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

Yuki Iida1,2,*, Qingyi Xiang3, Jun Okabayashi3, Hiroko Sukegawa3 and Seiji Mitani1,2

1Graduate School of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Ibaraki Japan.
2Research Center for Magnetic and Spintronic Materials (CMSM), National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, Japan.
3Research Center for Spectrochemistry, The University of Tokyo, Bunkyo, Tokyo, Japan.

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 \( M \), and the effective PMA energies \( K_{eff} \) was deduced to be 1.78 T and 0.77 MJ/m³, respectively, from the results of the VSM. On the other hand, \( M \), and \( K_{eff} \) of EB-grown samples was 1.90 T and 1.2 MJ/m³, 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.

References

* IDA.Yuki@nims.go.jp