Tuesday Morning, October 21, 2008

Nanometer-scale Science and Technology
Room: 311 - Session NS+NC-TuM

The Frontiers of Nanoscience
Moderator: M.C. Hersam, Northwestern University

8:00am **NS+NC-TuM1 The Missing Memristor Found: A Fundamental Element for Nanoelectronic Circuits**, ***R.S. Williams***, HP Labs **INVITED**

In 1971, Prof. Leon Chua of the UC Berkeley Electrical Engineering Department predicted from symmetry arguments for non-linear circuits that there should be a fourth fundamental passive circuit element to complement the capacitor, resistor and inductor. He called this element a memristor, a contraction for 'memory resistor', and showed that if it existed, it would have a great many interesting and useful properties. However, no one was able to construct such an element, so the idea faded away. On May 1 of this year, we announced that we had 'found' the missing memristor, and that the element we built indeed had the properties predicted by Chua when operated within a restricted parameter range. In this talk, I will describe the discovery of the memristor, what its properties are, how it is made, and how we have used it in a variety of hybrid integrated circuits with transistors, including nonvolatile random access memories and synaptic or "brain-like" circuits.

8:40am **NS+NC-TuM3 Driving Forces and Barriers in Formation of Nanostructured Assemblies at Surfaces**, ***D.L. Allara***, Pennsylvania State University **INVITED**

Much of the recent interest in micro- to nano-scale patterned molecular structures on substrates has arisen from applications ranging from molecule-based integrated logic circuits to “biochips.” In such structures the cascading details of hierarchial assemblies are critical. At the large scale the patterns are created as dictated by large scale needs such as circuit layouts or test probe spatial resolution while at the finest scale the structures may require precise single molecule placement and associated controlled local chemical and electrostatic environments. Throughout the hierarchical manifold of structures a wide range of chemical potential differences may exist in the components, leading to inherent instabilities, and large thermodynamic driving forces built into the processing conditions often result in unexpected nanostructures as subtle kinetic pathways steer the system into metastable and unexpected final states. These effects will be discussed with specific examples from our own work and selected work from other groups.

9:20am **NS+NC-TuM5 Linking Proteins, Particles, Wires and Dots with Ferroelectric Nanolithography**, ***D.A. Bonnell***, The University of Pennsylvania **INVITED**

Self assembly is a powerful strategy that utilizes chemical and physical forces to fabricate ensembles of nanostructures. The ultimate goal for some device strategies is to co assemble a variety of nanostructures with differing properties in arbitrary but pre defined configurations. Chemical self assembly alone presents serious challenges in this regard since it operates on one type of nanostructure: a layer of molecules, a lattice of particles, templated wires, etc. Ferroelectric Nanolithography is a directed assembly approach that positions nanostructures of various compounds into predefined functional configurations. The process relies on domain specific surface electronic structure and consequent reactivity. Starting from an understanding of the atomic structures of ferroelectric oxide surfaces, the origin of domain specific chemical reactivity will be illustrated with in situ thermal and optical SPM observations and with the deposition of metal and oxide nanoparticles. The use of electron beams and local electrodes to pattern ferroelectric substrates will be explained in terms of relevant electron/solid interactions. A critical aspect of both understanding assembly processes and characterizing device behavior is the ability to probe local electric, dielectric and ferroelectric properties. Scanning probe based techniques that access the frequency dependence of local properties will be described. Finally the lithographic approach will be illustrated with the fabrication of a molecular opto-electronic device made of 3nm – 50 nm metal particles, optically active porphyrins, and functionalized peptide tetramers on an oxide substrate. The generalization of the approach to include, for example, integration in hybrid systems and applications in flexible electronics will be summarized.

