Nanometer-scale Science and Technology Division
Room Hall A - Session NS-ThP

Nanometer-Scale Science and Technology Division Poster Session

NS-ThP1 A Low Temperature STM System for the Study of Quantum Electronic Systems@footnote 1@, ***J.A. Stroscio***, *R.J. Celotta,* National Institute of Standards and Technology

We describe a new experimental system with the goal of providing new measurement capabilities for the study of quantum electronic systems. Several experimental challenges are posed in the study of electronic systems confined to nanoscale dimensions. The physical information desired in such systems includes: the quantized electron energy distributions arising from spatial or magnetic confinement, the spatial extent of electronic wavefunctions, the role of electron-electron interactions and electron interactions with the confining boundaries, the exact physical structure of the system, the shape of the confining potentials, and finally, the physics of the electron transport. To meet these measurement challenges, we have designed a scanning tunneling microscope (STM) that will operate in the temperature range from 2-150 K with the capability of applying magnetic fields up to 10 Tesla. Equally challenging to the measurement methodology is the fabrication of quantum electronic systems. The STM is part of a facility that includes separate MBE fabrication systems for III-V semiconductor growth and thin metal film growth with in-situ transfer of samples to the STM system. In addition to these traditional fabrication techniques we are developing an autonomous atom assembler to fabricate quantum structures atom-by-atom on a large scale. In this poster we will describe the design of the overall system, its components, and performance to date. @FootnoteText@ @footnote 1@ This work is supported in part by the Office of Naval Research.

NS-ThP2 Development of Low-Temperature Ultrahigh-Vacuum Atomic Force Microscope / Scanning Tunneling Microscope (LT-UHV-AFM/STM) Using Two-Stage Coil-Spring Suspension Isolator, ***N. Suehira***, *K. Sugiyama, Y. Sugawara, S. Morita,* Osaka University, Japan

Recently, true atomic resolution imaging of The Noncontact Atomic Force Microscope (NC-AFM) was demonstrated, and the NC-AFM is expected as powerful tool to investigate the surface structure including insulators and the force acting on the surface. In such measurements, low temperature (LT) is one of the best environment, because it can reduce thermal noise in the force signal measured by using AFM cantilever and thermal drift between tip and surface. However, there is a few report on NC-AFM operating under low temperature and ultrahigh vacuum (UHV) condition. Here, we describe a new LT-NC-AFM/STM design. The most serious problem in the LT Scanning Probe Microscope (SPM) design is the vibration which influences the resolution of the images and the sensitivity of the signals such as tunneling current and the force. This is due to that, in the conventional LT-SPM design, the SPM body is mechanically connected with the bottom of the helium dewar, and hence the sufficient isolation of the various vibrations such as the building vibration, the acoustic noise and bubbling of the liquid nitrogen is difficult. In our design, such problem of the vibration is solved by using two stage coil-spring suspension isolation system with eddy current damper. Using a special designed gear mechanism, the SPM body is connected with the bottom of the helium dewar during cooling down, then it is mechanically isolated from the bottom of the helium dewar and suspended by the springs during measurement. The inertial translational mechanism is used for cryogenic coarse approach between tip and surface, because its compactness, rigidity and reliability. In the AFM measurement, the cantilever is scanned by the tube scanner, and its deflection can be detected by the fiber-optic interferometer inside the tube scanner. In the STM measurement, the tunneling tip is scanned instead of the AFM cantilever. Preliminary LT-STM imaging was demonstrated on Si(111)7x7 surface with atomic resolution and the LT-AFM measurement is under way.

NS-ThP3 Characterization of Various SiO@sub2@ by Scanning Capacitance Microscopy, ***G.H. Buh***, *C.J. Kang,* Seoul National University, Korea*; K. Mang,* Samsung Electronics, Korea*; S. Lee, C.K. Kim, C. Im, Y. Kuk,* Seoul National University, Korea

Although electrical charge in SiO@sub2@ system can cause an adverse effect on the device performance, little is known about its spatially resolved characteristics. By using scanning capacitance microscopy (SCM), dynamics of spatially distributed trapped charge in a SiO@sub2@ film on Si can be imaged with spatial resolution of ~20nm, which is determined by tip diameter. As in the case of macroscopic capacitance-voltage (C-V), trapped charge results in VT shift. The VT shift can be measured from C-V curves at various positions with good spatial resolution. Experiments were carried out with various kinds of SiO@sub2@ processed by thermal oxidation (wet, dry), plasma enhanced chemical vapor deposition(PECVD), and atmospheric pressure chemical vapor deposition(APCVD). The VT measured on PECVD oxide was found to be lower than that of thermal oxide. This result indicates the existence of positive fixed charges in the PECVD oxide. On the contrary to the VT shift in a thermal oxide with induced traps, the shift was not observed even after 4MV/cm stress. It is believed the traps in PECVD oxide is nearly saturated.

