## Nanometer-scale Science and Technology Division
## Room 4C - Session NS-WeP
### Poster Session

**NS-WeP1 Tip Passive Chemical Modification and Its Effects on Tribological Measurements***, **X.D. Xiao**, L.M. Qian,* The Hong Kong University of Sci. & Tech., China

In this talk, we present our experimental results on the passive chemical modification process of the silicon nitride AFM tip by OTE/Mica, OTE/SiO@sub 2@, and SiO@sub 2@. The modified tips have different friction and adhesion properties against mica reference samples as compared to their pristine conditions. The resultant tip modification not only depends on the OTE SAM but also on the substrates the OTE SAM is prepared on. In the case of OTE/Mica, the friction of the modified tip against mica reference is much reduced; in the case of OTE/SiO@sub 2@, the friction of the modified tip against mica reference is much increased. It is surprising that bare SiO@sub 2@ can also chemical modify the Si@sub 3@N@sub 4@ tip to increase the friction against mica reference. In the case of OTE modification, it was found that the tips could be cleaned by repetitive friction scans on mica. However, tip modified by SiO@sub 2@ cannot be mechanical cleaned. Moreover, it was also found that humidity and load could also affect the tip chemical modification. Our results here is important for interpreting tribological data since the actual contact chemistry was often over-looked in the AFM experiments in the past.

**NS-WeP2 Velocity Dependent Friction***, **J.A. Heimberg**, K.J. Wahl, I.L. Singer,* Naval Research Laboratory*; A. Erdemir, G. Fenske,* Argonne National Laboratory

Low friction, low wear diamond-like carbon (DLC)@footnote 1@ films have been studied under dry N@sub 2@ and dry air using a reciprocating tribometer. It was found that as the velocity decreased from mm's/sec to 10's µm/sec the friction coefficient dropped over an order of magnitude. The friction behavior was dependent on environment and counterface material. Tracks and balls have been analyzed for wear using optical and Raman microscopy. Conditions leading to the lowest friction will be discussed. The friction behavior can be quantitatively described in terms of gas adsorption models. @FootnoteText@ @footnote 1@ Work partially supported by the U.S. Department of Energy under Contract W-31-109-Eng-38. .

**NS-WeP3 Gold Nano-wire Fabrication on Si(111) Using Piezoresistive Cantilevers***, **T. Uchihashi**, U. Ramsperger, H. Nejoh,* National Research Institute for Metals, Japan

Recent development of STM-based technology offers us unique opportunities to fabricate nano-scale structure in various ways in ultra-high vacuum (UHV). Although it is getting more and more established, measurement of electron conduction through nanostructures made in UHV has not been realized yet, except for scanning tunneling spectroscopy. Considering that there is a great demand for downsizing electronic circuit to nano-scale level, and that clean UHV condition is desirable to avoid surface contamination, such a measurement is highly demanded. Here, we present a novel but simple way of fabricating nano-scale metal wire on a clean substrate in UHV, which will enable us to realize such a measurement. As a gold-coated atomic force microscope (AFM) cantilever is brought into contact with a Si(111) sample surface, gold was transferred onto the sample surface, forming wires while the cantilever was moved laterally on the surface. Piezoresistive cantilevers (Piezolever,@footnote 1@ spring constant 2 - 10 N/m) were first coated with gold by thermal evaporation to a thickness of 50 to 60 nm. To fabricate gold wires on Si(111) surface, a gold-coated cantilever was brought into contact with sample surface and was moved laterally in a speed of 4 -32 nm/s. After this procedure, clear protruded line patterns were observed using STM. The minimum width of the lines was around 23 nm. In non-contact AFM mode, however, we found unusual line contrast change, according to the polarity of tip bias voltage. The probable reason for the line contrast change is charge transfer between silicon surface and gold. We also succeeded in connecting gold nano-wires to silver electrode pads, which was made by thermal evaporation in situ. The electrode pattern was defined by a through-hole mask, which was made of a titanium foil cut by focused ion beam. This demonstrates the possibility of measuring the properties of electron conduction through nanostructures made in UHV. @FootnoteText@ @footnote 1@ Courtesy of Park Scientific Instruments

**NS-WeP4 Dual-Wavelength Scanning Near-Field Optical Microscopy***, **P.R. LeBlanc**, M. Gu, P. Grutter,* McGill University, Canada*; D. Gray,* PAPRICAN, Canada

