



THE UNIVERSITY OF UTAH

Regional-Use EELS Chemical Imaging System

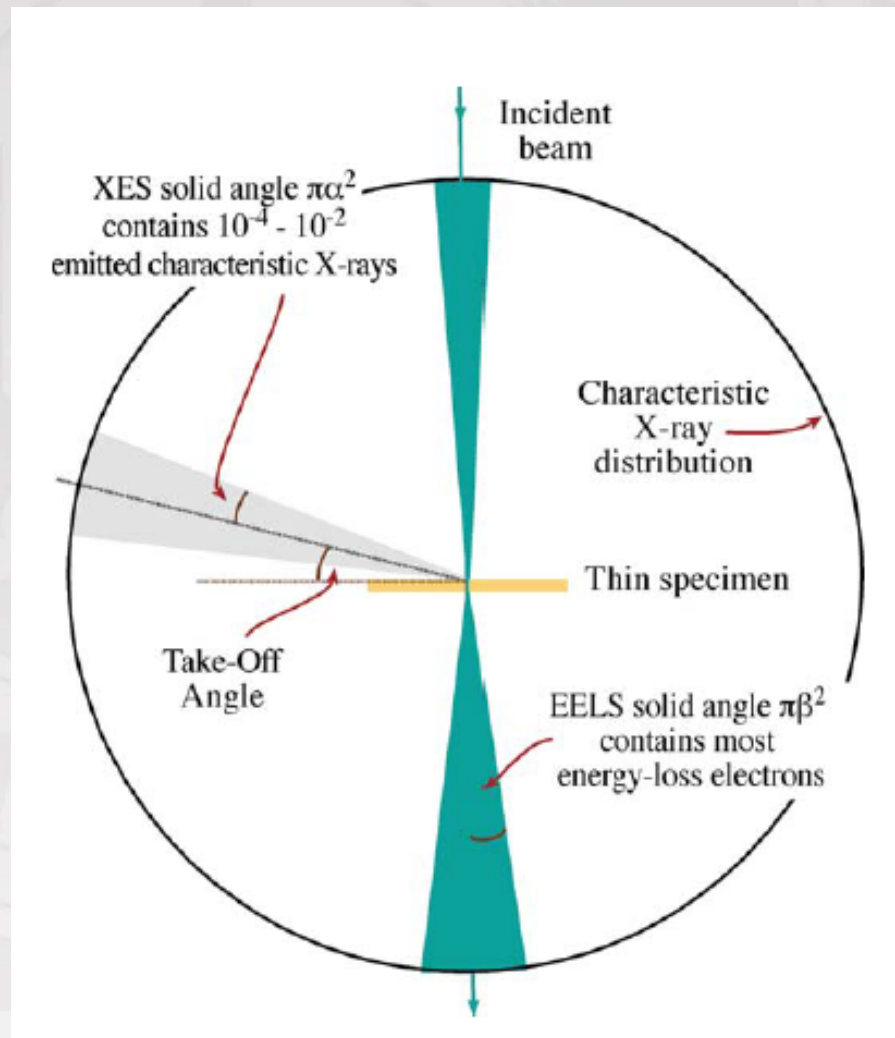
William Rankin

