Interagency Grantees Meeting/Workshop
Nanotechnology and the Environment: Applications and Implications

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Introduction

The mission of the National Institute of Standards and Technology (NIST) is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life. This mission is accomplished through direct collaboration with industry, governmental agencies and universities.

Through the National Nanotechnology Initiative (NNI), NIST has a unique and critical role to

- Develop needed measurements, data, and standards;
- Develop infrastructure measurement capabilities;
- Provide the metrology tools and techniques; and
- Transfer measurement capabilities to the appropriate communities.

NIST has an active program in nanotechnology. Researchers in NIST's laboratories are developing the measurements, standards, data and models that will provide the enabling infrastructure to facilitate the commercialization of nanotechnology. In addition, NIST's nanotechnology work is making possible new, quantum-based realizations of the fundamental units of measurement (meter, kilogram, second, mole, Kelvin, candela, ampere) in support of traceability for international metrology, and ultimately international trade.

NIST works closely with other federal agencies, including all of the NNI agencies, to exploit nanotechnology in areas such as national security, environmental protection, and space science, to the benefit of the missions of all the partnering agencies.

Nanotechnology efforts in the NIST laboratories encompass five key technical areas which are united by a focus on measurements, data, and standards,

- ***Fundamental science and basic measurement capabilities.*** NIST is working to deliver nanoscale traceability to the factory floor. Nanomanufacturing will require traceable nanoscale measurements of length, time, force, mass, and chemical composition.

- ***Nanoscale electronics, optoelectronics, and magnetics.*** *As industry approaches the limits of CMOS, NIST is anticipating and addressing the* *pressing metrology, process-control and quality requirements for the future of the nation's semiconductor, magnetic-data-storage, and optical-communications industries.*

- ***Nanochemistry and characterization of nanostructured materials.*** NIST is embarking on a new program to deliver reliable, accurate three-dimensional chemical imaging for location of atoms and molecules in nanostructured materials. This will be a key capability in bringing nanoscience from the "lab to the fab," enabling vital commerce in nanotechnology.

- ***Nanobiotechnology****.* NIST is developing metrology to support leading-edge nanobioscience with programs in gene expression, tissue engineering, and proteomics measurement and manipulation of single biomolecules,

- ***Quantum computing and communications***. Quantum information science has the potential to meet the IT needs of the future in computation and secure communications. Internationally recognized for pioneering work in laser cooling of atoms and ions, NIST is making vital contributions to efforts to realize the vast potential of quantum information and quantum communication technologies.

Questions

- **How does NIST view its research agenda as it relates to the environment?**

Measurements and standards related to the environment are a notable component of the NIST nanotechnology portfolio. This is especially true of the ultrafine particles associated with nanotechnology. NIST is developing a number of different measurement methods that will allow characterization of the dimension, morphology, magnetic characteristics, and chemical nature of nanoscale particles as well as other agents of environmental concern. They could be naturally occurring or engineered materials that will be incorporated into new products, or they could be by-products that are generated during a manufacturing process. The measurement methods developed by NIST in its nanotechnology effort provide sound scientific and engineering methods to detect, characterize and quantify these materials.

For example, NIST will investigate the role of nanoscale particles as selective sensors of chemical species. The unique spectral and chemical properties of nanoparticles will enable new process sensing metrologies to be developed, and to enable the development of robust and selective environmental monitoring approaches.

The measurement tools that are anticipated to emerge from the NIST nanotechnology portfolio are expected to impact broad industrial areas from electronics to pharmaceuticals. We remain alert to opportunities to leverage all of our metrology programs to assist the nation in addressing environmental issues.

- **Can the research be applied to an environmental problem?**

Monitoring environmental issues at the nanometer length scale will require new measurement techniques. Much of the work that NIST has done in particle characterization in the micro realm can be directly applied to nano-scale research. There is a great deal of leveraging of previous work that can be applied to this problem. While improvements in existing measurement techniques may be able to satisfy the measurement challenges in some nanometer scale issues, new measurement methods and measurement science are likely to emerge from the NIST nanometrology effort that will have to be analyzed for their relevance to environmental problems of interest.

