Growth of $Mn_{4-x}Cr_xN$ epitaxial films and analysis of their magnetic structure by X-ray magnetic circular dichroism

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[Introduction] Antiperovskite ferrimagnetic Mn_4N film is a candidate of the future domain wall (DW) motion devices. We achieved v_{DW} ~ 900 m/s at a current density $j = 1.3 \times 10^{12}$ A/m^2 with Mn_4N strips only by spin transfer torque at room temperature(RT)[1]. In addition, the magnetic compensation in $Mn_{4-x}Ni_xN$[2] and $Mn_{4-x}Co_xN$[3] was revealed at RT by X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) measurements. Domain wall velocity approaching 3000 m/s (j=1.2× 10^{12} A/m^2), which exceeds that of Mn_4N[4], was obtained around the magnetic compensation composition of $Mn_{4-x}Ni_xN$ at RT. This time, we cast a new spotlight on $Mn_{4-x}Cr_xN$ epitaxial films as another candidate because Cr also belongs to 3*d* transition metal and its preferential occupation sites may differ from those of Ni[2] or Co[3]. However, the growth of $Mn_{4-x}Cr_xN$ films have never been reported as far as we recognize. In this work, we succeeded in the epitaxial growth of $Mn_{4-x}Cr_xN$ films for the first time and performed XAS and XMCD measurements to reveal the magnetic structures.

[Experiment] We grew 25-nm-thick $Mn_{4-x}Cr_xN$ (x = 0.13 and 0.37) films on $SrTiO_3$(001) substrates by molecular beam epitaxy. XAS and XMCD measurements were performed at the twin APPLE-II undulator beam line BL-16A of KEK-PF in Japan. The magnetic fields of ± 5T and circularly polarized X-rays were applied at an incident angle of 54.7° (magic angle)[5] from the sample normal.

[Result] Figure 1 shows XAS and XMCD spectra of Mn-$L_{2,3}$ absorption edges in (a) $Mn_{3.87}Cr_{0.13}N$ and (b) $Mn_{3.63}Cr_{0.37}N$. No significant difference was observed in the XAS spectra. In XMCD spectra, the sign reversal which suggests the magnetic compensation point was not observed. However, the intensity of peak β of $Mn_{3.63}Cr_{0.37}N$ became smaller than that of $Mn_{3.87}Cr_{0.13}N$. Considering that the sharp peak α originates mainly from isolated Mn atoms at corner (I) sites, whereas more-itinerant Mn atoms at face-centered (II) sites contribute to the broad peak β[6], we concluded that Cr atoms preferentially replaced Mn(II) atoms at x = 0.13 and 0.37 unlikely to the case of Ni- or Co-doped Mn_4N.

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[Reference]

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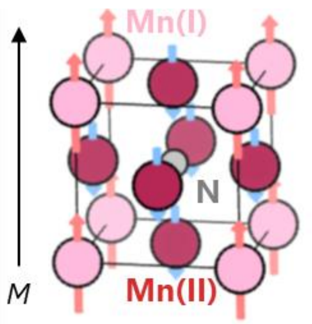

Fig. 1 Antiperovskite crystal structure of Mn_4N.

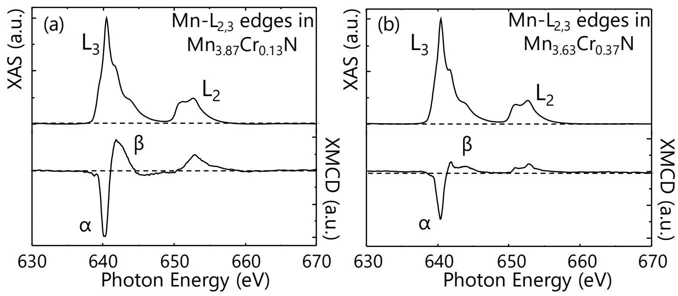

Fig. 2 XAS and XMCD spectra in (a) $Mn_{3.87}Cr_{0.13}N$ and (b) $Mn_{3.63}Cr_{0.37}N$ films at Mn-$L_{2,3}$ edges.