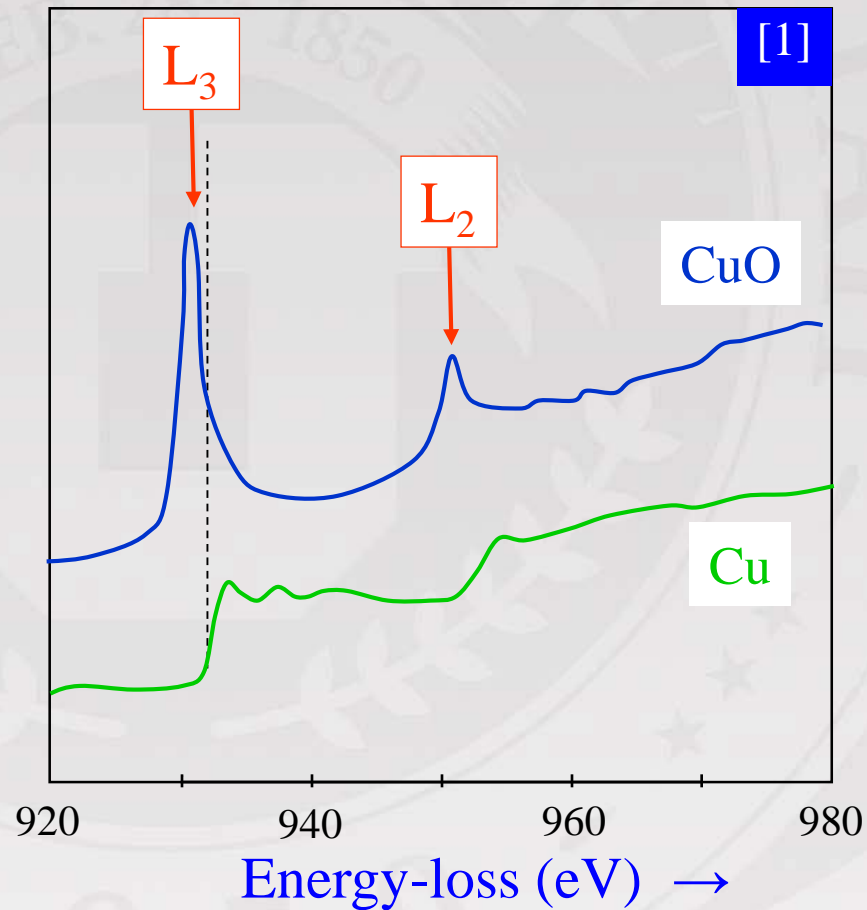
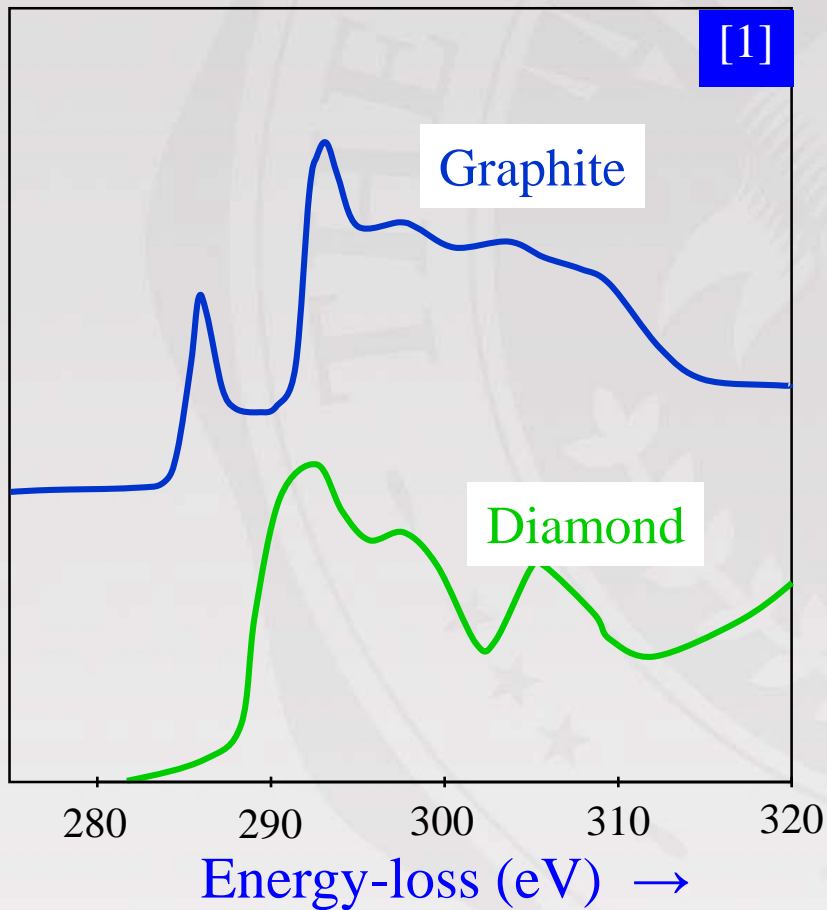
NanoUtah15

October 13, 2015

What is EELS?

