

Nanocharacterization

The emphasis on nanotechnology around the world and the successful implementation of the National Nanotechnology Initiative in the U.S. are accelerating the development of science and technology at the nanoscale. Nanotechnology is expected to play a key role within the next 10 years in a wide spectrum of industry sectors including manufacturing, information technology, electronics, and healthcare. Novel devices at the micro- and nanoscale will become increasingly important in all of these industries. The ability to measure dimensions, characterize materials, and elucidate structures of new and novel materials at the nanoscale will be critical to the advancement of nanotechnology. In addition, one of the exciting prospects of nanotechnology lies in the ability of molecules or particles, under specific conditions, to self-assemble to form new materials with unusual properties. Successful development of these new materials will require the ability to monitor such processes at the nanoscale in real time. Metrology, the science of measurement, is therefore the foundation of nanotechnology. Standards and reference materials will also provide essential infrastructural support to this emerging technology.

The objective of the program in the NIST Materials Science and Engineering Laboratory (MSEL) is to develop basic measurement metrology at the nanoscale for the determination of bulk and surface material properties and for process monitoring. Measurement methods are being developed for use in conjunction with new instrumentation and calibration artifacts.

The scope of the program encompasses metals, ceramics, and polymers in various forms — particles, thin films, nanotubes, and self-assembled structures — and also includes studies of nanocomposites and liquid-state properties for microfluidics-based fabrication and measurement techniques. Physical properties such as mechanical strength, elastic moduli, friction, stiction, adhesion, and fatigue strength are measured, as well as the size of nanoparticles and the structure and dispersion behavior of nanoparticulate systems. Other properties such as electrical conductivity, thermal conductivity, magnetic properties, electronic properties, and optical properties are also examined. While the

program focuses on developing measurement techniques at the nanoscale, proper data interpretation requires fundamental studies in nanomechanics, scaling laws, and imaging techniques.

There are currently ten projects under the program:

- Bridging Length Scales in Theory and Modeling;
- Electrochemical Processing of Nanoscale Materials;
- Metrology for Nanoscale Properties;
- Nanofiller Processing;
- Nanoindentation;
- Nanomechanics and Standards;
- Nanoscale Manufacturing;
- Nanotribology and Surface Properties;
- Particle Metrology and Standards; and
- Physical Properties of Thin Films and Nanostructures.

In many of these individual projects, objectives are directed toward the study of a particular class of materials or material properties, but the underlying theme of the program as a whole is to develop reliable, accurate measurement techniques for a broad range of materials and material properties at the nanoscale. As just one example, four methods for the determination of the elastic properties of thin films — atomic force acoustic microscopy, surface acoustic wave spectroscopy, Brillouin light scattering, and nanoindentation — are being compared using common sets of specimens. This study will lead to a better understanding of the complementary nature of these techniques for measuring nanostructured materials and their combined use to determine supplementary properties such as film thickness or density. Standard reference materials are being developed in collaboration with other National Measurement Institutes around the world for use in the verification of the performance of these instruments.

Contact: Stephen M. Hsu