We have developed a dual-wavelength Scanning Near-Field Optical Microscope to investigate biological samples in air. Using a helium-cadmium laser, we couple 442 nm and 325 nm light into a tapered optical fiber. Light transmitted through the sample is detected in a confocal arrangement. A dichroic mirror separates the two optical channels which are then detected by photomultipliers. The fiber tip is shaped, by immersion into a buffered hydrofluoric acid solution, to an aperture of less than 100nm and then coated with aluminum, defining a true sub-wavelength light source. Once coated, the tip is glued onto one of the tines of a quartz tuning fork which is then oscillated either parallel or perpendicular to the sample surface a few nanometers away. We have found that the latter method (gently tapping the surface) yields a resolution of greater than 20 nm topographical and 50 nm optical. An optical and topographical standard was created by lift-off of a 100 nm aluminum film evaporated on a close-packed monolayer of 500 nm diameter polystyrene spheres. Our initial focus for this instrument has been centered on the investigation of the lignin distribution in Black Spruce fibers. Lignin, a cross-linked phenolic polymer, is of paramount importance in the pulp and paper-making processes. It is a primary component of the wood cell wall and absorbs preferentially in the ultraviolet (it is the only component of the cell to do so). The dual-wavelength capability of our instrument permits the discrimination between chemical species density and topographical variations of the sample as well as near-field optical artifacts.

**NS-WeP5 Influence of Secondary Tip Shape and Imaging Mode on Illumination Mode NSOM Images***, **S.J. Stranick**, C.E. Jordan, G.W. Bryant, R.R. Cavanagh, L.J. Richter,* National Institute of Standards and Technology

We report illumination-mode near-field optical microscopy images of individual 80-115 nm diameter Au particles with metal-coated fiber probes. It is found that the images are strongly influenced by the thickness of the metal coating. Theoretical models are presented which are in good agreement with the images. Wide probes with thick coatings (~lambda/2) produce images consisting of three extrema, due to a resonance-like polarization of the probe end. Narrow probes with thinner coatings produce wavy images, due to interference between the direct radiation from the tip and propagating tip fields scattered by the particles. Additionally, we have demonstrated a method for acquiring images that allows for the construction of three different imaging modes from one data set: constant-gap, constant-height, and constant-intensity. The method is based on the acquisition of topographic and optical data in a three-dimensional rather than a two-dimensional scanning format with controlled scans along the dimension normal to the surface. In this way, we acquire the topographic features of the sample surface as well as its optical response at various heights. This allows for the construction of constant-height and constant-gap images from the same data set and provides a means of identifying and correcting features that are a result of topographically induced optical contrast. Comparison between images recorded in this format to images 'lift-off' corrected by a single or small number of retraction curves indicates significant artifacts can still be present in corrected images.

**NS-WeP6 InGaAs Quantum Dots fabricated by Separated-Phase Enhanced Epitaxy with Droplets (SPEED)***, **T. Mano**, K. Watanabe, S. Tsukamoto, Y. Imanaka, T. Takamasu,* National Research Institute for Metals, Japan*; H. Fujioka,* University of Tokyo, Japan*; G. Kido,* National Research Institute for Metals, Japan*; M. Oshima,* University of Tokyo, Japan*; N. Koguchi,* National Research Institute for Metals, Japan

Highly uniform InGaAs quantum dots (QDs) were successfully grown by Separated-Phase Enhanced Epitaxy with Droplets (SPEED) method. The SPEED is a novel method for self-organizing growth with highly dense Ga droplets produced by Droplet Epitaxy.@footnote 1@ All samples were grown on GaAs (001) substrates by molecular beam epitaxy method. After the growth of a GaAs buffer layer, an As-stabilized c(4x4) surface was formed as an initial surfaces. On this surface, 1.75ML of Ga, 2.5ML of In, and 50ML of Ga were supplied at 200°C, in order to compensate the 1.75ML excess As on c(4x4), to form the InGa droplets, and to form the highly dense Ga droplets surrounding the InGa droplets, respectively. After the formation of these droplets, which were very uniform in size, As flux was supplied at 200°C for crystallization and the sample was annealed at 500°C. At that time, the highly dense Ga droplets prevented the 2-dimensinal growth of the InGaAs and the separated-phase effect of InGaAs-

GaAs was enhanced. Finally, a GaAs capping layer was grown. To confirm the effect of highly dense Ga, a reference sample was also fabricated with the same procedure except for the supply of 50ML Ga. In the case of the sample with the 50ML of Ga, not Stranski-Krastanov (S-K) mode but a flat surface is observed after the crystallization and annealing process. However, without 50ML of Ga, the S-K mode occurs. Although photoluminescence spectra of these samples are observed at same wavelength around 950 nm, the FWHM of the PL spectrum with 50ML Ga (22meV) is narrower than that of without 50ML Ga (100meV), and the intensity of PL spectrum with 50ML of Ga is thirty times stronger than that of without 50ML Ga. These results indicate that the uniform InGa droplets changed into the uniform InGaAs QDs embedded in GaAs. Therefore, the SPEED is very useful fabrication method for the high quality InGaAs QDs. @FootnoteText@ @footnote 1@ N. Koguchi and K. Ishige, Jpn. J. Appl. Phys. 32, 2057 (1993).

