Quadrupole electronic structure in $Mn_{3-x}Ga$ studied by angular-dependent x-ray magnetic linear 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). Tetragonal $Mn_{3-x}Ga$ alloys are widely recognized as hard magnets which exhibit highly anisotropic, ferrimagnetic, and metallic properties [1]. We have investigated the mechanism of PMA and large coercive fields in $Mn_{3-x}Ga$, consisted of two kinds of Mn sites, by x-ray magnetic circular and linear dichroisms (XMCD/XMLD) [2]. Recently, we have developed novel technique to detect the XMLD for the PMA samples using the remanent magnetization states. By using this technique, the origin of PMA in $Mn_{3-x}Ga$ alloys can be explained by the quadrupole contribution along the z-axis. In order to investigate the quadrupole structures by the charge asphericity, we perform XMLD with angular dependence to detect detailed quadrupole shapes and quadrupole moments with $3z^2$-r^2 oblate type through deducing the quadrupole tensor along z direction Q_{zz} and in-plane Q_{xx} and Q_{yy} in $Mn_{3-x}Ga$, which results in the mechanism of PMA in $Mn_{3-x}Ga$.

The samples were prepared by magnetron sputtering on MgO substrates. The 50-nm-thick $Mn_{3-x}Ga$ were deposited and capped by 2-nm MgO. We prepared the samples of x=0 (Mn_3Ga), and x=2 (Mn_1Ga) cases. X-ray absorption spectroscopy (XAS) and XMCD/XMLD were performed at BL-7A and BL-16A in the Photon Factory (KEK) using linearly and circularly polarized beams. XMLD was detected by the difference between horizontal and vertical beams. The total-electron-yield mode was adopted, and all measurements were performed at room temperature.

Mn $L_{2,3}$-edge XAS and XMLD intensities in $Mn_{3-x}Ga$ increase with the Mn concentration contrary to XMCD, resulting in antiferromagnetic coupling. Since the integrals of XMLD line shapes are proportional to Q_{zz}, we confirmed that the integral converges to positive value, suggesting the positive sign of Q_{zz}, which means $3z^2$-r^2 orbitals in Mn 3d states are elongated to easy-axis direction. The results of XMLD are consistent with those analyzed by XMCD line shapes. Angular dependence in XMLD exhibits the suppression of XMLD intensity from the setup detecting the charge distributions along out-of-plane (Q_{zz}) to that along in-plane (Q_{xx}, Q_{yy}), which confirms the oblate charge distribution in Mn sites. Therefore, as for the origin of PMA in $Mn_{3-x}Ga$, we found that not orbital moment anisotropy but elongated charge distribution can be a main factor for PMA in $Mn_{3-x}Ga$. These results are consistent with the theoretical calculations [3]. In the presentation, we discuss the site-specific magnetic and quadratic properties depending on the Mn contents in $Mn_{3-x}Ga$.

References

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