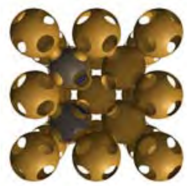
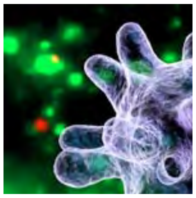
Nanoscience at EMSL

At EMSL, **nanoscience and nanotechnology play a critical, crosscutting role in our mission** to integrate experimental and computational resources for innovations that support the U.S. Department of Energy (DOE) and the nation. As a national scientific user facility located at Pacific Northwest National Laboratory (PNNL), the Environmental Molecular Sciences Laboratory (EMSL) provides wide-ranging, integrated capabilities with various applications in nanoscience and nanotechnology. Along with in-house staff expertise, these tools are available to the scientific community for the design, synthesis, characterization, and application of novel nanomaterials, and to measure the characteristics and properties of nanoparticles. At EMSL, we don't pursue nanoscience for its own sake. Rather, we recognize that "doing the little things right" at a fundamental level is tied closely to achieving the solutions our society needs most, especially those related to the environmental and energy challenges of our time. Below are a few examples of nanoscience research at EMSL and the societal benefits these projects are working to deliver.



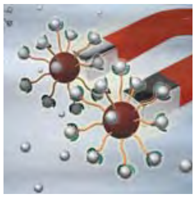
ALTERNATIVE ENERGY

Effective catalysts are vital to pollution prevention and clean energy production. The nanoscale structure of metal and oxide catalysts frequently determines their behavior, and EMSL users and scientists are involved in many fundamental and applied aspects of catalysis. One example is the design of nanoscale structures that prevent catalyst particle sintering, an important scientific and technical challenge. PNNL researchers have used EMSL capabilities to intricately study a new cubic mesostructured silica catalyst support that uses its cage-like 3-D structure to protect metal and metal oxide nanoparticles from sintering during heating. Using electron microscopy resources at EMSL, the team of scientists not only demonstrated the effectiveness of these "nanocages," but in the process also developed a class of regenerable metal catalysts that remove unwanted sulfur from syngas fuel. Optimizing efficient catalysts leads to enhanced, less costly removal of pollutants during chemical manufacturing, energy production, and automobile use.



CELLULAR HEALTH

EMSL's extensive microscopy and biology resources allow scientists to explore the cellular interactions of nanoparticles at the molecular level. Recently, a team of EMSL and PNNL scientists focused on identifying the underlying mechanisms that govern these interactions. Using EMSL's time-lapse single-molecule fluorescence microscopy capability, the team studied amorphous silica nanoparticles in macrophages (an important part of the human immune system). The high-sensitivity microscope allows researchers to track individual nanoparticles in real time as they enter and interact with the living cell to better understand their ultimate fate and impact on the cell. With a greater understanding of the cellular interactions and responses to nanoparticles, government agencies and scientific associations can set realistic standards for how these particles can be used, safeguarding human health and the environment while speeding innovations in energy, medicine, and materials sciences.



ENVIRONMENTAL CLEANUP

EMSL scientists and collaborators are engaged in synthesizing novel nanoparticles that can help mitigate the threats posed by environmental contaminants. For example, using magnetic sorbent materials to overcome limitations posed by traditional heavy-metal remediation methods may become an important part of an advanced method to eliminate toxic heavy metals from aquatic systems and drinking water. In a progressive research effort, scientists from PNNL, the University of Washington, and Oregon Health & Science University produced a novel approach showcasing a viable, relatively simple method for engineering high-performance, superparamagnetic, iron oxide nanoparticles functionalized to serve as heavy-metal sorbents. Magnetically manipulating sorbent materials and tuning the affinity toward a variety of analytes could provide a rapid, easy, and cost-effective water purification system. In addition, heavy-metal removal methods could improve large-scale water remediation.

CLIMATE CHANGE

The chemistry of nanosized atmospheric aerosol particles holds implications that could prove critical in addressing climate change. During a June 2010 field campaign in California's Sacramento Valley, several EMSL instruments were put to work—aboard aircraft and on the ground—examining the intricacies of these particles. This work was part of the Carbonaceous Aerosols and Radiative Effects Study (CARES), a major collaborative effort to improve climate models coordinated through DOE's Atmospheric Radiation Measurement Climate Research Facility. The month-long campaign employed the single particle mass spectrometer known as SPLAT II, an EMSL-developed instrument that simultaneously measures the number concentration, size, composition, density, shape, morphology, fractal dimension, and hygroscopic properties of individual particles as small as 50 nanometers in diameter. For its multi-dimensional characterization of nanoparticles, SPLAT II is making high-impact contributions to climate-related studies, as well as various other applications, including emerging nanotechnologies.

