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Element-specific magnetic properties of compensated ferrimagnet $Mn_2Co_{1-x}V_xAl$ Heusler alloy films

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Half-metallic antiferromagnets or fully compensated ferrimagnets have attracted much attention for spintronics. They have no stray magnetic field and may significantly reduce switching current of spin-torque due to no net magnetization. Such intriguing materials have been originally proposed theoretically [1]. One of the candidates for such materials is the Heusler alloy. Some of the elemental compositions are believed to be half-metals and those magnetisms can be tuned by valence electrons according to the well-known Slater-Pauling-like rules in full Heusler alloys [2]. The rules lead the net magnetic moment $M_t = Z_t - 24$, where Z_t is the total valence electron number and allows us to obtain half-metals with no net magnetic moments at Z_t =24. The electronic structure for $Mn_2(V_xCo_{1-x})Z$ (Z=Al, Ga) has been anticipated as negligible magnetic moments as well as half-metallic band gap at the Fermi level for minority spin states. In this study, we investigate the element-specific magnetic states of $Mn_2(V_{1-x}Co_x)Al$ with various compositions x to understand the spin configuration of the magnetization compensation using x-ray absorption and magnetic circular dichroism (XAS/XMCD).

All samples were deposited on MgO(001) single-crystal substrates using a magnetron sputtering technique. The 30-nm-thick $Mn_2(V_{1-x}Co_x)Al$ was grown with 2-nm-thick MgO capping. The XMCD were performed at BL-7A in PF. A magnetic field of ±1 T was applied along the incident polarized soft x-ray and magnetic field directions are switched, defining the absorption signals as μ^+ and μ^-. The total electron yield mode was adopted in the measurements at 80 K.

The XAS and XMCD spectra are displayed in Fig. 1 after the normalized divided by incident photon intensities. The XAS intensities of Mn remain almost unchanged and those of V and Co are systematically changed with regard to the element substitution. Clear metallic peaks are observed, which confirms preventing the mixing of oxygen atoms in the $Mn_2Co_{1-x}V_xAl$ layer. Shoulder structures appear in the higher photon energy region of Co L_3 XAS peaks. These structures correspond to the Heusler alloys due to the Co-Co bonding states within the molecular orbital calculations and observed in the XMCD of ordered Co-based Heusler alloys.

XMCD line shapes shown in Fig. 1(b) are quite unique. The end compositions, Mn_2VAl and Mn_2CoAl, exhibit clear XMCD signals. In Mn_2CoAl, the spins of Mn and Co sites are coupled in parallel. On the other hand, the spins of Mn and V sites in Mn_2VAl are coupled in anti-parallel. Two kinds of components appear in Mn_2VAl, one has a peak at 638 eV and the other is 640 eV for L_3 edge. Former peak position is the same as that in the Mn XMCD of Mn_2CoAl. At the intermediate compositions, positive and negative signs in XMCD are observed for V, Mn, and Co L-edges and their systematic changes are also depicted. With increasing V composition into Mn_2CoAl, the Mn XMCD spectra clearly exhibit two kinds of sites with opposite sign. This clearly indicates the swapping for different atomic sites with different exchange coupling in Mn_2VAl, resulting in antiferromagnetic coupling between Mn and V sites. We found that the existence of anti-parallel coupled sites in both Mn and Co contributes to the antiferromagnetic compensation in x=0.5 [3].

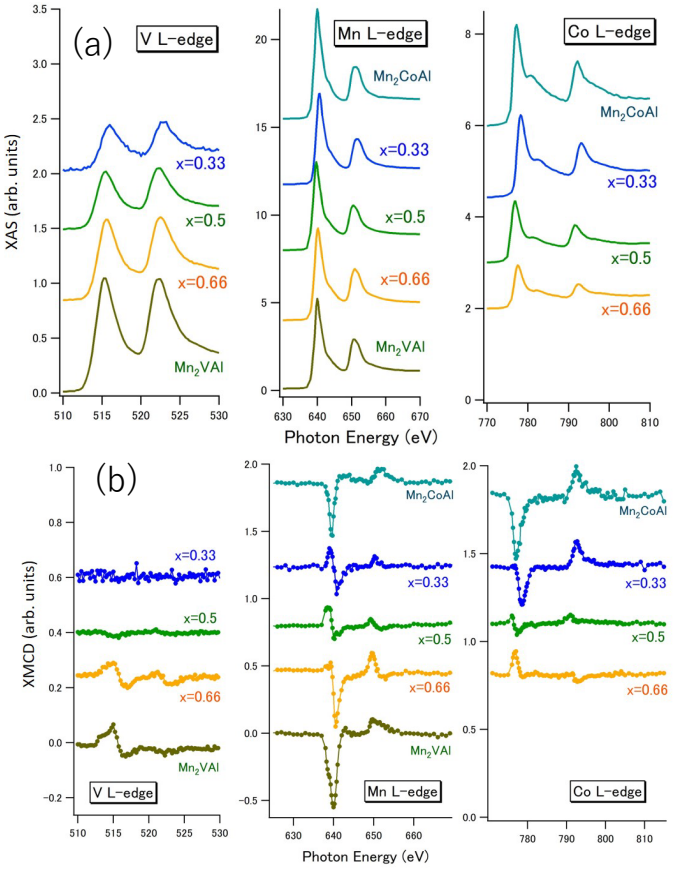

Fig. 1, (a) XAS and (b) XMCD of V, Mn, and Co L-edges for various composition in $Mn_2Co_{1-x}V_xAl$ films.

References

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