MAGNETIC HYSTERESIS MEASUREMENTS OF XMCD IN Gd/Fe MULTILAYER

X-ray magnetic circular dichroism (XMCD) is one of the most useful types of measurement to investigate magnetic properties using synchrotron radiation X-rays. XMCD is measured at the X-ray absorption edge of a specified element in a sample, which enables element-selective measurement. The intensity of XMCD is proportional to the mean magnetic moment projected onto the direction of the incident X-ray, and the sign reflects the direction of the probed moment relative to that of the total magnetization.

In this study, the above features and a polarization-modulation technique which has been newly developed in SPring-8 have been brought together, and magnetic hysteresis loops of XMCD have been measured at the Gd L_3- and the Fe K-edges in Gd/Fe multilayers. The sample was prepared by alternately depositing Gd (20 Å) and Fe (20 Å) on a polyimide film using an rf magnetron sputtering system. The measurements were made at the beamline **BL39XU** with an X-ray phase retarder to modulate the circular polarization of the incident beam in the hard X-ray region, instead of a usual field-reversal method [1].

Figures 1 and 2 show magnetic hysteresis loops of XMCD at the Gd L_3- and the Fe K-edges, respectively. A magnetization curve is also plotted for comparison in Figure 1. The sign of XMCD at Gd is opposite to that at Fe. This result means that coupling between Gd and Fe moments is fundamentally antiferromagnetic, and also that the Gd moments are parallel and the Fe moments are antiparallel to the field direction at 20 K. The intensities of XMCD gradually decrease with increasing magnetic fields higher than 0.5 kOe, whereas the magnetization monotonously increases.

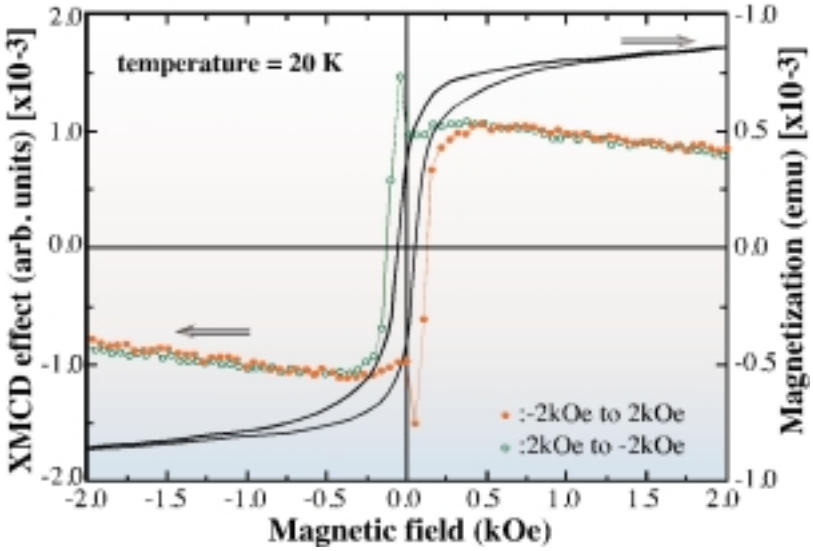

Fig. 1: Magnetic hysteresis loop of XMCD (○ and ● dots) measured at the Gd L_3-edge in a Gd(20Å)/Fe(20Å) multilayer, compared with its magnetization curve (solid line).

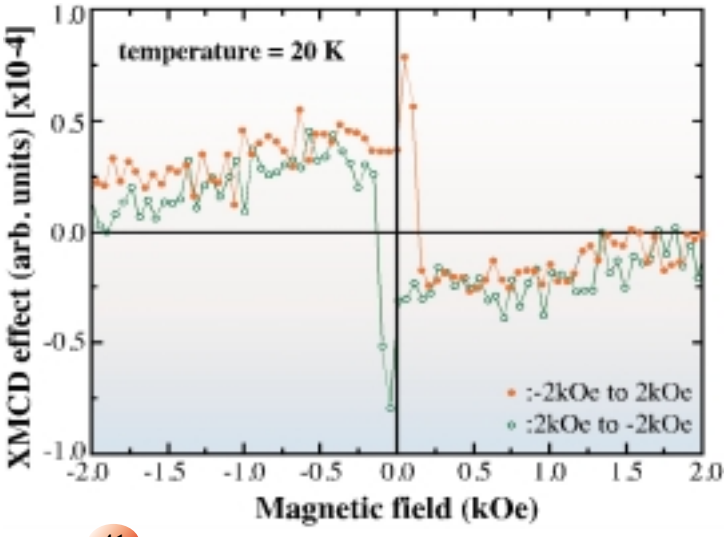

Fig. 2: Magnetic hysteresis loop of XMCD measured at the Fe K-edge in a Gd(20Å) / Fe(20Å) multilayer.

