Soft X-ray magnetic circular dichroism on Fe/Tb multilayer films

Katsuyoshi TAKANO, Miki FURUHATA, Kazuhiro IKEUCHI, Hiroshi SAKURAI, Fumitake ITOH, Hiromi OIKE
Department of Electronic Engineering, Gunma Univ., 1-5-1 Tenjin-cho, Gunma, 376-8515, Japan

Fe/Tb multilayers were prepared on Al foil by a dual-type radio frequency sputtering method (Table 1. A) and MBE at the SVBL, Gunma University (Table 1. B~D). The sample A~D have almost same Tb thickness with different Fe thickness. The sample A has almost the same Fe thickness and Tb thickness as the sample B, but has rough interface.

Table 1

Sample	Fe [nm]	Tb [nm]	Stack [No.]
A	0.7	0.5	25
B	1.0	0.4	125
C	1.9	0.5	125
D	5.7	0.8	125

The Soft X-ray Magnetic Circular Dichroism (SXMCD) was measured on the beam line AR-NE1B of KEK, Japan. The SXMCD spectra at both the Fe $L_{2,3}$-edge and the Tb $M_{4,5}$-edge were taken with the total electron yield method under the magnetic field applied perpendicular to the sample plane of 1 T at room temperature. The SXMCD spectra were normalized with the "edge-jump" of the X-ray absorption spectra. Figure 1 shows the SXMCD spectra of the Fe/Tb multilayers. In the sample B~D, SXMCD signals at the Fe L_3-edge are negative and those at the Tb M_5-edge are positive. This shows clearly the magnetic moment of Fe align to the magnetic field and the magnetic moments of Tb are coupled ferri-magnetically with Fe moments. This is consistent with the result by hard X-ray MCD.[1] However, The SXMCD signals at both the Fe L_3-edge and Tb M_5-edge are negative in sample A. Namely, the Fe and Tb moment are coupling ferro-magnetically in case of thin Tb layer.

Figure 2 shows the individual m_{orb} (a) and m_{spin} (b) of the Fe (solid circle) and Tb (open circle) that obtained from the magneto-optical sum rule.[2][3] We used the values of 6.61 and 8 for as a number of Fe 3*d* [4] and Tb 4*f*, respectively. The m_{orb} and m_{spin} of Fe in these samples is small in compared to the bulk Fe, $0.085\mu_B$ and $1.98\mu_B$.[4] The m_{orb} of the Fe almost zero in the sample B~D. But in the sample A that has $0.032\mu_B$. The m_{spin} of Fe and Tb decrease with decreasing the Fe thickness in the sample B~D. In sample A, the m_{spin} of Tb moment is enhanced and the m_{spin} of Fe moment is suppressed.

We suggest the following model; In the B~D, the Fe moments have stronger in-plane anisotropy with decreasing the Fe thickness. The Tb moment also cant to in-plane keeping the ferri-magnetically coupling with the Fe moments. Then the m_{spin} of Fe and Tb decrease with decreasing the Fe thickness. In the sample A with rough interface, the Tb moments cant to the applied field, but Fe moments have still in plane anisotropy. Then out of plane contribution is enhanced in Tb moment and is suppressed in Fe moment. A semi-quantitative simulation is required for analysis of this phenomenon.

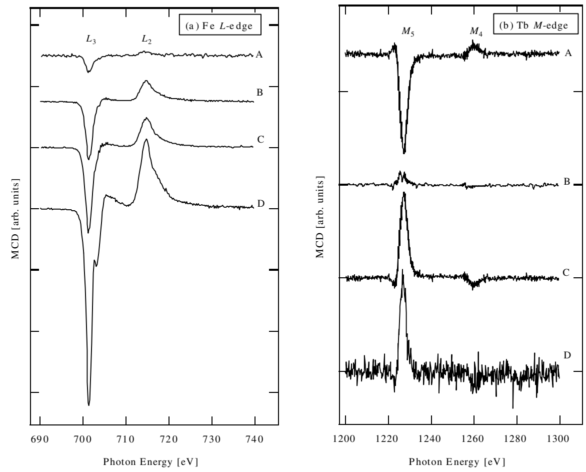

Figure 1. The SXMCD spectra at Fe $L_{2,3}$-edge (a) and Tb $M_{4,5}$-edge (b) at 298K.

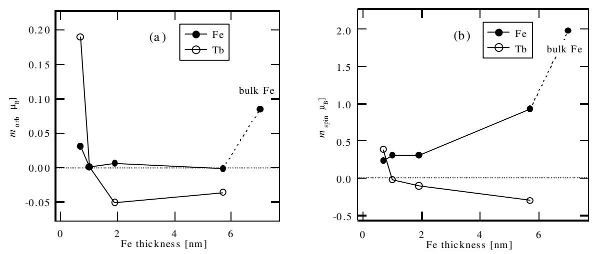

Figure 2. m_{orb} (a) and m_{spin} (b) of Fe (solid circle) and Tb (open circle).

References

[1] K. Takano, M. Fruhata, S. Kobayashi, H. Sakurai, F. Itoh, J.Magn.Magn.Mater. **240**, 565(2002).
[2] B. T. Thole, P. Carra, F. Sette, and G. van der Laan, Phys. Rev. Lett. **68**, 1943 (1992).
[3] P. Carra, B. T. Thole, M. Altarelli, and X. Wang, Phys. Rev. Lett. **70**, 694 (1993).
[4] C. T. Chen, Y. U. Idzerda, H. –J. Lin, N. V. Smith, G. Meigs, E. Chaban, G. H. Ho, E. Pellegrin, and F. Sette, Phys. Rev. Lett. **75**, 152(1995).
* ktakano@el.gunma-u.ac.jp