TENDER-ENERGY X-RAY ABSORPTION SPECTROSCOPY AND IMAGING (TES)

BROOKHAVEN NATIONAL LABORATORY

NATIONAL SYNCHROTRON LIGHT SOURCE II

SCIENTIFIC SCOPE

TES is a beamline for spatially resolved and *in-situ* X-ray absorption spectroscopy and imaging of heterogeneous or structured materials in a wide range of scientific fields. Optimized for the "tender" energy range from 1-5 keV (reaching up to 8 keV) in a helium (non-vacuum) environment, TES offers microbeam EXAFS and X-ray fluorescence imaging (for materials, geo/environmental, planetary, biological and climate sciences) and *in-situ* and *operando* electrochemistry (fuel-cell, battery, catalysis). Fast on-the-fly scanning of the stage and monochromator enables rapid imaging and XAS of dynamic systems.

BEAMLINE CHARACTERISTICS

TECHNIQUES:

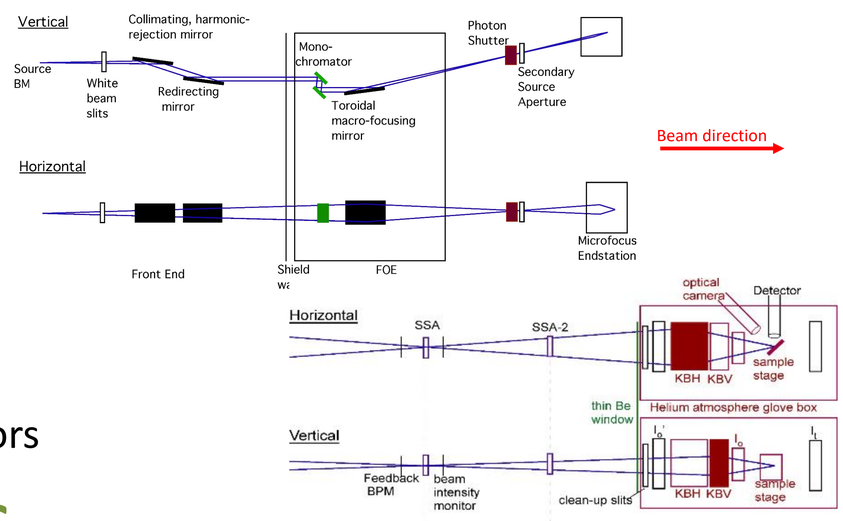
- Scanning X-ray fluorescence imaging with a user-defined beam size from approximately 1 to 100 μm and over an energy range of 2-8 keV (1-2 keV still being commissioned).
- Microbeam X-ray absorption spectroscopy (XANES and EXAFS) with beam size approximately 1 to 100 μm and energy range 2-8 keV (1-2 keV still being commissioned).
- *In-situ/operando* electrochemistry for battery and fuel-cell measurements (room temperature).

ENDSTATION DETAILS:

- Helium atmosphere
- Achromatic KB mirror optics
- Tandem Ge and Si fluorescence detectors

TES at NSLS-II:

- Enables micron-scale **spatially-resolved** and ***in-situ*** studies of speciation and local structure by XAS, X-ray fluorescence and spectroscopic imaging, in a helium *non-vacuum environment*
- Chemical sensitivity to **key lighter elements** Mg through Ti, and advantageous heavier-element L and M edges such as Zr, Cd, Pd, U.

