Science for Discovery at the Ultrasmall

The Center for Functional Nanomaterials (CFN) at Brookhaven National Laboratory is one of five Nanoscale Science Research Centers built and supported by the Office of Basic Energy Sciences within the U.S. Department of Energy's Office of Science. This 94,500-square-foot user-oriented science facility will be a hub for cutting-edge nanoscience research and is expected to attract an estimated 300 scientists annually from the northeastern United States and other parts of the world.

Scientists analyzing images of nanoparticles

Achieving energy independence

Addressing the nation's energy needs is the primary scientific focus of the CFN. Breakthroughs in the effective use of renewable energy through improved energy conversion, transmission, and storage are key to overcoming our nation's reliance on imported fossil fuels and attaining energy independence.

The study and design of materials at the nanoscale— on the order of *billionths* of a meter — has the potential to address these significant challenges because nanomaterials have different chemical and physical properties than bulk materials. Understanding these properties will allow CFN scientists to tailor materials for specific uses. Some uses envisioned by scientists at Brookhaven's CFN include:

- nanostructured catalysts to improve the efficiency of fuel cells and manufacturing processes
- technologies based on biological molecules to enhance energy conversion and molecular self-assembly
- new electronic materials to improve solar energy conversion and storage devices.

Periodic array of enzymes interspersed with gold nanoparticles

A View of Brookhaven

Funded by the U.S. Department of Energy, Brookhaven National Laboratory is a multipurpose research institution located on a 5,300-acre site on Long Island, New York. The Laboratory operates large-scale scientific facilities and performs research in physics, chemistry, biology, medicine, applied science, and advanced technology.

In addition to Brookhaven's 2,600 scientists, engineers, and support staff, some 5,000 researchers from across the country and around the world come to the Laboratory each year to use its research facilities and collaborate with its scientific staff.

An aerial view of Brookhaven National Laboratory

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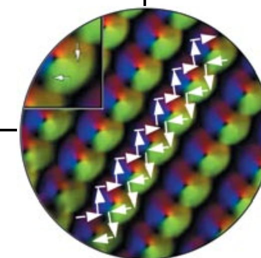
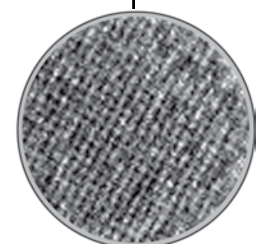
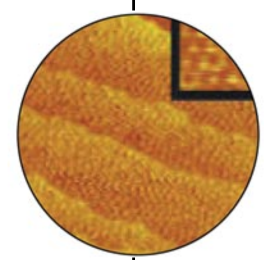
07/07

Center for Functional Nanomaterials

Brookhaven National Laboratory







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Nanoscience: Manipulating Materials At the Atomic Level

What is nanoscience?

Nanoscience is the synthesis and study of structures with atomic-scale sizes, or about a *billionth* of a meter (one nanometer = 0.000000001 meter). In contrast, the diameter of a human hair is approximately 80,000 nanometers.

Tools for nanoscience

Brookhaven Lab's Center for Functional Nanomaterials (CFN) provides scientists with state-of-the-art capabilities for fabricating and studying nanometer-scale functional materials. Facilities and tools include:

- chemical-vapor deposition for synthesis of nanomaterials
- advanced materials processing
- structural, optical, and electrical characterization
- clean rooms with class-100 clean areas and state-of-the-art instrumentation for device preparation
- optical, e-beam, and nanoimprint lithography systems
- scanning probe tunneling microscopies
- advanced surface and interface analysis
- confocal optical microscopy
- cw and ultrafast optical spectroscopy
- dedicated beamline at NSLS

