result in responsiveness to drug therapies and sensitivity of certain disease. Therefore, SNP is considered as one of the keys to predict the affect in pharmacogenomic medicine. In this study, SNP detection has been demonstrated on this thermal controllable EWOD platform in order to approach the goal of “lab-on-a-chip”.
Synthesis and Characterization of Iron Carbide Nanorod under Pulsed Plasma

Soemsak Yooyen, Takahiro Kawamura, Shigeo Kotake and Yasuyuki Suzuki
Mei University, Japan

Abstract - Study on the growth of nanorod by means of pulsed plasma chemical vapor deposition was reported. Pure iron plate was used as a substrate acted as both the supporter for growing nanorod and the catalyst itself. The effects of negative plasma in preheat and synthesis processes were studied. Nanoparticles were formed on substrate treated by negative hydrogen plasma while nanorods were formed on these substrates after further treatment by methane negative plasma. The optimum times for negative plasma in preheat and methane treatment were 10 min. Nanorod was about 60 nanometer in diameter and about 600 nanometer in length. The diffraction of nanorods was agreed with crystal structure of iron carbide.

Dynamics of VO$_2$:Cr coated microcantilevers in aqueous media

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2. University of Puerto Rico at Mayagüez, USA

Abstract - Three silicon micro-cantilevers coated with a Cr-doped vanadium dioxide (VO$_2$:Cr) thin film were photothermally actuated with a pulsed red laser in order to study its dynamic performance in air and in water. Micro-cantilever vibration amplitudes with a magnitude similar to that of DC operation were obtained in air up to 600 Hz. In water, a decrease in amplitude started at ~ 100 Hz, but it did not go below -3 dB until a few hundreds of Hz. Deflection transients of all micro-cantilevers were also measured in both media. This revealed that, in water, the deflection response to the laser pulses is greatly hampered by the amount of time required for the micro-cantilevers to heat. However, in air, there was no apparent difference in the transients between heating and cooling. These results suggest the use of VO$_2$:Cr coated micro-cantilevers as optically driven actuators with large deflections in liquid media suitable for biological based applications.
Temperature Dependent Carrier Dynamics of ZnO Nanowires by Terahertz Time-Domain Spectroscopy
Soner Balci, William Baughman, David Wilbert, Gang Shen, Patrick Kung and Seongsin Margaret Kim
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Abstract - We present a comprehensive study of the characteristics of carrier dynamics using temperature dependent Terahertz Time Domain Spectroscopy. By utilizing this technique in combination with numerical calculations, the complex refractive index, complex dielectric constant, and complex conductivity of undoped, and Al-doped ZnO NWs were obtained. The unique temperature dependent behaviors of major material parameters were studied at THz frequencies, including plasma frequency, relaxation time, carrier concentration and mobility. Frequency and temperature dependent carrier dynamics were subsequently analyzed in these materials through the use of the Drude-Smith model.

Rapid Micro-Patterning of a Conductive PANI/MWNTs-Polymer Composite Using an Optically-induced Electrokinetics (OEK) Chip
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3. Dept. of Power Mechanical Engineering, National TsingHua University, Hsinchu, Taiwan

Abstract - A flexible, dynamically programmable and low-cost method applicable to micro-patterning of a conductive polymer/carbon nanotube composite solution is significant due to the potential applications in many areas. This paper demonstrates a new micro-patterning method for fabricating electrodes from a conductive polyaniline (PANI)/MWNT composite using an optically-induced electrokinetics (OEK) chip. This method quickly patterns flexible polymeric electrodes with different geometries when a square waveform signal with amplitudes from 16-20 Volts and frequencies from 20-30 kHz are applied. The geometric dimensions of the electrodes can be varied dynamically by controlling the size and exposure time of the light pattern. The surface morphology of electrodes patterned by this method is scanned by an atomic force microscope (AFM) and a scanning electron microscope (SEM) which shows that the electrodes are uniform and continuous. Furthermore, the geometric dimensions and resistances of the electrodes are measured and analyzed. Experimental results reveal that the relationship between the resistance and geometries of the electrodes obey Ohm’s law and the resistivity of the electrodes is about 0.03 Ohm-m.
Friday, October 19, 2012

**Keynote Talk 2**  
Diamond-Based Nanomedicine for Targeted  
Chemotherapy and Imaging (by Prof. Dean Ho)

**Keynote Talk 3**  
Molecular-Scale Electronic Devices (by Prof. Takhee Lee)

**Plenary Talk 3**  
CMOS-CNT Integration: A New Path to  
Achieving Ultra-High Sensitivity in Electrical  
Bio-Sensor (by Prof. Young June Park)

**Plenary Talk 4**  
Multiscale Mechanics of Hierarchical  
Nanomaterials and Structures: Concept,  
Design, Processing and Applications (by Prof. Jian Lu)

