

Momentum-resolved Electron Energy Loss Spectroscopy as a Magnetic Anisotropy Probe

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Motivation

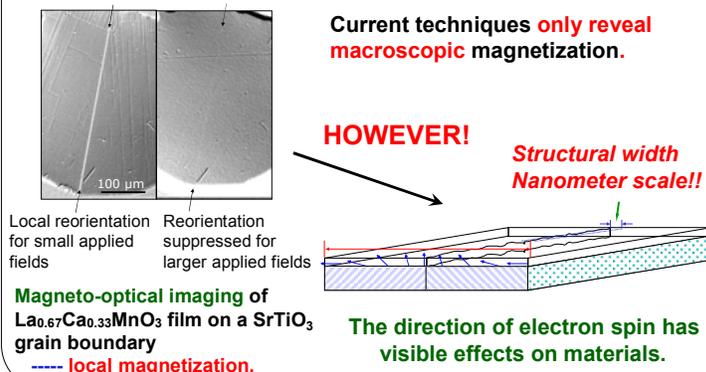
- Understanding its basic mechanisms and limiting factors of **spin dynamics** is one of the major challenges.
- Compelling need** for new techniques capable of probing bulk **magnetic anisotropy** with a spatial resolution of **less than a few-nanometer**.

Can We Probe Electron Spin (i.e. Magnetism) on the Nanometer Scale?

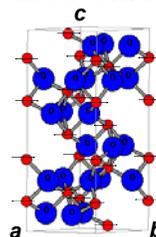
Yes!

Momentum-Resolved Electron Energy Loss Spectroscopy (MREELS) in a Scanning Transmission Electron Microscope can probe spin orientation (**Magnetic Linear Dichroism**) on the **SUB-Nanometer** level!

Example: Probing Reorientation of Electron Spin at a Grain Boundary

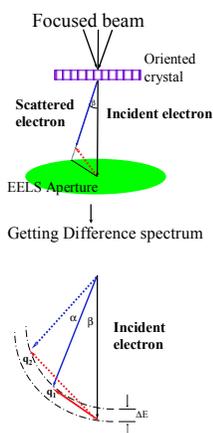


Model material: Iron Oxide ($\alpha\text{-Fe}_2\text{O}_3$)

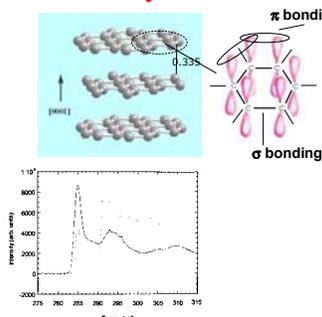


- Layered structure of the ordered spins --- Magnetic Anisotropy.
- Antiferromagnet**
- Spins are parallel to the basal plane at room temperature.

How to Sense Anisotropic Properties of Materials



Crystalline Anisotropy

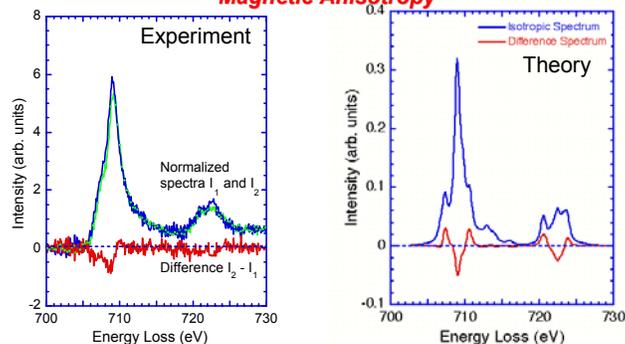


Solid line: Small focus angle. (π^* bonding dominating)

Dotted line: Large focus angle. (σ^* bonding dominating)

N.K. Menon, J. Yuan, Ultramicroscopy 74, 83 (1998)

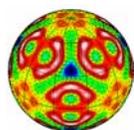
MREELS: Experiment vs Theory



Magnetic Linear Dichroism: Experiment and Simulation. Difference spectrum --- spins are parallel to the basal plane.

- MREELS** --- **Magnetic Linear Dichroism** with a spatial resolution of less than a few nanometer. \Rightarrow Direct study of the fundamental origin of **NANOMAGNETISM** !
- Fundamental knowledge of **anisotropy** \Rightarrow Advances in **switches, high capacity storage and sensors on the NANOSCALE**.
- Complementary** with the X-ray Nanoprobe at the Center for Nanoscale Materials.
- Full potential by the cutting-edge *in situ* microscope developed under the **DOE Transmission Electron Aberration-corrected Microscope (TEAM)** project.

Reference: Ito, Y., M. van Veenendaal, R.E. Cook, N. Menon, B.D. Armstrong, D.J. Miller, (2003) *Microscopy and Microanalysis* 9 Suppl. 2 314CD.



BES - DOE

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