Nanometer-scale Science and Technology Division
Room 612 - Session NS-TuA

Innovative Nanoscale Measurements

Moderator: E.T. Yu, University of California, San Diego

2:00pm **NS-TuA1 Size, Shape, Strain, and Composition Inhomogeneities of In@sub 0.5@Ga@sub 0.5@As QDs Grown by Migration Enhanced Epitaxy**, ***N. Liu***, *C.K. Shih, O. Baklenov, A.L. Holmes, Jr.,* The University of Texas at Austin

We report cross-sectional scanning tunneling microscopy (XSTM) studies of In@sub 0.5@Ga@sub 0.5@As self-assembled quantum dots (SAQD) grown using migration enhanced epitaxy (MEE). Samples were cleaved in-situ to reveal either (110) or (1-10) cross-sectional surfaces. For the 10 ML QDs, they exhibit truncated-pyramid shapes with well-defined facets on both (110) and (1-10) projections. On the (110) surface, the orientation of the facets is about 35 degrees with respect to the base of the QDs, and on the (1-10) surfaces about 25 degrees with respect to the base. The average height of the 10 ML QDs is about 10 nm, while the average base length is about 45 nm along the (110) projection and about 61 nm along the (1-10) projection. We further discovered that the In-concentration in this kind of truncated-pyramid shaped QDs is inhomogeneous. In fact the qualitative concentration contours at high concentration show an inverted triangle shape. Similarly the distribution of the lattice parameters (as determined from the STM) within and around the QD is also inhomogeneous with its inhomogeneity consistent with an inverted triangle shape of high In-concentration in the QD. Detailed analysis and possible mechanism responsible for such a concentration distribution profile will be discussed.

2:20pm **NS-TuA2 Cross-Sectional Scanning Tunneling Microscopy as a Probe of Atomic-Scale Order in MOVPE Grown GaInP@footnote 1@**, ***J. Steinshnider***, *M. Weimer,* Texas A&M University*; M. Hanna,* National Renewable Energy Laboratory

III@sub a@-III@sub b@-V alloys grown by metal-organic vapor phase epitaxy (MOVPE) exhibit varying degrees of CuPt-B order in which III@sub a@ and III@sub b@ atoms preferentially enrich alternating -B planes during growth to form a monolayer superlattice. We have used cross-sectional scanning tunneling microscopy (STM) to examine and characterize spontaneous ordering in MOVPE-grown GaInP films lattice-matched to GaAs. We show how cross-sectional STM permits the direct, real-space visualization of CuPt order based on III@sub a@-III@sub b@ site discrimination, and indicate how the degree of local order in selected regions of a sample may be quantitatively assessed through the In-In pair correlation function constructed from atomic-resolution data. We introduce a local order parameter, based on the pair correlation function, that is identified with the Bragg-Williams parameter in the case of long range order and which allows a direct comparison of the STM results with optical or x-ray measurements. We have examined the spatial evolution of the local order parameter in the vicinity of the alloy / buffer interface, where the STM images show evidence for atomically-abrupt antiphase boundaries, and find that the onset of recognizable group-III sublattice order requires approximately twenty monolayers. The ability of cross-sectional STM to probe the development of local order on these length scales suggests it will be a powerful tool for studying the mechanism of atomic ordering as well as optimizing the growth of ordered films. @FootnoteText@ @footnote 1@Work supported in part by a grant from the National Science Foundation, Division of Materials Research.

