Research Activity: Nanoscience Centers

Division: Scientific User Facilities
Primary Contact(s): Kristin A. Bennett (Kristin.Bennett@science.doe.gov; 301-903-4269)
Altaf (Tof) Carim (carim@science.doe.gov; 301-903-4895)
Division Director: Pedro A. Montano

Portfolio Description:

This activity supports the establishment and operation of five Nanoscale Science Research Centers (NSRCs) at Department of Energy (DOE) national laboratories. These are: the Center for Nanophase Materials Sciences (CNMS) at Oak Ridge National Laboratory (ORNL); the Molecular Foundry at Lawrence Berkeley National Laboratory (LBNL); the Center for Integrated Nanotechnologies (CINT) at Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL); the Center for Nanoscale Materials (CNM) at Argonne National Laboratory (ANL); and the Center for Functional Nanomaterials (CFN) at Brookhaven National Laboratory (BNL). The first four of these will be in full operation in FY 2007 and the fifth in FY 2008. All encompass state-of-the-art equipment and expert staff to support the synthesis, processing, fabrication, and analysis of materials at the nanoscale. The NSRCs are major user facilities serving researchers from academia, national laboratories, and industry and are anticipated to collectively serve over 800 users annually once all are in full operation.

Unique Aspects:

Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications. With a nanometer corresponding to one billionth of a meter, nanoscale phenomena occur at the level of small numbers of atoms, molecules, and supramolecular structures. The NSRCs will make sophisticated research tools for nanoscience and nanotechnology available to the broad scientific community, and will facilitate access to other collocated major facilities including synchrotron radiation light sources, neutron scattering centers, and electron beam microcharacterization facilities. The NSRCs are the DOE signature activity in nanoscale research and constitute the nation's largest scientific infrastructure investment under the National Nanotechnology Initiative (NNI).

NSRCs provide unique scientific and engineering capabilities not available in any of the parallel programs sponsored by other entities. For example, other federal agencies sponsor research in nanoscience at universities, but such program are generally limited in scope and size, centered on specific research issues or topical areas, and primarily involve researchers of the host institution and a limited number of partners. The NSRCs are larger-scale facilities with a broad remit and range of capabilities and are broadly accessible without usage fees for non-proprietary work, with instrument time and staff support allocated on the basis of peer-review of proposals. The purposes of the NSRCs are as follows:

- Advance the fundamental understanding and control of materials at the nanoscale regime
- Provide an environment to support research of a scope, complexity, and disciplinary breadth not possible under traditional individual investigator or small group efforts
- Provide the foundation for the development of nanotechnologies important to DOE
- Provide state-of-the-art equipment to in-house laboratory, university, and industry researchers and optimize the use of national user facilities for materials characterization employing electrons, photons, and neutrons
- Provide a formal mechanism for both short- and long-term collaborations and partnerships among DOE laboratory, academic, and industrial researchers
- Provide training for graduate students and postdoctoral associates in interdisciplinary nanoscale science, engineering, and technology research

Relationship to Other Programs:

The fundamental science being carried out at the NSRCs is closely related to BES programmatic research on the nanometer scale at both universities and national laboratories. Researchers supported by BES, by other parts of the Office of Science, by other parts of DOE, and by other federal agencies participate in the overall NSRC user community. A major benefit is the opportunity for users to collaborate with the NSRC scientists. In addition, the NSRCs are collocated with, and serve as access points to, existing major BES user facilities for x-ray, neutron, and electron scattering. The DOE nanoscience activities as a whole are coordinated with other agencies through the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology

Council (NSTC); this Subcommittee is responsible for the federal NNI program and is currently co-chaired by representatives from BES and the Office of Science and Technology Policy.

