Oxidation State in Perpendicularly Magnetized Fe/CrO/MgO studied by X-ray Absorption Spectroscopy

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Interface perpendicular magnetic anisotropy (PMA) at ferromagnetic metal/oxide layered structures is an important functionality for spintronic devices, especially for perpendicular magnetic tunnel junctions (p-MTJs).[1] Single-crystalline Fe/MgO(001) interface shows large interfacial PMA energy K_i of 2.0 mJ/m^2 when they were grown using molecular beam epitaxy or electron beam evaporation.[2,3] In this work, we explore the possibility of achieving high K_i using an industrially viable sputtering process.

A multilayered stack of MgO(001) substrate//MgO(5 nm)/Cr(30 nm)/Fe(0.7 nm)/MgO(2 nm) was prepared by rf-sputtering. The MgO substrate and the Cr buffer were annealed at 500 ºC after deposition and the stack was post annealed at different temperature T_a. Nanostructural analyses by scanning TEM revealed the oxidation of Fe layer in as deposited samples and the formation of a rock-salt type CrO layer between the Fe and MgO layers, i.e., Fe/CrO/MgO, after annealing at T_a = 500 ºC. Figure 1 shows schematic diagrams of the observed structures of the as-deposed and annealed samples. K_i of 1.55 mJ/m^2 was achieved in the Fe/CrO/MgO, which indicates that the flatness of the Fe/CrO interface is high enough to show the large interfacial PMA. In order to investigate the oxidation state in detail, x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) measurements were performed at KEK-PF BL-7A. In XAS and XMCD spectra at the Fe $L_{2,3}$ edges, the peak intensities due to the oxidation decreased and XMCD intensities increased with increasing T_a. On the other hand, in Cr $L_{2,3}$ edges, the peak intensities due to the oxidation increased with increasing T_a. This result suggests that the redox reaction of Fe-oxide by Cr proceeds as the annealing temperature increases. In the Cr L_3 edge, peak shift due to the oxidation from a metallic Cr peak was 1.25 eV, which is smaller than that of Cr^{2+} (1.8 eV).[4] Considering that the CrO has a rock-salt structure, the valence state of Cr is deduced to be less than 2+. FeO is also 3d transition metal oxide with a rock-salt structure, and magnetic anisotropy in Fe/FeO/MgO strongly depends on the composition of FeOx.[5] Therefore, even in Fe/CrO, the composition of CrOx is considered to have a great influence on PMA.

Acknowledgement

We thank J. Uzuhashi for the structural analyses. This work was partly supported by the JSPS KAKENHI Grant Number 16H06332. Y. I. acknowledges the National Institute for Materials Science for the provision of the NIMS Graduate Research Assistantship.

Reference

[1] S. Ikeda *et al*., Nat. Mater. **9**, 721 (2010).
[2] J. W. Koo *et al*., Appl. Phys. Lett. **103**, 192401 (2013).
[3] T. Nozaki *et al*., Phys. Rev. Appl. **5**, 044006 (2016).
[4] C. Xu *et al*., Surf. Sci. **258**, 23 (1991).
[5] K. Nakamura *et al*., Phys. Rev. B **81**, 220409(R) (2010).

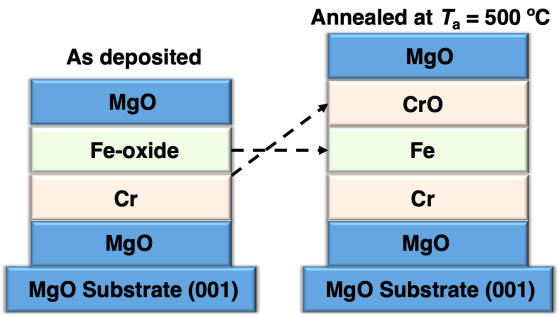

Fig. 1. Schematic diagrams of as-deposited and annealed stacks.

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