Wednesday Morning, October 20, 2010

Nanometer-scale Science and Technology
Room: La Cienega - Session NS+AS+MN-WeM

Characterization and Imaging at Nanoscale
Moderator: E.I. Altman, Yale University

8:20am **NS+AS+MN-WeM2 Surface Preparation of Supported Flat Gold Nanoparticles for use as Au(111) Single Crystal Substrates**, *D.H. Dahanayaka, L.A. Bumm*, The University of Oklahoma
Flat gold nanoparticles (FGNPs) grown in aqueous solution have large Au(111) facets that are excellent substrates for scanning probe microscopy. However adsorbed stabilizers (e.g. polyelectrolytes) must be removed or displaced before the FGNP surfaces can be used as single crystal surfaces. We have explored the effects of plasma cleaning, UV ozone, and thermal annealing on the surface roughness and the Au(111) terrace structure using STM.

8:40am **NS+AS+MN-WeM3 Determination of the Adsorption Site for Alkanethiol Monolayers on Au(111)**, *Q. GUuo*, University of Birmingham, UK
The bonding sites for Au-adatom-octanethiolate within the $(\sqrt{3}\times\sqrt{3})R30°$ structure on Au(111) has been investigated with high-resolution scanning tunneling microscopy (STM) imaging. By establishing the relationship between the lateral positions of adsorbates on the top layer of gold and those inside an etch pit, we are able to determine the adsorption configuration with a high degree of accuracy for the illusive $(\sqrt{3}\times\sqrt{3})R30°$ molecular layer. Within any one particular domain, the Au-adatom-octanethiolate species are found to occupy either the fcc hollow or the hcp hollow site.

9:00am **NS+AS+MN-WeM4 Atomic Co Wires: Room and Low Temperature STM/STS Measurements**, *N. Zaki*, Columbia University, *D. Acharya*, Brookhaven National Laboratory, *D.V. Potapenko*, Columbia University, *P. Johnson, P. Sutter*, Brookhaven National Laboratory, *R.M. Osgood*, Columbia University
We recently reported [1] on a new surface phase of the Co-vicinal-Cu(111) system which exhibits self-assembled uniform Co quantum wires that are stable at 300K. STM images show that the wires form along the leading edge of the step rise, differentiating it from previously theoretically predicted atomic-wire phases as well as experimentally observed step-island formation. Our observations allow us to comment on the formation kinetics of the atomic-wire phase and on the fit of our data to a recently developed lattice-gas model. Low-temperature STS measurements, taken on self-assembled Co chains, reveal a resonance at the Fermi energy. While it has been shown that single Co atoms and Co-Cu$_n$ clusters [2] exhibit a Kondo effect, a Co chain at a Cu step may exhibit a different many-body effect that is the cause for our Fermi-energy resonance observation. Furthermore, we have observed different charge-density modulation that is dependent on tip bias. Since these charge-modulations are observed for tip-bias relatively far away from the Fermi level, we suspect that these modulations are not ground state charge-density-waves (CDW), but rather excited states of this 1-D system.

[1] N. Zaki et al, Phys. Rev. B 80, 155419 (2009)

[2] N. Néel et al, Phys. Rev. Lett. 101, 266803 (2008)

9:20am **NS+AS+MN-WeM5 Atomic-Resolution Spin Mapping by Exploiting Magnetic Exchange Forces**, *R. Wiesendanger**, University of Hamburg, Germany **INVITED**
While Spin-Polarized Scanning Tunnelling Microscopy (SP-STM) [1] is nowadays well established for revealing atomic spin configurations at surfaces, its application is limited to electrically conducting samples such as magnetic metals or semiconductors. In order to map atomic spin structures at surfaces of insulators and to open up the exciting possibility of studying spin ordering effects with atomic resolution while going through a metal-insulator transition, we have developed Magnetic Exchange Force Microscopy (MExFM) [2]. This technique is based on the detection of short-range spin-dependent exchange and correlation forces at very small tip-sample separations (a few Angstroms), in contrast to Magnetic Force

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* NSTD Recognition Award

Microscopy (MFM) where the magnetic dipole forces are probed with a ferromagnetic probe tip at a typical tip-to-surface distance of 10-20 nm [3]. MExFM has allowed a first direct real-space observation of spin structures at surfaces of antiferromagnetic bulk insulators [2] as well as ultrathin films [4]. Moreover, it provides a powerful new tool to investigate different types of spin-spin interactions based on direct-, super-, or RKKY-type exchange down to the atomic level. By combining MExFM with high-precision measurements of damping forces [5] localized or confined spin excitations in magnetic systems of reduced dimensions become experimentally accessible [1].

[1] R. Wiesendanger, Rev. Mod. Phys. **81**, 1495 (2009).

[2] U. Kaiser, A. Schwarz, and R. Wiesendanger, Nature **446**, 522 (2007)

[3] Y. Martin and K. Wickramsinghe, Appl. Phys. Lett. **50**, 1455 (1987); J. J. Saenz, N. Garcia, P. Grütter, E. Meyer, H. Heinzelmann, R. Wiesendanger, L. Rosenthaler, H. R. Hidber, and H.-J. Güntherodt, J. Appl. Phys. **62**, 4293 (1987)

[4] R. Schmidt, C. Lazo, H. Hölscher, U. H. Pi, V. Cacius, A. Schwarz, R. Wiesendanger,

and S. Heinze, Nano Lett. **9**, 200 (2009).

