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Scanning Probe Evaluation of Electronic, Mechanical and Structural Material Properties[1]

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We present atomic force microscopy (AFM) studies of a range of properties from three different classes of materials: mixed ionic electronic conductors, low-k dielectrics, and polymer-coated magnetic nanoparticles. (1) Mixed ionic electronic conductors are being investigated as novel diodes to drive phase-change memory elements. Their current-voltage characteristics are measured with direct-current and pulsed-mode conductive AFM (C-AFM). The challenges to reliability of the C-AFM method include the electrical integrity of the probe, the sample and the contacts, and the minimization of path capacitance. The role of C-AFM in the optimization of these electro-active materials will be presented. (2) Low dielectric constant (low-k) materials are used in microprocessors as interlayer insulators, a role directly affected by their mechanical performance. The mechanical properties of nanoporous silicate low-k thin films are investigated in a comparative study of nanomechanics measured by AFM and by traditional nanoindentation. Both methods are still undergoing refinement as reliable analytical tools for determining nanomechanical properties. We will focus on AFM, the faster of the two methods, and its developmental challenges of probe shape, cantilever force constant, machine compliance and calibration standards. (3) Magnetic nanoparticles are being explored for their use in patterned media for magnetic storage. Current methods for visualizing the core-shell structure of polymer-coated magnetic nanoparticles include dye-staining the polymer shell to provide contrast in transmission electron microscopy. AFM-based fast force-volume measurements provide direct visualization of the hard metal oxide core within the soft polymer shell based on structural property differences. In particular, the monitoring of adhesion and deformation between the AFM tip and the nanoparticle, particle-by-particle, provides a reliable qualitative tool to visualize core-shell contrast without the use of additional contrast enhancing agents.

[1]In collaboration with Jane Frommer, IBM.