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and Photoelectron Emission Using Ultrathin Magnetic  
Alloy Films**

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# CORRELATION OF MAGNETIC DICHROISM IN X-RAY ABSORPTION AND PHOTOELECTRON EMISSION USING ULTRATHIN MAGNETIC ALLOY FILMS

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## ABSTRACT

We have begun a program to characterize magnetic alloy overlayers using both magnetic x-ray circular dichroism (MXCD) and magnetic x-ray linear dichroism (MXLD). This will allow a direct comparison of MXCD-absorption and MXLD-photoelectron emission. First results from the Advanced Light Source will be presented.

## INTRODUCTION

Magnetic dichroism techniques based upon the spectroscopy of core levels permit an element-specific probing of magnetic structure. Examples of this include magnetic x-ray circular dichroism (MXCD) and magnetic x-ray linear dichroism (MXLD) in photoelectron emission<sup>1-10</sup> as well as MXCD in x-ray absorption<sup>12-15</sup>. Because core-level energies tend to be elementally-unique, one is able to specify which element is being interrogated simply by varying the photon and electron energies. The magnetic sensitivity arises because of the construction of a chiral environment, either by the application of circularly-polarized x-rays<sup>1-5,10,12-15</sup> (i.e., right- or left-handed) or by the imposition of a chiral configuration of vectors, including the poynting and linear polarization vectors of the x-rays, the electron emission direction, the crystallographic vectors, and the magnetization vector<sup>6-11</sup>. Here are reported some of the first results of a program in which MXLD-photoemission and MXCD-absorption are used to study ultrathin films composed of magnetic alloys of Co and Fe.

## EXPERIMENTAL

The MXLD measurements were performed at the Spectromicroscopy Facility<sup>11</sup> at the Advanced Light Source in Berkeley, California. The MXCD studies were done at the Stanford Synchrotron Radiation Laboratory (SSRL), using the Beamline 8-2 facilities<sup>1-3,10,14</sup> of the University of California/National Laboratories Participating Research Team. Spectroscopic experimental details are available elsewhere<sup>1-3,10,11,14</sup>. The FeCo magnetic alloy films were grown on Cu(001), *in situ*, using molecular beam epitaxy (MBE) techniques in a UHV environment<sup>11,16</sup>.

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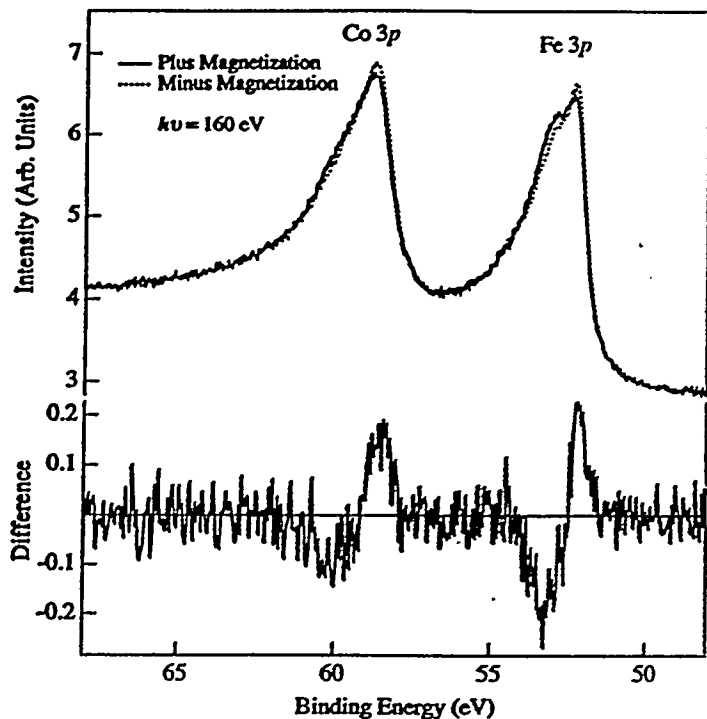
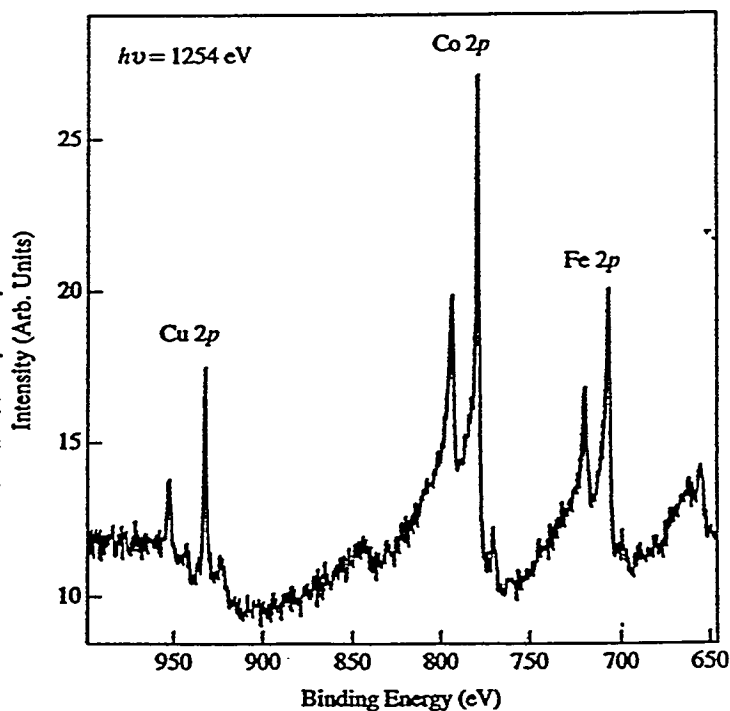


