Nanometer-scale Science and Technology Division
Room 321/322/323 - Session NS+AS-FrM

Innovative Nanoscale Measurements

Moderator: S. Semancik, National Institute of Standards and Technology

8:20am **NS+AS-FrM1 Nanoscale Variations in Surface Potentials at Interfaces***, **B.D. Huey**, D.A. Bonnell,* University of Pennsylvania, US

Nanoscale variations in the electronic properties of individual oxide grain boundaries have been directly measured. In-situ application of atomic force microscopy used as a Kelvin probe maps local field variations in the presence of lateral applied bias and current flow within an oxide grain boundary device, providing measurements while the device is in operation. The in-situ experiment involves: 1) applying a lateral bias across microfabricated contacts on varistor and SrTiO@sub 3@ bicrystals, and 2) simultaneously mapping the surface potential in the vicinity of grain boundaries. Voltage dependent properties of both multiple boundaries as well as carefully characterized individual interfaces are thus measured. The non-linear voltage dependence of potential barriers at the grain boundaries is additionally obtained at the nanoscale as a function of local orientation, chemical content, and position.

8:40am **NS+AS-FrM2 Noncontact Measurement of Electrical Dissipation using Ultrasensitive Cantilevers***, **T.D. Stowe***, Stanford University*; D. Rugar,* IBM Almaden Research Center*; D.J. Thomson,* University of Manitoba, Canada*; T.W. Kenny,* Stanford University

We have used ultralow loss 0.17 µmm thick silicon cantilevers to measure electrical dissipation in insulators and doped silicon samples using a technique similar to the one originally developed by Denk and Pohl.@footnote 1@ Images were taken by recording the mechanical Q of a self-oscillating cantilever as it was scanned 10-100 nm above the sample surface in a perpendicular orientation. All experiments were performed at room temperature in vacuum with cantilevers having 10@super -4@-10@super-3@ N/m spring constants and 10-100 kHz resonant frequencies. Electrical dissipation was measured as function of applied voltage, tip-sample distance, and resistivity. We were able to measure electrical dissipation as small as 10@super -14@ N-s/m and ohmic losses as small as 10@super -18@ Watts. Using tips with 50 nm radii, we were able to simultaneously image permanent charge in the surface oxide and doping levels between 10@super 15@-10@super 19@ /cm@super 3@ in silicon with 200 nm spatial resolution. Possibilities for improving the spatial resolution and doping sensitivity of this technique will be discussed. @FootnoteText@ @footnote 1@W. Denk and D. W. Pohl, Appl. Phys. Lett. 59, 2171 (1991).

9:00am **NS+AS-FrM3 Nanocalorimetry for Thermodynamic Measurements of Nanostructures***, **L.H. Allen**,* University of Illinois, Urbana-Champaign **INVITED**

This talk will focus on a novel calorimetry technique@footnote 1,2,3@ for measuring the thermodynamic properties of nanometer size material. The thermodynamic properties of material having small nanometer dimensions can be considerably different as compared to material in bulk form (e.g., the reduction of melting point). This occurs because of the tremendous influence of the surface energy. Conventional differential scanning calorimetry (DSC) techniques are extremely difficult to apply to the study of small structures because the total amount of heat generated during the transformation is too small as compared with the background heat capacity of the calorimeter. The new nanocalorimeter is fabricated using standard MEMS thin film techniques and it has the capability of measuring the dynamics of the energy exchange at the level of 0.2 nanojoule. This technique is so sensitive that it can easily measure the melting process of 1 Angstrom of Sn, which has been deposited on a Si-N surface. Results of specific materials studies will be discussed including the size-dependent melting point depression of small particles of Sn and Al and preliminary work on the coalescence of small clusters. @FootnoteText@ @footnote 1@S.L. Lai, J.Y. Guo, V. Petrova, G. Ramanath and L.H. Allen, "Size-Dependent Melting Properties of Small Tin Particles: Nanocalorimetric Measurements", Phys. Rev. Lett. 77, 99-103 (1996) @footnote 2@S.-L. Lai, P. Infante and L. H. Allen, "Heat capacity of Sn nanostructures via Thin Film Differential Scanning Calorimetry," Appl. Phys. Lett., 70, 43-46(1997). @footnote 3@S. L. Lai, J. Carlsson and L. H. Allen, "Melting Point Depression of Al Clusters Generated During the Early Stages of Film Growth: Nanocalorimetry Measurements," Appl. Phys. Lett., Appl. Phys. Lett. 72, 1098 (1998)

9:40am **NS+AS-FrM5 Recent Advances in Scanning Capacitance Microscopy***, **C.C. Williams**, J.S. McMurray, V.V. Zavyalov, J. Kim,* University of Utah **INVITED**

Scanning Capacitance Microscopy is a rapidly developing technique for the characterization of the electronic properties of semiconductor materials on a 10 nanometer scale. Oxide, semiconductor interface and near surface "bulk" properties can be studied by this technique. Recently, new capabilities have been developed to extract quantitative dopant/carrier profiles near electrical junctions in cross-sectioned devices. Built-in internal electric fields have been measured and compared with electrical models. Random distributions of nanometer scale "defects" have been observed at the surface of uniformly doped and oxidized silicon samples. Two-dimensional diffusion of dopant impurities has been measured by SCM and directly compared with predictions of TSUPREM4. These new developments and capabilities of the Scanning Capacitance Microscope will be described and presented.