Read more EMSL science highlights at **www.emsl.pnl.gov**.

See the reverse side for a look at EMSL tools that are moving nanoscience forward.

EMSL's suite of world-class capabilities enables the design, characterization, property measurement, and computational modeling of nanomaterials. Resources include high-resolution microscopies, a variety of optical and electron spectroscopies, several surface and interface characterization methods, and an assortment of computational tools that can be used on our supercomputer. Staff expertise is a strength and passion at EMSL: we assist users in the technically challenging work of applying these state-of-the-art tools to nanomaterials. Highlighted below are several exciting new additions provided by Recovery Act funding, as well as additional instruments frequently applied to nanoscience. Like all of EMSL's resources, these tools are available at no cost to the scientific community—from academia to industry—for open research through EMSL's many proposal opportunities: **www.emsl.pnl.gov/access**.

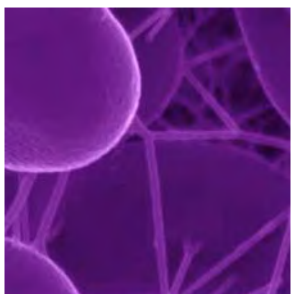
A LEAP FORWARD

Atom probe tomography unveils new nano details

EMSL scientists have recently brought online the LEAP® 4000 XHR local electrode atom probe, a $2.25 million atom probe tomography instrument that will enable the first-ever comprehensive and accurate 3-D chemical imaging studies of low electrical conductivity materials such as ceramics, semiconductors, and oxides. The implications could lead to advances in materials science, ceramics, metallurgy, geochemistry, and biomineralization. EMSL scientists are using the LEAP to explore new ways to apply the method to detailed analysis of nanoparticle coatings.

MOVING IN FOR A CLOSE-UP

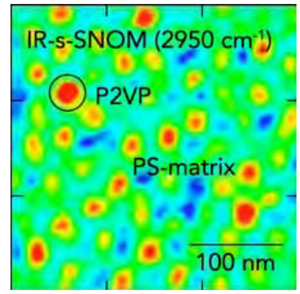
Helium ion microscope (HIM) offers high-resolution (0.35 nm) imaging and chemical analysis with He^+ ion probe



EMSL's new $2 million ORION® PLUS HIM is only the third helium ion microscope operating in the United States, and the first expected to conduct variable sample testing that crosses multiple scientific areas—it is also the first openly available to scientific users around the country. HIM can provide 3-D chemical analysis with near-atomic-level resolution. Features unique to HIM allow a high depth of field and ease of application to insulating materials, making it particularly relevant for the examination of complex, insulating nanostructured and biological materials.

PARTNERING FOR NANOSPECTROSCOPY

EMSL and the University of Washington collaborate on new infrared chemical nano-imaging and spectroscopy capability



Adding the first environmental, tunable, infrared scattering-type scanning near-field optical microscope represents a significant expansion of EMSL's chemical surface and nanostructure characterization capabilities. The instrumentation allows for infrared vibrational spectroscopy and imaging with nanometer-scale spatial resolution and molecular chemical specificity, with applications in biomembranes, organic photovoltaics, heterogeneous catalysts, biomineralization, fuel cells, and more.

REVOLUTIONARY IMAGING

Scanning/transmission electron microscopy (S/TEM)

In a major addition to one of EMSL's most requested capabilities, this new aberration corrected TEM provides physical and electronic structure and chemical state information for nanostructured materials. These high-resolution images yield important understanding of geochemical, biogeochemical, and catalytic processes. In addition, the S/TEM allows scientists to see critical information about the structure and composition of buried interfaces and microstructures of new materials designed for energy production and storage.

Other EMSL capabilities commonly applied to nanomaterials:

- Dual Beam focused ion and scanning electron microscopy
- Atomic force and scanning probe microscopy
- Time-of-flight secondary ion mass spectrometry
- X-ray photoelectron spectroscopy
- X-ray diffraction (microbeam and conventional)
- Energetic ion analysis (Rutherford backscattering spectroscopy, nuclear reaction analysis)
- Stochastic optical reconstruction microscopy
- Single-particle mass spectrometry
- Energetic ion analysis
- Confocal, multi-photon/FLIM integrated microscopy
- Nuclear magnetic resonance spectrometry

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