Figure 1. MXLD photoelectron spectroscopy of 3.5ML (FeCo<sub>2</sub>)/Cu(001) is shown here. The Fe3p peak is near a binding energy of 53eV and the Co3p peak near 59eV. To obtain MXLD, the magnetization direction is reversed while all else is kept the same. These spectra are for a photon energy of 160eV and for electrons collected along the surface normal. The asymmetries of 1% to 2% are calculated by including the total underlying electron background. If pre-peak regions are set to zero, asymmetries of roughly 3% are obtained.

Figure 2. X-ray photoelectron spectroscopy (XPS) of the Fe, Co, and Cu2p levels. The photon energy is 1254eV, the output of a MgK $\alpha$  x-ray tube. The Fe2p peaks are at binding energies of 707 and 720eV; the Co2p peaks are at 778 and 793eV; and the attenuated Cu peaks are at 932 and 952eV. The sample is the same as that for Figure 1. This spectrum is typical of those samples prepared at the ALS.



## RESULTS AND DISCUSSION

An example of MXLD-photoelectron emission is shown in Figure 1. Here a dichroism is observable in both the Fe3p and Co3p peaks. In this photon energy range, the cross-sections are energy-dependent. Intensities require further corrections for utilization in composition analysis. In fact, at low photon energies and these film thicknesses, it is often impossible to get a strong Cu3p substrate peak. Thus, film composition and thickness analysis require another measurement, an example of which is shown in Figure 2. From this, we estimate that the composition of the film is Fe<sub>36%</sub>Co<sub>64%</sub> and the thickness is 3.5 monolayers of 1.8Å each. Alternatively, the 3p levels can be used for composition analysis, if a higher photon energy is used. Figure 3 shows a result for a photon energy of 563eV, taken at SSRL. Here the composition is Fe<sub>29%</sub>Co<sub>71%</sub>, again nominally FeCo<sub>2</sub>. The coverage is estimated to be 2.4 monolayers. At SSRL, the MXCD-absorption experiments are performed. In Figures 4 and 5, the absorption spectra of the Fe2p and Co2p levels are shown, respectively. Here MXCD-absorption dichroisms are easily seen in both the Fe2p and Co2p levels of this sample, 2.4ML(FeCo<sub>2</sub>)/Cu(001).

## SUMMARY

Preliminary results have been presented, from our program investigating ultrathin magnetic alloy epitaxial films with MXLD-photoemission and MXCD-absorption. We anticipate being able to correlate MXCD and MXLD results for a wide range of samples in the future.

## ACKNOWLEDGMENTS

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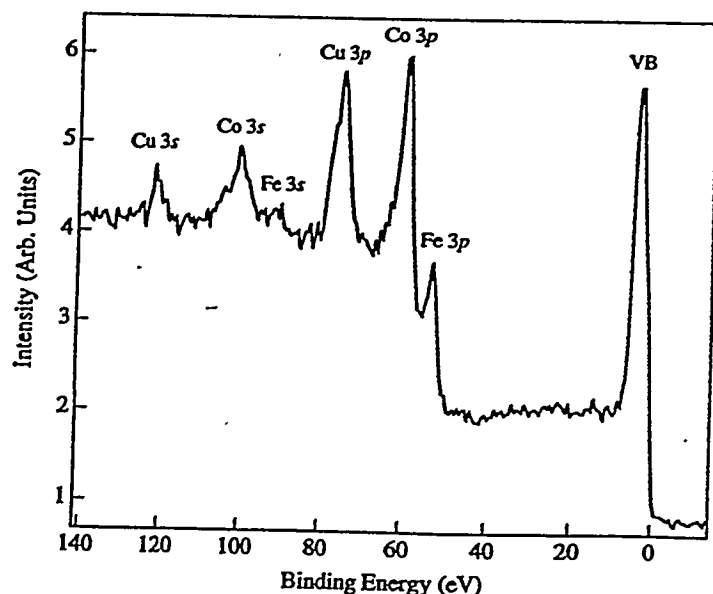


