

Tuesday Morning, October 29, 2013

Nanometer-scale Science and Technology
Room: 203 B - Session NS+EM+EN-TuM

Nanoscale Transport and Devices

Moderator: V.P. LaBella, University at Albany-SUNY

8:00am **NS+EM+EN-TuM1 Electrical Transport in 2-dimensional van der Waals Material Heterostacks**, *P. Kim*, Columbia University, *C. Dean*, CCNY **INVITED**

The recent advent of atomically thin 2-dimensional materials such as graphene, hexa boronitride, layered transition metal chalcogenide and many strongly correlated materials, has provide a new opportunity of studying novel quantum phenomena in low dimensional systems and their heterostructures utilizing them for novel electronic devices. With a strong built-in anisotropy in their components, vdW materials often show a quasi-low dimensionality leading to strongly correlated electron behaviors. Moreover, combination of different layered constituents may produce heterogeneous and functional materials. In this lecture, we will discuss to develop the method of transferring two-dimensional atomic layers of van der Waals solids to build functional heterostacks. We will discuss novel electron transport phenomena can occur across the heterointerfaces of designed quantum stacks to realize exotic charge transport phenomena in atomically controlled quantum heterostructures.

8:40am **NS+EM+EN-TuM3 Transition in Mechanisms of Size Dependent Properties at Nanoscale Interfaces**, *J. Hou*, *S.S. Nonnenmann*, *W. Qin*, *D.A. Bonnell*, University of Pennsylvania

As electronic and optoelectronic devices scale down to nanometer lengths, the properties of interfaces dictate performance. An important class of interfaces, metal-semiconductor and/or oxide contacts, have been shown to exhibit size dependent electronic properties. In this work, the mechanisms of size dependent properties at interfaces of noble metal nanoparticles and substrates is examined. Electron transport and interfacial atomic structure of a model system -- Au/SrTiO₃ (STO) junctions, is systematically investigated with conductive Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM). In the range of 200 nm to 20 nm interface transport properties are size dependent, with ideality factor and Schottky barrier height derived from I-V curves. The relative amounts of tunneling and thermionic emission transport are quantified. A transition between two mechanisms of size dependence is identified. Implications to resistive switching are discussed.

9:00am **NS+EM+EN-TuM4 Quantum Correction to the Transition Localization in La_{2/3}Sr_{1/3}MnO₃ Thin Films at Low Temperatures**, *Y. Gao*, Max Planck Institute for Solid State Research, Germany, *W. Sigle*, Max Planck Institute for Intelligent Systems, Germany, *J. Zhang*, Shanghai University, Republic of China, *D. Zhou*, Max Planck Institute for Intelligent Systems, Germany, *G.X. Cao*, Oak Ridge National Laboratory, *H.U. Haberman*, Max Planck Institute for Solid State Research, Germany

The low-temperature magnetotransport properties of manganite thin films are characterized by the occurrence of resistivity minima, ρ_{\min} , below 60 K whose origin and especially role of disorder has not yet been explored in detail. In order to contribute to the clarification of the physical mechanism giving rise to the resistivity minimum in these systems, an appropriate concentration (20% and 30%) of nanoscaled nonmagnetic ZrO₂ particles are introduced as a secondary phase into La_{2/3}Sr_{1/3}MnO₃ thin films. We present the quantum corrections to conductivity in La_{2/3}Sr_{1/3}MnO₃ thin films with ZrO₂ nano-particles. As impurities increases, the upturn of resistivity enhances. The interesting results were analyzed by perturbation/quantum correction theory and a model which deviates from the traditional concept of localization was established, where the conductivity originates from the "impurity band". Using the tight-binding scaling theory of localization model, we change the density of impurities and tune the degree (intensity) of disorder, making the state of disorder change from weak localization to strong localization in 2 dimensional (2D) and 3 dimensional (3D) cases. The HR-TEM/ABF/HAADF images also confirm our conclusion that indicates the coexistence of 2D and 3D behavior in one system.

9:20am **NS+EM+EN-TuM5 Nano-enabled Chemical, Bio and Radiation Sensors**, *M. Meyyappan*, NASA Ames Research Center **INVITED**

We have been pursuing development of chemical and biosensors using CNTs for the last several years and this talk will present our progress to date. In the case of chemical sensors, we use an interdigitated electrode as a chemiresistor, where purified SWCNTs serve as the conducting medium.

When the chemiresistor is exposed to a gas or vapor, the change in resistance is recorded; if SWCNTs do not respond to a particular gas or vapor, then doping or functionalization strategies are used. A sensor array is constructed with 32-96 sensor elements with chemical variations across the sensor array. In the sensor training mode, a pattern of resistance changes is generated from the sensor array for a particular analyte at a given concentration and humidity level; this needs to be repeated for various concentrations and humidities and the generated information is stored for later use. In the identification mode, a pattern recognition algorithm is used to identify that analyte from the background using the information stored during training. This talk will present examples from our work to demonstrate the functioning of the sensor in security and biomedical applications. This sensor has also been integrated in an iPhone. We have recently made these sensors on cellulose paper substrates as well. In the case of the biosensor, a "lock and key" approach is used wherein a preselected probe for a given target is attached to the tip of a carbon nanofiber (CNF). CNFs in a patterned array are grown using PECVD on a silicon wafer which serve as individual, freestanding, vertical electrodes. This nanoelectrode array (NEA) can use DNA, aptamer and antibody probes, and electrochemical impedance spectroscopy is used upon probe-target binding for signal analysis. Results will be presented for identification of e-coli and ricin using this NEA and applications for security and biomedical sectors will be illustrated. For radiation sensing, we have developed a nanogap FINFET-like device wherein the nanogap can be filled with a radiation-responsive gel or liquid and demonstrated detection of gamma radiation. An array of devices with different liquids can be used in a multiplexed mode as a radiation nose. The author thanks Jing Li, Yijiang Lu, Jessica Koehne and Jinwoo Han.