**Regular Session 6**  
Nanomaterials and Fabrication Techniques

**Invited Session 10**  
Graphene
Paper ID: 293
Microinjection Molding of Polypropylene (PP) Filled with MWCNT: Influence of Processing Parameters on the Mechanical Properties
Michael Heinrich, Freddy Sichting and Lothar Kroll
Chemnitz University of Technology, Germany

Abstract - Polypropylene composites with different contents of multiwalled carbon nanotubes (MWCNT) were microinjection molded to investigate the influence of melt temperature and injection velocity on the final mechanical properties. Therefore, samples of various MWCNT loadings from 1 wt% to 5 wt% were prepared by diluting commercial masterbatches. Microinjection molding was used to prepare micro tensile bars under different processing conditions. The nanocomposites expose mechanical properties significantly influenced by nanotube loading, injection velocity and melt temperature.

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Paper ID: 42
Self-Assembly Patterning of Nanomaterials using Electrostatic Interaction in Solution
Shinya Kumagai1, Shigeo Yoshii2, Naofumi Okamoto3, Kazuaki Nishio2 and Ichiro Yamashita3
1. Toyota Technological Institute, Japan
2. Panasonic, Japan
3. Nara Institute of Science and Technology, Japan

Abstract - Self-assembly patterning of nanomaterials using electrostatic interaction in solution was investigated. The electrostatic adsorption conditions were numerically analyzed by considering the Debye length in solution and the electric charge densities displayed on the surfaces of nanomaterials and substrates. Using the analyzed conditions, nanoparticles as large as 10 nm were successfully patterned one by one on a substrate. Moreover, increasing electric charge density on the nanoparticle achieved single nanoparticle placement onto an electrostatic adsorption pattern that was larger than the size of the nanoparticle. The electrostatic patterning was applied to various nanomaterials.
VO2 Thin Films for Micromanipulators
Caitlin Ramsey, Rafmag Cabrera, Emmanuelle Merced and Nelson Sepulveda
Michigan State University, USA

Abstract - The use of VO$_2$ thin films as the active element in micromanipulators of multiple degrees of freedom is studied. It is shown that the insulator-to-metal transition of VO$_2$, which occurs at around 68°C, can be used to create localized stress gradients in micro-structures. By controlling the location and intensity of these stress gradients, precise and multiple inflection points within a cantilever beam can be achieved. This transition can be induced locally by any form of heating. In this work the transition is induced by optical radiation which allows remote actuation of the micromanipulators and by joule heating through electrodes, which simplify the actuation system. Due to the relatively low transition temperature of VO$_2$ and particularly localized heating, these micromanipulators can be used in the different fields of bio-engineering.

Preparation and Self-Assembly of Functional Organic-Inorganic Nanocomposite Particles
Hiroshi Yabu
Tohoku University, Japan

Abstract – We show here the Self-Organized Precipitation (SORP) method for preparation of nanostructured polymer particles. Preparation of organic-inorganic composite particles and future outlook of nano-structured polymer particles is discussed.
Photoresist Spray Coating For 3D MEMS/NEMS

Shinya Kumagai, Taichi Yamamoto, Hironori Kubo and Minoru Sasaki
Toyota Technological Institute, Japan

Abstract - Spray coating of a photoresist was investigated for three-dimensional (3D) MEMS/NEMS. To improve the uniformity of photoresist deposition onto a sample with 3D surface structure, the gas flow in the vicinity of the sample was numerically analyzed to understand the physics for uniform photoresist deposition. The numerical analysis revealed that the gas flow that flowed horizontally in the vicinity of the sample degraded the uniformity of the resist deposition. The horizontal flow could be blocked by setting a shield plate with an aperture over the sample. Moreover, using the shield plate enhanced vertical velocity component in the aperture area, which could improve uniformity of the resist deposition on trench bottom, trench top. Angled exposure technique enabled photoresist patterning on the sidewall. With this “3D photolithography”, 3D MEMS/NEMS devices can be fabricated. For the demonstration, 100 photo cells of pn junction were connected in series by 3D wirings to achieve 10V.
Direct Graphene and h-BN Growth on Oxides and Nitrides for Device Applications

Jeffry Kelber¹, Cao Yuan¹, Yaroslav Lasovyy¹, Lingmei Kong² and Peter Dowben²
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2. University of Nebraska-Lincoln, USA