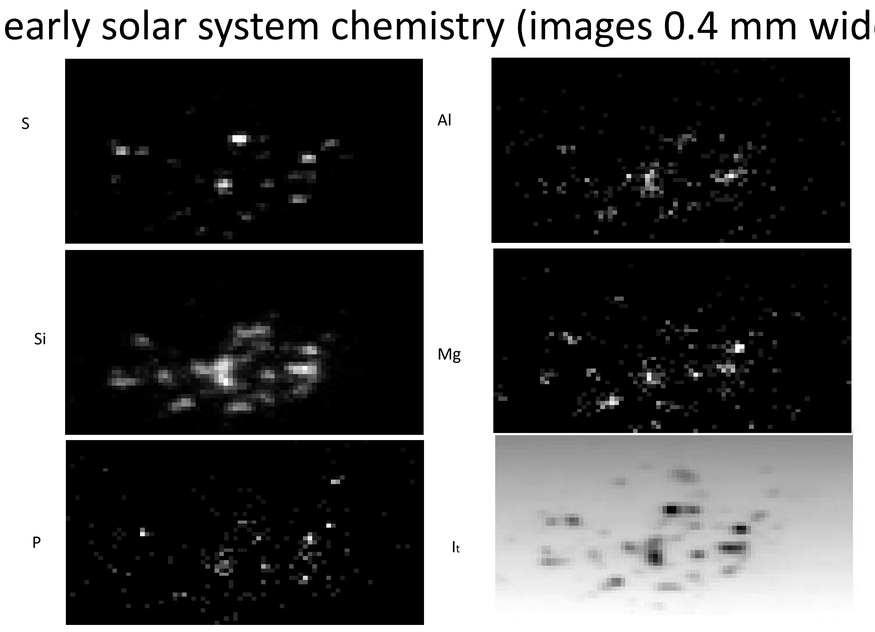


SCIENTIFIC APPLICATIONS

- **Energy Materials**: Photovoltaic, fuel-cell, superconducting and battery (nano)materials.
- **Catalysis**: Materials (zeolites, thin films, nanomaterials), reactions and intermediates, poisoning of catalysts.
- **Environmental Science**: Redox and biogeochemical processes, contaminant behavior and remediation.
- **Climate**: Terrestrial/marine C cycling, ocean chemistry, carbonate (bio)mineralization, geologic record of climate change.
- **Earth & Planetary science**: NASA return mission samples, interplanetary dust particles, high-pressure phases.
- **Sustainability**: Nutrient (P, S, K, Ca, Mg, Fe) cycling, transport and bioavailability, biofuel/biomass productivity, poor or highly-leached tropical soils.
- **Biology**: light-element chemistry at cellular and micron scales.

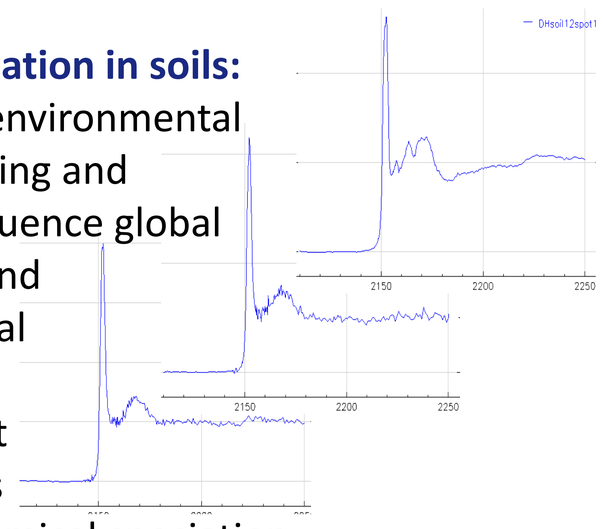
Interplanetary Dust Particles:

Highly heterogeneous aggregates representing early solar system chemistry (images 0.4 mm wide).



Phosphorus speciation in soils:

Key nutrient but environmental contaminant: cycling and bioavailability influence global photosynthesis, and biofuel/agricultural productivity and sustainability. But behavior depends on microscale chemical speciation – bulk analyses are not representative.



Overview

PORT: 8-BM

SOURCE: Dipole Bend Magnet

ENERGY RANGE: 1-8 keV (optimized 2-5)

ENERGY RESOLUTION: $\Delta E/E = 10^{-4}$

SPATIAL RESOLUTION: ~1-100 μm (user-tunable)

BEAMLINE STATUS: Open to users

BEAMLINE PHONE: 631.344.1808

BEAMLINE WEBSITE: www.bnl.gov/nsls2/beamline/8-BM

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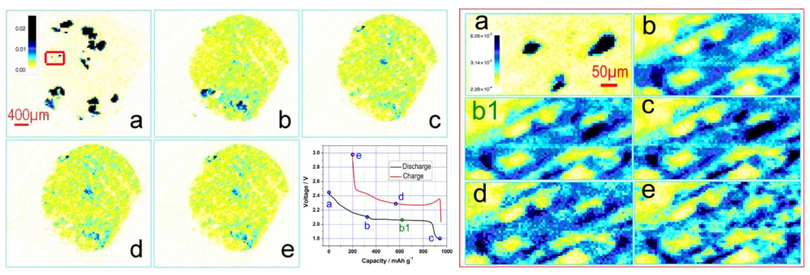
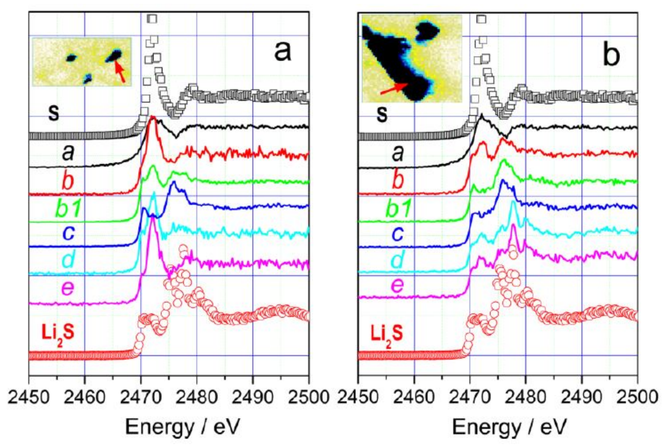
Apply for Beam Time

Beamlines at NSLS-II are available to all scientific researchers through a peer-review proposal process. For more information, see the NSLS-II Users' Guide at:

www.bnl.gov/ps/userguide/

Operando Battery research: S micro-XAS:

Using rapid on-the-fly imaging and quick-scanning XAS on a windowed Li-S cell *in-operando*, we demonstrated dissolution and precipitation of different S species during the first discharge-charge cycle.

Yu, et al., Advanced Energy Materials, 2015. DOI:10.1002/aenm.20150007