Figure 3. A synchrotron radiation photoelectron spectrum of FeCo<sub>2</sub>/Cu(001), prepared at SSRL and excited with photons of 563eV energy. The valence bands are easily observable near the Fermi energy (binding energy of zero), as are the Fe3p (53eV), Co3p (59eV), Cu3p (75.77eV), Fe3s(91eV), Co3s (101eV), and Cu3s (122eV).

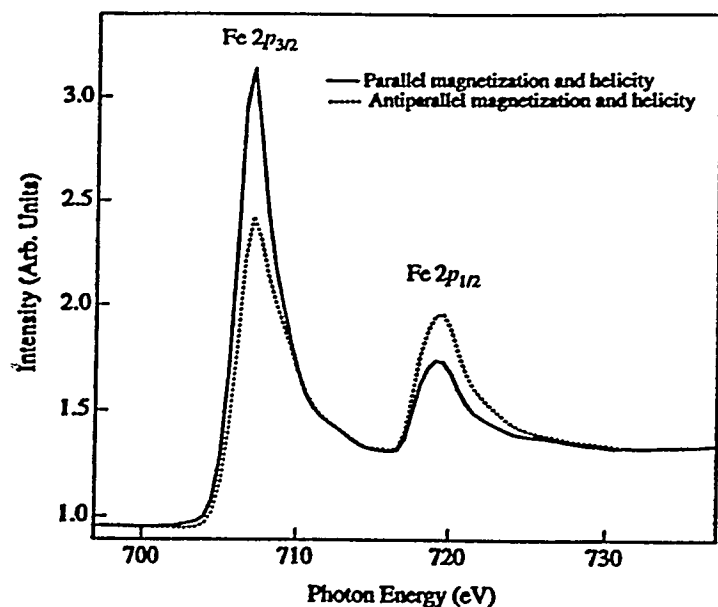


Figure 4. The absorption spectra of the Fe2p<sub>3/2</sub> (707eV) and Fe2p<sub>1/2</sub> (720eV) levels, for parallel and anti-parallel helicity and magnetization. For ease of operation and high counting rate, these measurements were taken with an estimated circular polarization of about 70% as opposed to the usual values of 85–90%<sup>1,14</sup>. Nevertheless, a strong dichroism is easily observed. The sample is the same as that used in Figure 3. Over the Fe edge region, an interpolated I<sub>0</sub> was used to correct for photon intensity, because of absorption at the Fe edge by part of the I<sub>0</sub> assembly. The interpolated I<sub>0</sub> was obtained by measuring the I<sub>0</sub> spectrum after removing the Fe from the I<sub>0</sub> assembly.

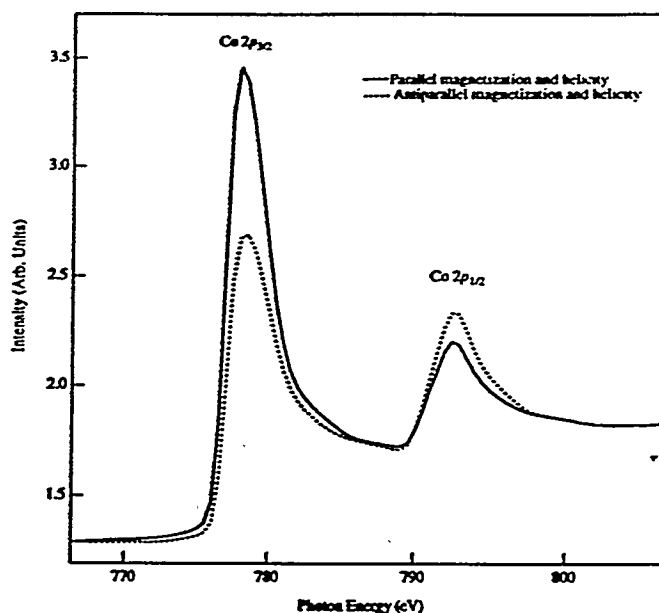


Figure 5. X-ray absorption spectra of Co2p<sub>3/2</sub> (778eV) and Co2p<sub>1/2</sub> (793eV), same as Figure 4. As in Figure 4, the data has been matched at the pre-peak and post-peak regions.

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