NS-ThP4 Automated, High Precision Measurement of Critical Dimensions using the Atomic Force Microscope, ***D.A. Chernoff***, *D.L. Burkhead,* Advanced Surface Microscopy, Inc.

Atomic Force Microscopes are used in many industries for research, engineering and process control. Until now, AFM operators have usually made dimensional measurements of sub-micron features by manually placing cursors on images or cross-section plots. Time constraints and operator fatigue limit the number of measurements. This in turn limits the extent of statistical analysis. We have developed a high accuracy measurement process which overcomes these limitations. On DVDs (Digital Versatile Discs), the smallest features are about 400 nm long, 320 nm wide, 120 nm high, with a track pitch of 740 nm. We use a specific data capture protocol and automated image analysis to measure the following parameters: track pitch@footnote 1,2,3@, bump height, bump width (at various threshold levels), bump length, and four sidewall slope angles. In a single 10x10 micron image of a DVD stamper, containing about 100 bumps, we tabulate about 1000 values. It is useful to pool the data from several images. In a plot of bump width vs. bump length, we see that width at half height increases from 315 nm for the shortest bumps (420 nm long) to about 380 nm for bumps longer than 1100 nm; this matches the increase seen for corresponding optical signals produced when a finished disc is played. Where sidewall angle deviates from the norm, we are able to review the image data to identify the specific nature of the defect. @FootnoteText@ @footnote 1@D.A. Chernoff, "Nano-metrology for the data storage industry", abstract of paper presented at AVS National Meeting 10/97, p.113 @footnote 2@US Patent # 5,644,512 and other patents pending @footnote 3@see also www.a1.com/asm

NS-ThP5 Use of Phase Imaging Tapping Mode AFM to Spatially Resolve Areas of Different Doping Densities on Patterned Si Wafers, ***M.W. Nelson***, *P.G. Schroeder, R. Schlaf, B.A. Parkinson,* Colorado State University

The continuously shrinking dimensions of integrated circuits demand new methods for spatially resolved characterization of doping profiles in patterned semiconductor structures. Scanning probe microscopies offer the lateral resolution required to characterize structures down to atomic dimensions. Among these methods atomic force microscopy (AFM) has the advantage that the imaging process does not depend on the conductivity of the sample surface which offers easy characterization of oxidized samples in ambient conditions. In our experiments we demonstrate the use of tapping mode AFM (TMAFM) with additionally applied bias to spatially resolve areas of different doping densities and types on Si wafers. We observed changes in the phase contrast in regions of different doping densities as a function of the applied bias. Additional measurements on metallic substrates revealed that the cantilever phase and resonance frequency are strongly influenced by the bias induced Coulomb force between cantilever and sample. This allowed the discussion of the observed phase contrast variations in terms of semiconductor surface potential changes depending on the applied bias and the doping type of the various areas.

NS-ThP6 Metallic Adhesion at the Atomic Scale, ***A. Schirmeisen***, *G. Cross, P. Grütter,* McGill University, Canada*; U. Dürig,* IBM Research Division, Switzerland

A unique AFM / STM / FIM system operating in UHV has been shown to measure directly force interactions of an atomically defined tip-sample junction. A W(111) tip, terminated by only three atoms, approaching an atomically flat Au(111) surface showed structural stability even upon touching the surface. The measured force distance curves reveal adhesion peaks of 5 nN and a contact stiffness of about 40 N/m. Moreover, there are no indications of a jump to contact. The yield strength of the junction (maximum contact pressure divided by the tip radius) reaches values of up to 25 GPa. The observed metallic short range adhesion forces show

substantial contributions over an unexpectedly large distance range, which can not be explained within in the standard model for metallic adhesion by Ferrante and Smith.@footnote 1@ This study is being extended to different tip materials. First results of an Ir tip approaching a Au surface will be presented. Furthermore, to complement this study, MD simulations were performed at Tampere University by J. Nieminen. @FootnoteText@ @footnote 1@ J.H.Rose, J.R.Smith, J.Ferrante, Phys.Rev.B 28, 1835 (1983)

