Chemical Imaging
at the Nanometer Scale

DELIVERING NEW CAPABILITIES FOR IN SITU, NANOMETER-SCALE IMAGING

The majority of microbes in natural and engineered environments live within structured communities or biofilms (seen here using confocal laser scanning microscopy). Biofilms include a poorly characterized organic matrix, termed extracellular polymeric substance (EPS), which facilitates certain biogeochemical reactions. We are enhancing visualization, compositional analysis, and functional characterization of EPS to better understand its influence on subsurface reactions vital to environmental and energy issues.

Having a complete, precise, and realistic view of the molecular interactions that occur in chemical, materials, and biochemical processes is vital to exponential scientific progress and to solving the nation’s energy, environmental, and security issues. Numerous U.S. government-sponsored reports have identified imaging as critical for scientific advancement. However, current instrumentation cannot reach the needed level of clarity, leaving scientists to infer what is occurring from secondary sources and mathematical models.

At Pacific Northwest National Laboratory, the Chemical Imaging Initiative is developing a suite of unique tools with nanometer-scale resolution and element specificity that will allow scientists to go from model system observation to real-world manipulation on a molecular level. These real-time, in situ tools will be achieved through near-nanometer in-house imaging, nanoscale molecular imaging, and multimodal analysis and integration framework for chemical imaging.
To obtain the instruments necessary for a nanoscale view of molecules and molecular interactions, the Chemical Imaging Initiative, which began in October 2010, consists of interdisciplinary teams of scientific and technological leaders. These leaders include experts in atmospheric sciences, biology, chemical physics, chemistry, computational frameworks, imaging and scientific instrumentation, and materials sciences, to name a few. These teams are working on projects in three key thrust areas:

**Near-Nanometer In-House Imaging:** Combine microscopies to understand chemical and biological mechanisms.

We are coupling *in situ* electron microscopes, mass spectrometers, scanning probe microscopes, high-resolution vibrational spectrometers, and atom probe tomography together or with light-source capabilities to image materials of importance to the nation’s energy and environmental issues.

**Nanoscale Molecular Imaging:** Develop probes for three-dimensional tomographic, structural, and element-specific interrogation at the molecular level. We are coupling light-source-based x-ray and vacuum ultraviolet probes with laboratory-based imaging capabilities. Use of these new techniques, for example, could provide an atomic-resolution, *in situ* “movie” of a functioning photocatalyst or clear characterizations of nanoporous materials and their active sites for batteries and biomolecules.

**CURRENTLY FUNDED PROJECTS IN THE CHEMICAL IMAGING INITIATIVE**

**Near-Nanometer In-House Imaging**

- Site-Specific Atomic Resolution Probing of Structure-Property Relationship under Dynamic and/or *Operando* Conditions using *In Situ* and *Ex Situ* Chemical Imaging Based on Multi-Instrument Approach.
  **Principal Investigator:** Dr. Chongmin Wang

- Development of New Soft Ionization Mass Spectrometry Approaches for Spatial Imaging of Complex Chemical and Biological Systems.
  **Principal Investigator:** Dr. Julia Laskin

- Facet-Specific Chemistry of Nanoscale Crystalline Alumina Using an Enhanced Scattering Infrared Scanning Near-Field Optical Microscopy Instrument.
  **Principal Investigator:** Dr. Scott Lea

**Nanoscale Molecular Imaging**

- Correlative High-Resolution Imaging and Spectroscopy to Characterize the Structure and Biogeochemical Function of Microbial Biofilms.
  **Principal Investigator:** Dr. Matthew Marshall

- Integrated Nanoscale Imaging for Investigating Applications and Implications of Nanomaterials.
  **Principal Investigator:** Dr. Galya Orr

- Chemical Imaging Analysis of Environmental Particles.
  **Principal Investigator:** Dr. Alexander Laskin

**Multimodal Analysis and Integration Framework for Chemical Imaging**

- A Multimodal Integration Framework for Chemical Imaging.
  **Principal Investigator:** Dr. Kerstin Kleese van Dam

For more information, please contact:

Dr. Lou Terminello  
Pacific Northwest National Laboratory  
P.O. Box 999, MSIN K9-80  
Richland, WA 99352  
(509) 371-6790  
louis.terminello@pnl.gov  
www.pnl.gov

Scientists are probing the electronic structure of catalyst and energy materials. For example, one project is exploring, in part, the microstructural evolution of SnO₂ anode upon initial charging.

**ABOUT PNNL**

Pacific Northwest National Laboratory, a U.S. Department of Energy Office of Science laboratory, solves complex problems in energy, the environment, and national security by advancing the understanding of science. PNNL employs more than 4,900 staff, has a business volume exceeding $1.1 billion, and has been managed by Ohio-based Battelle since the Lab’s inception in 1965.