10:40am **NS+NC-TuM9 Complex Spin Structures on the Verge of Instability—Imaging and Manipulation by Spin-Polarized STM**, ***M. Bode***, Argonne National Laboratory **INVITED**

Within the recent years spin-polarized scanning tunneling microscopy has become a mature tool for high spatial resolution studies of spin structures down to the atomic scale. Together with its high surface sensitivity this makes SP-STM particularly suited for the investigation of complex antiferromagnetic or superparamagnetic surfaces which— because of the lack of macroscopic magnetization—could only be studied in some rare cases with very moderate spatial resolution in the past. One particularly graphic example is the two-dimensional atomic-scale antiferromagnetic (AFM) structure observed within a Mn monolayer on tungsten (110).[1] On the atomic scale SP-STM data reveal periodic stripes running along the [001] direction with an inter-stripe distance of 0:47 ± 0.03 nm, indicating row-wise AFM order. Large scale images reveal, however, that the magnetic amplitude is not constant but is modulated with a period of about 12 nm. Magnetic field-dependent experiments show that this modulation is caused by an AFM spin spiral. First-principles calculations identify a cycloidal spin spiral which is caused by the Dzyaloshinskii-Moriya (DM) interaction as the driving mechanism for this complex magnetic order. Due to thermal excitations this spin structure becomes unstable in nano-scale islands. Switching the magnetization of a magnetic bit by injection of a spin-polarized current offers the possibility for the development of innovative high-density data storage technologies. We show how individual superparamagnetic iron nanoislands with typical sizes of 100 atoms can be addressed and locally switched using a magnetic scanning probe tip, thus demonstrating current-induced magnetization reversal across a vacuum barrier combined with the ultimate resolution of spin-polarized scanning tunneling microscopy.[2] Our technique allows us to separate and quantify three fundamental contributions involved in magnetization switching (i.e., current-induced spin torque, heating the island by the tunneling current, and Oersted field effects), thereby providing an improved understanding of the switching mechanism.

[1] M. Bode et al., Nature 447, 190 (2007)
[2] S. Krause et al., Science 317, 1537 (2007).

11:20am **NS+NC-TuM11 Albert Nerken Award Lecture - Atomic Tool for Nanofabrication Based on Atomic Force Microscopy**, ***S. Morita****, *Y. Sugimoto*, Osaka University, Japan, *Ó. Custance*, NIMS, Japan, *M. Abe*, Osaka University, Japan, *P. Pou*, Universidad Autónoma de Madrid, Spain, *P. Jelinek*, Academy of Science of the Czech Republic, *R. Pérez*, Universidad Autónoma de Madrid, Spain **INVITED**

We have been developing a novel bottom-up nanostructuring system at room temperature (RT) based on ultra high vacuum (UHV) atomic force microscopy (AFM). It can image individual atoms, identify chemical species, and then manipulate selected atom species one-by-one to the designed site to assemble complex nanostructures consisted of multi atom species at RT under UHV environment. In this invited talk, we will shortly introduce principles of high-performance and high-resolution UHV-AFM, and then, introduce our recent results related to not only nanocharacterization but also nanofabrication based on UHV-AFM such as (1) site-specific force spectroscopy and force mapping related to chemical identification of individual atoms,[1-3] (2) vertical/lateral mechanical atom manipulation.[4,5] (3) atom interchange lateral/vertical manipulation and following assembly of embedded atom letters at RT.[6]

[1]Y. Sugimoto et al. "Real topography, atomic relaxations, and short-range chemical interactions in atomic force microscopy: The case of the Sn/Si(111)-(r3xr3)R30 surface", Phys. Rev. B 73 (2006) 205329.
[2]M. Abe et al. "Drift-compensated data acquisition performed at room temperature with frequency modulation atomic force microscopy", Appl. Phys. Lett. 90 (2007) 203103
[3]Y. Sugimoto et al. "Chemical identification of individual surface atoms by atomic force microscopy", Nature, 446 (2007) pp.64-67.
[4]N. Oyabu et al. "Mechanical Vertical Manipulation of Selected Single Atoms by Soft Nanoindentation Using Near Contact Atomic Force Microscopy", Phys. Rev. Lett. 90 (2003) 176102.
[5]Y. Sugimoto et al. "Mechanism for room-temperature single atom lateral manipulations on semiconductors using dynamic force microscopy", Phys. Rev. Lett. 98 (2007) 106104.
[6]Y. Sugimoto et al. "Atom inlays performed at room temperature using atomic force microscopy", Nature Materials, 4 (2005) pp.156-159.

***** Albert Nerken Award Winner

Authors Index

Bold page numbers indicate the presenter