FY 2010 NSF Priorities in Nanoscale Science and Engineering

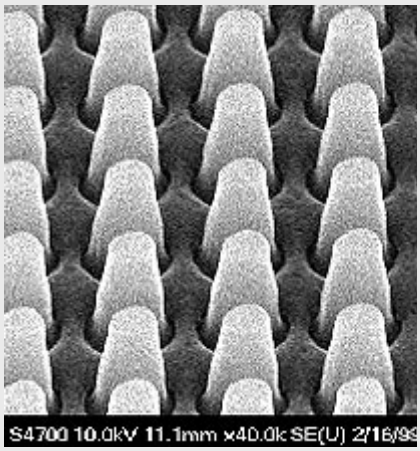
NSF leads the nation in fundamental nanoscale science and engineering research. This leadership is both in NSF's launching and subsequent support of the interagency National Nanotechnology Initiative (NNI), and through its own investments in nanoscale research.

New Frontiers in Nanotechnology

The long-term objectives of this broad initiative focus on building a foundation of fundamental research to understand nanoscale concepts, and to apply novel principles to the most promising opportunities in measuring, manipulating and use of matter on the nanoscale for the benefit of society. A corresponding objective is ensuring that U.S. institutions have access to a full range of nano-facilities, enabling access to nanotechnology education, and catalyzing the creation of new commercial markets that depend on three-dimensional nanostructures.

The rudimentary capabilities of nanotechnology today for systematic control and manufacture at the nanoscale are envisioned to evolve into four overlapping generations of nanotechnology products: passive nanostructures, active nanostructures, systems of nanosystems with three-dimensional features, and heterogeneous molecular nanosystems.

The following eleven areas are recommended as nanoscale frontiers that need increased research.



Silicon semiconductor electronics and beyond is central to advances in information technology and creation of high-quality jobs. CMOS scaling will reach fundamental limits at the nanoscale in the next 15-20 years. To enable discovery and innovation of new approaches to electronics, the NSF has embarked on collaborative efforts with the semiconductor industry and the Semiconductor Research Corporation (SRC) on the theme of *Silicon Nanoelectronics and Beyond (SNB).* Research in SNB will explore ultimate limits to scaling of features and alternative physical principles for devices employed in sensing, storage, communication, and computation, including biological, molecular, and other emerging areas of electronics/photonics at the nanoscale.

Development of Nanotechnology

- Tools for measuring, simulation and restructuring matter with atomic precision, time resolution of chemical reactions, and for domains of engineering and biological relevance. A special focus will be on new tools for characterization of nanoscale phenomena in biological systems, including mechanical properties of life at the cellular and sub-cellular levels.
- Understanding and use of quantum phenomena and how they influence nanoscale and microscale processes and engineered structures. A special focus will be on (1) gaining control of nanoscale features and devices at the atomic level of precision; (2) understanding the impact and simulation of quantum phenomena in the nanoscale regime; and (3) connecting quantum and nanoscale phenomena predictively across length and time scales with the macro properties of molecules and materials. These activities require the development of novel instrumentation techniques and theoretical and modeling tools.
- Understanding and use of self assembly from basic principles and on multiple scales
- Nanobiotechnology for understanding and simulation of cells, tissues, and nervous systems, with application to biomedicine and neuromorphic engineering.

- Nanomanufacturing with a focus on active nanostructures and nanosystems. A special focus will be on energy efficient manufacturing and catalysts.

Integration of Nanotechnology

- Nanoelectronics with long-term research targets including replacing electron as carrier of information in logic and storage devices, and new circuits and architectures for developing long range computing platforms with nano-scale devices. This topic has been initiated in 2004 by ENG, MPA and CISE and it is a foundation for the proposed NSF-wide priority in 2010 on Science and Engineering Beyond Moore's Law.
- Energy conversion and storage using new principles; energy efficient materials and manufacturing as related to nanoelectronics, catalysts, nano-mechanics, and other areas. Using nanotechnology for addressing sustainable development is a main objective.
- Water filtration and desalinization with industrial and international partners
- Nanoscale interfaces between the living systems (plants, animals, and the human body) and manmade devices. A special focus will be on new sensors with nanoscale features for use in medicine, agriculture and basic biological research.
- Development of nanoscale sensor capacity to drive advances in networking, communications, and the development of smart sensor arrays for environmental benchmarking and monitoring.
- Nano-informatics for better communication and nanosystem design. It includes defining the ontology of terms, interconnecting databases, using specific informatics tools, and connecting to bioinformatics.