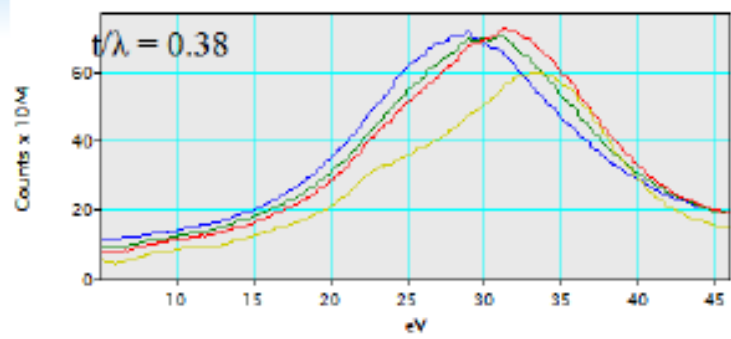
- Analysis of the energy distribution of electrons that have come through a sample
- Energy resolution $< 1\text{eV}$
 - Can distinguish between chemical states
- Sub-nanometer spatial resolution
- Can quantify light and heavy elements
- High analytical sensitivity
- Reveals information about:
 - Bonding/valence state
 - Nearest-neighbor atomic structure
 - Dielectric response
 - Free electron density
 - Band gap
 - Specimen thickness





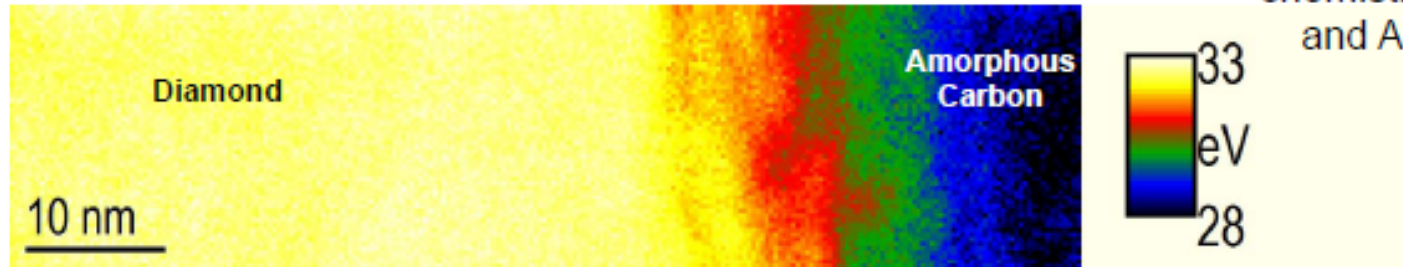
Differences between C edge between graphite and diamond

Change in Cu L edge as Cu metal is oxidized

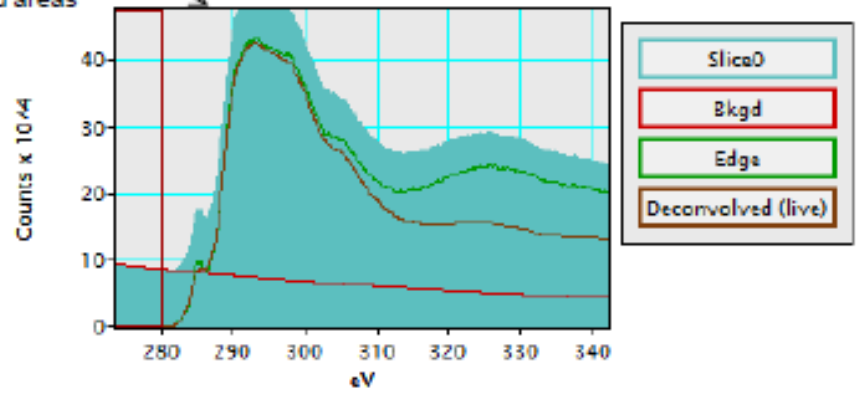
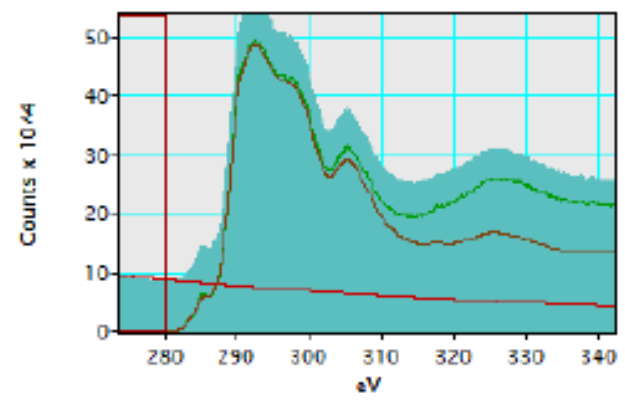


Plasmon peak position across the interface

- The region in blue is pure amorphous C
- The region in yellow is diamond
- The regions in red and green show an intermediate chemistry between Diamond and Amorphous Carbon



