Scientific Highlights from the Soft X-ray Spectromicroscopy (SM) Facility at the Canadian Light Source

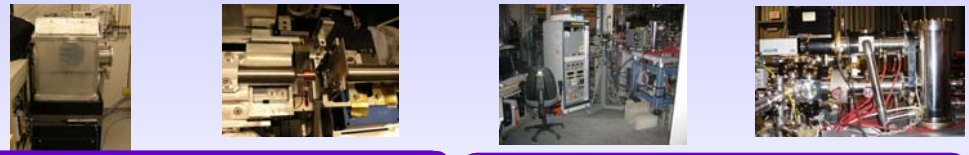
C. Karunakaran, J. Wang, Y. Lu, U.D. Lanke, S.G. Urquhart, A.P. Hitchcock

Canadian Light Source Inc., University of Saskatchewan, BIMR & McMaster University

Canadian Light Source | Centre canadien de rayonnement synchrotron

Elliptically Polarizing Undulator | Front End | M1 mirror and POE | Monochromator | M3PEEM | M3STXM | Exit Slit | M4PEEM

STXM | STXM-Inside view | PEEM | PEEM-Energy Analyzer

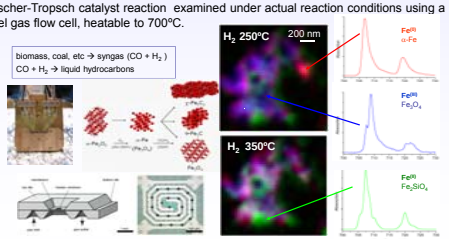


Materials Science

in situ Catalysis

Smit E. De. et al. *Ang. Chemie Int. Ed.* 48 (2009) 1-6.

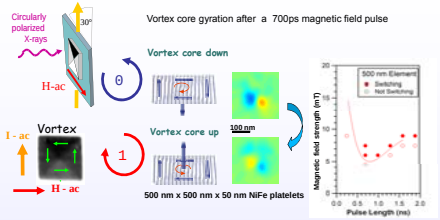
• Fischer-Tropsch catalyst reaction examined under actual reaction conditions using a novel gas flow cell, heatable to 700ºC.



Time-resolved Magnetic Spectromicroscopy

Weigand, M. et al. Phys. Rev. Lett. 102 (2009), 077201 – (1-4).
Waeyenberge, B. Van. et al. 2008 CLS Activity Report (2009), 16-17.

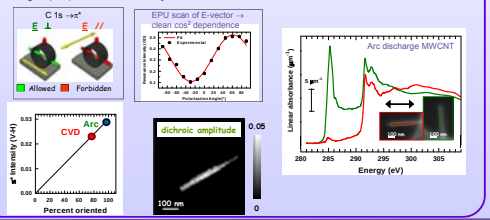
• Fast vortex core reversal by short magnetic field pulses understanding & optimizing switching parameters.



Mapping Defects in Carbon Nanotubes

Najafi, E. et al. Small 4 (2008) 2279-2285.

• Strong dichroic signal observed in individual multi-wall carbon nanotubes for the first time; Can this be used to map defects along a single carbon nanotube ?
• Chemical vapor deposition (CVD) nanotubes are much more defective than arc discharge (AD) nanotubes. They show weaker dichroism

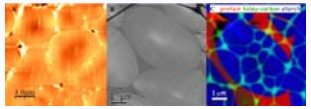


Life Science

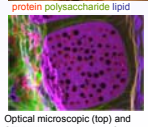
Composition of Wheat Grain

Gaillard, C. et al. (INRA), Nantes, France.

• Comparison of AFM, TEM, and STXM in order to evaluate utility of STXM for seed research.
• Wheat seed section map shows protein/lipid in the aluerone layer, polysaccharides in the internal pericarp and sub-aluerone wall .
• Starch granule on holet carbon film shows protein/lipid layer around the starch granules.



AFM height image (A), TEM bright field image (B), and STXM composite chemical map (c) of starch granules

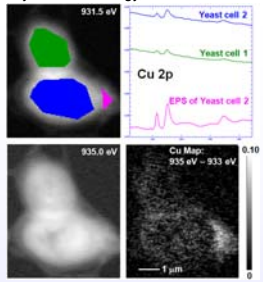


Optical microscopic (top) and STXM (bottom) images of wheat seed section

Interaction of Copper with Yeast Nucleus

Harkness, T. Department of Anatomy and Cell Biology, UofS.

• STXM has been used to determine the feasibility to investigate metal labelling, and metal binding sites related to DNA and proteins.
• In this study, the binding sites of copper in the nucleus of yeast cell has been investigated. More work is being continued.
• With 3-D chemical imaging, a better and more accurate understanding can be achieved to localize copper accumulation yeast cells and to determine copper-DNA interactions.

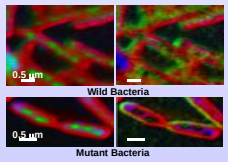


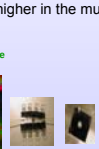
Soft X-ray tomography setup

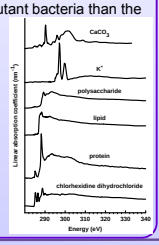
Chlorhexidine-tolerant and Chlorhexidine-sensitive *Delftia acidovorans*

Dynes J.J. et al. 2007 CLS Activity Report (2008), 104-105.