NS-ThP7 Tribological Properties of Crystalline Surfaces, ***A.J. Gellman***, *J.S. Ko,* Carnegie Mellon University

Atomic scale influences on the macroscopic tribological properties of surfaces have been explored through studies of friction between single crystalline metallic surfaces prepared and characterized under ultra-high vacuum conditions. Our experiment allows two single crystalline surfaces to be brought into contact under an applied load and then sheared at constant velocity while measuring friction forces developed at the interface. The presentation will describe observations made using Cu(111) surfaces that have been modified by adsorption of atomic and molecular species. These studies show quite clearly that in order to observe lubricating effects between Cu(111) surfaces it is necessary to adsorb at least one complete monolayer of adsorbed species. A second set of measurements have explored the frictional properties of single grain quasicrystals. Quasicrystals nominally possess low friction surfaces, however, all prior measurements have made use of surfaces contaminated by exposure to air. Under vacuum conditions the Al@sub 70@Pd@sub 21@Mn@sub 9@ quasicrystal surfaces have been cleaned prior to making friction measurements. While these yield coefficients of friction for perfectly clean surfaces that are significantly lower than those observed with clean metal surfaces they are much higher than those measured with quasicrystals in air. Controlled oxidation of the Al@sub 70@Pd@sub 21@Mn@sub 9@ quasicrystal surfaces has been shown to lower friction coefficients but not to the point observed in air. While surface contamination must be responsible, at least in part, for the low friction measurements reported in the past, oxidation alone cannot account fully for the properties of these surfaces.

NS-ThP8 Frictional Force Microscopy Study of Discrete Surface Functional Group Assembled by Langmuir-Blodgett Technique, ***M. Nakamura***, *A. Shimizu, Y. Nakayama, Y. Nagasawa,* Toray Research Center, Inc., Japan

Obtaining a flat surface which contains discrete functional groups with aimed density is doubtless valuable for nanometer science and technology. The functional groups can be used as nucleation sites for vacuum deposition or as adsorption sites for biomolecules. Furthermore, such a surface can be used as a test structure for scanning probe microscopy in terms of chemical identification. For this purpose, we have studied the Langmuir-Blodgett (LB) films formed with the mixture of stearic acid (SA) and stearyl mercaptan (SM) on atomically flat silicon substrates. The length of SM is approximately same as that of SA, but SM has a -SH group instead of a hydrophilic -COOH group. We therefore expect some part of the -SH groups in the bilayer film of the mixture to protrude from the surface. It was confirmed with atomic force microscopy (AFM) that flat and tight films were obtained with the mixtures which contain less than 10% of SM. Topographic and frictional force images showed that the surfaces contained number of protrusions exhibiting higher frictional force. The diameter of the higher friction spots was more than a few nanometer and varied with the AFM tip. Their density was nearly proportional to the concentration of SM. The distribution of the topographic height of these spots clearly exhibited two peaks around 1.6 and 2.6 Å, which can be explained by the models where the -SH shifts outward for one and two -(CH@sub 2@)- units of an alkyl chain. These results imply that the expected surface was successfully obtained. An interesting point is that the distribution of the maximum friction at these spots has only single peak in contrast to the height distribution.

NS-ThP9 Quantitave Surface Force Gradient Measurements Using Atomic Force Microscopy, ***L.A.W. Sanderson***, *M.A. George, J.J. Weimer,* University of Alabama, Huntsville

The accepted theory that reconciles attractive and repulsive forces has become known as the Deryaguin-Landau-Verwey-Overbeek (DLVO) theory and may be simply stated as V@sub S@ = V@sub C@ + V@sub A@ + V@sub R@ , where V@sub S@ is the total potential, V@sub C@ is the core repulsive potential due to Pauli exclusion, V@sub A@ is the Van der Waals attractive potential and V-@sub R@ is the double layer repulsive potential. The DLVO theory is widely regarded as a cornerstone for understanding colloidal systems and forces on the molecular scale. The objective of this study is to characterize the forces between two surfaces at the molecular scale using an atomic force microscope (AFM) and to relate the results quantitatively to parameters in DLVO theory. Investigations have been made using an AFM of surface forces present between a standard Si@sub 3@N@sub 4@ AFM tip and mica substrates for water, ethanol, and carbon tetrachloride. Results agree with those previously reported in the literature. Colloidal probes over mica and silica substrates are being used in on going research to provide easier geometries for comparison to the DLVO theory. Variations in surface forces as a function of pH and salt concentrations are being examined. The goal is to obtain a means of characterizing molecular scale forces over thin films such as aminopropyltriethoxysilane and polyethyleneglycol anchored to substrates. From a fundamental side, understanding of these forces is also important in analyzing the behavior of such molecules in solution, and the results can be used to select solutions for improving image resolution with the AFM.

