Deconvolution of two kinds of Mn sites in spin and orbital magnetic moments of $Mn_{3-x}Ga$

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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). Tetragonal $Mn_{3-x}Ga$ alloys are widely recognized as hard magnets which exhibit highly anisotropic, ferromagnetic, and metallic properties [1]. Two kinds of Mn sites, which couple antiferromagnetically, consist of the $Mn_{3-x}Ga$ with the $D0_{22}$-type ordering. On the other hand, the $L1_0$-type ordered Mn_1Ga alloy possesses the single Mn site. In order to investigate the mechanism of PMA and large coercive fields in $Mn_{3-x}Ga$, site-specific magnetic properties have to be investigated explicitly. X-ray magnetic circular dichroism (XMCD) can become a powerful tool to study them. However, the difficulty in deconvolution of two kinds of Mn sites has prevented the site-resolved detailed investigations. Some assumptions are required for the analysis [2]. First-principles calculations are also performed, resulting in the small orbital moment anisotropy in the Mn compound cases because of the small spin exchange splitting [3]. In this study, we perform the deconvolution of each Mn site using the systematic XMCD measurements for different Mn contents in $Mn_{3-x}Ga$. We discuss the site-specific spin and orbital magnetic moments which are deduced from angular-dependent XMCD.

The samples were prepared by magnetron sputtering on MgO substrates. On the 40-nm-thick Cr and 30-nm-thick CoGa buffer layers [4], 3-nm $Mn_{3-x}Ga$ were deposited at room temperature and capped by 2-nm MgO. We prepared the samples of x=0 (Mn_3Ga), 1 (Mn_2Ga), and 2 (Mn_1Ga) cases. X-ray diffraction peaks originated from $D0_{22}$ and $L1_0$-type orderings were clearly observed. 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.

Mn $L_{2,3}$-edge XAS in $Mn_{3-x}Ga$ shows clear metallic line shapes. XMCD intensities decrease with increasing the Mn contents, resulting in antiferromagnetic coupling. With increasing Mn contents, the fine structures in XMCD line shapes which come from two kinds of Mn sites are clearly detected. Based on the spectrum of Mn_1Ga which consists of single Mn site, the subtraction from Mn_1Ga XMCD spectrum after the normalization of spectral intensities deduces the anti-parallel coupled another Mn site. After the deconvolution processes, the spin and orbital magnetic moments for each site are estimated using magneto-optical sum rules. Furthermore, clear hysteresis curves at Mn L_3-edge XMCD can be also detected, which is consistent with the results of magneto-optical Kerr effects. In the presentation, we discuss the site-specific magnetic properties depending on the Mn contents.

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References

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