• Chlorhexidine is distributed in the centre of the bacteria.
• Chlorhexidine concentration was higher in the mutant bacteria than the wild bacteria.





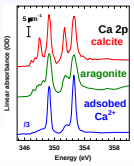


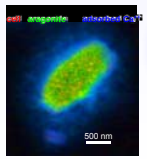
Environmental Science

$CaCO_3$ Biomineralization

Obst, M. et al. Geochimica et Cosmochimica Acta (2009) in press.

• Bacterial biomineralization is a major component of the carbon cycle.
• Understanding may assist development of bacterial mediated carbon sequestration schemes.
• Detailed studies of supersaturation, nutrient, pH dependence of $CaCO_3$ at cell surface led to new model.

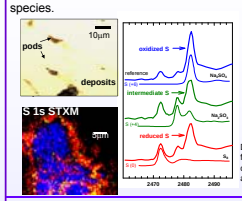


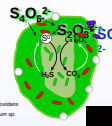


Sulfur Metabolizing Co-operatives

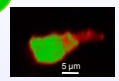
Norlund, K.L.I. et al. Envir. Science and Technol. (2009) in press..

• Sulfur metabolism in Acid Mine Drainage (AMD) bacterial biofilms is poorly understood. It is a key aspect of their survival at low-pH and high [S].
• Understanding the mechanism may help optimize bio-remediation strategies.
• Additional STXM studies (S 2p, C 1s @ ALS) & fluorescent in situ hybridization (FISH) show complex synergy of oxidizing and reducing bacterial species by two symbiotic species.



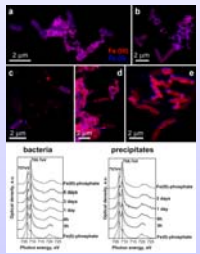


Deposits from floating biofilm pods contain S(0), S(4+) and S(6+)



Iron Oxidizing Bacteria

Miot J. et al. (2009) Geochim. Cosmochim. Acta. 73, 696-711.



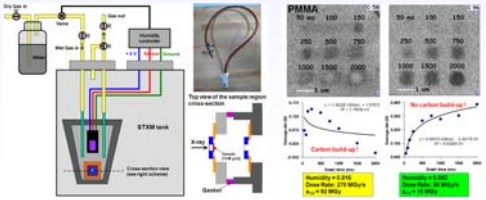
• Bacteria are capable of oxidizing Fe(II) under anoxic conditions, which is a potential mechanisms that was leading to large iron-mineral deposits on our planet in the precambrium.
• The mechanisms of the Fe(II) oxidation and mineral precipitation are not fully understood.
• This STXM and TEM study showed that the nitrate-reducing Fe-oxidizer BOFEN1 (*Acidovorax*) oxidized Fe(II) in the periplasm, which finally results in en encrustation of the bacteria, whereas the phototrophic, anoxic Fe(II) oxidizer *Rhodobacter ferrooxidans* does not encrust.

Beamline and Recent Developments

Humidity Cell

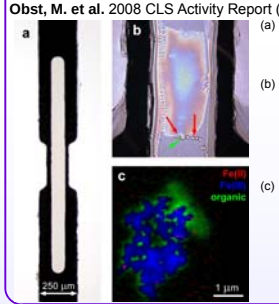
Jian, W. et al.

• Humidity control in situ soft X-ray spectromicroscopic analysis.
• This cell can also be used to vary sample gas environment to oxidation or reduction.
• PMMA X-ray damage under humid environment shows almost no carbon build-up and smaller critical dose.



Luxel Wet Cell

Obst, M. et al. 2008 CLS Activity Report (2009), 142-143..



(a) Optical microscopy image of a wet cell prototype based on a metal frame, covered on both sides by 30 nm LUXFilm™.
(b) Optical microscopy image of the wet cell loaded with Fe-oxidizing bacteria (indicated by red arrows). Newton fringes clearly indicate the presence of water between the two polyimide films. The particle indicated by the green arrow was analyzed by STXM.
(c) Species maps of the particle derived from an Fe-2p image sequence. The precipitate was mainly Fe(III) (blue). However, a few spots contained the spectral signature of the reduced Fe(II) species (red). The particle was surrounded by extracellular microbial polymers.

Beamline Specification

Source: Apple II type Elliptically Polarizing Undulator
Monochromator: Plane Grating Monochromator
Energy range: 150-2500 eV
Energy resolving power: normal ~3000, can reach >10,000
Polarization: Circular, linear from -90 to +90º
Endstations:
1. Scanning Transmission X-ray Microscope (STXM)
2. Photoelectron Emission Microscope (PEEM)

Flux: 10^8 ph/s in <50 nm spot(STXM)
10^{12} ph/s in 20 µm (PEEM)

For more information please contact the SM beamline team or visit the SM website at: http://exshare.lightsource.ca/sm/Pages/SM-Home.aspx

Our Operating Funding Partners

NSERC CRSNG | Canada National Research Council Canada Conseil national de recherches Canada | University of Saskatchewan | CIHR IRSC Canadian Institutes of Health Research Instituts de recherche en santé du Canada | Saskatchewan Industry and Resources | Canada Western Economic Diversification Canada Diversification de l'économie de l'Ouest Canada

www.lightsource.ca