2:40pm **NS-TuA3 Interpreting Atomic-Scale Structure in Cross-Sectional STM Images of III-V Superlattices**, *W. Barvosa-Carter,* ***B.Z. Nosho***, *M.J. Yang, L.J. Whitman,* Naval Research Laboratory

Cross-sectional scanning tunneling microscopy (XSTM) is a powerful method for quantifying the structural and interfacial quality of III-V semiconductor superlattice structures. Although a variety of III-V systems have been studied with XSTM, there are a number of aspects related to image interpretation, particularly on the atomic-scale, that are still a matter of discussion. One rarely discussed issue is that on the (110) cleavage face only every other III-V growth layer within the superlattice can be directly observed by XSTM. This fact can have important consequences when investigating properties of the superlattice such as the roughness between heteroepitaxial layers, interfacial defects, or variations in chemical bonding at the interface. The impact is especially significant when these effects occur predominantly within a volume only two to three monolayers (ML) wide. We are systematically investigating the appearance of III-As and III-Sb bonds at arsenide-antimonide interfaces as a function of cleavage direction and even-versus-odd layers in specially prepared MBE-grown superlattices. We find it is possible to differentiate between the two bond types, but their appearance depends on cleavage-face and layer order. In addition, a model of the measurement of interfacial roughness reveals errors in the measured power spectrum as the actual interface roughness decreases below 2 ML. A simple method for reconstructing the actual power spectrum from the STM data will be described. Funded by the Office of Naval Research and the Air Force Research Laboratory. Present address for W. Barvosa-Carter is HRL Laboratories, Malibu, CA.

3:00pm **NS-TuA4 The Importance of Many-body Effects in the Clustering of Charged Zn Dopant Atoms in GaAs**, ***Ph. Ebert***, Forschungszentrum J@um u@lich, Germany*; T.-J. Zhang,* University of Tennessee*; F. Kluge, M. Simon,* Forschungszentrum J@um u@lich, Germany*; Z. Zhang,* Oak Ridge National Laboratory*; K. Urban,* Forschungszentrum J@um u@lich, Germany

The spatial distribution of negatively charged Zn dopant atoms in GaAs has been investigated by cross-sectional scanning tunneling microscopy. At high densities, the dopant atoms exhibit clear clustering behavior, suggesting the existence of an effective attractive interaction in addition to the screened Coulomb repulsion between two dopants. By analyzing the data through Monte Carlo simulations, we have extracted the intrinsic screening length at different dopant densities, and attributed the origin of the effective attraction to strong many-body effects in the dopant-dopant repulsion.

3:20pm **NS-TuA5 New Methods to Measure Electrical, Optical, and Magnetic Properties on the Nanometer Scale**, ***M. Aono***, Osaka University and Institute of Physical and Chemical Research, Japan **INVITED**

In order to measure electrical, optical, and magnetic properties of materials on the nanometer scale, we have developed (a) a scanning tunneling microscope (STM) that has three tips operated independently, (b) a photon-detecting STM equipped with a polari zation analyzer, and © a spin-polarized STM with a nonmagnetic high-Z material tip, respectively. In the present paper, we show selected experimental results obtained with these apparatuses. Also we would like to show interesting experimental results on local polymerization of organic molecule in monolayer films. They include chain polymerization of diacetylene compound molecules triggered by a STM tip.

4:00pm **NS-TuA7 Field Dependent Electric Potential Gradients at Atomically Abrupt Oxide Interfaces**, ***D.A. Bonnell***, *B. Huey, S. Kalinin,* University of Pennsylvania

Scanning Surface Potential Microscopy has been used to measure spatial variations in electric fields near atomically abrupt interfaces in SrTiO@sub 3@ and ZnO. The field dependence of potential gradients is determined by using microlithography to isolate regions of the interface and apply local electric fields during the measurements. The local potential drop is used to determine the interface density of states. A procedure for extracting actual interface potential from separation dependence is proposed.[100] symmetric tilt boundaries in SrTiO@sub 3@ with tilt angles ranging from 15°-60° are examined and interface potential is related to atomic structure.

