Nanometrology

Nanotechnology will revolutionize and possibly revitalize many industries, leading to new and improved products based on materials having at least one dimension less than 100 nm. The federal government's role in realizing the full potential of nanotechnology is coordinated through the National Nanotechnology Initiative (NNI), a multi-agency, multi-disciplinary program that supports research and development, invests in a balanced infrastructure, and promotes education, knowledge diffusion, and commercialization in all aspects of nanoscale science, engineering, and technology. NIST's unique and critical contribution to the NNI is *nanometrology*, defined as the science of measurement and/or a system of measures for nanoscale structures and systems. NIST nanometrology efforts focus on developing the *measurement infrastructure* — measurements, data, and standards — essential to advancing nanotechnology commercialization. This work provides the requisite metrology tools and techniques and transfers enabling measurement capabilities to the appropriate communities.

MSEL plays a vital role in nanometrology work at NIST with efforts in four of the seven NNI Program Component Areas — *Instrumentation Research, Metrology and Standards for Nanotechnology; Nanomaterials; Nanomanufacturing;* and *Fundamental Nanoscale Phenomena and Processes.* Innovative projects across MSEL are defining and addressing the forefront research issues in these areas.

Instrumentation Research, Metrology and Standards for Nanotechnology

R&D pertaining to the tools needed to advance nanotechnology research and commercialization. The design, development, and fabrication of nanodevices will require nanomechanical measurements that are rapid, accurate, predictive, well-understood and representative of a device or system's environment in real time. MSEL is addressing this need by developing instrumentation, methodology, reference specimens and multi-scale modeling approaches to quantitatively measure mechanical properties such as modulus, strength, adhesion, and friction at nanometer-length scales. This year, novel instruments for measuring adhesion and friction forces between surfaces and nanoparticles were developed jointly with industrial partners. Quantitative maps of elastic modulus were obtained by innovative methodologies based on atomic force microscopy and strain-induced elastic buckling instability. To address the need for quantifying measurements made with widely-used commercial nanoindentors and scanned probe microscopy instruments, MSEL is developing reference specimens and SI-traceable force calibration methodology.

Nanomaterials

Research aimed at discovery of novel nanoscale and nanostructured materials and at a comprehensive understanding of the properties of nanomaterials. Among the many classes of nanomaterials, nanotubes have received great attention due to their remarkable physical properties relevant to many applications. In response to needs expressed by industry and other federal agencies, MSEL has embarked on a new effort to develop a suite of metrologies and standards aimed at characterizing key structural features and processing variables of carbon nanotubes. These include dispersion, fractionation, orientation, alignment, and manipulation of individual single-walled nanotubes, all critical to establishing efficient bulk processing schemes to meet the imminent high demand for carbon nanotubes.

Nanomanufacturing

R&D aimed at enabling scaled-up, reliable, cost-effective manufacture of nanoscale materials, structures, devices, and systems. Nanoimprint lithography (NIL) is rapidly emerging as a viable high-throughput technique for producing robust structures with a patterning resolution better than 10 nm. MSEL is developing metrologies that are crucial to advancing NIL as an industrial patterning technology for the electronics, optics, and biotechnology industries. The current focus is on characterizing shape and the fidelity of pattern transfer, two key factors in achieving widespread commercial application of NIL.

Fundamental Nanoscale Phenomena and Processes

Discovery and development of fundamental knowledge pertaining to new phenomena in the physical, biological, and engineering sciences that occur at the nanoscale. The magnetic data storage industry needs the ability to measure and control magnetization on nanometer length scales and nanosecond time scales to meet increasing demands for reduced size and increased speed of devices. MSEL is developing measurement techniques to elucidate the fundamental mechanisms of spin dynamics and damping in magnetic thin films. Work this year has focused on measurements of the effects of interfaces and interface roughness on magnetization dynamics and magnetic characterization of edges in magnetic devices.

Through these and other research activities, MSEL is maintaining its committed leadership in developing the measurement infrastructure for current and future nanotechnology-based applications.

Contact: Debra L. Kaiser (Ceramics Division)