Nanometer-scale Science and Technology
Room: 212B - Session NS-MoM

Nanotools and Nanodevices
Moderator: Jun Nogami, University of Toronto, Canada

9:00am **NS-MoM3 Peter Mark Memorial Award Lecture: Taking Control of the Nanoscale with Scanning Programming Microscopy**, ***Peter Maksymovych****, Oak Ridge National Lab **INVITED**

Manipulation of single atoms and molecules is undoubtedly one of the most striking achievements of nanoscience. It has been repeatedly utilized to create clean model systems for surface physics, and it foretold the dream of atom-by-atom synthesis and atomic-scale control. However, it is also apparent that establishing atomic manipulation as a synthetic methodology for realistic materials faces major challenges. The first of these is scaling the complexity of atomic control – extending onto crystalline lattices, 3D objects, larger scales and increasingly complex chemical interactions. A related and equally potent challenge is increasing the energy scale of manipulation (and, conversely, the stability of manipulated matter), which necessitates control over chemical bond breaking. Essentially, we need to advance atomic manipulation toward the accuracy of macroscopic chemistry while retaining control over 1-100 nm length-scales. Over the last several years, we have explored the effects of large electric field, electronic current density and mechanical stress in progressively complex chemical reactions on surfaces and solid state materials with rich defect chemistry. Our goal is to peer into "pre-breakdown" window of material properties, that would normally be associated with destruction, desorption or amorphization. Quite on the contrary, using the unique capabilities of scanning probe microscopy, we have found this regime to be rich in chemical and electrochemical transformations, including reversible motion of oxygen vacancies in deep sub-surface volume of perovskite oxides (1-4) and delocalized chemical reactions involving rearrangements of chemical bond-order and strongly chemisorbed molecules (5-8. We established that local electrochemical control is key to understand and subsequently control specific phenomena, such as metal-insulator transitions in perovskite oxides in non-uniform stress and electric fields. Furthermore, hot-electron currents and electric fields can drive chemistry that is not thermally accessible, pointing toward novel catalytic and surface reactions. At the same time, many of these transformations exhibit memory, hysteresis and training. We therefore speculate that they provide a stepping stone to programmable materials, a distinct paradigm where the shape and function of the materials will be defined by a programmed protocol of excitation, relaxation and stresses. Programmable materials can be made adaptive and eventually even computing. Ultimately, we envision programmable metamaterials, wherein a "quilt" of nanoscale chemical compositions with distinct chemical boundaries produces a unique collective function.

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9:40am **NS-MoM5 Directing Nanoscale Mass and Energy Transport using Cantilever-Free Scanning Probes**, ***Keith A. Brown***, *D.J. Eichelsdoerfer, C.A. Mirkin*, Northwestern University **INVITED**

Advances in lithography have driven the information revolution by allowing semiconductor manufacturers to shrink integrated circuits at an exponential rate for nearly 50 years. Given the explosion of interest in biomedical research and engineering, a major challenge that must be addressed in the coming decades will be the difficulty in developing high quality techniques for patterning soft and bioactive materials at the nanoscale. Scanning probe techniques are poised to be a major player in this advance because they allow one to direct mass transport at the nanoscale, thus attaining high resolution without processing steps that might damage biological materials. Despite their promise, the chief limitation inherent to scanning probe techniques is throughput, as patterning with a single probe is in many cases prohibitively slow. Recently, it has been shown that this problem can be circumvented by replacing the cantilever that conventionally supports a single probe with an elastomeric film on a rigid surface that supports a massive array of probes. While this new cantilever-free architecture intrinsically addresses the scalability challenge, many questions remain about how these probe arrays differ from their cantilever-based counterparts, specifically relating to how the transfer of energy and materials is governed by the hard/soft composite probe array. Here, we explore such transfer processes including the transport of liquids and light from cantilever-free tips to a surface. Specifically, we overview the transfer of polymeric solutions from a tip to a surface and find that, in many cases, the details of materials transfer are dictated by how the capillary bridge between the tip and surface ruptures. This observation allows for the patterning of sub-20 nm polymer features. Ultimately, however, our work is motivated by the desire to answer previously inaccessible questions through the development of new synthetic techniques. Thus, we explore these probe arrays as candidate techniques for performing massive-scale combinatorial experiments in nanoscience, and develop new methods for pushing the state-of-the-art in terms of ink complexity, feature size, and feature density. Based upon these advances, we describe preliminary screening experiments for the identification of novel nanoparticle-based heterogeneous catalysis. This work sets the stage for scanning probe-based tools to fill many emerging needs in nanoscience, biology, and materials science.

11:20am **NS-MoM10 NSTD Nanotechnology Recognition Award Talk: Nanomaterials in Sensor and Electronics Development**, ***Meyya Meyyappan†***, NASA Ames Research Center **INVITED**

Nanomaterials such as carbon nanotubes (CNTs), graphene and silicon nanowires (SiNWs) have received much attention for sensors and nanoelectronics due to their interesting properties. This talk will provide an overview of recent development in these fields at NASA Ames Center for Nanotechnology. We have developed CNT based chemical sensors for space exploration needs such as crew cabin air quality monitoring and fuel leak detection; the chemiresistor based sensor array is operated as an electronic nose and demonstrated for the detection of various gases and vapors at ppm-ppb levels. Routine astronaut health monitoring and water quality monitoring in the International Space Station and future crew vehicles require compact, low power lab-on-a-chip that can provide rapid analysis. Our nanoelectrodes array based biosensor uses PECVD-grown vertically aligned carbon nanofibers and provides electrochemical response from CV and/or impedance spectroscopy upon probe-target interaction. Sample results for the sensitive detection of three biomarkers for heart disease and the potential for multiplexing will be presented. We have also taken a "More-than-Moore" philosophy in the construction of radiation sensors where a conventional silicon FINFET-like structure uses a radiation-responsive gel dielectric in the nanogap created from the removal of SiO_2 dielectric. Both n- and p- type devices show excellent response to gamma radiation, demonstrating the potential to construct a radiation nose. Finally, we have been developing nanoscale vacuum tubes using entirely silicon technology for future radiation-immune electronics. Devices with a 50 nm source-drain gap provide an excellent drive current, on/off ratio of 10^6 and drive voltage of < 5 V. The author acknowledges contributions from Jessica Koehne, Ramprasad Gandhiraman, Adaikappan Periyakaruppan, Jin-woo Han, Ami Hannon, Beomsok Kim, Yijiang Lu, Taiuk Rim, Chang-Ki Baek and Jeong-Soo Lee.

*** Peter Mark Memorial Award Winner**

† NSTD Recognition Award

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