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Investigation of perpendicular magnetic anisotropy in sputter-deposited Fe/MgO heterostructures by X-ray absorption spectroscopy

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1 Introduction

Ultrathin Fe/MgO heterostructures are known to show large interface perpendicular magnetic anisotropy (PMA) [1], which is an important factor for consisting of perpendicular magnetic tunnel junctions (p-MTJs). It is usually prepared by electron beam evaporation (EB) or molecular beam epitaxy (MBE) while there are few reports about sputter-deposition [1-4]. Considering the recent developments of wafer bonding techniques for MTJs, needs for sputter-deposition of Fe/MgO is increasing [5].

In this study, we prepared Fe/MgO heterostructures with PMA by rf-sputtering and revealed the differences of interface states with EB-grown samples by the X-ray absorption spectroscopy.

2 Experiment

The multilayered stack of MgO-seed(5 nm)/Cr-buffer(30 nm)/Fe(0.7 nm)/MgO(2 nm) was deposited on MgO(001) substrate by rf-sputtering. The sputter-deposition was performed at room temperature. MgO substrate, Cr-buffer and top-MgO were post-annealed at 500 ˚C. As the reference, we also prepared EB-grown Fe/MgO, which stack is same with sputter-deposited samples. The EB-growth was performed at 150 ˚C. MgO substrate, Cr-buffer, Fe and top-MgO were post-annealed at 800 ˚C, 800 ˚C, 250 ˚C and 400 ˚C, respectively. Magnetic properties were characterized by the vibrating samples magnetometer (VSM). In order to investigate more detailed interface states, the X-ray absorption spectroscopy was performed at KEK-PF BL-7A using the total electron yield mode. Circularly polarized soft x-ray is incident in the direction perpendicular to the sample's surface. At the same time, the magnetic fields of ±1.0 T were applied parallel to incident X- ray.

3 Results and Discussion

In sputter-deposited samples, the saturation magnetization M_s and the effective PMA energies K_{eff} was deduced to be 1.78 T and 0.77 MJ/ m^3, respectively, from the results of the VSM. On the other hand, M_s and K_{eff} of EB-grown samples was 1.90 T and 1.2 MJ/m^3, respectively. Although the K_{eff} obtained in sputter-deposited samples was larger than that in other ferromagnetic/oxide interfaces [6], it was not as high as that in EB-grown ones.

Figure 1 shows the X-ray absorption spectroscopy of Fe $L_{2,3}$-edges for samples made by (a) sputtering and (b) EB. In Fig.1 (a), the satellites were observed at 708, 722 eV, while they were not confirmed in Fig.1 (b). These satellites indicate the Fe surface is oxidized in sputter-deposited samples with PMA. These results are different from the theoretical calculation, where the PMA energies significantly decrease at Fe-O/MgO interfaces [7]. Therefore, the observed PMA might be derived from another mechanism enhancing PMA at the interface between Fe and Fe compounds. Further investigation including structural analysis would be necessary.

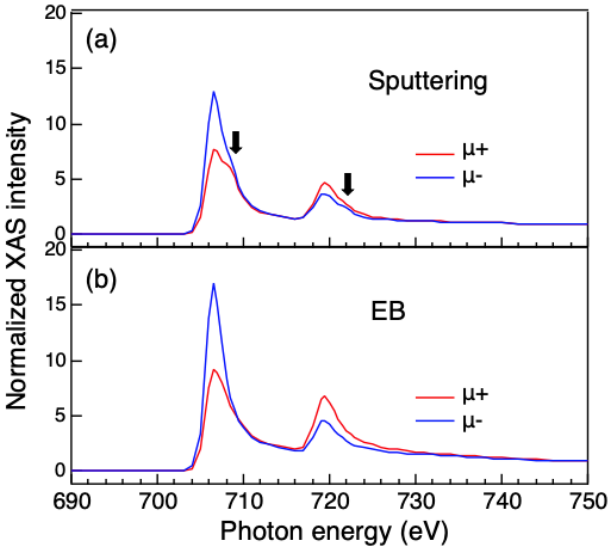

Figure 1 Normalized XAS of Fe $L_{2,3}$-edges for samples made by (a) sputtering and (b) EB. μ+, - indicates the right- and the left-hand side circularly polarized X-ray, respectively. In Fig.1 (a), black arrows indicate the satellites.

References

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