Thursday Afternoon, November 5, 1998

Nanometer-scale Science and Technology Division
Room 321/322/323 - Session NS-ThA

Nanoscale Manipulation and Chemical Modification

Moderator: R.J. Hamers, University of Wisconsin, Madison

2:00pm **NS-ThA1 Nanomanipulation for Material Properties, Interactions and Devices**, ***R. Superfine,*** University of North Carolina, Chapel Hill **INVITED**

We have pursued the study of nanometer-scale materials, including colloids, viruses, DNA and nanotubes, through the use and development of an advanced interface for scanning probe microscopy (SPM). The ability to manipulate objects efficiently on surfaces makes available a wide variety of experiments on the interactions between the sample and substrate, on the physical properties of individual objects and on the creation of unusual devices incorporating the nanometer objects. For example, the simple pushing of an object with the AFM tip, with the measurement of the applied lateral force, measures the surface adhesion and friction. Dynamical phenomena such as stick/slip, sliding and rolling has been observed. Manipulation can be used to deform objects, and the response of the objects to large strain reveals phenomena such as buckling and fracture. Finally, manipulation allows us to begin the study of unusual device structures incorporating nanometer samples such as nanotubes. Making these experiments possible is the nanoManipulator, an interface for SPM's. The interface allows for real time control of the AFM tip while simultaneously recording topography, lateral forces, as well as device features such as conductivity. In addition, the data is rendered as 3-d, directionally illuminated surfaces providing immediate, intuitive interpretation of the SPM data.

2:40pm **NS-ThA3 Monitored Mechanical Nano-Manipulation**, ***B.E. Koel,*** *C. Baur, A. Bugacov, A. Madhukar, N. Montoya, T.R. Ramachandran, A.A.G. Requicha, R. Resch, P. Will,* University of Southern California

We have investigated the mechanical positioning of colloid particles deposited on a flat substrate. The positioning is achieved by pushing the particles with the tip of an Atomic Force Microscope (AFM). We gained fundamental insight into this manipulation process by monitoring the tip deflection and other signals during the pushing event. We also developed a procedure that allows the operator to compensate for instrument errors such as creep, hysteresis and thermal drift, especially important for operation in ambient air and at room temperature. This has lead to manipulation with high spatial certainty and increased the reliability considerably. We demonstrate precise positioning of arrays of colloidal particles and building and manipulating 3-D and linked 2-D structures of nanoparticles. It is possible to adapt this generic type of manipulation to a variety of environments and materials promising a high potential for fabrication of nano-scale devices such as those required in applications ranging from high-density data storage to single-electron electronics and nanoelectromechanical systems (NEMS) prototyping and fabrication.

3:00pm **NS-ThA4 Field-Induced Manipulation of Ag Clusters for Tailoring of Nano-Structures on Silicon Surface**, ***K.-H. Park,*** *J.S. Ha, W.S. Yun, E.-H. Lee,* ETRI, Republic of Korea

A precise nano-fabrication method was devised by using field-induced manipulation of Ag clusters with a tip of scanning tunneling microscope(STM). After deposition of Ag on Sb-terminated Si(100) surface, we were able to selectively desorb(redeposit) Ag clusters from(to) the surface by applying a voltage pulse. The manipulation of metal clusters was found to be precisely controlled due to the weak bonding strength between the clusters and an Sb-terminated Si(100) surface. We investigated those field-induced manipulation by varying bias voltage, pulse duration, and distance between tip and sample. Under suitable conditions for manipulation, we could fabricated various kinds of metallic nanostructures on the Sb-passivated silicon surface. Of interest, single electron charging and tunneling behaviors were observed in the local current-voltage (I-V) measurements on top of Ag clusters at room temperature. We have found that Coulomb staircases in tunneling spectroscopy at Ag nano-clusters sensitively depended on the distribution of surrounding clusters, indicating that the lateral conduction channel through neighboring Ag clusters was very important for the tunneling I-V characteristics. This result can be further utilized for the construction of single electron devices operating at room temperature by means of lateral conduction channels.

