ESRF	**Experiment title:** "Magneto-crystalline anisotropy in a Cu/Ni/Cu multilayer studied by magnetic linear dichroism in inelastic x-ray scattering"	**Experiment number**: HE915
Beamline: ID16	**Date of experiment**: from: February 15th, 2001 to: February 19th, 2001	**Date of report**: March 1st, 2001 *Received at ESRF:*
Shifts: 15	**Local contact(s)**: Abhay Shukla	

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Report:

It has recently been found that thin films can show an easy magnetization direction perpendicular to the film plane for a certain range of thickness. This magnetic property is referred to as perpendicular magnetic anisotropy and is determined by the magnetocrystalline anisotropy energy which is the change in the free energy of a crystal upon rotation of the magnetization. The magnetic anisotropy can be manipulated by varying the individual layer thickness of appropriate elements. A well-known and widely studied system is Ni on Cu: the preferential direction of magnetization is out-of-plane when the thickness of the Ni layer is between 15 and 120 Å, and in-plane otherwise.

The anisotropy in the orbital moment determined by sum rules applied to Magnetic Circular Dichroism in the absorption process on the similar Au/Co/Au system failed to provide (through the theory of ref. [3]) the directly observed magnetocrystalline energy [1]. Magnetic Linear Dichroism in absorption provides a direct probe of anisotropic crystal field effects, and sum-rules have been developed that relate the linear dichroism to the anisotropic magnetic moment [2]. As an alternative, we have proposed to investigate magnetic anisotropy by using the technique of Magnetic Linear Dichroism in x-ray emission (XES-MLD). From the experimental point of view, in contrast to absorption- or photoemission dichroism techniques which probe 3d moments, XES-MLD is performed in the hard x-ray regime, thus not requiring high vacuum environment. Moreover, the technique does not require circular polarization and can also be applied to antiferromagnets.

The experiment (Proposal HE915) has been performed on ID16 during 15 shifts of 2/3 mode filling (February 15th to 19th), utilizing the dedicated setup for inelastic x-ray scattering (IXS) from electronic excitations. We have studied Si(001)/Cu/Ni/Cu samples having a Ni layer of 80 and 500 Å, grown on a 2000 Å thick Cu buffer and capped with

50 Å of Cu. The excitation energy was set to 8.4 keV, i.e. 70 eV above the 1s Ni edge (8.333 keV) and we monitored the $K\beta_1$ (3p-1s) fluorescence.

The spectra were taken at a fixed backscattering angle of 100 degrees. This angle was chosen to significantly reduce Compton scattering while being still able to detect the elastic scattering, useful for calibration and resolution check. A permanent magnet of 0.4 T was used to saturate the magnetic field of the samples. The magnetic field was kept fixed with respect to the sample, and was always along the easy magnetic axis (in-plane for the 500 Å sample and out-of-plane for the 80 Å sample). The linear dichroism was measured by changing the sample position from situation (A) - beam hitting the sample at 10 degrees grazing incidence and outgoing beam perpendicular to the sample surface - to situation (B) - beam perpendicular to the sample surface and exiting direction at 10 degrees from the sample surface (see figure below).

The count rate on the $K\beta_1$ peak was 2000 cps for the 500 Å thick Ni film and 450 cps for the 80 Å film with an electron beam of 200 mA in the ring

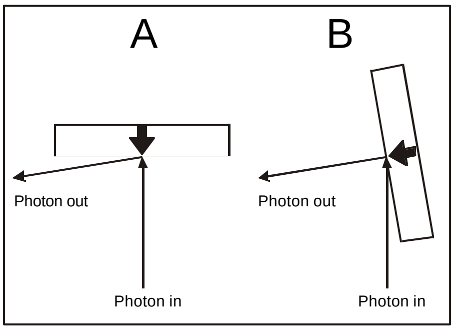
The dichroic signal shows a sign reversal for the 80 and 500 Å thick samples (see figures below) consistent with the different easy-axis directions. The size of the dichroic signal for the 80 Å sample is around 1% of the total intensity, for the 500 Å sample around 0.5% of the total intensity. A zero-check test was done on a non-magnetized Ni foil, giving no detectable dichroism. For the 17 Å thickness the count rate was found to be 150 cps, showing the feasibility of the experiment on an ultrathin sample (for thickness below 17 Å the easy magnetization axis switches again to the in-plane direction).

