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P.J. Bedrossian
J.G. Tobin
G.D. Waddill
A.F. Jankowski
T.C. Anthony
J.A. Brug

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Magnetic Coupling in Spin-Valves from Magnetic Circular Dichroism

P. J. Bedrossian¹, J. G. Tobin¹, G. D. Waddill², A. F. Jankowski¹,
T. C. Anthony³, and J. A. Brug³

(1) *Lawrence Livermore National Laboratory, Livermore CA 94550*

(2) *University of Missouri-Rolla, Rolla MO 65401*

(3) *Hewlett-Packard Laboratories, Palo Alto Ca 94305*

Spin valves, consisting of two, coupled magnetic films separated by a thin ($<30\text{\AA}$) spacer layer, offer the oscillatory magnetic coupling of giant magnetoresistance (GMR) devices but with greatly reduced saturation fields as compared with multilayer structures. Because the optimization of spin valve performance depends on precise control of the magnetic moments of coupled layers, the reliable, quantitative measurement of the moments of the constituent elements in the device is critical. The elemental specificity of magnetic circular dichroism (MXCD) in *L*-edge x-ray absorption offers the means to detect the magnetic moments of each component of such devices and has already been applied extensively to extract magnetic moments in multilayers.¹⁻⁴

We have applied magnetic x-ray circular dichroism (MXCD) to extract elemental magnetic moments for real, thin-film spin valve devices and demonstrated the correlation between MXCD and R-H measurements on those devices. The spin valves consisted of NiFe/Co/Cu/Co/NiFe sandwiches with variable Cu spacer-layer thickness, grown on a thick NiO film, as described previously.⁵ One permalloy layer is therefore magnetically pinned to the substrate which it contacts.

Spin-polarized, X-ray absorption spectra were collected using beamline 8-2 at the Stanford Synchrotron Radiation Laboratory. The Poynting vector of the incident beam was aligned at grazing incidence to the films, either parallel or antiparallel to their remanent magnetization. For each spin valve,

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four absorption spectra were collected. With the remanent magnetization initially parallel to the incident beam direction, a pair of spectra were recorded, one with the helicity of the incident photons parallel to the remanent magnetization of the device, and one with their helicity antiparallel to the remanent magnetization. Next, the samples were rotated in order to align their remanent magnetization antiparallel to the incident beam direction, and a pair of absorption spectra was similarly obtained from beams polarized with opposite helicity. Finally, each absorption spectrum was normalized to the incident photon flux.

Figure 1 displays one pair of normalized spectra acquired using opposite photon helicities, as indicated, with the remanent sample magnetization parallel to the incident beam direction. Strong white lines are evident at the *L* edges of Fe, Co, and Ni, whereas the Cu edge signal from the thin, spacer layer occurs in the region dominated by the Ni EXAFS signal. Each pair of white lines for a particular element in fig. 1 exhibits a strong dependence of relative intensity on incident beam helicity.

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Figures

1. Pair of normalized absorption spectra from a spin valve sample, one acquired using a beam helicity parallel, and one antiparallel, to the remanent magnetization. *L* absorption edges are indicated.

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