EELS spectra extracted from the selected areas

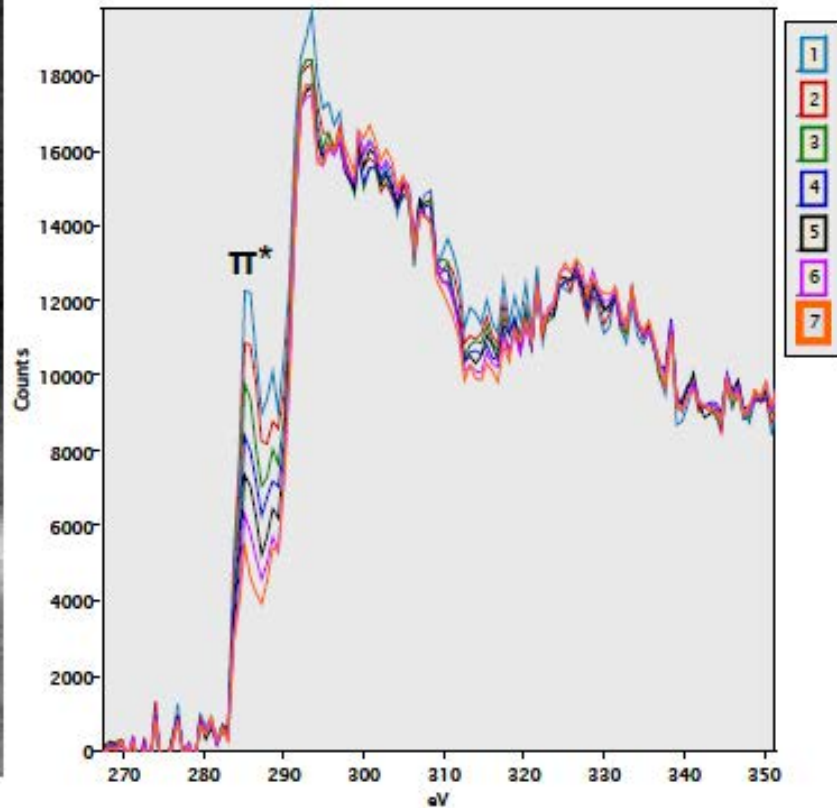


MW-CNT– Extracted Spectra



- Orientation of π -bonds rotate over tube – parallel to beam at center, perpendicular at edge