[5] M. Ashino, D. Obergfell, M. Haluska, S. Yang, A. N. Khlobystov, S. Roth,

and R. Wiesendanger, Nature Nanotechnol. **3**, 337 (2008);

M. Ashino, R. Wiesendanger, A. N. Khlobystov, S. Berber, and D. Tomanek,

Phys. Rev. Lett. **102**, 195503 (2009)

10:40am **NS+AS+MN-WeM9 Chemical Imaging and Interaction Quantification on the Surface Oxide Layer of Cu(100) Using High-Resolution Atomic Force Microscopy**, *M.Z. Baykara, T.C. Schwendemann, H. Mönig*, Yale University, *M. Todorovic, R. Pérez*, Universidad Autónoma de Madrid, Spain, *E.I. Altman, U.D. Schwarz*, Yale University
Chemistry is governed by the interactions between atoms and molecules. On surfaces, chemical forces extending into the vacuum direct the behavior of many scientifically and technically important phenomena including surface catalysis. Therefore, it would be useful to map and quantify the interactions between a catalytically active surface and a probe with atomic resolution in order to study the role and effectiveness of various surface defects such as vacancies, impurities, steps, kinks, and domain boundaries as active sites. An ability to discriminate between different chemical species on the sample surface would offer further insight. In this talk, we will show with the example of an oxygen-reconstructed copper (100) surface that much of this information can be derived from combining the new method of three-dimensional atomic force microscopy (3D-AFM) [1], a variant of noncontact atomic force microscopy, with scanning tunneling microscopy. The surface oxide layer of Cu(100) features domain boundaries and a distinct structure of the Cu and O sublattices that is ideally suited for such model investigations. While different tips show different chemical contrasts, 3D data sets enable site-specific quantification of force interactions and tunneling currents. In order to clarify the different contrast modes data, DFT total-energy calculations and Non-equilibrium Green's Function (NEGF) methods for electronic transport have been used to determine the interaction and the tunneling current [2-4] for a large set of tip models. These calculations provide insight into (1) the fundamentals of contrast formation in this experimental technique and (2) into the correlation between tip-sample forces and local chemical reactivity, factors that are essential for the further development and application of this novel approach to characterizing catalytic activity.

[1] B. J. Albers et al., Nature Nanotechnology **4**, 307 (2009)

[2] Y. Sugimoto et al., Nature **440**, 46 (2007)

[3] P. Jelinek et al., Phys. Rev. Lett. **101**, 176101 (2008)

[4] J. M. Blanco, F. Flores, and R. Perez, Prog. Surf. Sci. **81**, 403 (2006)

11:00am **NS+AS+MN-WeM10 Comparison of Resonant-Frequency Techniques for AFM Nanomechanical Mapping**, *D.C. Hurley, J.P. Killgore, A.B. Kos*, NIST, *A. Gannepalli, R. Proksch*, Asylum Research
Contact-resonance force microscopy (CR-FM) is an emerging AFM technique for quantitative imaging of near-surface nanoscale mechanical properties. In CR-FM, the resonant frequency f of the cantilever is measured when the tip is in contact with the sample. Mechanical-property values are obtained from the frequency data with the use of models for the vibrating cantilever and the tip-sample contact. Contact-resonance measurements were originally made at a fixed sample position with off-the-shelf

electronics. However, to achieve sufficient speed for CR-FM imaging, it has been necessary to develop new instrumentation approaches. Here we describe work to directly compare three methods for CR-FM imaging: the SPRITE (Scanned Probe Resonance Image Tracking Electronics) approach developed at NIST, the DART (Dual AC Resonance Tracking) approach developed by Asylum Research, and the BE (Band Excitation) method originally developed at Oak Ridge National Laboratory and implemented by Asylum Research. Each method enables contact-resonance frequency mapping but achieves it through different practical implementations. First, we will discuss the concepts on which each method is based. Next, results of comparison experiments will be presented in which images were acquired with each method in succession on the same AFM instrument. A variety of specimens were imaged to probe the strengths and limitations of each method. For example, we found that DART could operate at higher scan speeds, while SPRITE and BE were better able to track very asymmetric peaks that presumably originate from nonlinear tip-sample interactions. Both DART and BE provide values of the resonance quality factor Q in addition to the resonant frequency f, while currently SPRITE measures f only. Despite these differences, the methods yielded similar results in many cases. The availability of a broader array of frequency mapping tools will ultimately facilitate the widespread application of CR-FM to nanoscale materials science.

11:20am **NS+AS+MN-WeM11 Single Molecule Structural Transitions of Water Polymer Chains in a Nanoscale Confined Space Studied by COIFM**, *B.I. Kim*, Boise State University

Interfacial water structures have been investigated in an ambient environment between two silica surfaces using a newly developed cantilever based optical interfacial force microscope (COIFM). As the gap distance decreases between the tip and the substrate, a remarkable oscillatory behavior is oberved in normal and friction forces. Our further analysis suggests that water molecules confined between tip and substrate in an ambient environment form a bundle of water chains through hydrogen bonding. Each chain length is analyzed by a model called "freely jointed chain" (FJC) model in which the individual segments can rotate freely. The bundle of water chains experiences multiple layering transitions (without single layer transition) from $l = 36$ diameters to $l=12$ diameters as the tip approaches the surface. The analysis shows that the number of links (l) decreases by 5,4,3,3,3,3,4,5 in water diameters. The result indicates that, as the gap between the tip and the substrate decreases, the interfacial water molecules favor multilayer transitions to stepwise, single layer transitions. The multilayer transitions consist of a sequential reduction of total chain length by integer number of water diameters. The loss of one water diameter in overall chain length represents a highly cooperative transition, whereas the loss of two additional water diameter along the sigmoidal shape is reminiscent of a well-known two state transition. As a model to describe these transitions, a kink is introduced in the chain by rotating one water molecule 90 degrees while maintaining the number of hydrogen bonds in the chain. The other remaining molecules still follow the freely jointed chain model.

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