10:40am **NS+EM+EN-TuM9 Ultraflexible and Stretchable Organic Devices for Biomedical Applications**, *T. Someya*, *M. Kaltenbrunner*, The University of Tokyo, Japan, *S. Bauer*, Johannes Kepler University, Austria, *T. Sekitani*, The University of Tokyo, Japan **INVITED**

We have successfully manufactured ultraflexible organic thin-film transistors and photovoltaic cells on ultrathin plastic film with the thickness as small as 1.2 μm . These novel organic devices are much lighter than bird's feathers. First, we have demonstrated polymer based photovoltaic devices on plastic foil substrates of 1.2 μm thick, with equal power conversion efficiency to their glass-based counterparts. They can reversibly withstand extreme mechanical deformation and have unprecedented solar cell specific weight. Instead of a single bend, we were able to form a random network of folds within the device area. We have also manufactured organic transistors on ultrathin plastic films in order to achieve sharp bending radius less than 50 μm . Bending cycle experiments will be presented to show the mechanical durability. Moreover, the issues and the future prospect of flexible organic devices such as thin-film transistors, photovoltaic cells, and memories will be addressed. Furthermore, ultraflexible and stretchable electronic systems have been exploited for biomedical applications such as medical catheters and implantable devices.

11:20am **NS+EM+EN-TuM11 Ultrahigh Thermal Conductivity Gold Nanowire-Filled Polymer Composites and Interfaces**, *I. Seshadri*, *N. Balachander*, *R.J. Mehta*, *L. Schadler*, *T. Borca-Tasciuc*, *P. Koblinski*, *G. Ramanath*, Rensselaer Polytechnic Institute

Realizing high thermal conductivity nanocomposites is a major challenge because of difficulties in incorporating high fractions of uniformly dispersed nanofillers and countering low filler-matrix interfacial conductance. Here, we obviate these issues by using < 3 volume% ultrathin sub-10-nm gold nanowire fillers to obtain a unprecedented 30-fold increase in polydimethylsiloxane [1] thermal conductivity to $\sim 5 \text{ Wm}^{-1}\text{K}^{-1}$ that is 6-fold higher than any previously reported nanocomposite filler including graphene, carbon nanotubes and silver nanowires, at lower filler loadings, and exceeds theoretical predictions. The nanowire diameter and aspect ratio are key to obtaining cold-welded networks that enhance thermal conductivity, while fostering low modulus and electrical conductivity. The nanocomposites exhibit high compliance with a low elastic modulus of $\sim 5 \text{ MPa}$ conducive for conformal formation of interface contacts. However, the interfacial thermal contact conductance of the nanocomposites interfaced with copper is low, e.g., $\sim 1.5 \text{ kWm}^{-2}\text{K}^{-1}$. Rheology measurements reveal that the low conductance is due to a liquid-solid transition that is sensitive to the nanowire loading fraction. In particular, the filler loading corresponding to the formation of a percolation network and maximizing the nanocomposite thermal conductivity also corresponds to a large increase in the polymer pre-cure viscosity. These results provide insights on designing processes to increase the thermal contact conductance at interfaces where efficient heat transport is of importance, e.g., in device packaging applications.

I. N. Balachander, I. Seshadri, R.J. Mehta, L.S. Schadler, T. Borca-Tasciuc, P. Keblinski, and G. Ramanath, "Nanowire-filled polymer composites with ultrahigh thermal conductivity," *Applied Physics Letters*, vol. 102, 2013, pp 093117 – 093117-3.

11:40am **NS+EM+EN-TuM12 Microscopy and Spectroscopy Study of Immobilization of Molecularly Imprinted Nanoparticles on (3-glycidoxypropyl)trimethoxysilane Modified Silica**, *T. Kamra, L. Ye*, Lund University, Sweden

Molecularly imprinted nanoparticles (MIPs) are polymeric structures which are prepared to the attachment of specific molecules in bio-sensing applications. Ideally, MIPs should be covalently immobilized on solid supports to allow efficient and easy use. Here we have studied a particular two-step method of immobilization, which makes use of an epoxide binding layer. For characterization we have used an array of different methods: scanning electron microscopy (SEM), atomic force microscopy (AFM), fluorescence microscopy, water contact angle measurements, and x-ray photoelectron spectroscopy (XPS).

The first step of the method is the modification of a silica support by an epoxide binding layer. This is achieved by treating the surface with 3-glycidoxypropyltrimethoxysilane (GPTMS) [1]. We find that we can achieve uniform, stable, and dense GPTMS layers with the desired epoxide termination. In the second step the amine-functionalized core-shell MIPs (300nm) specific to the sensing of propranolol are bonded to the surface via the terminal epoxy groups of the GPTMS layer. Covalent bonding is achieved via a ring opening reaction. Our microscopy experiments and water contact angle measurement show that the procedure results in a MIP layer with good surface homogeneity and coverage, although XPS shows that the layer is not completely dense. Nonetheless, we can conclude that GPTMS is highly effective for holding large polymeric core-shell MIPs for robust sensor applications.

[1]Vladimir V. Tsukruk, Igor Luzinov, and Daungrut Julthongpiput, *Langmuir* **1999**, 15, 3029-3032.

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