NS-ThP10 The Durability of Optical Fiber Probe Tips for Surface Profilometry, ***J.E. Griffith***, *R. Raghunathan, L.E. Plew, J.B. Bindell,* Bell Laboratories, Lucent Technologies*; J. Carlson, A. Berghaus, J.J. Plombon, C.E. Bryson,* Surface/Interface, Inc.

The performance of a surface profiler strongly depends on the shape of the stylus or probe tip. Changes in the shape of the probe, caused by erosion or contamination during scanning, can be especially troublesome. The durability of the stylus depends on its shape, its composition, the composition of the sample, and the force sensor employed. We use cylindrical, silica glass probes etched from a specially chosen optical fiber. The glass probes are used in conjunction with a balance beam force sensor with sensitivity of approximately 10 nN. These probe tips have been used for extended periods on samples ranging from photoresist to silicon nitride with very little change in their shape from either erosion or contamination.

NS-ThP11 Force Measurement of Optical Evanescent Field using Kelvin-Null Method, ***K. Sawada***, *M. Abe, Y. Sugawara, Y. Andoh, S. Morita,* Osaka University, Japan

We have measured an optical evanescent field using a noncontact mode atomic force microscope (AFM) combined with a frequency modulation detection method.@footnote 1@ Using a semiconductor AFM tip, the surface photo voltage (@delta@@phi@) is induced by the optical evanescent field. It causes the electrostatic force acting on the tip. This force (F) can be expressed by F=(V-@phi@)(@delta@C/@delta@z)@delta@@phi@. Here, V, @phi@, C, and z are the bias voltage, the contact potential difference, the capacitance and the distance between the tip and the sample, respectively. In this method, the electrostatic force is affected not only by the potential change @delta@@phi@ due to the evanescent field but also by the contact potential difference @phi@ between tip and sample which is not uniform on the surface. In this paper, we propose a novel method to detect only the variation of the surface photo voltage due to the optical evanescent field without the influence of the contact potential difference. Applying Kelvin-Null method,@footnote 2@ bias voltage V is controlled so that V-@phi@ is kept constant. Simultaneously, the incident beam is modulated at a frequency w, and the w component of the force gradient is measured which is proportional to the optical evanescent field. @FootnoteText@ @footnote 1@M. Abe, Y. Sugawara, Y. Hara, K. Sawada and S. Morita, Jpn. J. Appl.Phys. Vol. 37 (1998) pp. L167-L169 @footnote 2@M. Nonnenmacher, M. P. O'Boyle and H. K. Wickramasinghe, Appl. Phys. Lett. Vol. 58, No. 25, (1991) pp. 2921-2923

NS-ThP12 Tunneling and Photon Emission of Colloidal Particles, ***G.S. McCarty***, *C.D. Keating, P.S. Weiss, M.J. Natan,* Pennsylvania State University

Binding of molecules of interest to colloidal particles allows the optical properties of the molecules to be studied using techniques such as surface enhanced Raman spectroscopy. By binding these colloidal particles to a conducting surface the electronic properties of the molecules can be probed using scanning tunneling microscopy. We have imaged gold and silver colloids bound to Au[111] coated with 2-mercaptoethylamine. The particles were then studied using photon emission scanning tunneling microscopy to probe the electronic and optical properties of single particles.

NS-ThP13 Temperature Dependence of the Raman Scattering Spectra in Zn/ZnO Nanoparticles, ***J. Xu***, National University of Singapore, Repubic of Singapore*; W. Ji, Z.X. Shen, S.-H. Tang,* National University of Singapore, Republic of Singapore

By using the gas evaporation technique with induction heating method, Zn nanoparticles coated with ZnO were prepared in Ar. The Raman spectra of

the Zn/ZnO nanoparticles have been studied over a wide range from room temperature through liquid nitrogen temperature and up to 873 K. Heating in air, we have, for the first time, successfully observed the transformations from the surface phonon mode to bulk vibrational mode in Zn/ZnO nanoparticles.

