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X-ray Magnetic Circular Dichroism Study of Meta-Stable bcc Co_3Mn Films

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The huge tunnel magnetoresistance (TMR) ratio based on the coherent tunneling mechanism has been predicted in MgO-based magnetic tunnel junctions (MTJs) with bcc Co(001) electrodes, discussed to be higher than those with Fe(001) electrodes. Indeed, Yuasa *et al.* reported that MgO-based MTJs with the ultrathin bcc Co(001) electrodes exhibited the TMR ratio of 410% at RT and 507% at LT [1]. However there were no other experimental reports on the high TMR effect in MgO- based MTJs with bcc Co(001) electrodes and there are some debates. One candidate is the metastable bcc $Co_{1-x}Mn_x$. In bulk of Co-rich $Co_{1-x}Mn_x$ binary, fcc or hcp disordered phase is thermodynamically stable. For these phases, magnetizations are remarkably reduced with increasing the Mn concentration x, then magnetic phase transition occurs into antiferromagnetic ordering at x = 0.3 - 0.4. However, the magnetism of the metastable bcc $Co_{1-x}Mn_x$ are quite distinct at x = 0.2 - 0.4 from fcc/hcp phases.

We focus on 10-nm-thick bcc films with x = 0.25 fabricated by sputtering whose saturation magnetization is 1.6 MA/m, which is slightly larger than that of fcc or hcp Co, 1.4 MA/m, whose TMR ratio is approximately 250% at RT, and greater than 600% at low temperature in the Co_3Mn/MgO/Co_3Mn(001) MTJs [2]. We employed the x-ray magnetic circular dichroism (XMCD) to probe microscopic magnetism.

The sample of MgO(001)/ Cr(40 nm)/ $Co_{1-x}Mn_x$(10 nm)/ MgO(2.4 nm) were prepared using a magnetron sputtering. All layers were deposited at RT. X-ray absorption spectroscopy (XAS) and XMCD measurements were performed at BL-7A, KEK-PF. The XAS spectra with different helicities were obtained by switching the magnetic fields in the parallel and antiparallel directions along the incident beam. The total-photoelectron-yield mode was adopted. XAS and XMCD measurements were performed at room temperature. A magnetic field of ±1 T was applied along the direction of incident polarized soft X-rays.

Figure 1 displays the typical data of the XAS and XMCD spectra for Co and Mn L-edges measured in the x = 0.25 film. The XAS spectra were normalized to one at the post-absorption edge. Almost similar metallic line shapes were detected for both Co and Mn edges. The element specific magnetization curves at each Co and Mn L_3-edge XMCD also exhibit similar shapes as in-plane easy axis due to the strong exchange coupling between Co and Mn. Intensity ratios between Co and Mn are also changed systematically considering ionization cross sections. The similar XAS and XMCD spectra were obtained for the films with other x, except for the x= 0.5 film. Hysteresis loops taken at Mn and Co L_3-edges show similar shapes as in-plane magnetic easy axis [3].

Magneto-optical sum rules were adopted to deduce spin and orbital magnetic moments using the spectral integrals of XAS and XMCD for the $Co_{1-x}Mn_x$ films. The total magnetic moments m_{tot} evaluated from the sum rules are in good agreement with those obtained from the magnetization measurements. The m_{tot} for fcc $Co_{1-x}Mn_x$ is much smaller; 0.5 μ_B at x = 0.25 and negligible value at x = 0.35. The magnetic moment of Co for the x = 0.14 films is 1.91 μ_B, being slightly larger than that for the Co film, 1.75 μ_B. Then, the values of m_{Co} only slightly decrease with increasing x. On the other hand, the magnetic moments of Mn m_{Mn} exhibit relatively large change with x. The m_{Mn} value are in the range of 1.6 - 2.3 μ_B for x=0.14 - 0.34. The enhanced m_{Co} qualitatively agrees with the previous report m_{Co} = 2.38 μ_B at for the x = 0.24 films [4]; however the enhancement observed in this study is much lower.

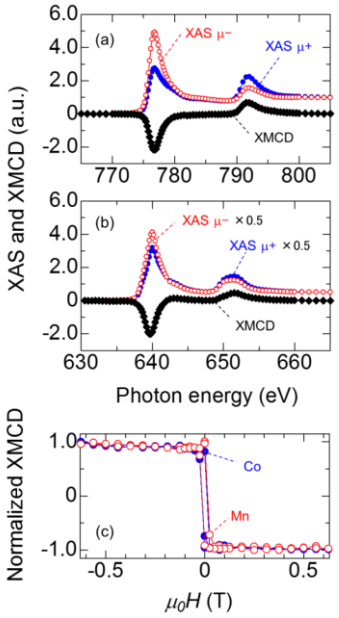

Fig. 1, XAS and XMCD of (a) Co and (b) Mn L-edges in the $Co_{75}Mn_{25}$ films. (c) Magnetic hysteresis curve of XMCD for the Co and Mn L_3-edge. The data are normalized.

References

[1] S. Yuasa *et al.*, Nature Mater. **3**, 868 (2004).
[2] K. Kunimatsu *et al.*, Appl. Phys. Exp. **13**, 083007 (2020).
[3] K. Kunimatsu *et al.*, arXiv:2010.03775
[4] R. J. Snow *et al.*, J. Magn. Magn. Mater. **419**, 490 (2016).

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