Quantitative Analysis of Electronic Properties of Carbon Nanotubes by Scanning Probe Microscopy: from Atomic to Mesoscopic Length Scales

S.V. Kalinin,[1] V. Meunier,[2] C. Staii,[3] A.T. Johnson,[3] J. Shin,[1,4]
A.P. Baddorf,[1] and R.J. Harrison[2]

[1]*Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831*
[2]*Computer Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831*
[3]*Department of Physics and Astronomy, The University of Pennsylvania, Philadelphia, PA 19104*
[4]*Department of Physics and Astronomy, The University of Tennessee, Knoxville, TN 37996*

Scanning Probe Microscopy (SPM) techniques are the key to real space imaging of electronic transport properties, including the electrostatic potential distribution and local field effects, in low-dimensional systems. Despite the wealth of experimental data, the interpretation of SPM data to extract the local electronic properties of 1D systems such as carbon nanotubes requires quantitative analysis of the tip-nanotube interactions. We present here a new approach to quantitatively interpret SPM which treats the interaction between the probe and the system using a combination of first principles density functional calculations and continuum electrostatics modeling. In addition, an original approach for experimental measurement of the tip radius of curvature from the electrostatic SPM data is presented. Within this approach, we can quantitatively describe, for the first time, the capacitive tip-surface interactions and predict the magnitude of the tip gate effect in nanoscale systems, such as carbon nanotubes, oxide nanobelts and semiconductor nanowires, permitting quantitative determination of electronic properties of atomic defects in these systems. The various aspects of the model are applied to a number of recently acquired and published images of nanotube circuits with varied back gate voltages, and the interpreting power of the approach is demonstrated.

Research was sponsored by the U.S. Department of Energy, under contract DE-AC05-00OR22725 with UT-Battelle, LLC and by the National Science Foundation grant DMR-0072998. Research performed as a Eugene P. Wigner Fellow (SVK).

To Symposium II