Significant Accomplishments:

Physical construction of new buildings is complete or nearly so for four of the five NSRCs, constituting major progress in the challenging process of establishing these facilities. All five have had robust pre-operations "jump-start" user programs in which existing capabilities of the host laboratories were made available to outside users as a prelude to operations of the NSRCs themselves. Over 400 user proposals were accommodated during this period, leading to substantial advances in a number of areas; a few examples include the development and application of methods for the controlled synthesis of hollow or filled nanospheres; new insights on charge transport within two-dimensional and quasi-one-dimensional nanocrystal arrays; and the development of modular microlaboratories that facilitate sophisticated, reproducible measurement of the behavior and properties of nanomaterials.

Mission Relevance:

A part of the mission of the Office of Science is to "deliver the premier tools of science to our Nation's research enterprise." The NSRCs join the suite of major DOE user facilities that fulfill this objective. A seminal DOE-BES workshop and subsequent report on *Basic Research Needs to Assure a Secure Energy Future* cited nanoscience as a critical cross-cutting theme, and this has been reiterated in follow-up reports on *Basic Research Needs for the Hydrogen Economy* and *Basic Research Needs for Solar Energy Utilization.* In addition, BES and the NSTC cosponsored a major workshop and report on *Nanoscience Research for Energy Needs* that identified key research targets and foundational themes for energy-related nanoscience. As stated in the Executive Summary of that report, "At the root of the opportunities provided by nanoscience to enhance our energy security is the fact that all of the elementary steps of energy conversion (e.g., charge transfer, molecular rearrangement, chemical reactions, etc.) take place on the nanoscale."

Scientific Challenges:

Strategic investments in scientific areas of opportunity are required to help our nation develop a balanced research and development infrastructure, advance critical research areas, and nurture the scientific and technical workforce of the new century. Nanotechnology R&D is a top federal priority with broad potential implications for the nation's competitiveness. DOE's response has been the development of the NSRCs, whose goals include: (1) to attain a fundamental scientific understanding of nanoscale phenomena, particularly collective phenomena; (2) to achieve the ability to design and synthesize materials at the atomic level to produce materials with desired properties and functions; (3) to take full advantage of other existing major user facilities, and (4) to develop experimental characterization techniques and theory/modeling/simulation tools necessary to drive the nanoscale revolution.

There are a large number of scientific challenges, all of which involve the collocation of disparate disciplines in order to fabricate and assemble nanosized components. One of the most challenging scientific problems is interfacing hard and soft matter, i.e., the world of electronic and structural materials with the world of biomaterials. These centers will employ advanced experimental and theoretical tools to tailor and control the functionality (e.g., detection ability and sensitivity), compatibility, performance, and integration of materials at such interfaces.

Funding Summary:

Dollars in Thousands

	FY 2005	FY 2006	FY 2007 Request
Construction:			
Other Project Costs	600	993	500
Project Engineering and Design	1,996	0	0
Center for Nanoscale Materials, ANL	12,000	14,000	0
Center for Nanophase Materials Sciences, ORNL	17,669	0	0
The Molecular Foundry, LBNL	31,828	9,510	257
Center for Integrated Nanotechnologies, SNL/LANL	30,650	4,580	247
Center for Functional Nanomaterials, BNL	18,317	36,187	18,864
Operation:			
Center for Nanoscale Materials, ANL	0	3,500	19,190
Center for Nanophase Materials Sciences, ORNL	0	17,800	19,190
The Molecular Foundry, LBNL	0	8,100	19,190
Center for Integrated Nanotechnologies, SNL/LANL	0	11,900	19,190
Center for Functional Nanomaterials, BNL	0	0	0
TOTAL	113,060	106,570	96,628

Projected Program Evolution:

The NSRCs are transitioning to standard user operations within the new facilities and with their initial suite of specialized technical equipment. The completion of this process will bring major new resources on-line for users, including nanoprobe beamlines at synchrotron radiation sources, extensive cleanroom facilities, nanoscale electron beam writers, and extensive nanomaterials synthesis and assembly capabilities. User programs will expand and adapt to respond to the needs of the community. The NSRCs are expected to perform as world-leading institutions, excelling both in scientific impact and productivity and in working with users.