Friday Morning, October 6, 2000

Processing at the Nanoscale/NANO 6 Room 302 - Session NS+NANO6+MC-FrM

Nanoscale Spectroscopy

Moderator: L.J. Whitman, Naval Research Laboratory

8:20am NS+NANO6+MC-FrM1 Identification of Atom Species on Semiconductor Surface Using Noncontact AFM, Y. Sugawara, Osaka University, Japan INVITED

Recently, the noncontact atomic force microscope (AFM) using frequency modulation (FM) technique achieved true atomic resolution imaging. In order to apply the noncontact AFM as a powerful scientific tool for resolving the atomic features in variety of fields such as materials and biological sciences, it is very important to clarify the imaging mechanisms of the noncontact AFM. The imaging mechanism of the noncontact AFM was not establish clearly, however the investigation concerning the imaging mechanism has been making progress gradually on various surfaces. In this paper, we experimentally investigated the force interaction between silicon tip and Si(111)@sr@3x@sr@3-Ag surface by using the noncontact AFM. In case of reactive silicon tip, the AFM images showed the strong distance dependence dominated by the chemical-bonding interaction due to onset of the orbital hybridization very close to surface. On the other hand, in case of the adsorbed silver atom tip, the AFM images showed no distance dependence, and the individual silver atom on the top most layer of the surface could be resolved, corresponding to the true topography.@footnote 1@ This tip-sample force interaction seems to be dominated by physical bonding interaction such as the van der Waals force between the silver atom on the tip and the silver atom on the surface. These experimental results suggest that the noncontact AFM images drastically change depending on the atom species on the tip apex. It should be emphasized that there is a possibility to identify or recognize atom species on a sample surface using the noncontact AFM, if we can control an atomic species at the tip apex. @FootnoteText@@footnote 1@K.Yokoyama, T.Ochi, Y.Sugawara and S.Morita: Phys. Rev. Lett., 83 (24) 5023, 1999.

9:00am NS+NANO6+MC-FrM3 Dynamic Polarization Imaging using Heterodyned Electrostatic Forces, *D.R. Oliver*, *A. Pu*, *D.J. Thomson*, *G.E. Bridges*, University of Manitoba, Canada

Electric fields at the surface of dielectric materials will produce dipoles related to the polarizability of the material. In this paper we will present a technique that measures the polarization induced by a conducting probe near a surface. The images obtained are derived from the electrostatic forces between the probe and surface. In favourable geometries, the spatial resolution approaches the probe diameter. This measurement technique can be extended to frequencies well above the mechanical resonant fr equency of the probe cantilever by utilizing amplitude modulation heterodyning. Using heterodyning, both time- and frequency-domain forms of this technique can be realized. We expect this technique to be useable up to frequencies of at least 20 GHz and time resolution of 100 ps. We present calculations of the forces generated assuming simple probe geometries and also thermal noise. Experimental results presented compare favourably with these calculations.

9:20am NS+NANO6+MC-FrM4 Atomic Scale Chemical Identification on Si(111)@sr@3x@sr@3-Ag by Atom Probe-Scanning Tunneling Microscope, T. Shimizu, H. Tokumoto, JRCAT-NAIR, Japan

A scanning probe microscope (SPM) can determine atomic arrangement of various surfaces. It is, however, difficult to identify the chemical species of the atoms and molecules with the SPM. In order to know the atomic arrangement and its chemical species, there are several trials by combining the SPM with chemical analysis technique such as time-of-flight (TOF) mass spectroscopy and XPS. Spence has first demonstrated the possibility of TOF technique for chemical analysis. Then we have shown the usefulness of the TOF combined system in several cases. Furthermore a group in Delft Univ. has just tried to construct a TOF combined system. Nishikawa's group has already constructed a different kind of TOF. Here we shall present our challenge to atom-by-atom chemical analysis on solid surfaces by combining an Atom Probe of single atom sensitivity with the SPM ability of single atom manipulation (AP-STM). We have already demonstrated the following facts: (1) More than hundred Si atoms transferred from Si surfaces to a W-tip are detected; (2) The transferred Si atoms intermix with the tip material and form silicide; (3) Highly doped arsenic can segregate to the surface layers during annealing, form strange triangular step structure

on Si(001) and the ratio of Si to As can be quantitatively determined. In this study, we will demonstrate the single atom identification on Si(111)@sr@3x@sr@3-Ag, whose atomic structure is supported by the Honeycomb Chained Trimer (HCT) model. The model is as follows. The topmost layer is formed by Ag atoms with the HCT arrangement. Below the Ag HCT layer, there is a Si trimer layer. From this model, it is believed that STM bright spots with sample plus voltage correspond to neither Ag nor Si atoms on the surface, but to the center of the triangle formed by three Ag atoms. To confirm the model directly, we are trying to identify the atomic position of Ag by extracting atoms from the surface and detecting the chemical species of extracted atoms.

