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Perpendicular magnetic anisotropy in W-inserted Fe/MgO interfaces studied by X-ray magnetic circular dichroism

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Large perpendicular magnetic anisotropy (PMA) energy is strongly required to stabilize the direction of magnetization in magnetic tunnel junctions. The highest PMA energy (K_{eff}) was reported at single-crystalline Fe/MgO interfaces [1]. In order to improve K_{eff} values, heavy metal doping to the interfaces has been investigated thoroughly [2], First-principles calculation suggests that the large interface PMA energy can be expected when the lattice constant of inserted W is distorted and matched to that of Fe or $MgAl_2O_4$ [3]. In this study, we aim to achieve the large PMA energy by inserting W to epitaxial Fe/MgO interface and investigate interface spin and orbital states.

The samples of MgO-seed(5 nm)/ Cr-buffer(30 nm)/Fe(0.7 nm)/MgO(2 nm) were deposited on the MgO substrate using molecular beam epitaxy at 150˚C, while W was deposited to Fe/MgO interfaces or into Fe using rf sputtering at room temperature. An annealing process was carried out at 800˚C for MgO substrate and Cr buffer, at 250˚C for Fe, 400˚C for top-MgO. X-ray absorption spectroscopy (XAS) and magnetic circular dichroism (XMCD) measurements were also performed for Fe $L_{2,3}$ edges to evaluate the spin and orbital magnetic moments M_{spin}, M_{orb} for grazing incidence (GI) and normal incidence (NI) geometries.

As shown in Fig. 1, in the case of Fe/W/MgO, PMA energies decrease by the insertion of W, while larger PMA energies can be obtained than that of normal Fe/MgO interfaces when 0.05nm-thick W is inserted into Fe.

M_{spin} and M_{orb} of various Fe(0.7 nm)/W(t_W nm)/ MgO(2 nm) heterostructures were deduced from XMCD analyses. Figure 2 shows XAS and XMCD taken at NI and GI. In the case of 0.15nm thick W insertion, XMCD in both NI and GI keep resemble line shapes as shown in Fig. 2(b), suggesting that the anisotropy of orbital moment ΔM_{orb} decreases with the insertion of W. Therefore, the PMA can be explained by orbital moment anisotropy as the K_{eff} is proportional to ΔM_{orb} [4,5]. Further, we found that Fe and W were completely mixed by the structure analysis of Fe/W(0.05 nm)/MgO using transmission electron microscopy. It suggests that W penetrates into Fe due to the large mass of W atoms.

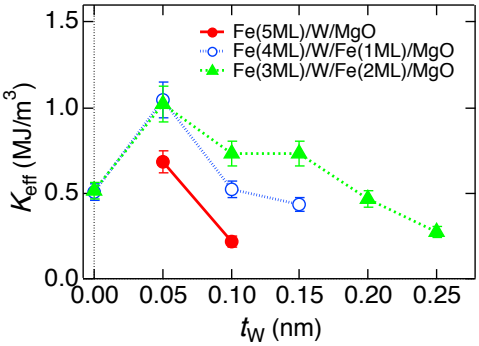

Fig. 1 K_{eff} values depending on t_W by magnetization measurement. Each line indicates the position of W in Fe/MgO interfaces.

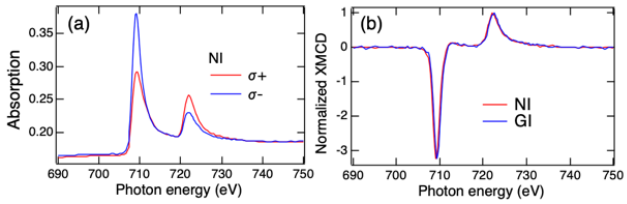

Fig. 2 (a) Fe-$L_{2,3}$ edges absorption spectra in NI and (b) XMCD in Fe(0.7 nm)/W(0.15 nm)/ MgO(2 nm).

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