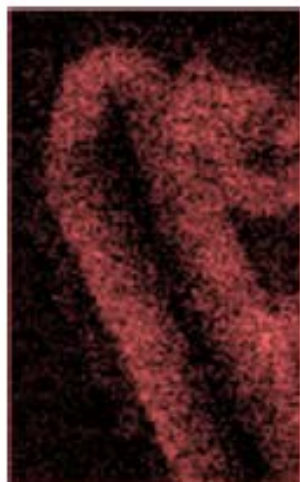
Variation C-K edge



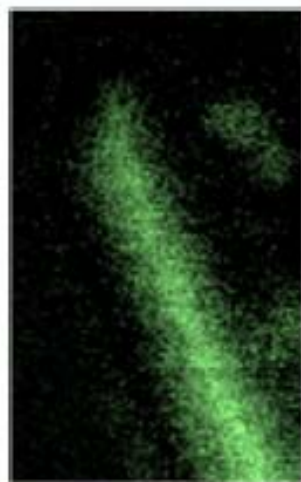
MW-CNT / WS₂ – MLLS Fitting

- MLLS mapping of C K orientation and ELNES

Strong π^* Coupling



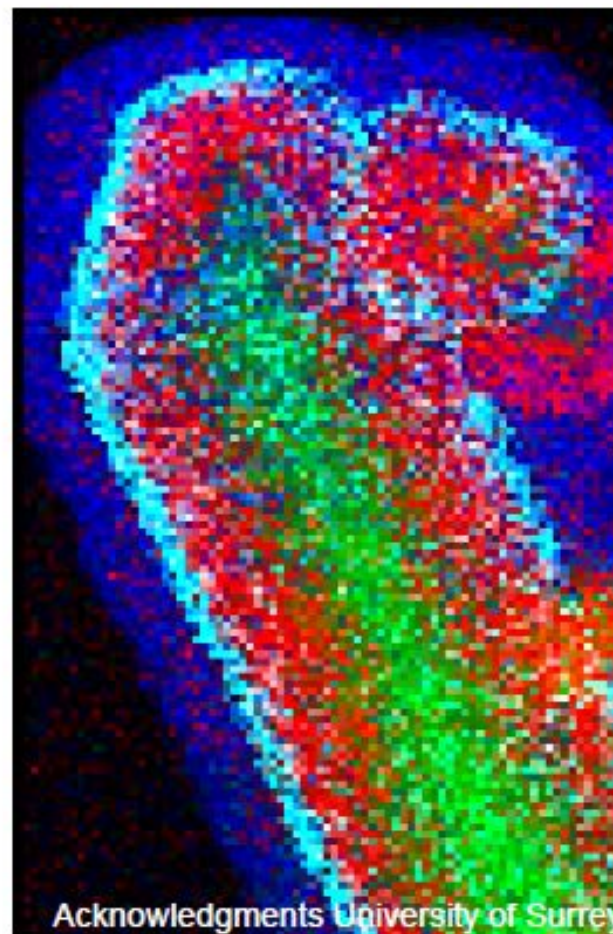
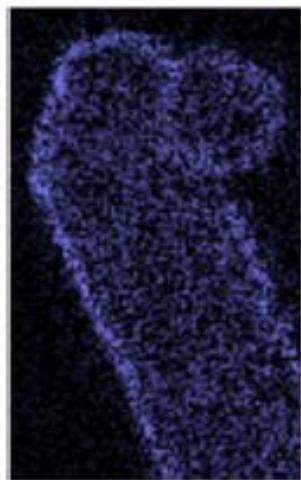
Weak π^* Coupling



Amorphous



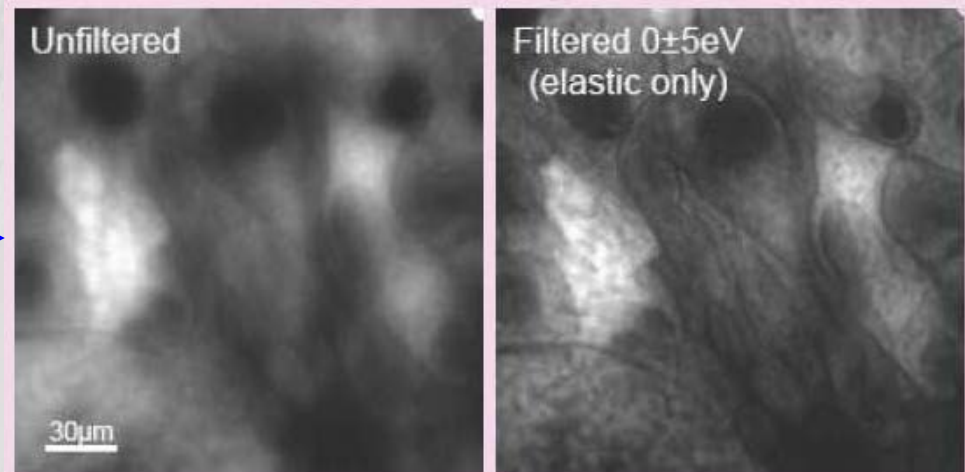
S-L₂₃ Map



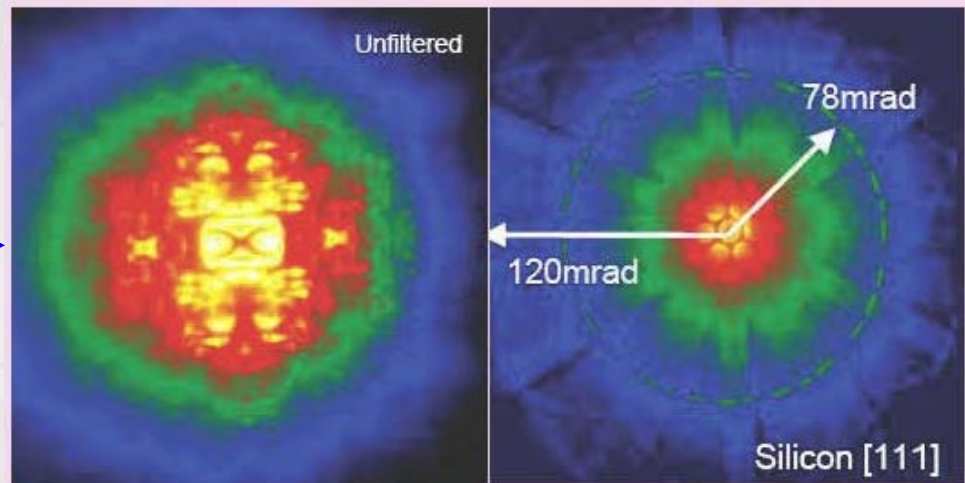
Filter out the inelastically scattered electrons

