Environmental Science Research Facilities at Synchrotron Light Sources

Each of the four major synchrotron user facilities has its own strengths and specialized capabilities for conducting environmental research. For information on incorporating these capabilities into your research program contact the OBER representative or consult the laboratory web pages.

The Advanced Light Source

http://esd.lbl.gov/ALS_environmental/index.html

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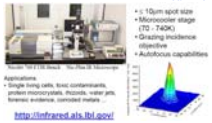
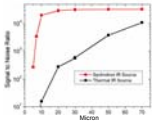
Environmental Science Program

Infrared Spectromicroscopy (IR)

Beamline 1.4.3



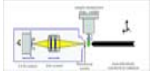
The use of a commercially available IR microscope makes beamline operations very user friendly.



The advantage of synchrotron IR comes from the dramatically increased flux at lower spot sizes.

Microtomography

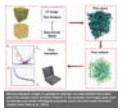
Beamline 8.3.2



- Experiment consists of illuminating the sample with a normally parallel beam and recording a projection using a 2-D detector (CCD)
- The 3-D optical density is reconstructed by calculation using fairly standard algorithms

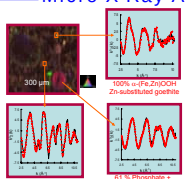
Beamline 8.3.2 allows for collection of three dimensional images of solids with a few micron resolution.

Images can be collected below and above the absorption edge for a single element in order to increase element specific resolution.



Micro X-Ray Absorption Spectroscopy

Beamline 10.3.2



What is the proportion of each Zn species in the bulk soil ?

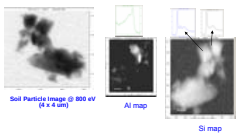
Beamline 10.3.2 provides for the rapid collection of X-ray fluorescence maps and point X-ray absorption and powder diffraction data with 5μm spatial resolution.

Energy range from 2.5keV (Sulfur) to 17keV (Uranium)

Scanning transmission X-ray microscopy (STXM), X-ray photoelectron spectroscopy (XPS), and NEXAFS

Beamline 11.0.2

STXM can be used to obtain images with tens of nanometers resolution. By taking images of the same particle at difference X-ray energies absorption spectra (NEXAFS) can be obtained for given elements.



Beamline 11.0.2 also has a spectroscopy end station that can be used to obtain XPS spectra at ambient pressures as well as NEXAFS spectra of solids and solutions

Advanced Photon Source

http://www.aps.anl.gov

Bruce Ravel

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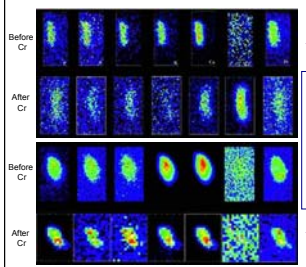
Three sectors – MRCAT (10), GSECARS (13), PNC (20) – devote much of their scientific effort to environmental science.

X-ray microscopy

Beam line 2ID-D



Planktonic cells

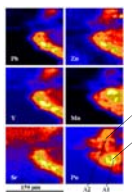
We can measure hard x-ray fluorescence with 150 nm spatial resolution to obtain elemental maps and quantitative chemical analyses of single planktonic and adhered cells of *Pseudomonas fluorescens* before and after addition of chromium. We see differences between the planktonic and adhered cells with regard to morphology, elemental composition, and their sensitivity to Cr(VI).

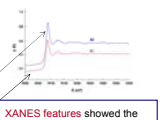
Adhered cells

Micro-spectroscopy

Beam line 13BM

We can combine imaging with 5-10 μ resolution with spectroscopy. XANES mapping can be done to provide a speciation map or EXAFS mapping can provide detailed structural maps.



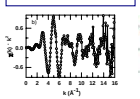


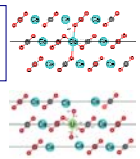
XANES features showed the Pu to be in either Pu^{4+} or Pu^{5+} (or a mixture of the 2) but not Pu^{6+}.

