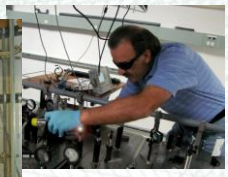
The Center for Nanophase Materials Sciences

cnms.ornl.gov

OVERVIEW

The Center for Nanophase Materials Sciences (CNMS), one of five Department of Energy (DOE) funded Nanoscale Science Research Centers (NSRCs), combines a vibrant research effort to understand and control the complexity of electronic, ionic, and molecular behavior at the nanoscale with a multidisciplinary user environment. It provides peer-reviewed access to equipment, capabilities and expertise in a broad range of nanoscience areas. Precision synthesis, nano-fabrication, advanced imaging techniques, functional characterization, and theoretical tools are applied to a broad range of user projects as well as to the CNMS' in-house research.

The work at the CNMS ties closely to neutron science capabilities at ORNL, with about one-sixth of CNMS users also accessing either the Spallation Neutron Source or the High Flux Isotope Reactor. CNMS's Nanomaterials Theory Institute provides users with expertise in modeling and simulation and ties closely to ORNL's capabilities in high-performance computing (ORNL's Leadership Computing Facility and the National Center for Computational Sciences). The CNMS hosts around 600 unique users per year, with nearly 60% coming from U.S. universities. Depending on the scope of work, users spend as little as a few days to as much as several months at the CNMS.



In concert with its joint mission to deliver both user support and an outstanding science program, the CNMS has built **three distinguished research themes**:

Electronic and Ionic Functionality on the Nanoscale

- Developing instrumentation and techniques to image and understand the functionality of nanoscale materials and interacting assemblies
- Research on optoelectronic, ferroelectric, ionic and electronic transport, and catalytic phenomena at the nanoscale
- Understanding energy transfer at nanoscale interfaces

Functional Polymer and Hybrid Architectures

- Advancing our fundamental understanding of the links between polymer structure, property and function that are controlled by weak intermolecular interactions and interfacial phenomena
- Understanding the role of macromolecular topology in self-assembly
- Understanding how the optoelectronic properties of conjugated material architectures and hybrid systems are determined by their structure

Collective Phenomena in Nanophases

- Builds on strong theoretical and experimental efforts focusing on understanding the emergence and ramifications of collective behavior
- Developing and applying multiscale methods to understand and predict how atomic structure, nanoscale confinement, and quantum mechanical effects impact electronic processes/properties within materials and across interfaces
- Understanding reactivity and chemical transport in crowded and confined environments to enable nanostructured systems with capabilities rivaling those of living systems

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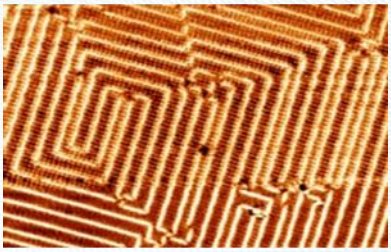
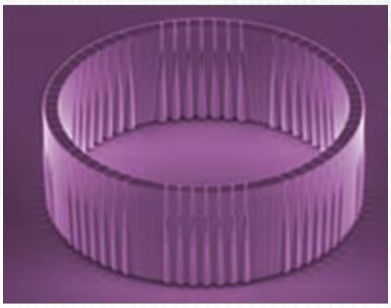
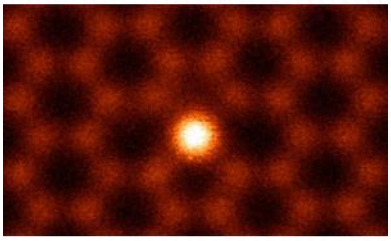
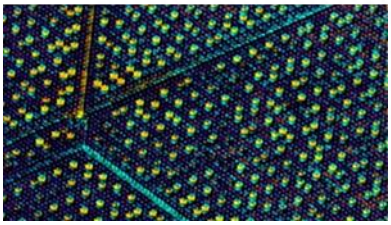
RESEARCH CAPABILITIES









The main CNMS facility is located on the Chestnut Ridge Campus of ORNL, adjacent to the Spallation Neutron Source, while some microscopy and atom-probe tomography instruments are located on the main ORNL campus. The CNMS is equipped with a wide range of specialized tools for synthesis, characterization, and fabrication of novel nanoscale materials and assemblies, including the integration of hard and soft materials. CNMS encompasses expertise and instrumentation for user research in a broad range of disciplines selected to address forefront research in nanoscience and nanotechnology.

- **Imaging, Microscopy, and Nanoscale Characterization**: Scanning probe microscopy for imaging and dynamics in nanostructures including ionic and electronic transport, electromechanics, energetics, magnetic domains, chemical reactions, and electronic, structural and spin phases and transitions. Sub-Ångstrom electron microscopy and spectroscopy, soft-matter TEM, and atom-probe and electron tomographies.
- **Nanomaterials Theory Institute**: Multiscale modeling, nanomaterials design, virtual synthesis and characterization using high performance computing capabilities to establish and enhance links with experiments and to aid understanding, prediction, and exploration.
- **Nanofabrication Research Laboratory**: Controlled synthesis and directed assembly of nanomaterials in a Class 1000 cleanroom environment; chemical and biological functionalization of nanoscale materials.
- **Nanomaterials Synthesis and Functional Assembly (Polymers)**: Synthesis and molecular level characterization of small molecule building blocks, polymers, and polymer-modified interfaces, including biologically inspired systems, deuterated molecules and polymers for neutron scattering studies.
- **Nanomaterials Synthesis and Functional Assembly (Optoelectronics)**: Specialized laser and CVD synthesis of carbon nanomaterials, oxide heterostructures, nanoparticles, and organic nanowires with real-time diagnostics. Processing, electronic/optical measurements, and environmental testing of oxide electronics and organic optoelectronics over multiple length scales.
- **Nanomaterials Synthesis and Functional Assembly (Catalysis)**: Template- and surfactant-mediated synthesis of functional, nanostructured oxides and carbons; catalysis characterization; non-ambient and dynamic x-ray characterization and elemental analysis; battery characterization; multi-wavelength Raman scattering.

Many user projects take advantage of multiple capabilities in tackling research to understand complex nanoscale phenomena. The Nanomaterials Theory Institute provides collaborative workspaces, visualization equipment, and high-speed connections to the ultrascale computing facilities of the National Center for Computational Sciences. The intense neutron beams from the Spallation Neutron Source and from the High Flux Isotope Reactor afford unique and expanding opportunities for fundamental studies of the structure and dynamics of nanomaterials.

User Program

The CNMS user program provides access to equipment and technical expertise for nanoscale research that defines the state of the art. The program is open to users from academia, the private sector, and research institutes worldwide. Users join a vibrant research community that brings together ORNL research staff, technical support staff, students, postdoctoral fellows, and collaborating guest scientists. The program accommodates both short-term and long-term collaborative research partners. Access is obtained through a brief peer-reviewed proposal with no charge for users who intend to publish their results. Access is available on a cost-recovery basis for research that is not intended for publication. Prospective users are encouraged to consult CNMS staff to learn more about the Center's science and capabilities.