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# Out-of-plane ferromagnetic resonance study of magnetically coupled Fe/Cr/Fe films (abstract)

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Magnetically coupled single-crystal Fe/Cr/Fe (001) sandwiches have been studied by ferromagnetic resonance (FMR) techniques. Such films have been previously shown to be antiferromagnetically coupled for a chromium layer thickness range 12 Å $< t_{Cr} <$ 25 Å by variable frequency ferromagnetic resonance measurements along principal crystallographic axes, and other techniques.[1] These measurements have been extended to include oblique angle application of the applied magnetic field (**H**) between principal crystallographic axes in the film plane and the film normal. Measured films had $t_{Cr} = 13$, 16, 17, and 28 Å. Ferromagnetic resonance measurements were taken using a fixed frequency 9.5-GHz cavity. Resonances corresponding to the in-phase and out-of-phase precession of film moments $\mathbf{M}_1$ and $\mathbf{M}_2$ were observed for the three thinnest films with **H** lying in the film plane. These resonances could be tracked to high ($\sim 85°$) oblique angles before disappearing, with the in-phase resonance strengthening near perpendicular. Perpendicular FMR measurements on the $t_{Cr} = 13$-Å-thick sample show a weaker resonance $\sim 680$ Oe above the in-phase resonance, corresponding to the out-of-phase precessional mode. This value can be directly compared to $4J/M_s \sim 540$ Oe result from earlier work,[1] perhaps indicating some anisotropic exchange. An extension of the model presented in Ref. 1 is presented to explain the resonance behavior as a function of angle.

[1] J. J. Krebs, P. Lubitz, A. Chaiken, and G. A. Prinz, Phys. Rev. Lett. **63**, 1645 (1989).

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