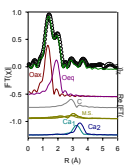
Absorption spectroscopy

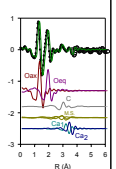
Beam line 10ID

We can analyze the extended XAS spectrum for *detailed* information about local structural environments.









NSLS

National Synchrotron Light Source

http://www.nsls.bnl.gov/

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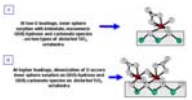
EnviroSuite Program

X-ray Absorption Spectroscopy

X-ray Absorption Spectroscopy yields average chemical state information for a solid or solution samples of a few grams.

Ideal for characterization of samples containing relatively few components or for quantification the various components identified using micro-techniques



Uranium binds to TiO_6 surfaces differently at different high and low surface loadings.

Low-energy XAS

Suited for analysis of Phosphorous or Sulfur containing samples.

Energy Range 2-5KeV

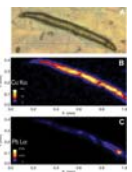
Hard X-ray Microprobes

Copper and Lead Distribution in Nematodes

Capabilities include
Imaging
Tomography
μ-XANES
μ-EXAFS
Microdiffraction

Optical (A) and XRF (B and C) images of a nematode exposed to both copper (B) and lead (C).

Lead rich area was identified as pyromorphite by microdiffraction



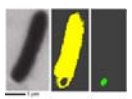
X-ray spot size of 10 μm x 15 μm

http://www.nsls.bnl.gov/newsroom/science/2005/08-Jackson.htm

Soft X-ray Analysis

Scanning Transmission X-ray Microscopy (STXM)

Energy Range 250-800 eV
Includes Elements C, O, and N



STXM image of Clostridium sp. showing spore formation process in progress. The green region was identified by comparing the carbon spectra from different regions of the cell.

http://www.bnl.gov/bnlweb/pubaff/pr/PR_display.asp?prID=05-77

Infrared microscopy/spectroscopy

Experimental End station #1 (U10B):
Spectrometer end station: Nicolet Magna 860 Step-Scan FTIR and Spectra Tech Continuum IR microscope
Frequency Range (cm-1): 500 - 4000
Spectral resolution (cm-1): 2.0
Spatial resolution: diffraction-limit (i.e. ~ 3 to 10 microns)
Brightness (compared to a black body): 100x to 1000x
Smallest practical targeting aperture size: 2 microns square
Beamline angular acceptance: (milliradians): 40H x 40V (100% vertical collection down to 240 cm-1)

Lab Facilities

Radioactive sample preparations facilities
Beam time access through the general User Program
Information at: www.nsls.bnl.gov

Stanford Synchrotron Radiation Laboratory

A national user facility for academia, industry, and national laboratories

http://www-ssrl.slac.stanford.edu/

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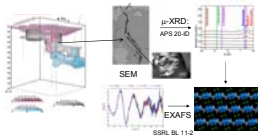
Facility Highlights

Environmental Sciences Beam Station

(BL 11-2) High-flux wiggle, 5 – 40 KeV XAS
Radioactive sample facility
Grazing-incidence EXAFS, XSW, Reflectivity

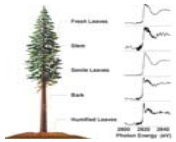
BX-102 Slant Bore Hole

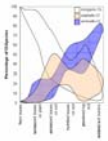


What is the speciation of uranium in the contaminated vadose zone? Is it adsorbed onto mineral surfaces or precipitated as a solid phase?

Sulfur, Chlorine, Phosphorous Spectroscopy

BL 6-2 –High-flux wiggler, 2.1 - 17 KeV XAS
• Low-energy sample chamber





Hard X-ray Actinide Microprobe

BL 2-3, 5 – 23 KeV
Optimized for U – Tc XAS, XRD, XRF
2 μm spot
Commissioning in 2006

Instrumentation and Facilities

Sample Preparation Labs
- Centrifuges, Anaerobic chamber, fume hoods, balances, shakers, etc.
- Located near beam lines

High-resolution fluorescence crystal analyzer for XAS

Grazing-incidence spectrometer