Societal Dimensions

The following areas are recommended as nanoscale frontiers that need increased societal dimensions activities, including: economic and societal implications; sustainable development using nanotechnology; environmental, health and safety issues of nanotechnology (nano-EHS); education and outreach; and social shaping and social implications of nanoscale science and engineering. They are focused on fundamental research, infrastructure and education in support of NSF mission.

a. Several nano-EHS priorities are:

- New measurement methods and instrumentation for nanoparticle characterization in air, soil and water, for exposure rates and for toxicity of nanomaterials,
- Transport phenomena of nanoscale aerosols and colloids, interaction of nanomaterials with cells and living tissues (human, animal and plant);
- Physico-chemical-biological processes of nanostructures dispersed in the environment and at the working place; develop models for predicting impact of nanomaterials on health and safety over the entire life cycle
- Nano-bio interface and ecological aspects. Predictive models for interaction of nanomaterials with cells/living tissues
- Separation of nanoparticles from fluids, including water filtration
- The safety of manufactured nanoparticles at working place and for consumers
- Research on risk governance methods to address nano-EHS
- Development of user facilities, and
- Educational programs related to nano-EHS.

b. Education and Outreach priorities:

- Engaging K-12 students, teachers, undergraduates, and the public in nanoscale science and engineering will be increasingly critical to fostering a diverse, well-prepared workforce and well-informed citizenry. Existing initiatives in formal and informal learning—the Nanoscale Center for Learning and Teaching and the Nanoscale Informal Science Education Network, along with related EHR, ENG, MPS and other directorate projects—have identified fruitful directions and established a foundation for the following educational investments:
  - Educational research in formal and informal settings on learning complex topics drawn from emerging science and technology
  - Introducing nanotechnology education at the earliest appropriate levels in order to bring current research into the curriculum and to create long-term interest in nanotechnology.
  - Development and testing of educational materials for teaching multidisciplinary scientific concepts at the nanoscale and for teacher professional development
  - Exhibits, media, programs, and other educational resources for engaging the public in nanoscience and nanotechnology
  - Public forums for learning about and discussing the societal issues raised by nanotechnology
  - Development of innovative courses and materials on nanoscience and technology at the undergraduate level.

c. ELSI priorities:

- Research on economical, social, legal and long-term human development implications of nanotechnology development. It includes research on patterns in the U.S. and of global diffusion and distribution of nanoscale research and technology.
- Testing of methods for building capacity for anticipatory governance of nanotechnology development. That is, demonstrating how democratic governance can be effectively used as a mechanism for shaping and promoting nanotechnology development and distribution. It includes research on national and international regulatory capacity of governing nanomaterial safety.
- Research on the development of methods for improved integration of public perceptions of risk and formal and informal science education efforts.
- Research on the social and cultural variability in different publics' understanding of nano-related environmental and health risks. Understand how different values, practices, and knowledge shape perceptions of risk.
- Research on improving interdisciplinary and international cooperation in nanoscale science and engineering.
- Continued monitoring of public values and beliefs as they relate to nanomaterials.