NS-ThP14 Electromagnetic Coupling Efficiency of a Metal Coated Optical Fiber Tip, ***L. Alvarez,*** CICESE, Mexico*; M. Xiao,* UNAM, Mexico

The optical coupling of a metal coated optical fiber tip is calculated by using the direct moment method. The purpose of the calculation is to study the transmission efficiency of the near field probe tips widely used in the scanning near field optical microscopy. In the scanning near field optical microscopy, the near field probe is often made of tapped optical fiber tip which is coated with a metallic thin layer to form a subwavelength aperture at the very end of the tip. It is of great importance to study the transmission efficiency of the tip as functions of the size of the aperture, the thickness of the metal coat as well as the shape and optical characters of the fiber tip. One wants to know that for a given incident light, how much light would effectively contribute to the final readout of the microscope. In the literature in near field optics, the tip transmission was studied with various two dimensional simulations and with microscopic discretional theories. In the present work, a general three dimensional electromagnetic theory is however proposed. As examples, numerical results of the coupled electromagnetic waves as functions of the aperture size, the coat thickness and the materials properties of the fiber tip are presented for the simplified case where the incident light is assumed to be a plane wave, and the results are discussed with regards to the imaging of the scanning near field optical microscope. Finally, it is pointed out that the proposed model calculation would be useful to provide guidances for the manufacture of the probe tip in the scanning near field optical microscopy.

NS-ThP15 Annealing Atmosphere and Electron Irradiation Effects on Gold Nanocrystals Buried in MgO, ***A. Ueda,*** *R. Mu, M.H. Wu, D.O. Henderson,* Fisk University*; R.M. Uribe,* Kent State University*; A.F. Hepp, E.M. Gordon,* NASA Lewis Research Center*; C.W. White, J. Budai, A. Meldrum, R.A. Zuhr,* Oak Ridge National Laboratory*; P. Wang,* University of Texas, El Paso

We have reported previously annealing effects on the surface plasmon (SP) of gold nanocrystals (NCs) formed by Au ion implantation in MgO. Annealing the samples after implantation promotes the diffusion of gold atoms, nucleation and growth of the NCs. The SP absorption for the Au/MgO system annealed in an oxidizing atmosphere (OA) is observed at ~560 nm, while annealing the same sample in a reducing atmosphere (RA) shifts the SP to ~524 nm. The process is entirely reversible. We propose that the SP shift originates from the creation of F@sub n@-centers when the samples are annealed in a RA, while they are annihilated in an OA. The F@sub n@ center acts as an e@super -@donor to the Au NCs that causes a blue shift of the SP. Subsequent annealing in an OA annihilates the F@sub n@ centers and the SP shifts back to 560 nm. TEM studies on Au NCs in MgO indicate the crystals are cubic and are aligned along the direction of the MgO lattice. Maxwell-Garnet effective medium theory was used to simulate the absorption spectra of the Au NCs formed in MgO under RA and OA. A good fit was obtained for sample annealed in an OA, but the fit for the annealed sample in a RA deviated from the experimental results. This is attributed to a change in the dielectric function of the Au NC that was caused by electron transfer from the F@sub n@ center. Electron beam irradiation of the Au/MgO samples was also investigated as an alternative method to study F@sub n@center creation and their interaction with the gold NCs. The optical spectra in the SP region are presented for the electron irradiated Au/MgO samples and are compared to those annealed in a reducing atmosphere.

NS-ThP18 The Shape Evolution of Patterned Submicron Structures under Thermal and Chemical Activation, ***K.C. Lin,*** University of Maryland, College Park, U.S.A*; D. Kohn, K. Thuermer, J.E. Reutt-Robey, E.D. Williams,* University of Maryland, College Park

Lithographic techniques developed extensively for microelectronics applications provide new opportunities to design experiments to explore the nanoscale realm, where traditional continuum based descriptions of morphology are likely to fail. In particular, the preparation of defined surface patterns with crystalline subfeatures, e.g. facets and steps, allows physically-based studies of mass transfer processes in response to the changes of physical and chemical environments. We utilize electron beam lithography and lift-off techniques to pattern submicron lines, squares and dots of noble metals on silicon oxide and silicon substrates, and use STM and AFM to characterize their structure and evolution. These structures are chosen to mimic the microelectronic device contact lines and model heterogeneous catalysts. We find, for example, the surfaces of submicron Au lines, as prepared, exhibit a uniform surface texture consisting of 3-D islands of ca. 50 nm size. Thermal activation for 20 hrs at 200 ° C breaks the lines into grains with ~0.2 μm size. Structures with initial size less than 0.2 μm are thermally stable and develop crystalline features. The sensitivity of these features to the carbonaceous impurities introduced during fabrication are currently being tested with the aid of an in situ plasma.@footnote 1@ @FootnoteText@ @footnote 1@work supported by UMD, NSF-MRSEC

