Interfacial Exchange Coupling between Transition Metal and MnGa Studied by X-ray Magnetic Circular Dichroism

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Magnetic ordered alloys have attracted significant attention for use as spintronics materials because they are highly likely to exhibit perpendicular magnetic anisotropy (PMA). Using the advantage that $Mn_{3-\delta}Ga$ is a hard magnetic film, the deposition of other ferromagnetic materials on $Mn_{3-\delta}Ga$ layers can be used to induce perpendicular exchange coupling through exchange interactions without the use of heavy metal elements. Ultra-thin transition-metal (TM) Fe or Co layers deposited on $Mn_{3-\delta}Ga$ couple ferromagnetically or antiferromagnetically, depending on their annealing conditions. For $Fe_{1-x}Co_x$ layers, antiferromagnetic coupling has been demonstrated in high-Co-concentration regions, while low-Co-concentration regions have been shown to exhibit ferromagnetic coupling [1]. However, the abruptness and element-specific magnetic properties at the interfaces between $Mn_{3-\delta}Ga$ and TM layers must be clarified explicitly. Here, X-ray magnetic circular dichroism (XMCD) is employed to investigate the element-specific magnetic properties at an TM/$Mn_{1.5}Ga$ interface. In particular, we discuss the interfacial coupling, which may be ferromagnetic or antiferromagnetic depending on the annealing of the samples.

The samples were prepared by magnetron sputtering on MgO substrates. On the 30-nm-thick MnGa, 1-nm Fe or Co were deposited at room temperature and capped by 2-nm MgO. We prepared the samples of as-grown and annealed up to 400 °C after the growth. The X-ray absorption spectroscopy (XAS) and XMCD were performed at BL-7A in the Photon Factory (KEK). The total-electron-yield mode was adopted, and all measurements were performed at room temperature and the geometries were set to normal incidence configuration.

Figure 1 shows the polarization dependences of the XAS and XMCD results for the Mn and Co $L_{2,3}$-edges in Co/MnGa after the annealing. By comparing these spectral line shapes with those in the as-grown case, it is evident that the XAS intensity ratios between Mn and Co are modulated, which suggests that the Co atoms diffuse chemically into the MnGa layer within the probing depth of approximately 5 nm. Opposite XMCD signs are observed in Fe and Co as shown in Fig. 1 because of the anti-parallel coupling between Co and MnGa layers. On the other hand, XMCD of Fe on MnGa results in the parallel coupling. In the presentation, we discuss the interfacial element-specific magnetic properties depending on the annealing processes.

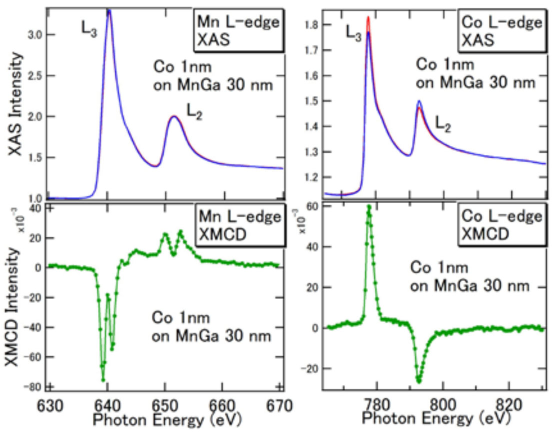

Fig. 1. (a) XAS spectra of Mn and Co *L*-edges in Co/$Mn_{1.5}$Ga annealed sample. (b) XMCDs of Mn and Co *L*-edges.

[1] Q. L. Ma et al., Phys. Rev. Lett. **112**, 157202 (2014).