3:20pm **NS-ThA5 Probe Induced Manipulation of Bromine, Iodine, and Sulfur on Si (100)**, ***C.F. Herrmann,*** *J.J. Boland,* University of North Carolina, Chapel Hill

Scanning tunneling microscopy was used to study probe induced manipulation of the chemisorption sites of molecules on the Si (100) 2x1 surface. Specifically, the behaviors of bromine, iodine, and sulfur were studied. These adsorbates initially adsorb to the room temperature surface on adjacent dimers of the same row. Using the probe tip, one of the atoms can then be shifted to another dimer in this row, leaving one or more bare Si dimers in between them. This relocation occurs due to an increase in the field between the probe tip and the Si surface, which is induced by applying a voltage pulse to the probe tip. The separation efficiency as a function of probe tip voltage was measured for each adsorbate and it was found that each adsorbate exhibited a different threshold voltage. The diatomic molecules can also adsorb to the surface along a single dimer unit. A comparison study of the behaviors of the two different adsorption configurations was also conducted.

3:40pm **NS-ThA6 Two Mechanisms of Nanostructure Growth for STM Assisted CVD@footnote 1@**, ***I. Lyubinetsky,*** *S. Mezhenny,* University of Pittsburgh, U.S.*; J.T. Yates, Jr.,* University of Pittsburgh

A large Cu-containing organometallic molecule, [CuI (hfac) (vtms)],@footnote 2@ has been employed to produce nanostructures under the action of the STM tip on Si(111) exposed to the molecular flux in a UHV system at room temperature. The nanostructure growth mechanism, induced by dissociative electron attachment, exhibits an electron energy threshold of 4.5 eV. A second growth mechanism is related to an electric field-assisted activation process, which takes place in a narrow sample voltage bias range from +6 to +10 V. The topology of the deposited structure produced by the two mechanisms is strikingly different. Electron-induced growth leads to flat and broad structures which extend up to 100 nm laterally with an increase of electron energy to +15 eV. Field-induced growth leads to column-like structures with a HWHM down to 4 nm and a high aspect ratio up to 3. Comparative studies of the electron attachment mechanism have been carried out using a broad beam electron gun and x-ray photoelectron spectroscopy of the deposit on Si(111) to confirm the 4.5 eV energy threshold observed under the STM tip, and to measure elemental composition of the deposit. @FootnoteText@ @footnote 1@Work supported by the Office of Naval Research; @footnote 2@Hexafluoroacetylacetonate Cu (I) vinyltrimethylsilane, a CVD precursor for Cu deposition.

4:00pm **NS-ThA7 Nano Scale Selective Al Growth on the Si(001)-H Surface using Dimethylethyamine Hydride**, ***T. Mitsui,*** *E. Hill,* University of Minnesota, US*; E. Ganz,* University of Minnesota

I will discuss nano-scale selective growth of Al on a hydrogen patterned Si(001) surface. We have studied Al growth on the clean and mono-hydride terminated Si(001) surface over a range of temperatures using Dimethylethyamine Hydride (DMAH). We have found that Al growth occurs upon dosing the clean Si(001) surface heated above 150 °C but does not occur on a mono-hydride Si(001) surface up to 300 °C. Patterning a mono-hydride terminated Si(001) surface with the STM tip,@footnote 1@ we have created nano-scale regions of bare Si(001). Heating this surface to 200 °C and dosing with DMAH, we observe the selective growth of Al from DMAH on the clean silicon region. The mechanism for selectivity will be discussed. @FootnoteText@ @footnote 1@Lyding et al, Science. 268 (1995) 1590

4:20pm **NS-ThA8 Modifications of Thioaromatic Monolayers by Low Energy Electrons**, *W. Geyer, V. Stadler, W. Eck, M. Zharnikov,* ***A. Gölzhäuser,*** *M. Grunze,* Universität Heidelberg, Germany