NS-ThP19 Processing and Characterization of Nanometer Sized Copper Sulfide Particles, *S. Seal,* ***L. Bracho,*** *C. Urbanik, M. Hampton,* University of Central Florida*; J. Morgiel,* Polish Academy of Science, Poland

Nanomaterials, commonly characterized by their size smaller than 100 nm, have attracted a scant attention in the modern-day technology. These materials provide unique physical, mechanical and chemical properties in the nano-crystalline state. In this paper, sulfide nanoparticles of industrial interest are formed by sol-gel process using metal chloride precursors dissolved in a mixture of silica gel and organic cellulose network followed by a reaction with hydrogen sulfide gas. Particles are then heated in a vacuum oven. Variations in the sol-gel composition are used to study the particle growth rate and fractal density resulting from the reactivity of the large surface area nano particles. While scanning and transmission electron microscopy and x-ray diffraction are used to study their morphology and structure in the nanometer scale, x-ray photoelectron spectroscopy (XPS) is employed to understand the bonding chemistry and the stoichiometry of the sulfide particles. XPS results show a change in the binding energy of the sulfide particles with various temperature treatments. Secondary ion mass spectrometry is also used to show the distribution of precursor elements with depth, i.e. the chemical reactivity from surface to bulk. Nanometer sized gold particles are also produced using this method. The results from this study are expected to show promising applications and production of other oxides, sulfides and their compounds using this modified sol-gel synthesis.

NS-ThP20 Film Formation and the Onset of Multilayer Growth in Chloromethylphenylsilane Films as Determined by Atomic Force Microscopy, ***W.J. Dressick,*** Naval Research Laboratory*; J.M. Calvert,* Shipley Co.*; M.-S. Chen, S.L. Brandow,* Naval Research Laboratory

Organosilane films containing benzyl chloride functional groups are of interest for use as imaging layers in high resolution lithography due to the extreme sensitivity of the carbon-chlorine bond to cleavage by either photon or electron radiation. For applications where feature sizes are on the nanometer scale it is important to have an understanding of the surface coverage and intermolecular order of these films. We have developed protocols for the reproducible deposition of two organosilanes, p-chloromethylphenyltrichlorosilane (CMPTS) and 1-(dimethylchlorosilyl)-2-(p,m-chloromethylphenyl)ethane (CMPEMS), on native oxide silicon and fused silica substrates. Film growth was characterized using several techniques including UV absorbance, ellipsometry, and contact angle measurements. Atomic force microscopy was found to be a powerful tool for monitoring the onset of oligomer formation in the CMPTS films, ultimately allowing the macroscopic properties of the films to be correlated with their nanometer scale morphologies. Results indicate that film growth which is limited to direct chemisorption at the surface results in low coverage, disordered films. In the CMPTS system multilayer growth was found to be a predominant pathway even at sub-monolayer coverages. The significance of these observations on the design of imaging layers capable of molecular scale resolution in nanolithographic applications is discussed.

NS-ThP21 Room Temperature Fabrication of Transparent ZrO@sub 2@/Polymer Nanocomposite Thin-Films with Controlled Thickness by the Ionic Self-Assembled Monolayer (ISAM) Method, ***A. Rosidian,*** *Y. Liu, R. Claus,* Virginia Polytechnic Institute and State University

Nanocomposites of transparent multilayer structures of ZrO@sub 2@/polymer thin-films have been fabricated on silicon and quartz substrates utilizing the Ionic Self-Assembled Monolayer (ISAM) method. This method is based on the alternating adsorption of anionic and cationic polyelectrolytes in the aqueous forms. The deposition process was monitored by UV/Vis spectroscopy and ellipsometry. A linear behavior of both optical absorption and film thickness as the number of bilayers increases was observed, which indicated the formation of homogeneous and uniform thin-films on both substrates. The study also showed the control of film thickness by changing the ZrO@sub 2@ concentrations. It was observed that the thickness of each bilayer of the thin-films increased with the ZrO@sub 2@ concentration. For the films with ZrO@sub 2@

concentrations of 10 and 30 mg/ml, the thickness of each adsorbed bilayer were 18 and 24 Ångstroms, respectively.

