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A Biased View on the Nanoworld: from Transport Imaging to Ferroelectric Memories

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The hallmark of our time is a drive for miniaturization of electronic and mechanical devices. Achieving the full potential of nanotechnology requires quantitative knowledge of material and device properties on the nanoscale level for applications ranging from fundamental studies of physical properties to failure analysis in commercial devices. In this presentation, Scanning Probe Microscopies (SPM) are demonstrated as powerful tools for characterization of frequency dependent nanoscale electronic transport phenomena. These microscopies are illustrated with an example of Scanning Impedance Microscopy of electroactive interfaces that combines the spatial resolution of traditional SPMs with the precision of conventional electrical C-V and I-V measurements. Another example is Scanning Gate Microscopy of carbon nanotubes, for which quantitative image interpretation using first principles density functional theory and quantum electrostatics allows transport behavior to be accessed on the level of individual atomic defects.

In the second part of the talk, the effects of local charge density on the chemistry and physics of ferroelectric surfaces are explored. The kinetics and thermodynamics parameters of adsorption are assessed by variable temperature SPM. Localized photochemical activity of ferroelectric surfaces is explored as a new tool for fabrication of metallic nanostructures. Piezoresponse force microscopy is used to engineer domain patterns on ferroelectric surfaces. The image formation mechanism in PFM and other electromechanical SPM techniques is analyzed in detail and the potential of these techniques for hysteresis loop measurements and local domain patterning is illustrated. These applications can lead to nearly atomic density ferroelectric storage and lithography.

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Sergei Kalinin is currently a Wigner Fellow and research staff member at the Oak Ridge National Laboratory. He completed his Ph.D. in Materials Science at the University of Pennsylvania in the fall of 2002 working with Prof. Dawn Bonnell. His previous undergraduate and graduate work was completed in Materials Science at Moscow State University, Russia. During his academic career, Sergei has been the recipient of the Ross Coffin Purdy Award of the American Ceramic Society (2003), the American Vacuum Society Graduate Student Award (2002) and the Materials Research Society Graduate Student Award (Gold, 2001; Silver, 1999 and 2000), along with the Wigner fellowship at ORNL (2002). He is the author of more than 50 scientific publications and five book chapters. Currently he is working with Art Baddorf and Ward Plummer on the synthesis and SPM characterization of electronic and transport phenomena in transition metal oxides on the nanoscale.