Effect of heavy metal doping on the Morin transition of epitaxial a-Fe_2O_3 (0001) thin films

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Hematite (a-Fe_2O_3), which is an antiferromagnetic material with high Néel temperature (T_N = 950 K), is attracting great interest, because this material can be applied for assisting layer of perpendicular magnetic devices, e.g., electric-field-writing-hard-disk drives. In pure a-Fe_2O_3, the Morin transition, which is the antiferromagnetic to weak ferromagnetic transition, occurs at 253 K, so that c-axis oriented a-Fe_2O_3 thin films have the in-plane spin configuration and show weak ferromagnetism at room temperature. Recently, Shimomura *et al.* reported that the Morin transition temperature (T_M) can be enhanced above 400 K in c-axis oriented a-Fe_2O_3 thin films by doping 1% Ir [1]. The Morin transition can be explained by the competition between magnetic dipolar anisotropy K_{MD} and single ion anisotropy K_{FS}. The enhancement of T_M is caused by the increase of K_{FS}. In this study, we report the heavy-metal-doping effect for Morin transition of c-axis oriented a-Fe_2O_3 thin films.

Heavy metal (Ru, Ir and W) doped a-Fe_2O_3 films of about 80 nm in thickness were deposited on Al_2O_3(0001) substrates by pulsed laser deposition method at various substrate temperatures in background oxygen pressure of 10 Pa. X-ray diffraction (XRD) measurement and conversion electron Mössbauer spectroscopy were performed for these samples at room temperature.

XRD measurement clarified that the growth direction of the heavy-metal-doped a-Fe_2O_3 films on Al_2O_3(0001) substrates was along c-axis. Figure 1 shows the Mössbauer spectra of 5% Ru doped a-Fe_2O_3 films deposited at the substrate temperature of 300°C, 400°C and 500°C. The angle q between the average spin direction and the vertical axis of film plane can be estimated by the intensity ratio of the six peaks of the Mössbauer spectra. When the spin direction is perpendicular to the film plane (q = 0°), the peaks indicated by the arrows disappear. The results show the peaks indicated by red arrows decrease with increasing growth temperature. The Mössbauer spectra indicated that the spin direction of 5% Ru doped a-Fe_2O_3 films deposited at the substrate temperature of 300°C is nearly in-plane (q = 76°) and that the T_M is below room temperature, while the spin direction of the 5% Ru doped a-Fe_2O_3 films deposited at the substrate temperature of 500°C is almost perpendicular (q = 16°) and the T_M is higher than room temperature. The spin direction angle of 5% Ru doped a-Fe_2O_3 films deposited at the substrate temperature of 300°C is 31°, indicating that the T_M of this sample is near room temperature. These results imply that the lattice location of Ru ions in a-Fe_2O_3 films varies with changing deposition temperature and that the difference of spin-orbit interaction of Ru ions affects the enhancement of K_{FS}.

In this presentation, we will also demonstrate the effect of other heavy metal (Ir and W) doping on Morin transition of a-Fe_2O_3 films.

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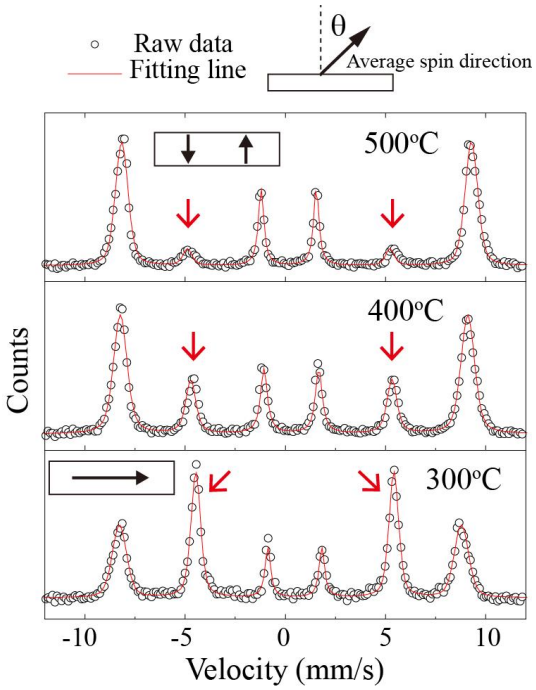

Fig. 1 Mössbauer spectra of 5% Ru doped a-Fe_2O_3 films deposited at the substrate temperature of 300°C, 400°C, and 500°C

Reference

1) N. Shimomura *et al.*, J. Appl. Phys., **117**, 17C736 (2015).