NS-ThP22 Nanowire Formation Using a Resistively-Heated Piezoresistive Cantilever, ***T. Uchihashi***, *U. Ramsperger, H. Nejoh,* National Research Institute for Metals, Japan

The main aim of our research is to fabricate atomically thin metal wires on a clean sample surface in UHV, and to investigate the electronic transport properties of such systems. For that system, it is expected that new phenomena, e.g., single electron tunneling effect, quantization of conductance, will be observed, and that relation between a structure of the wire and transport properties will be clarified. The procedures required to reach this aim would be as follows. 1) Evaporate a defined electrode pattern on a clean sample using a through-hole mask in UHV. This pattern has macroscopic electrodes, on which the four-point-probe leads is pressed, and microscopic electrodes for which a gap distance is a few micrometers. 2) Draw atomically thin metal wires in the gap between the electrodes in UHV using a scanning tunneling microscope (STM) or an atomic force microscope (AFM). 3) Measure electronic transport properties of the wire in UHV, and at low temperatures if necessary. We succeeded in fabricating a through-hole mask using a discharge cutter machine and focused ion beam (FIB) machining. The discharge cutter machine is used for building the macroscopic pattern, and FIB for the microscopic structure of the through hole mask. Further we also succeeded in drawing thin gold wires with a width of a few tens of nanometer using an AFM cantilever. A piezoresistive cantilever (provided by Park Scientific Instruments) was first coated with gold by thermal evaporation. This cantilever can be heated up resistively with a power of about 30 mW by current running through it.@footnote 1@ The gold on the cantilever tip was transferred onto the surface of both a silicon and sapphire substrate. The minimum width of gold wires fabricated thus far is around 50nm. The fabrication method using a heated AFM cantilever can be applied not only to a conductive sample but also to a insulating sample like sapphire. This fact will eliminate the difficulty in measuring conductivity of ! ! ! nano-scale wire, especially at room temperature. @FootnoteText@ @footnote 1@ H. J. Mamin, Appl. Phys. Lett. 69, 433 (1996)

NS-ThP23 Adsorbate Effect on Conductance Quantization in Metallic Nanowires, ***C.Z. Li***, *H. Sha, M. Adam, N.J. Tao,* Florida International University

We have studied conductance quantization in metallic nanowires upon adsorption of molecules with different adsorption strengths. The conductance still changes in a stepwise fashion even in the presence of strong adsorption, and the average sharpness, length and number of the conductance steps remain unchanged. However, the step positions deviate significantly from the integer values of the conductance quantum, 2e2/h. While the deviation may be attributed to the scattering of the ballistic electrons by the adsorbates, evidence shows that the adsorbates also affect the conductance by changing the atomic configurations of the nanowires. @FootnoteText@ Financial support is acknowledged through grants from AFSOR (F49620-96-1-0346) and NIH (GM-08205).

NS-ThP24 Substrate Effects on Electronic Properties of Atomic Chains, ***T. Yamada***, MRJ, NASA Ames Research Center

Atomic chains, precise structures of adatoms created on an atomically regulated surface, are candidates for constituent elements in future electronics. It was predicted that Si chains were metallic and Mg chains were semiconducting, and a doping method was also discussed.@foot 1@ The substrate was assumed to work as a noninteracting template holding the adatoms. However, this scheme requires a low-temperature environment so that the adatoms will not displace from their ideal positions due to unwanted thermal agitation. For better structural stability, we may seek a scheme to allow the adatoms to form chemical bonding with the substrate atoms and secure their positions. The chemical bonding has two major effects on the chain electronic properties. First, only the remaining s and p orbitals in an adatom not used for the chemical bonding can decide chain band structures, rather than the full set of orbitals previously assumed.@foot 1@ Second, because of a possible HOMO energy difference between adatom and substrate atom, semiconducting chains are unintentionally doped. These effects are studied with a selfconsistent tight-binding method with universal parameters. With one adatom per unit cell, adatom chains are semiconducting (1) if adatoms are of group III and form one chemical bond per adatom, or (2) if adatoms are of group IV and form two chemical bonds. The previous result@foot 1@ of realizing semiconducting chains by group II adatoms without chemical bonds is consistent with this picture. When the HOMO energy in an adatom is shallower than that in a substrate atom, the entire chain is positively polarized, unintentionally achieving p-type doping. When deeper, the chain is negatively charged, achieving n-type doping. Specific examples will be discussed. @FootnoteText@ @footnote 1@T. Yamada, Y. Yamamoto, and W. A. Harrison, J. Vac. Sci. Technol. B 14, 1243 (1996); T. Yamada, to appear in J. Vac. Sci. Technol. A 16 (1998).