Problems of likely relevance include the characterization of particulate matter in the nanoscale size regime. Similarly, measurement tools that can differentiate different forms of carbon nanotubes may become important for environmental issues in the same way that standards for asbestos fibers have come to play an important role in the nations' environmental posture. It is widely known that ambient concentrations of particulate matter (PM) are strongly associated with changes in background rates of chronic and acute respiratory symptoms, as well as mortality rates, and those particulates smaller than 2.5 micrometers are more harmful than those of a larger size. Yet at present, the respiratory impacts of particulates at the nanoscale are unknown. Determination of the particle size, chemical composition, morphology, and surface chemistry of these nanoparticles will be important for establishing when environmental controls for these species will be appropriate. Furthermore, characterization of nanosize particulate matter will enable environmental researchers to model their atmospheric reactions and transport, and for epidemiologists to develop concentration-response (C-R) functions that are used to relate changes in exposure to changes in mortality rates and a variety of morbidity effects. And with a foundation grounded in NIST nanometrology, researchers will be able to quantify the uncertainties associated with each modeling stage. In addition to the measurement tools that are being developed for nanoscale particles, NIST also supports research into measurement methods capable of addressing surfaces exposed to environmental factors – such as associated with vegetation exposure to chemical treatments. In this measurement realm, instrumentation capable of measuring surface forces on the nanoscale might be able to follow changes resulting from, for example, pesticide exposures. Mass spectrometric and other microanalytical methods with nanoscale spatial sensitivity could be used to follow the permeation of pesticides and pollutants into vegetation. Similarly, an understanding of how to accurately measure nanoscale chemical structures in areas such as molecular electronics can easily be anticipated to impact measurement needs in the area of environmental problems.

- **Can the research prevent an environmental problem?**

Through careful experimental programs in developing measurement tools that are adequate to address nanoscale systems, it should be practical to identify potential sources of problems before the emerging technology is adopted and begins to contribute to the inventory of environmentally deleterious materials that may ultimately need to undergo remediation.

Simply the ability to recognize that nanoscale particles are generated in a process will provide an indication that the process itself needs to be carefully monitored to insure that such particles are not being released into the environment.

Furthermore, as stated above, the ability to develop appropriate measurement methodologies to capture and characterize nanoscale particulate matter to allow the presence of these species to be correlated with observed health effects.

Development of validated computational chemistry methods offers a robust means to anticipate the chemical reactivity of the surfaces of nano-particulates, and to provide prior warning of potential hazards before they present a real hazard. In addition, improved understanding of the interactions of nanoparticles with living cells and cellular organelles will provide an initial assessment of the potential hazards.

In all these efforts, measurement scientists will need to work closely with environmental researchers and policymakers to translate their technical findings into a form relevant to decision making.

- **Might the research cause an environmental problem?**

The research that NIST is engaged in is not likely to generate environmental problems, if for no other reason than that the quantities of material under investigation will be so small as to be controllable. National record on handling chemical and biological agents provides evidence that such material can be safely handled in laboratory situations. The NIST research is more likely to identify problems before they have a chance to exert an environmental impact.

<u>Conclusion</u>

This presentation discusses only a portion of the work that can be leveraged at NIST regarding environmental-related nanotechnology research. Much of the knowledge and expertise already exists and is available to be leveraged. In the upcoming year, two new opportunities enhance this even further:

- New Memorandum of Understanding (MOU) between the University of Maryland and NIST in nanoparticle-based manufacturing and metrology provides the potential for “designer” particles for standards development (construction, size control, and deposition).

- Opening of the new Advanced Measurements Laboratory in early 2004 which will provide NIST programs and the NNI with significant technological improvements in metrology.

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Appendix

Partial Listing of Standard Reference Materials (SRM) and Reference Materials (RM) related to particle size:

Particle Size:
http://patapsco.nist.gov/srmcatalog/tables/view_table.cfm?table=301-1.htm

Particle Count Materials:
http://patapsco.nist.gov/srmcatalog/tables/view_table.cfm?table=301-5.htm

Surface Area and Porosimetry:
http://patapsco.nist.gov/srmcatalog/tables/view_table.cfm?table=301-2.htm
http://patapsco.nist.gov/srmcatalog/tables/view_table.cfm?table=301-4.htm