9:40am NS+NANO6+MC-FrM5 Tunneling Spectroscopy of Passivated Gold Nanocrystals, *R.B. Wyrwas*, *A.Y. Ogbazghi*, *T.P. Bigioni*, *L.E. Harrell*, Georgia Institute of Technology; *T.G. Schaaff*, Oak Ridge National Laboratory; *R.L. Whetten*, *P.N. First*, Georgia Institute of Technology

Scanning tunneling spectroscopy (STS) and microscopy (STM) have been used to study the electronic structure of small (< 2 nm diameter) alkanethiol-passivated gold nanocrystals. The nanocrystals were prepared via chemical methods, and their mass distribution was characterized by time-of-flight mass spectrometry. STM/STS measurements were done at room temperature, 77 K, and 8 K, with isolated nanocrystals immobilized on Au(111) surfaces by a xylenedithiol self-assembled monolayer (SAM). A histogram of nanocrystal heights measured by STM shows several peaks. These correlate well with distinct peaks in the mass spectrum. STS dl/dV spectra vary with nanocrystal size, and show prominent features due to their quantized density-of-states. Spectra acquired repeatedly over a single nanocrystal or its passivation layer.

10:00am NS+NANO6+MC-FrM6 Scanning Probe Microscopy Study of Engineered Ferroelectric Domain Structures, *G. Rosenman, A. Agronin, Y. Rosenwaks, M. Lesnih, P. Urenski,* Tel-Aviv University, Israel

Ferroelectric domain engineering has recently become an attractive and perspective tool for diverse nonlinear optical applications based on the quasi-phasematching method (QPM). The QPM occurs by the use of specifically tailored ferroelectric domain configurations with alternate direction of spontaneous polarization. Various types of engineered domain structures (periodic, aperiodic and quasi-periodic) allow an effective generation of coherent light in spectral regions where conventional lasers are not available. In this work we have studied engineered domain configurations (fabricated by electrical poling method in ferroelectric KTiOPO4 crystals) using different scanning probe techniques like: piezoresponse imaging, Kelvin probe force microscopy, and conventional topography imaging. The different AFM methods image the periodically poled domains and domain walls with high spatial resolution. A detailed electrostatic analysis of the data, and the contrast between ferroelectric domains with opposite polarity is presented.

10:20am NS+NANO6+MC-FrM7 Imaging of Single Molecules by Low Energy Electron Point Source Microscopy, A. Eisele, B. Völkel, Universität Heidelberg, Germany; S. Rehbein, Universität Göttingen, Germany; B. Jäger, Universität Heidelberg, Germany; H.J. Kreuzer, Dalhousie University, Canada; A. Gölzhäuser, M. Grunze, Universität Heidelberg, Germany

Low Energy Electron Point Source Microscopy (LEEPS)@footnote 1,2@ has been used for taking in-line holograms of single DNA strands and carbon nanotubes. These two molecules were chosen to elucidate the extend to which the hologram images are determined by structural and electronic properties of the sample. The holograms were analyzed by reconstruction via the Kirchhoff-Helmholtz integral transformation.@footnote 3@ The resulting image is suggested to represent the scattering centers of the molecule, i.e. yielding its atomic structure. However, various effects can impose a limit to the resolution: vibrations between tip and sample, electronic charge deposition on the sample, non-ideal electron coherence. distortion of the electrical field near the sample molecule. It is discussed to which extend such artefacts are visible in the experimental data and whether they constrain the applicability of the Kirchhoff-Helmholtz transform. A comparison between the transformed images of DNA strands and carbon nanotubes shows differences that can be explained by properties of the molecules. @FootnoteText@ @footnote 1@ H.-W. Fink, W. Stocker and H. Schmid, Phys. Rev. Lett. 65, 1204 (1990). @footnote 2@ A. Gölzhäuser, B. Völkel, B. Jäger, M. Zharnikov, H.J. Kreuzer, M. Grunze, J. Vac. Sci. Technol. A16(5), 3025 (1998). @footnote 3@ H. J. Kreuzer, K. Nakumura, A. Wiezbicki, H.-W. Fink, and H. Schmid, Ultramicroscopy 45, 381 (1992).

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10:40am NS+NANO6+MC-FrM8 Atomically-resolved Observation of Single Surface States and Trapped Electrons at Semiconductor Surfaces using Photovoltage Imaging with STM, S. Aloni, I. Nevo, G. Haase, Weizmann Institute, Israel

Atomically-resolved, super- and sub-band-gap photon surface photovoltage (SPV) imaging was used to study surface states and a trapped exciton at semiconductor surfaces. Super-band-gap radiation that flattens the electronic bands gives rise to SPV that reflects the local band bending in the dark. On the other hand, a sub-band-gap photon can excite a localized electron in a surface state into the conduction band, and produce an SPV that reflects the new charge distribution. By studying the effect of the tip on the local band bending, we can learn about the nature of a single localized surface state on an otherwise surface-state-free surface. It turns out that a single adsorbate or a single atom-size defect, can sometimes screen efficiently a strong external electric field. When a filled deep surface state, such as As-vacancy defect on the surface-state-free GaAs(110) surface, was excited by 1064 nm (sub-band-gap) illumination, a trapped electron state was imaged: It's induced SPV feature had a slight positive value at a radius of ~20 AA, and a negative portion 5-50 AA further away, as expected for a localized positive charge with a wide (bias-dependent radius of 25-70 AA) electron-density distribution around it. An observed six-point star shape of the SPV feature is explained by the contribution of the surface atoms to the potential well shape.

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