The difference in slope between the XMCD curves indicates that the Gd and Fe moments gradually tilt from the field direction at different rates. A quantitative evaluation suggested that the Fe moments tilt about three times as fast as the Gd moments as the magnetic field increases. Hence, the compensation between such Gd and Fe moments results in an increase in the bulk magnetization. This behavior is consistent with theoretical prediction, what we call the bulk-twisted state, that the effective exchange coupling between the spins in different layers and the Zeeman energy of the spins in an external field compete with each other [2].

The most important finding is a characteristic sharp peak appearing at a coercive field $H_c = \pm 50$ Oe soon after the magnetic field is reversed. No indication associated with the peak is observed in the magnetization curve. A possible spin state corresponding to this peak is an Fe-aligned state, where Fe moments are dominant and parallel and where Gd moments are antiparallel to the field direction. Since the Zeeman energies of the Gd and the Fe moments are completely canceled out at H_c, the antiferromagnetic exchange coupling at the interfaces between the Gd and Fe layers plays an important role in determining the magnetic structure, although the effect of the magnetic anisotropy cannot be disregarded.

In conclusion, magnetic hysteresis measurements of XMCD have precisely revealed the magnetization process of each element in Gd/Fe multilayers, which is impossible by magnetization measurements. These results show the indispensable availability of XMCD measurements with the polarization modulation technique, for the study of magnetism in complicated materials.

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XMCD SPECTRUM AT PT $L_{2,3}$ EDGES RECORDED BY HELICITY MODULATION TECHNIQUE

X-ray magnetic circular dichroism (XMCD) at the Pt $L_{2,3}$ edge is a powerful tool for studying the magnetic properties of Pt 5*d* bands and sensitively reflects the TM 3d states in ferromagnetic TM-Pt_3 intermetallics (TM: transition-metal). We previously found that the Pt 5*d* magnetic states in MnPt3 have a quenched orbital component and are dominated by the spin character, whereas a main contribution in $CrPt_3$ is carried by the orbital moment rather than the spin component and the Pt moments couple antiferromagnetically with Cr moments [1].

To study this contrasting magnetic property, the Pt *L* edge XMCD in $(Cr_{1-X}Mn_X)Pt_3$ mixed crystal system is informative for a better understanding of the 3*d* magnetic states. In particular, we are interested in the crossover from orbital to spin character at an intermediate region, where the Pt magnetic moments will be quenched. The helicity-modulation technique [2] recently developed has been applied for measuring weak XMCD signals with a high accuracy. A synthetic diamond (111) crystal slab 0.73 mm thick is operated around the 220 reflection in the Laue geometry. The photon helicity is switched fast between plus and minus offset angles around the Bragg condition, which was previously determined from polarization measurements of the transmitted beam, as shown in Figure 1. In the energy range of the Pt $L_{2,3}$ edges, the photon helicity is alternately turned at 200 Hz by flipping between the offset angles of ±20 arcseconds.

Figures 2 and 3 show Pt L_3 and L_2 edge XMCD spectra, aligned at the absorption edge energy, in a $(Cr_{1-X}Mn_X)Pt_3$ mixed crystal system. When the Mn content is increased, the L_3 edge XMCD is systematically changed from positive to negative, and a dispersion type profile is observed in the intermediate range. This trend is interpreted as an increase in the volume fraction of ferromagnetic $MnPt_3$ in ferrimagnetic $CrPt_3$.

On the other hand, the L_2 edge XMCD always keeps a positive sign and shows a small amplitude at $(Cr_{0.5}Mn_{0.5})Pt_3$, which indicates the collapse of the Pt 5*d* magnetic moments. The L_3 (L_2) spectrum