NS-ThP25 Designing New Materials at the Molecular Scale - An Example in Etching and Deposition, *J.A. Gurney,* McGill University, Canada; ***E.A. Rietman***, Bell Laboratories, Lucent Technologies; *M.A. Marcus,* KLA Instruments; *M.P. Andrews,* McGill University, Canada

We desire the ability to design molecular-scale components and new materials using a heuristic programming technique such as genetic algorithms. To this end we have been investigating the possibility of designing new materials in the space of cellular automata. Molecules interact, more or less, only with their nearest neighbors. This suggests that cellular automata (arrays of nearest neighbor interacting finite state machines) may be used for modeling the dynamics of molecules. Since it is well known that structures can be "grown" in the space of the cellular automata (CA) we conjecture that by manipulation of the rule table or rule vector describing the CA dynamics we can evolve desired structures in the CA space. To support this supposition we present work on modeling the etching and deposition (dissolution and growth) of crystals. We empirically find a mapping between the automaton rule table and the surface physics of the crystal. @FootnoteText@ @footnote 1@ J.A. Gurney, E.A. Rietman, M.A. Marcus, and M.P. Andrews, "Mapping the Rule Table of a 2-D Probabilistic Cellular Automaton to the Chemical Physics of Etching and Deposition", Submitted, 1998

NS-ThP26 Spectroscopic Studies of Carbon Nanotube by Ballistic Electron Projection Microscopy, ***J.-Y. Park***, *S.-H. Kim, Y.D. Suh, W.-G. Park, Y. Kuk,* Seoul National University, Korea

Geometric and electronic properties of carbon nanotubes have been studied by ballistic electron projection microscopy(BEPM). An interference pattern between the scattered and transmitted e-beam was observed using coherent electron source from an atomically sharp emitter.@footnote 1@ In this work, a microcolumn in an SAFE(STM Aligned Field Emission) microcolumn system was replaced by carbon nanotubes or self-sustaining single crystal films on TEM grid.@footnote 2@ From images of single-walled carbon nanotubes, the performances of BEPM were tested. By adding an electrostatic energy analyzer, the electron energy loss of the nanotubes was measured. When the tip is positioned at < 2 nm, the tunneling I-V could be measured using BEPM. In addition to the nanotube, the results of free-standing single crystal metal and semiconductor will be presented. It was found that the Fourier transformation of inelastic scattering pattern gives information on scattering in the sample. @FootnoteText@ @footnote 1@H. -W. Fink, W. Stocker, H. Schmid, Phys. Rev. Lett. 65, 1204(1990). @footnote 2@J. -Y. Park et al., J. Vac. Sci. Technol. A 15, 1499(1997).

NS-ThP27 Synchrotron-Radiation-Induced Deposition of Nanocrystalline Particles, ***R.A. Rosenberg***, *Q. Ma, B. Lai, D.C. Mancini,* Argonne National Laboratory

The high-intensity, high-energy x-rays produced by third-generation synchrotron radiation sources have made possible many new applications, such as deep x-ray lithography, that take advantage of the long penetration lengths of the x-rays in lower-Z materials. Recently, we have initiated a program to evaluate the prospects for using x-rays for materials processing by performing Surface Photochemistry Induced by X-ray Irradiation (SPIXI). X-rays have significant advantages over more conventional sources. The high energy x-rays produced by the Advanced Photon Source have deep penetration lengths for low-Z materials. Therefore, they can be used to induce chemical reactions on surfaces of solids immersed in liquids containing low-Z molecules. The most likely mechanism by which these reactions proceed is through the production of electrons caused by core-level excitation of the substrate atoms. Therefore, the reaction rate should be both energy dependent and site specific. If the liquid contains a metal salt, then x-ray irradiation should induce deposition of metallic films or particles that can be in either polycrystalline or nanocrystalline forms. We present preliminary results which demonstrate the feasibility of the SPIXI approach for deposition of nanocrystalline particles. In particular we have deposited both gold and silver nanoparticles in liquids containing salts of the appropriate ion. In addition thin films have been formed on Mo substrates. In this paper we discuss the experiments, their results and prospects for future development. The submitted manuscript has been created by the University of Chicago as Operator of Argonne National

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