

Nature of Inhomogeneous Magnetic State in Fe/Gd Multilayer Artificial Ferrimagnet

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A collaboration between researchers at the Materials Science Division and the Advanced Photon Source has led to the direct observation of the nucleation and evolution of an inhomogeneous magnetic state in a model artificial ferrimagnetic system. Using grazing-incidence x-ray magnetic circular dichroism (XMCD), we directly probed, in real-space, the surface- and bulk-twisted spin states in antiferromagnetically-coupled Fe/Gd multilayer structures.

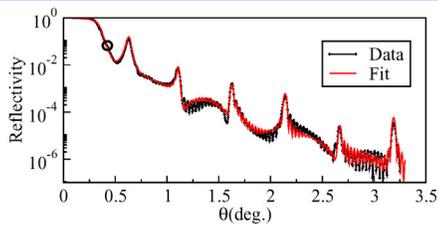
Motivation

Finite antiferromagnetically exchange coupled system

- Delicate balance between exchange and Zeeman interactions
- Symmetry breaking at surface
- Inhomogeneous magnetic structures

Fe/Gd multilayer artificial ferrimagnet

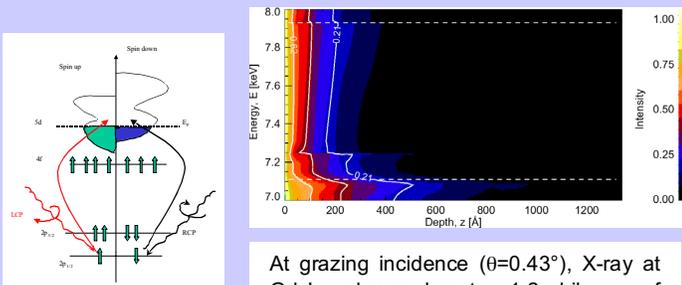
- Sputter deposited
- Markedly different Curie temperatures
- Antiferromagnetic interfacial coupling
- Rich phase diagram



Measured and fitted x-ray reflectivity of a $\text{Fe}_{35\text{A}}[\text{Gd}_{50\text{A}}/\text{Fe}_{35\text{A}}]_{15}$ multilayer.

X-ray Magnetic Circular Dichroism (XMCD)

- Difference in absorption of left- and right circularly polarized x-rays due to ferromagnetism.
- Element- and depth- sensitive.



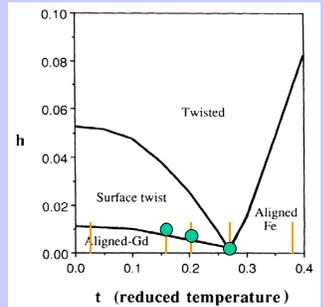
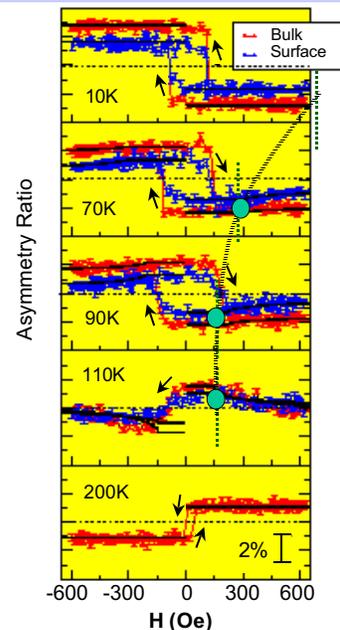
At grazing incidence ($\theta=0.43^\circ$), X-ray at Gd L_2 edge probes top 1-2 bilayers of the [Gd/Fe] multilayer.

D. Haskel, G. Srajer, Y. Choi, D. R. Lee, J. C. Lang, J. Meerschaut, J. S. Jiang, S. D. Bader, *Phys. Rev. B* 67, 180406(R), (2003).

Bulk- and surface- twisted spin structures

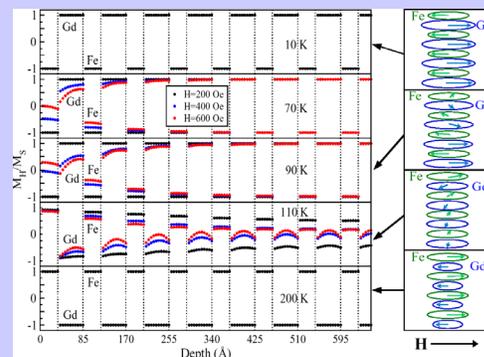
- XMCD hysteresis loops produce cuts in phase diagram
- Real-space determination of bulk and surface inhomogeneous magnetic states

Grazing-incidence \Rightarrow surface; larger-incidence angle \Rightarrow bulk

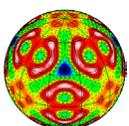


Gd XMCD hysteresis loops measured at various temperatures. The points at which the tilting in the surface and bulk loops deviates from each other delineate the phase boundary in the phase diagram. The solid lines in the loops are from micromagnetic simulations.

Micromagnetic Simulation



Magnetization depth profile calculated from the Landau-Lifshitz equation.



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