Energy Filtering

Imaging






Diffraction



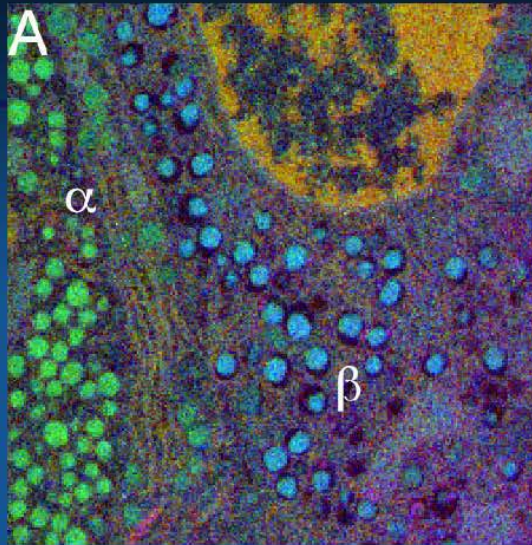
Leapman et al. (2003)

EFTEM elemental maps of mouse pancreatic islet cells

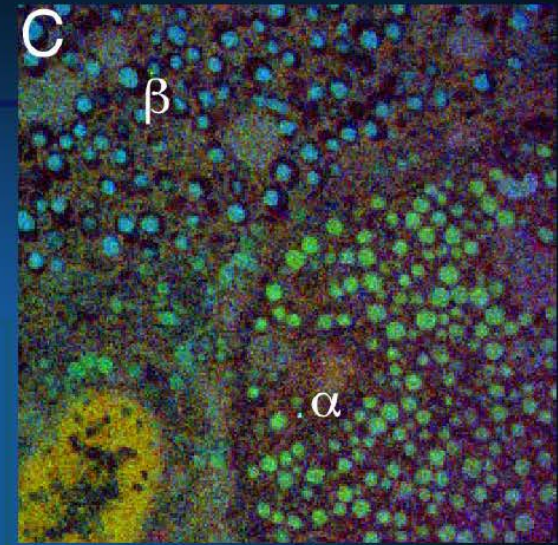
Shows sulfur-rich insulin granules in β cells

