FULL-FIELD INFRARED SPECTROSCOPIC IMAGING (IRI)

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BROOKHAVEN NATIONAL LABORATORY

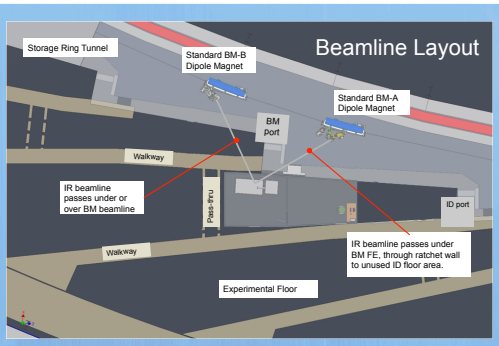
NATIONAL SYNCHROTRON LIGHT SOURCE II planned by Photon Sciences Directorate

TECHNIQUES AND CAPABILITIES

- TECHNIQUE: Fourier transform infrared spectroscopic imaging with a 64x64 focal plane array detector
- SOURCE: Dual dipole magnets
- ENERGY RANGE / RESOLUTION: 500 – 4000 cm^{-1} / 1 cm^{-1}
- SPATIAL RESOLUTION: ~1 – 5 µm with pixel oversampling and image deconvolution

IRI at NSLS-II:

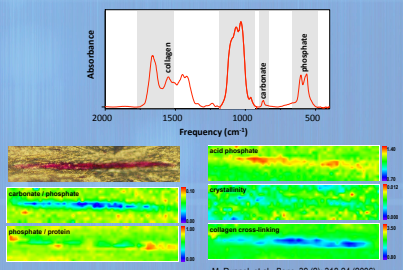
- Will enable in-situ studies of organic composition of materials by vibrational spectroscopy
- Measurements from microseconds to days with micromolar detection sensitivity and sub-micron spatial resolution
- The combination of high brightness and low noise of NSLS-II with a high throughput imaging system will be world leading



- Flexibility due to the unique extraction geometry of the M1 mirror, and the ease of steering infrared radiation.
- Since this beamline will utilize IR radiation from two dipoles, both a "BM-A" and "BM-B" dipole magnet will be used.

APPLICATIONS

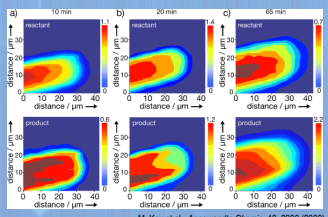
Bone Composition Differs in Microcrack Areas



M. Ruppel, et al., *Bone*, 39 (2): 318-24 (2006).

Bisphosphonates are current the most common treatment for osteoporosis but microdamage increases with high doses. Microcracks are 1 – 5 microns wide, requiring a synchrotron IR source to probe their composition. Results showed that bone composition was different in microcrack region. With too much accumulation of microdamage, the quality of bone may be reduced. With NSLS-II, lower drug doses, smaller cracks, earlier changes in composition.

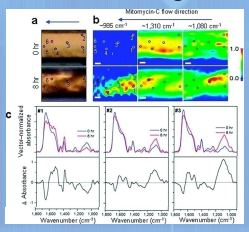
In Situ Synchrotron IR Imaging to Sulfur Removal in Fuel by Zeolites



M. Kox et al., *Angewandte Chemie*, 48, 8990 (2009).

The combination of label-free CARS and SIRMS were used to study the multidimensional distribution of thiophene reactants and products in zeolite crystals. The accumulation of active species in specific regions of the crystals illustrates the importance of diffusion barriers and capillary forces imposed by the pore network for the catalytic activity. This unique correlative approach is important for understanding of catalytic reactions on the micrometer scale under reaction conditions, thus introducing state-of-the-art chemical imaging techniques to the field of heterogeneous catalysis. With NSLS-II, reactions can be studied in real time to also determine rates as a function of crystal type, size, porosity, temperature, etc.

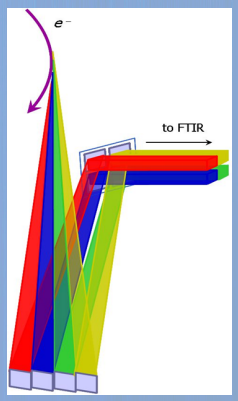
Real-Time Chemical Imaging of Bacterial Activity in Biofilms Using Microfluidics

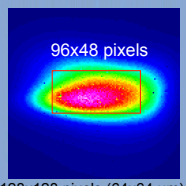


H.Y. Holman, et al., *PNAS*, 106, 12599 (2009)
H.Y. Holman, et al., *Anal. Chem.*, 81, 8564 (2009)

Real-time chemical imaging of bacterial activities can facilitate a comprehensive understanding of the dynamics of biofilm structures and functions. Open-channel microfluidic systems can circumvent the water-absorption barrier to study the developmental dynamics of bacterial biofilms. The spatial and temporal distributions of mitomycin-C uptake within a 1 day old *E. coli* biofilm at 985 cm^{-1} (DNA-MMC adducts), 1310 cm^{-1} (protein amide III), and 1080 cm^{-1} (polysaccharides). Scale bars = 10 µm. With NSLS-II, real-time studies can be performed on a large field of view with excellent spatial resolution to generate time-lapsed movies of reactions; better S/N will be necessary for small Δabsorbance for earlier time points and/or more subtle differences.

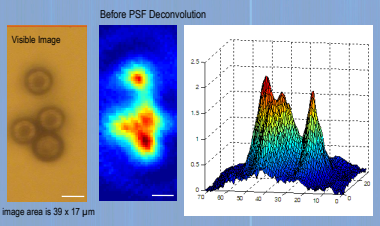
BEAMLINE PERFORMANCE: WHY NSLS-II?

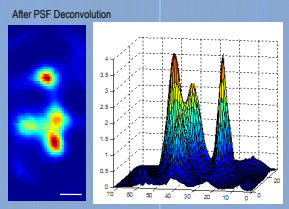




128x128 pixels (64x64 µm)

- With 90 mrad (H) at NSLS, we illuminated 4 distinct source points (Θ_v = 25 mrad at λ = 6 µm) or 96x48 pixels (36x16 µm area).
- With 50 mrad (H) at NSLS-II, a similar area is illuminated.
- With 2 NSLS-II dipoles, we will double the illumination area of the FPA to ~96x96 pixels (48x48 µm area).





- A 74X objective (0.65 NA) coupled to a 64x64 pixel, 40 µm pitch FPA yields a geometric effective pixel size of 0.54 µm. (approximately λ/10 at middle wavelengths => good for PSF deconvolution).
- High-brightness of synchrotron source should allow good S/N despite the small effective pixel area (can probably go another factor of 2 in magnification).
- (Left) FTIRI images of 6 µm-diameter polystyrene beads collected at Beamline U10B with a 74X objective (0.54 µm pixel size) and synchrotron IR source.
- (Top) Peak integration at 1450 cm^{-1}
- (Bottom) Same image after PSF Blind Deconvolution