4:20pm **NS-TuA8 Dynamics of Adsorbate Islands with Nanoscale Spacial Resolution: (OH)@sub n@ Formation during the NO/H@sub 2@ Reaction on Pt(001)**, *C. Voss, T. Visart de Bocarmé, T. Bär,* ***N. Kruse***, Université Libre de Bruxelles, Belgium

Studies by Field Ion Microscopy (FIM) of the catalytic NO hydrogenation (p@sub H2@ = 4 x 10@super -3@ Pa and p@sub NO@ = 3 x 10@super -3@ Pa at 500 K) on the (001) plane of a Pt tip have resulted in the observation of small islands with a size corresponding to 10-30 Pt surface atoms. Simultaneous atom-probe work allowed these islands to be consistently interpreted as being due to the intermediate formation of hydroxyl species in an O@sub ad@/H@sub ad@ coadsorbed layer. Imaging of this reaction phenomenon was achieved by field ionisation of NO at field strengths slightly above those usually present in Scanning Tunneling Microscopy (STM). OH@sub ad@ islands exclusively formed at the layer edge with subsequent movement into the (001) terrace region. Usually one to two islands were observed at the same time with no mergence occurring on collision. Mean lifetimes of several minutes were observed for individual islands before their annihilation at the layer edge. The formation of OH@sub ad@ clusters must be regarded as a collective reaction phenomenon involving a delicate balance of attractive and repulsive forces between adspecies. The results will be presented in a video sequence and compared to a sucessful computer simulation with an automaton lattice model.

4:40pm **NS-TuA9 Measuring Average Tip-sample Forces in Intermittent-contact (Tapping) Force Microscopy in Air**, ***S.C. Fain, Jr.,*** *K.A. Barry, M.G. Bush, B. Pittenger,* University of Washington*; R.N. Louie,* Pacific Lutheran University

Many soft substances such as polymers and biological molecules show much less damage when imaged with intermittent-contact (tapping) force microscopy; however, the tip-sample forces involved have never been directly measured. The mathematical solutions to the non-linear differential equations needed to calculate these forces can be extremely complicated even for mass-on-a-spring models. In these experiments piezoresistive cantilevers (from Park Scientific/ ThermoMicroscopes) are used to measure the average force on a silicon surface produced by the silicon tip of a separate mechanically-driven (active) cantilever. The procedure consists of slowly moving the two cantilevers toward and away from each other while measuring as a function of the change in distance between the two support points: the average deflection of the piezoresistive cantilever, the amplitude of the active cantilever, the change in phase of the active cantilever relative to the mechanical driver, and the change in the average deflection of the active cantilever. Recent simulations by Garcia and San Paulo (Phys. Rev. B., in press) predict the force exerted on a model substrate averaged over a complete cycle, the amplitude, and the phase shift as a function of distance; they find that the force starts to rise when the phase shift indicates repulsive tapping. These predictions are compared with our measurements. The limit on the sensitivity of our average force measurements is set by the 1/f noise of the piezoresistive cantilever. This work was supported by NSF DMR 96-23590 and the UW Royalty Research Fund.

5:00pm **NS-TuA10 Imaging the Near-field Intensity Gradients with a Tapping-mode Near-field Scanning Optical Microscope**, ***D.P. Tsai,*** *C.W. Yang,* National Chung Cheng University, Taiwan

A tapping-mode near-field scanning optical microscope system using a non-optical tuning fork method has been developed recently. One of the advantage of this new method is that tapping of the near-field optical fiber probe can provide the measurements of the near-field intensity gradients at different heights vertically. Based on the modulation of the near-field optical fiber probe, near-field intensity gradients were used as a new contrast mechanism of the NSOM. The imaging of the near-field field optical intensity gradients have been successfully applied on the study of both the propagating and evanescent field intensity. The propagating field with a constant intensity shows an image of zero gradients. The evanescent intensity gradients of the configurations of total international reflection or surface plasmons, on the other hand, indicate the local optical properties of the photon-matter interactions. Imaging contrast of the near-field optical intensity gradients of a focused spot on the clear cover glass slip and the gold-coated cover glass slip will be shown. Property of the local optical interactions of the gold thin film in near field was discerned. Results demonstrate the novelty of the imaging contrast of the near-field intensity gradients.

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