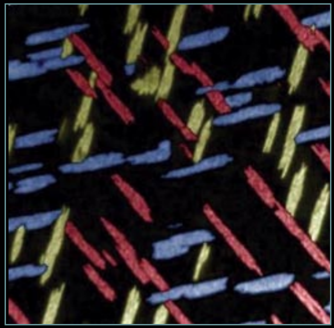
The CFN complements Brookhaven's other facilities and research programs aimed at developing sustainable, renewable energy, and builds on the Laboratory's long tradition of cross-disciplinary, synergistic research. The CFN is also complemented by other Brookhaven resources that enable the study of nanoscale structures:

National Synchrotron Light Source

- **National Synchrotron Light Source,** where intense light reveals the structure and function of a range of materials and specimens. A new synchrotron facility to be built adjacent to the CFN, dubbed NSLS-II, will be 10,000 times brighter than NSLS, enhancing scientists' capabilities.
- **Laser Electron Accelerator Facility,** where molecular charge transport is studied during certain chemical reactions.
- **Transmission Electron Microscopy Suite,** where the electronic, magnetic, and optical properties of materials are examined at the atomic level.

Main Nanoscience Project Areas at Brookhaven National Laboratory

Research at the Center for Functional Nanomaterials will focus on three key areas:



Ruthenium dioxide "nanoislands"

Nanocatalysis

Nanocatalysis uses tiny structures, a few nanometers in size, to speed up chemical reactions essential to modern life.

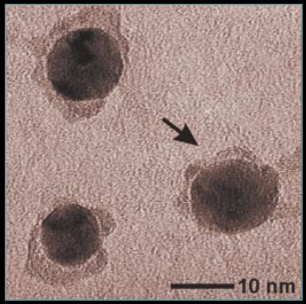
Metal-containing nanoparticles are indispensable ingredients in industrial chemical production and energy-related processes. For instance, fuel cells for powering electric vehicles use bi-metallic particles of platinum and ruthenium to catalyze the conversion of chemical energy into stored electrical energy.

These particles are less than 100 nanometers in size and make up only a few percent of the catalyst's weight, yet they provide the active sites where chemical reactions take place. CFN scientists are now developing new experimental and theoretical tools to image and understand chemical reactions activated by such nanoparticles.

Biological and Soft Nanomaterials

Soft nanomaterials include polymers, liquid crystals, and other relatively "squishy" materials that fall into a state between solid and liquid, whose properties can be engineered to replicate those of conventional "hard" materials, yet are lighter, transparent, cheaper, and, in some cases, biocompatible.

Of current interest is the development of methods that mimic nature to assemble hybrid nanosystems that combine inorganic and biological components that maintain biofunctionality. Such nano-engineered systems will find applications in advanced optical, magnetic, and electrical devices that require the placement of nanoobjects with high precision. To achieve this, scientists are developing novel ways to biofunctionalize nanoparticles and nanotubes with DNA and proteins.



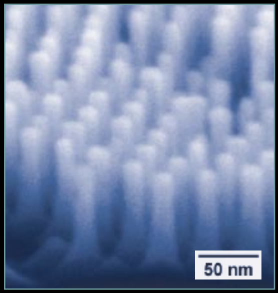
Gold nanoparticles with DNA shells

Using the advanced facilities available at the CFN, scientists are devising ways to use biomolecules as scaffolds, or "guides," to build two- or three-dimensional arrays of organized nanoobjects, and they are learning how cooperative effects among those objects can be exploited in applications.

Electronic Nanomaterials

At the nanoscale, materials can exhibit electrical and optical characteristics that are not present when they have macroscopic dimensions. For instance, the electronic mobility is enhanced drastically in certain nanomaterials, and, in others, their emission or absorption of light is improved significantly by their small size. These novel properties give electronic nanomaterials the potential for strongly impacting the performance of energy-conversion devices.

The CFN program emphasizes the preparation of nanomaterials and understanding of their optoelectronic properties to create both individual nanostructures and organized assemblies of them. Developing nanomaterial assemblies is important, for example, for use in large-area energy conversion devices.



Nanostructured silicon wire array

For more information on nanoscience at Brookhaven, go to www.cfn.bnl.gov