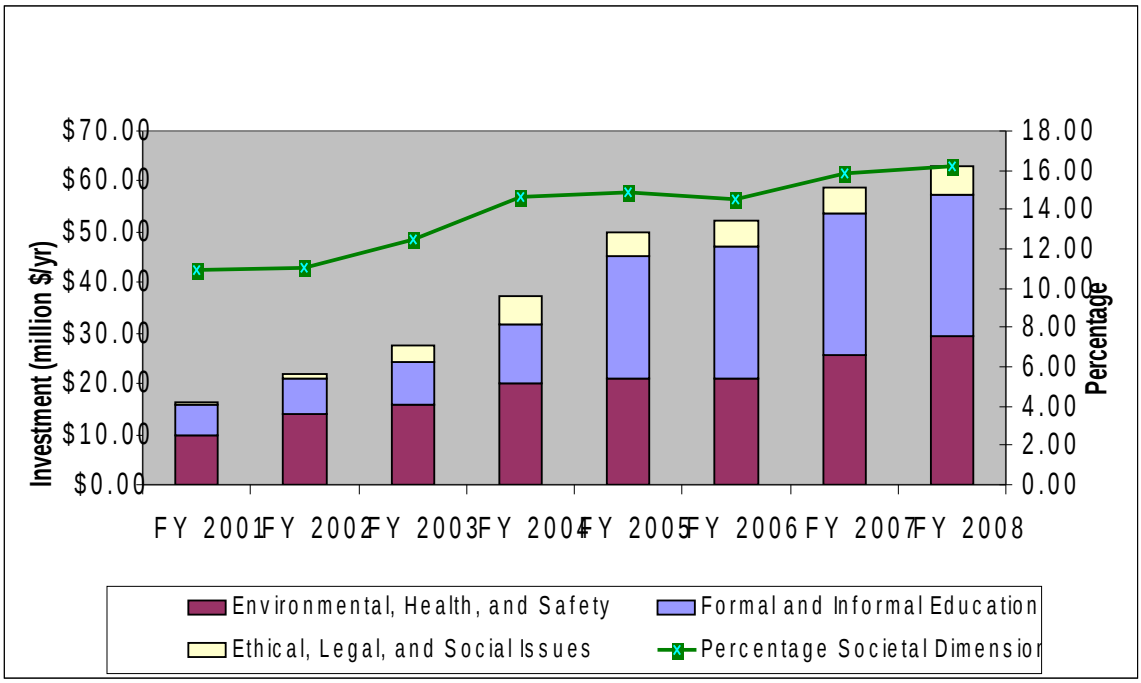
Partnerships

- Partnerships within NSF and with other agencies will be continued and strengthened with new emphases and directions.
- Partnerships with industry, including with industry sectors and technology transfer . . A corresponding objective in international partnerships is ensuring that U.S. institutions have access to a full range of nano-facilities, enabling access to nanotechnology education, enabling U.S. researchers to benefit from advances in nanoscale science and engineering research around the world, and catalyzing the creation of new commercial markets that depend on three-dimensional nanostructures.

Statement on Societal Dimensions at NSF in FY 2009

NSF supports fundamental research, infrastructure, and education on the "societal dimensions" of nanotechnology. **Societal dimensions** encompass three areas: environmental, health, and safety (EHS); educational aspects (EDUC); and ethical, legal, and social issues (ELSI).

In EHS, NSF-sponsored research addresses the three sources (natural, incidental, manufactured) of nanoparticles and nanostructured materials in different environmental settings (air, water, soil, biosystems, and the work environment), as well as the non-clinical biological implications. These topics are supported through programs in all research directorates.



NSF provides foundational knowledge, education and infrastructure for EHS in support of nanotechnology and other agency missions. NSF-sponsored research addresses the three sources (natural, incidental, manufactured) of nanostructured materials in different environmental settings (air, water, soil, biosystems, and the work environment), as well as the non-clinical biological implications. These topics are supported through programs in all research directorates. The programs are upstream, looking for the implications and applications of the current and new generations of nanomaterials.

It is focused on fundamental research on utilization, implications and risk mitigation of nanotechnology, infrastructure and education.

NSF has established an environmental component of his NNI investment since FY 2001 and now spends about 7% of the nanotechnology budget for this purpose. The NSF estimation for EHS is $29.2 million (7.5% of nanotechnology) in FY 2008, and $30.64 million (7.7% of nanotechnology request) in FY 2009 Request will be . This includes a new multidisciplinary center in collaboration with EPA to conduct fundamental research on the environmental, health, and safety impacts of nanomaterials. This research will explore the interactions between particles and materials at the nanoscale and the living world with development of innovative methods of investigation and instrumentation.