 Nitrogen
 Phosphorus
 Sulfur

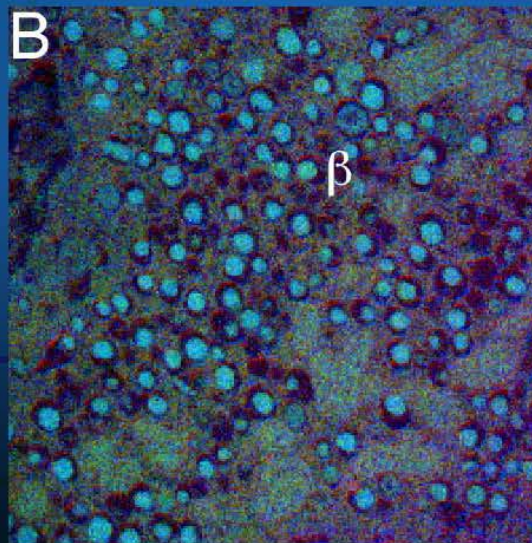
Mut



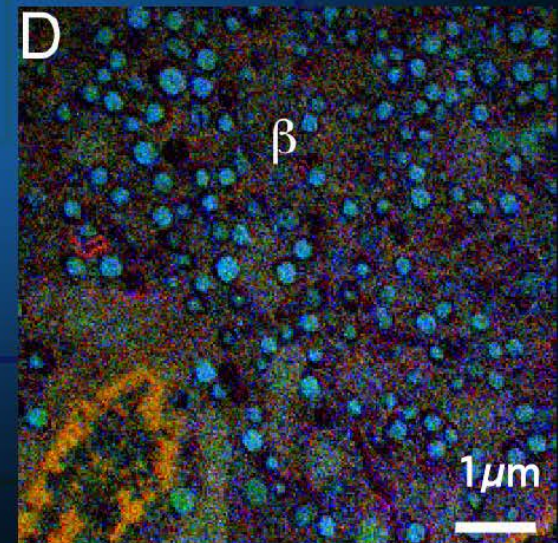
Cnt



Mut



Cnt



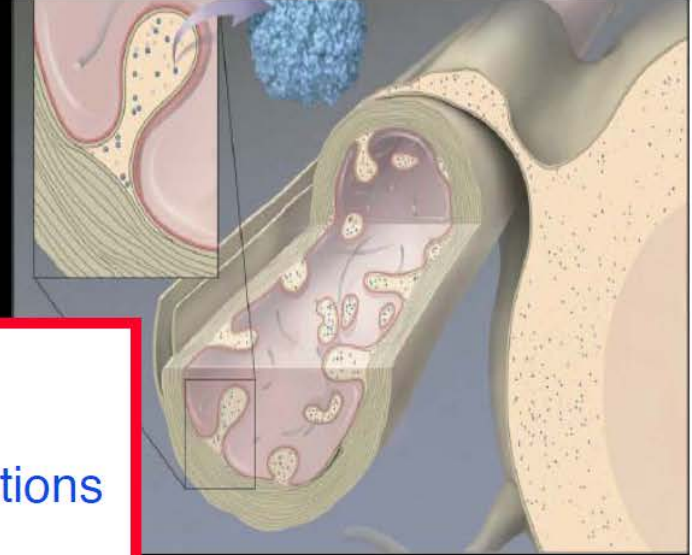
Mapping Ferritin in Brain: Misregulation of Iron Metabolism in IRP Knockout Mice

(P. Zhang et al., J. Struct. Biol. 2005)

Model of axon and oligodendrocyte showing anatomy of degeneration



Ferritin localized in invaginations of oligodendrocytes



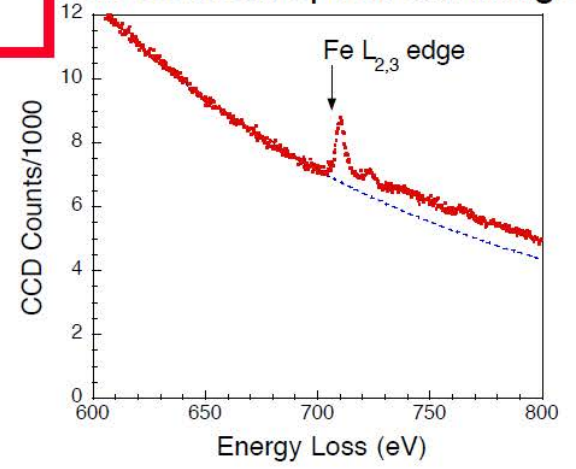
STEM-EELS

Pre Fe $L_{2,3}$

Post Fe $L_{2,3}$



EELS of ferritin molecule extracted from spectrum-image



In Conclusion

- EELS is a powerful technique that can quantify and characterize the entire periodic table, including light elements.
- EELS has a combination of analytical and spatial resolution that is unmatched by other techniques.
- We are currently working on an MRI proposal to bring EELS to the University of Utah.
 - Contact Dr. Brain van Devenner if you are interested in supporting this proposal
 - bvandev@chem.utah.edu

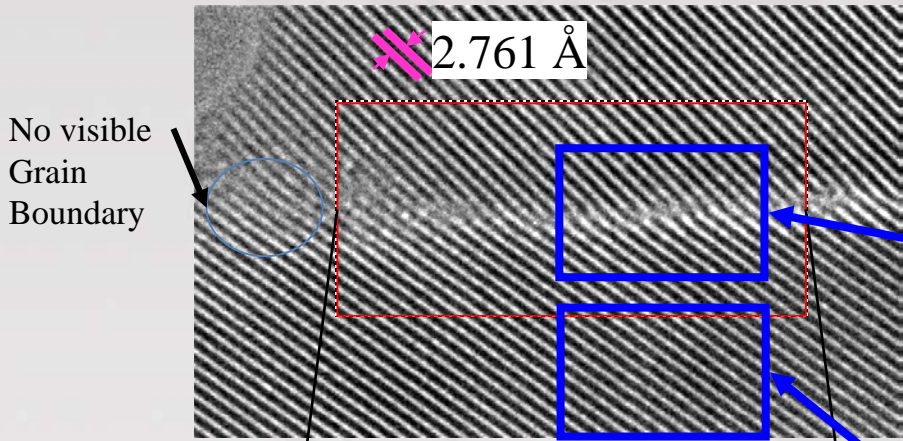
Overview of electron energy loss spectroscopy (EELS) and energy filtered TEM imaging