**NS-WeP7 Diamond Growth from a Reconstructed Diamond(100) Monohydride in a Non-uniform Electric Field***, **J.K. Kang**,* Stanford University

We will present the effect of an electric field on the growth from a reconstructed diamond(100) monohydride with mechyl radical of CH3 with a growth species, which was examined at the ab initio density functional cluster calculation of the B3LYP theory. First of all, activation energies of various reaction steps involving in this growth under a non-uniform electric field, which is calculated using the electron orbital energies and vibration frequencies of these various reaction steps via the ab initio cluster calculation on cluster models, C9H14 and C38H40, will be compared to activation energies without an electric field. Finally, we will address that the non-uniform electric field can drastically change the surface reaction pathway by modifying the electronic structures and vibration frequencies, which corresponds to the modification of activation energies of various reaction steps involving in this growth.

**NS-WeP8 Fabrication of a Nanosize Metal Aperture for NSOM Sensor using PR Removal and Sputtering Techniques***, M.Y. Jung, I.W. Lyo,* Yonsei University, Korea*; **S.S. Choi**,* Sun-Moon University, Korea

The scanning near-field optical microscopy(NSOM) can be used for imaging on a nanometer scale and identifying individual molecules with capability to surpass the resolution-limiting diffraction of conventional optical methods.@footnote 1@ In order to obtain better resolution limit, the diameter of the thin metal aperture has to be less than the optical wavelength. The fabricated nanosize Si tip using RIE have been thermally evaporated with a Au or Cr metal thin film. In order to have an aperture with diameter less than 100nm on top of the tip, several methods have been applied including sputtering and photoresist-stripping techniques.@footnote 2@ We have successfully fabricated the metal aperture with diameter less than ~0.3 nm on the silicon nitride tip. @FootnoteText@@footnote 1@ R.C. Davis, C.C. Williams and P. Neuzil, Appl. Phys. Lett. 66(1995) 2309. @footnote 2@M.Y. Jung, I.W. Lyo, S.S. Choi, MNE98, Sept.15-21, Leuven, Belgium. .

**NS-WeP9 Non-destructive 1-D SCM Dopant Profiling Determination Method and Its Application to the 3-D Dopant Profiling***, **E.-S. Kang**, J.-W. Kang, H.-J. Hwang,* Chung-Ang University, Korea

As the scaling of feature size in the GSI device technology is continuing, the device characterization and life cycle is greatly affected due to an unexpected doping profile which is caused by 3-dimensional effects in mask corners and edges. Therefore, the experimentally determined 3-D impurity doping profile is needed to estimate these 3-D effects precisely. In this work, we present a new 1-D doping profiling determination method, which extends to the quantitative 3-D dopant profiling extraction. This is the non-destructive technique and method, which is different from conventional AFM/SCM measurement/dopant extraction and we can measure directly at real MOSFET device having 3-D structure. Through SCM modeling, we found the depletion layer in silicon was of a form of spherical capacitor with SCM tip biased. 2-D FDM (Finite Differential Method) code with SOR (Successive Over Relaxation) solver was developed to model the measurements by a SCM of a semiconductor wafer that contains an ion-implanted impurity region. And we analyzed this capacitor theoretically and determined the depleted total volume charge (Q), capacitance (C) and the rate of capacitance change with bias (dC/dV). It is very important to observe the depleted carriers movement in the silicon layer by applying a bias to tip. So we calculated the depleted volume charge considering some factors such as tip size, oxide thickness and applied bias (dc + ac) which has effect on the potential and depletion charge. Finally, we developed 1-D inversion algorithm to convert SCM measurement output (dC/dV) into real dopant concentration, comparing SCM signal output with the calculated dC/dV through SCM modeling. We assume 1-D Pearson distribution function having several parameters as the initial profile. This profile extraction procedures consist of finding the profile that minimizes the least squares fit criterion between the calculated dC/dV and the measured dC/dV.

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