Electron induced modifications of aromatic self-assembled monolayers (SAMs) were investigated by x-ray photoelectron (XPS) and near edge x-ray absorption fine structure (NEXAFS) spectroscopy. SAMs of 1,1'-biphenyl-4-thiol (BP), 4'-nitro-1,1'-biphenyl-4-thiol (NBP) and 4'-amino-1,1'-biphenyl-4-thiol (ABP) were prepared on (111) textured gold surfaces. The subsequent characterization indicated that the films were well ordered. The films were then irradiated with low energy electrons (20 - 300 eV) and changes were observed in situ. Biphenyl SAMs are generally more stable to low energy electrons than alkanethiols exposed under similar conditions. The functionalized biphenyls (NBP, ABP) showed distinct differences in the reactions of their end groups with the incident electrons. Mechanisms of interactions between the electrons and the SAMs as well as possible applications in the tailoring of surfaces for electron beam lithography will be discussed.

4:40pm **NS-ThA9 Selective Etching of the SiO@sub 2@/Si Surface with Low Energy Electron Stimulated Reaction by using STM**, ***N. Li***, *T. Yoshinobu, H. Iwasaki,* Osaka University, Japan

Nano-fabrication on the SiO@sub 2@/Si surface is such an important subject that it may relate directly to the silicon industry. It has been shown that with focused high energy (tens to a few hundreds keV) electron beam, such as employed in TEM or SEM, nanometer scale windows can be cut through the SiO@sub 2@ overlayer and nano-structures can be formed on the exposed Si surface in a subsequent growth.@footnote 1,2@ However, large scale applications of this technique has been prevented by the relatively low efficiency of the high energy e-beam in etching the SiO@sub 2@ layer, particularly compared to the cost to build and maintain such a high energy accelerating system. Here we report an experimental study on selective etching of the SiO@sub 2@/Si surface with a low energy electron stimulated surface reaction by using STM. The investigation was carried out on Si(001) surface either with a thin native oxide overlayer or with a thermal oxide overlayer prepared in the UHV chamber. By applying a voltage of ~70 to 150 V across the tip-surface vacuum gap in the STM setup, while the tip-surface separation was adjusted to ~100 to 200 nm, a field emission current of ~5 to several hundred nA can be obtained, with which the SiO@sub 2@/Si surface was irradiated. Subsequent STM imaging shows that within the exposed area, the SiO@sub 2@ overlayer can be effectively evacuated by a thermal annealing of the surface at a temperature of ~650 to 700 °C. This can be shown evidently in the STM images by the obvious contrast change and clear atomic steps appeared within the exposed areas. By adjusting the beam energy, beam current and tip-surface separation, windows down to tens of nanometers in diameter can be etched through the SiO@sub 2@ overlayer. This result demonstrates the possibility of fabricating the SiO@sub 2@/Si surface with a low energy electron stimulated surface etching, and also presents another possibility of conducting such a nano-fabrication in a well controlled way with the STM. @FootnoteText@ @footnote 1@D.R. Allee, C.P. Umbach, and A.N. Broers, J. Vac. Sci. Technol. B9, 2838, (1991) @footnote 2@S. Fujita, S. Maruno, H. Watanabe, and M. Ichikawa, J. Vac. Sci. Technol. A15, 1493, (1997)

5:00pm **NS-ThA10 Current-Induced Local Oxidation: Mechanism, Quantum-Size Effects, and Applications**, ***R. Martel***, *T. Schmidt, Ph. Avouris,* IBM T.J. Watson Research Center

A novel method is introduced for locally oxidizing thin metal films with nanometer-scale resolution. Simply by subjecting Ti and Nb films in air to local current densities of 10@super 7@ A/cm@super 2@, metal-oxide tunneling barriers of 10-50 nm width can be fabricated in a self-limiting fashion. The high spatial resolution of the process results from its strongly non-linear dependence on the current density. Our experiments suggest that the oxidation involves current-induced atomic rearrangements and local heating. At the final stages of the barrier formation, when only atomic-scale channels remain unoxidized, the oxidation rate decreases drastically while the conductance drops in steps of about 2e@super 2@/h. This behavior gives evidence of conductance quantization and a superior stability of such metallic nanowires against current-induced forces compared with the bulk metal. This current induced local oxidation (CILO) process can be used in nanofabrication. Single electron transistor structures exemplifying Coulomb staircases at room temperature were fabricated in this manner.

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