MATERIALS METROLOGY IN NANOTECHNOLOGY

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Nanostructured materials are a new class of materials which provide one of the greatest potentials for improving performance and extended capabilities of products in a number of industrial sectors, including the aerospace, tooling, automotive, electronic, recording, cosmetics, electric motor, duplication, and refrigeration industries. Encompassed by this class of materials are multilayers, nanocrystalline materials and nanocomposites. Their uniqueness is partially due to the very large percentage of atoms at interfaces and partially to quantum confinement effects.

One critical need for the implementation of nanomaterials and devices is their characterization and measurement science, i.e., their metrology. For many properties, it is not known whether the exciting novel behavior found in these new materials is due to new physics or to a logical extension of large-size behavior to small dimensions. Examples include the deformation and fracture behavior (wherein it is not known whether dislocations even exist in these materials), optical characteristics (wherein uncertainties exist in whether the properties are due to interface or quantum mechanical effects), magnetic properties (wherein the origin of anisotropy and how magnetic domains move in response to an external field are still questionable), and thermal properties (wherein the propagation of phonons through interfaces needs improved understanding). Consequently, implementation of this new type of material into marketable products can be significantly delayed.

Important needs also include the identification of preparation methods for industrial-size quantities of material, measurement of particle size, extension of the capabilities of conventional measurement tools to the nanometer-size scale, and the development of consolidation methods which still retain the nanometer grain size of the initial nanocrystalline powders. For multilayers, understanding the development of epitaxy and control of both composition and interdiffusion at the interface are of critical importance.

Since the initiation of the National Nanotechnology Initiative (NNI) announced by President Clinton in the United Sates in 2000, there has been a significant increase in the research and development activity in nanotechnology all around the world. Much of this activity has been directed toward understanding the phenomena that are being discovered. However, much more needs to be done in the area of measurement science. Presently tools are being used at the limits of their resolution to probe these materials and phenomena, resulting in large measurement errors. Similarly, there is a lack in nanoscale calibration standards, thereby contributing to inconsistency in results being obtained around the world.

The fact that one of the nine “Grand Challenges” of the U.S. National Nanotechnology Initiative is focused toward the development of nanoscale metrology attests to the importance of the area. Here a description will be given of why things are different at the nanoscale and therefore what needs to be part of an effort on nanoscale metrology. Details of the NNI’s challenge in metrology and standards will be presented in addition to results of a NNI Grand Challenge workshop on “Instrumentation and Metrology for Nanotechnology” held at the National Institute of Standards and Technology earlier this year (January 27-29, 2004).