Microscopy

EMSL offers technologically sophisticated microscopy instruments capable of imaging a variety of sample types with nanoscale, and even atomic-scale, resolution. All instruments in EMSL's Microscopy Capability Group are selected in keeping with EMSL's goals to study systems in their native environments, analyze dynamic processes in real time, and characterize surfaces and interfaces with unprecedented resolution as well as support research that integrates both experimental and computational tools. Microscopy tools enable novel, fundamental research in EMSL's Science Themes of Biological Interactions and Dynamics, Geochemistry/Biogeochemistry and Subsurface Science, and Science of Interfacial Phenomena. Specific research topics include:

- **Biology**—characterizing cell membrane proteins, protein and biomolecule surface structures, and protein-protein interactions such as those involved in cell signaling, using standard and customized techniques, including an integrated nuclear magnetic resonance (NMR)-confocal system that enables *in situ* studies of microbial biofilms
- **Environmental research**—identifying the composition of non-volatile samples of atmospheric particles and the hydration properties of environmental particles, as well as revealing the structure, composition, and reaction kinetics of geological/biogeochemical samples at the nanoscale
- **Surface science**—studying nanoscale chemical processes, such as interfacial electron transfer, and imaging surfaces with energy and catalysis applications, including organic thin film devices, soft materials, and polymers.

CAPABILITY DETAIL

EMSL offers scientific users:

- A helium ion microscope (HIM) for fine structure visualization, chemical identification of native-state samples, and imaging of low Z elements
- Local electrode atom probe tomography for 3-D chemical imaging studies of low electrical conductivity materials
- Field emission and aberration-corrected scanning/transmission electron microscopy (S/TEM) with electron energy loss spectroscopy (EELS) capability
- An environmental TEM that combines TEM/STEM and enables high-resolution imaging of dynamic processes
- Low-temperature ultrahigh vacuum scanning probe microscopy to enable *in situ* observation of surface diffusion and reaction kinetics on model surfaces
- Environmental SEM for characterization of aerosol particles
- Scanning electron microscopes with focused ion beam for nanolithograph and sample preparation capabilities
- Integrated microscopy tools, such as NMR-confocal microscopy
- Scanning near-field optical microscope that enables nanoscale imaging of surfaces for infrared spectroscopic molecular signatures.

WHY MICROSCOPY AT EMSL?

- As part of an unmatched collection of microscopy tools, EMSL offers the only HIM at a national scientific user facility.
- EMSL's microscopy suite affords comprehensive, complementary sample imaging and analysis using standard and customized tools. For example, EMSL's HIM is equipped with Rutherford backscattering analysis capability.
- Microscopy tools and techniques at EMSL cater to well-established as well as emerging and specialty science areas, such as radiological sample and high-resolution chemical imaging.
- Dedicated microscopy experts with experience studying an unprecedented variety of samples pertaining to the work of researchers from all over the world are available to collaborate with EMSL users and assist with data analysis.

ABOUT EMSL

EMSL, a U.S. Department of Energy national scientific user facility located at Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation.

EMSL's distinctive focus on integrating computational and experimental capabilities as well as collaborating among disciplines yields a strong, synergistic scientific environment. Bringing together experts and an unparalleled collection of state-of-the-art instruments under one roof, EMSL has helped thousands of researchers use a multidisciplinary, collaborative approach to solve some of the most important and complex national scientific challenges in energy and environmental sciences.

To learn more about EMSL, the science conducted at EMSL, as well as the instruments and expertise available to users, visit www.emsl.pnnl.gov.

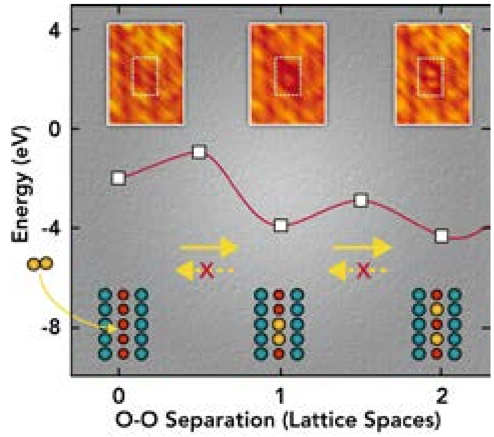
BECOME AN EMSL USER

Researchers are invited to access the world-class capabilities and collaborate with the internationally recognized experts at EMSL via its peer-reviewed proposal process. To submit a proposal, follow the five steps outlined on the EMSL website (www.emsl.pnnl.gov) under User Access. Current and potential EMSL users are encouraged to respond to Calls for Proposals, which are announced each spring. However, unique research proposals that fall outside the Calls for Proposal focus may be submitted at any time.

Applicants are encouraged to submit proposals for use of EMSL's capabilities with an emphasis on integrating computational and experimental tools. In general, most users whose open research proposals are accepted may use EMSL resources free of charge. Open research is loosely defined as science and engineering research for which the resulting information is published and shared broadly within the scientific community.

MICROSCOPY RESEARCH HIGHLIGHTS

Vacancies Needed

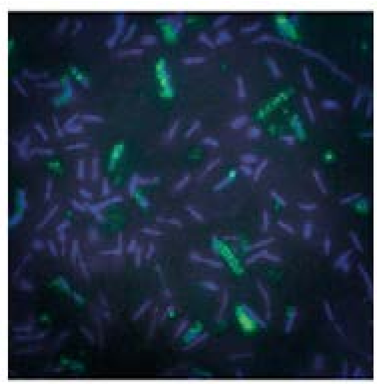


Using EMSL's UHV scanning tunneling microscope and computational capabilities at EMSL and NERSCC, researchers determined that electrons from the surface of titanium dioxide, rather than electrons from within the catalyst, play a critical role in the reaction between molecular oxygen and TiO_2. Upon reacting with TiO_2, O_2 breaks apart into elemental oxygen, borrowing electrons from the catalyst surface, thus leaving vacancies. The charged oxygens, or adatoms, then bind to titanium atoms on the catalyst only to quickly move further from one another on the surface. Such fundamental research offers insights into the interactions of small molecules with oxide surfaces and into how those reactions may be controlled for applications such as converting biomass to fuels, treating waste, and purifying water.

EMSL users: Pacific Northwest National Laboratory

Du *et al*. 2010 *PCCP* 112(7):2649–2653.

Rapid Transfer



Integrating microscopic, spectroscopic, and biochemical techniques led an EMSL research team to gain significant insights into the fundamental earth-life interaction of electron exchange at the mineral-microbe interface. The team showed that the outer-membrane cytochromes, MtrC and OmcA, of the metal-reducing bacterium *Shewanella oneidensis* MR-1 are key to reducing and transforming ferrihydrite. Moreover, both cytochromes undergo rapid electron exchange with ferrihydrite *in vitro*, and MtrC displays faster transfer rates than OmcA. Such studies allow a deeper understanding of the environmentally relevant effects of mineral-microbe electron exchange on contaminant migration, water quality, soil fertility, and trace metal availability.

EMSL users: Pacific Northwest National Laboratory; the University of Wisconsin, Milwaukee; and the University of Guelph

Reardon *et al*. 2010 *Geobiology* 8(1):56-68.

SCOTT LEA, PH.D.
Electron, Aerosols
Scott.Lea@pnnl.gov
509-371-6242

MARK BOWDEN
Mark.Bowden@pnnl.gov
509-371-7816

NANCY WASHTON
Nancy.Washton@pnnl.gov
509-371-7094

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

U.S. DEPARTMENT OF ENERGY

PNNL-SA-74136