Depth-Resolved Magnetism across a 2 nm Co Layer
Using Soft X-Ray Standing Waves

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Interesting magnetic phenomena are associated with the interface regions between magnetic and other layers. Examples include the transition from in-plane to perpendicular magnetic anisotropy, interfacial magnetic frustration or enhancement, and magneto-resistive properties involving both conductive and insulating non-magnetic spacer layers. While it can be expected that magnetic properties of nanoscale magnetic layers are different at interfaces with dissimilar materials than in the center of the magnetic layer, characterizing such differences with adequate depth resolution has remained a great experimental challenge.

We have developed standing wave techniques that will be generally useful in such studies, and have begun to apply them to study magnetic enhancements at buried interfaces associated with the transition from in-plane to perpendicular magnetic anisotropy. We have extended the well-known standing wave technique into the soft x-ray range by utilizing a non-magnetic multilayer x-ray interference structure as the standing wave generator (SWG) substrate. The magnetic structure of interest, in this case a Pd(20 Å)/Co(20 Å)/Pd(10 Å) tri-layer, is deposited directly atop the SWG substrate. The magnetic tri-layer structure is a small perturbation to the standing wave field produced by the SWG. Co magnetic circular dichroism spectra are then obtained as a function of standing wave position, from which we can resolve distinct changes in Co electronic and magnetic structure from the center of the Co layer to just 10 Å away at the bottom Co/Pd interface.

A large enhancement in the number of Co d holes is observed at the interface, as is a 300 % enhancement in the Co orbital moment and a smaller enhancement in the effective spin moment. The geometry of the measurements means that the enhanced orbital moment is oriented in-plane. This implies that Néel's model of surface magneto-crystalline anisotropy in which enhanced orbital moments are oriented perpendicular to the surface is oversimplified. We propose a model in which the interfacial Co is modified by chemical interaction with Pd and/or through effective strain on intermixing, to yield an interfacial Co-rich layer that is electronically and magnetically distinct from the more bulk-like Co at the layer center. This chemically modified interfacial Co layer is expected to play an important role in the reorientation transition from in-plane to perpendicular magnetic anisotropy. Experimental considerations and results will be discussed in the context of anisotropy reorientation transition.

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