Dr. Paolo Longo

Wednesday, October 21st at 2:15 pm

Room 2650 Sorenson Molecular Biotechnology
Building (SMBB)

EELS

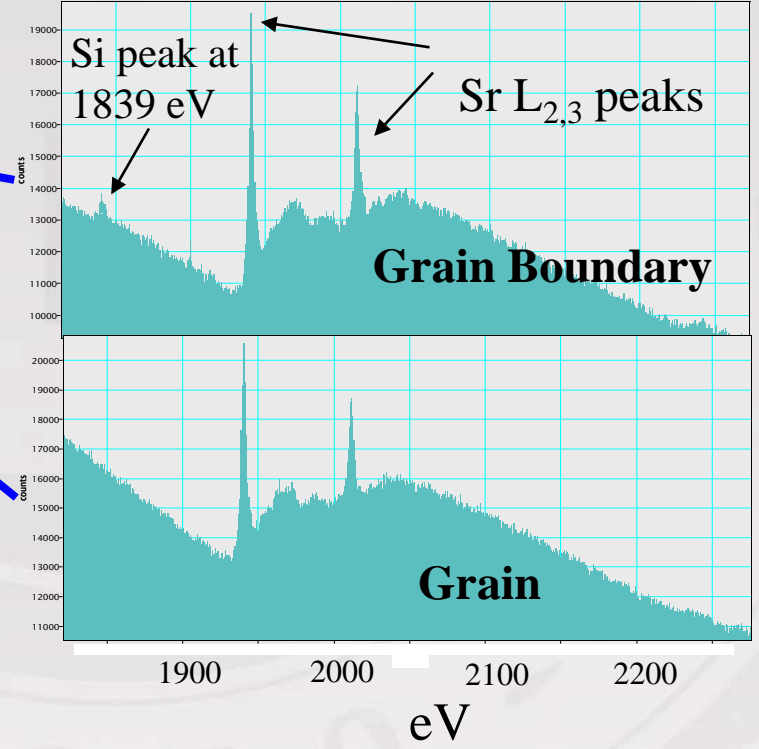
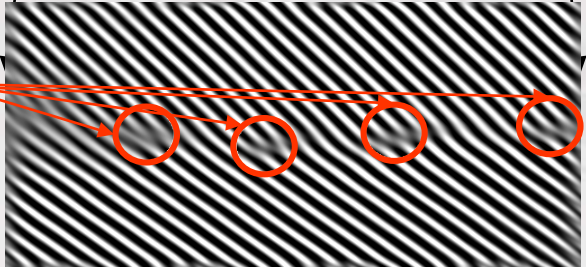


No visible Grain Boundary

2.761 Å

Fourier filtered image

Dislocation structures at the Grain boundary



Si peak at 1839 eV

Sr L_{2,3} peaks

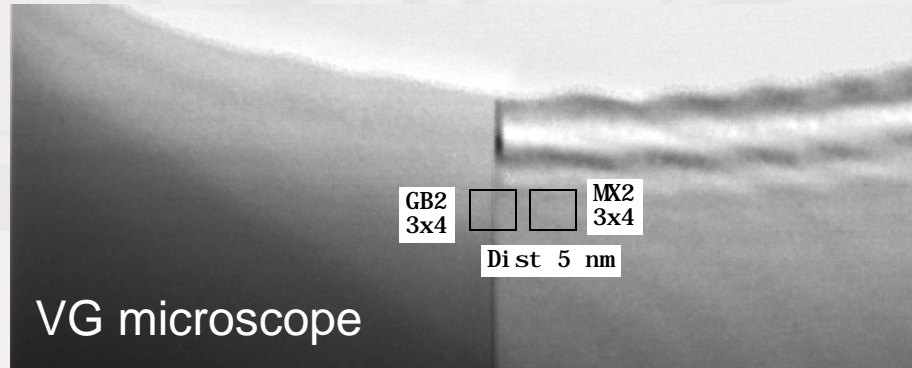
Grain Boundary

Grain

1900 2000 2100 2200

eV

~8° TILT BOUNDARY IN THE SrTiO₃ POLYCRYSTAL



VG microscope