10:20am **NS+AS-FrM7 Nanometer-scale Electrical Characterization of Semiconductor with a Scanning Capacitance Microscope***, **H. Tomiye**, Y. Takafumi,* Tohoku University, Japan

Recently, nanometer-scale material characterization has become a necessity in Si technology. The scanning probe microscope is one of the most powerful characterization techniques at this scale. A variety of information can be obtained by this technique which is of importance in the assessment of material and device aspects of silicon. Scanning capacitance microscope (SCaM) can clearly show local variation of capacitance, which reflects the electrical properties of a Si substrate, SiO@sub 2@/Si interface and SiO@sub 2@ layer. We have developed a SCaM/AFM consisting of a W wire cantilever and a capacitance sensor. The unique features of our microscope are as follows: (1) Our SCaM can directly detect a sample capacitance with / without using lock-in amplifier. It means we can measure capacitance (C) of the sample in addition to the capacitance derivative (dC/dV). (2) We can simultaneously obtain a SCaM image and C-V characteristics. It means we can achieve quantitative measurements of the capacitance at a nanometer-scale. (3) The spatial resolution for the capacitance measurements is estimated to be less than 20 nm. It is demonstrated that the local impurity concentration profiling of lateral p-n junction is achieved by the C-V measurements. We have injected electrical charge into a SiO2 layer and investigated the nature of charge storage at the SiO@sub 2@/Si system by the SCaM and C-V characterization. A shift of the flat-band voltage due to the trapped charges is observed, which enables one to estimate the density of trapped charge. This paper will report on the development of a SCaM and its applications to the characterization of SiO@sub 2@/Si and fabrication of a charge storage device.

10:40am **NS+AS-FrM8 A Study on the Post-stress Charges in SiO@sub2@ Films on Si by Scanning Capacitance Microscope***, **K. Mang**,* Samsung Electronics, Korea*; C.J. Kang, G.H. Buh, C.K. Kim, S. Lee, C. Im, Y. Kuk,* Seoul National University, Korea

Using scanning capacitance microscope, The induced traps on SiO@sub2@ were imaged with @<=@20nm spatial resolution. The static and dynamic behaviors of the electronic charges were evaluated. After a voltage stress, an anomalous post-stress charge generation and relaxation effect were found. Depending on the polarity of stress voltage, post-stress tip voltage and stressed time, different relaxation trend exists at the stressed area. The induced charge density in the stressed SiO@sub2@ film was higher with the stressed time The trap dynamics is also a function of initial stress field. With the high field applied to the SiO@sub2@ film, the larger and faster generation(or relaxtion) was observed. After the trapped charges are formed, the amount and polarity of the charge vary dynamically. It is believed that thermal excitation or tunneling of one or two electrons, can cause the turn around effect, which has been poorly understood so far.

11:00am **NS+AS-FrM9 Imaging Buried Interfacial Lattices with Quantized Electrons***, **I.B. Altfeder**, D.M. Chen,* The Rowland Institute for Science

We demonstrate that interfacial lattices buried under as much as 100 Å of a metal can be directly imaged by low temperature scanning tunneling microscopy with an unexpectedly high lateral resolution.@footnote 1@ To achive such a remarkable resolving power we expolite the presence of the quantum-size sigularities in the electron energy spectrum in the metal as well as its high sensitivity to the defects at the boundaries. Our theoretical model shows that this unique phenomena can be atrributed to the nondifractive scattering of the quantized electron waves at the interface as a result of their highly anisotropic motions in a two dimensional nano-structure. @FootnoteText@ @footnote 1@I. B. Altfeder, D. M. Chen, K. A.

Matveev, Phys. Rev. Lett. (in press). @footnote 2@I. B. Altfeder, K. A. Matveev, D. M. Chen, Phys. Rev. Lett. 78, 2815 (1997).

11:20am **NS+AS-FrM10 Nanoparticle Near-Field Spectroscopy by a Microscopically Narrow (Subnanometer) Electron-Beam***, H. Cohen,*

Weizmann Institute of Science, Israel*; T. Maniv,* Technion, Israel*; Y. Rosenfeld Hacohen, R. Tenne,* Weizmann Institute of Science, Israel*; O. Stephan, C. Colliex,* University of Paris-Sud, France

Single nanoparticle near-field spectroscopy is performed in a scanning transmission electron microscope at non-intersecting beam-particle configuration. Separating the surface collective modes from the entire excitations spectrum, the energy loss signal is quantitatively accounted for, using a relatively simple theoretical model. Advantaged by the sub nanometer size of the e-probe, the highly controlled beam-surface distance introduces an effective window in momentum space, exposed to a long wavelength relativistic dispersion, which provides an enhanced sensitivity to beam and particle size effects. The spatial dispersion of the particle dielectric function, associated with the electronic band structure, is practically filtered out. "Particle spectroscopy", namely the selective excitation of modes which characterize the particle geometry and size, is available at selected beam-particle distances.

Author Index

Bold page numbers indicate presenter