Further work on the data and theoretical analysis is being performed.

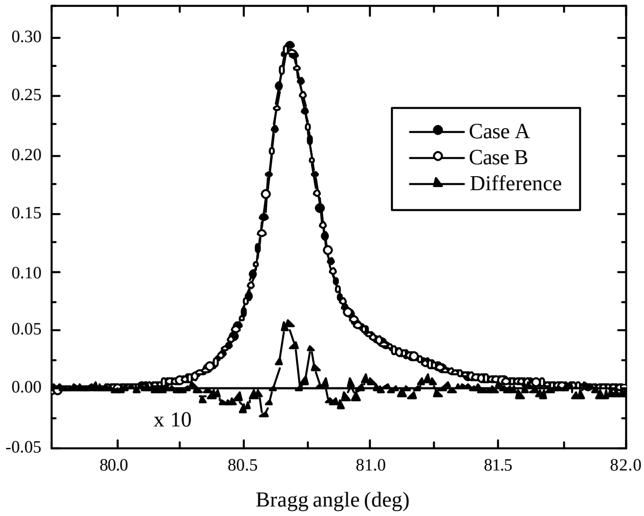
References

[1] D. Weller et al. PRL 75, 3752 (1995).
[2] Gerrit van der Laan, PRL 82, 640 (1999).
[3] P. Bruno, Phys. Rev. B 39, 865 (1989).

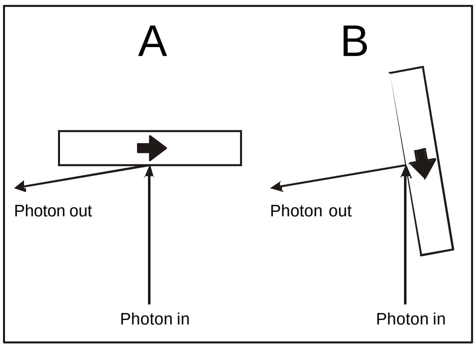
XMLD in Ni Kβ_1 fluorescence on a Cu/Ni/Cu sample with 80 Å thick Ni layer



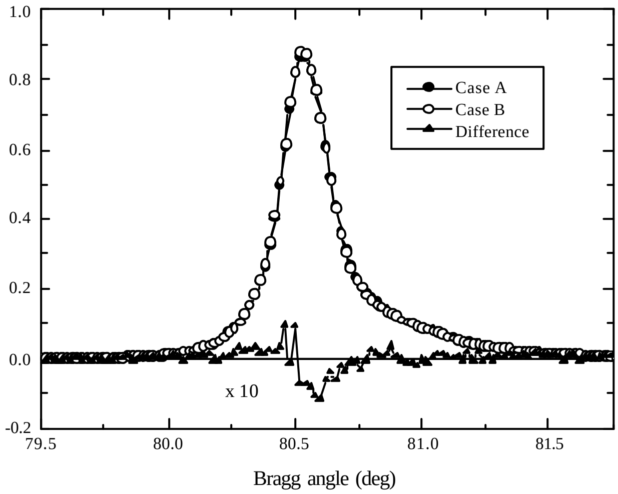
Experimental geometry: the sample is magnetized out-of-plane



XMLD in Ni Kβ_1 fluorescence on a Cu/Ni/Cu sample with 500 Å thick Ni layer



Experimental geometry: the sample is magnetized in-plane



Zero-check test on a non-magnetic Ni foil