Abstract - This lecture will review recent work on direct growth, without metal catalysts, of graphene on oxide and boron nitride substrates. Such direct growth is a critical step toward the development of practical graphene devices. These experiments demonstrate that the graphene interactions with different substrates impart different properties, with significant device implications. Graphene growth by chemical or physical vapor deposition on MgO(111) results in formation of a band gap of ~ 0.5-1 eV, useful of FET applications. The formation of a band gap is related to graphene/oxide interactions that destroy graphene lattice A site/B site chemical equivalence, thus lifting HOMO/LUMO degeneracy at the Dirac point. In contrast, graphene growth by molecular beam epitaxy on Co₃O₄(111)/Co(0001) does not lift graphene A site/B site equivalence, and this difference between graphene interactions on metal oxides with similar O-O nearest neighbor distances is apparently linked to the greater stability of the Co₃O₄(0001) (spinel) vs. MgO(111)(rocksalt) structures against adsorbate-induced reconstruction. However, the formation of graphene on a magnetic oxide may result in substrate-induced graphene ferromagnetism, and coherent spin transport within the graphene layer. Graphene deposition on monolayer/h-BN(0001)/Ru(0001) compared to graphene growth on h-BN nanoflakes demonstrates that the ability to grow few layer h-BN with precise thickness control may be important to modulate metal/BN/graphene charge transfer, and for recently discussed graphene-based vertical transistors. Recent results have demonstrated the ability of BCl₃/NH₃ atomic layer deposition to form h-BN bilayers on CoSi₂(111)/Si(111), as a possible route toward the practical realization of vertical transistor designs, and integration with Si.
Electron transport in graphene and graphene nanoribbons: Challenges to capitalize on graphene’s promises
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2. Dept. of Energy Resources Engineering, Stanford University, USA

Abstract - In this lecture we will present results of electron-transport calculations in graphene-based structures and discuss the challenges we must face when trying to exploit the potentially excellent electronic-transport properties of graphene in CMOS applications. Ideal, free-standing graphene sheets exhibit an electron mobility exceeding 200,000 cm²/Vs. We will show that this is consistent with results of Monte Carlo calculations based on electron-phonon scattering rates obtained using the rigid-ion approximation. However, realistic devices will employ graphene supported by an insulating substrate and top-gated. We will argue with theoretical results that the coupling of graphene-electrons with coupled plasmon-phonon modes at the graphene/dielectric interface(s) will degrade the mobility (significantly at low carrier density, down to 50,000 cm²/Vs or less, depending on the dielectric, at 10¹² carriers/cm²). In addition, armchair-edge graphene nanoribbons will likely be employed in order to open a gap, as needed in CMOS application. We will show that line-edge roughness will result in electron localization, and so in a very low mobility unsuitable to device applications. Thus, employing insulators with a low dielectric constant and obtaining ideally straight ribbon-edges appear to be requirements necessary to translate graphene’s promises into reality.

High-field Transport and Dissipation in Graphene Ribbons
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4. Beckman Institute, University of Illinois at Urbana-Champaign, USA

Abstract - This lecture will overview our recent studies of high-field transport and thermal dissipation in graphene devices and nanoribbons. We used infrared (IR) thermal imaging to visualize patterns of heat dissipation in functioning graphene transistors. Coupling such experiments with electro-thermal simulation has uncovered physical insights into their carrier densities, fields, temperature, and reliability during operation. We have also employed AFM-based techniques to measure the temperature with high resolution near graphene-metal contacts, and uncovered thermoelectric effects that could be engineered to partially mitigate the Joule heating generated during typical device operation. More recently, we examined high-field transport and dissipation in graphene nanoribbons (GNRs), finding that narrow GNRs benefit from (at first counter-intuitive) cooling effects due to heat spreading into their substrate and contacts. Through thermal engineering, we have achieved current densities >10⁹ A/cm² in GNRs, almost comparable to those of carbon nanotubes, despite a lower thermal conductivity of GNRs which appears limited by phonon-edge scattering. Combined, such studies offer a more complete picture of high-field transport and dissipation in graphene devices and interconnects under realistic operating conditions.

Dimitar Alexandrov¹,², Scott Butcher²,¹, Penka Terziyska¹, Rositsa Gergova¹, Peter Binsted¹, Dimka Georgieva¹, Vasil Georgiev¹

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Abstract - Investigation of optical properties of thin epitaxial layers of GaN and of InN grown on sapphire substrates (0001) by novel plasma based migration enhanced afterglow MOCVD (MEAGlow) is presented in this paper. Experimental results are obtained for several samples and they show variation of the optical absorption edge in range 1.4 – 3.9 eV for GaN and in range 0.6 – 2.8 eV for InN. Theoretical investigation of these unusual variations of the absorption edges is done by using LCAO electron band structure calculations. Variations of the lattice constants of the first deposited layers of GaN and of InN are found due to the influence of the sapphire substrate. It determines defects of the structure of GaN and of InN and the corresponding LCAO matrix elements are determined. The LCAO electron band structures are calculated in consideration of interactions between nearest-neighbour orbitals. The calculations are performed by method previously developed by the authors. Electron energy pockets are found in both the conduction and the valence bands at points Γ of the electron band structures. Also it is found that these pockets are on distances, for which there are overlaps between electron wave functions describing localized states belonging to the pockets, and as result tunnel optical absorptions have places. This type of absorption determines the variations of the optical absorption edges.