Characterization of anisotropic short-range order in amorphous $SmFe_2$ films with various magnetic anisotropy

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Perpendicular magnetic tunnel junctions with a giant negative magnetostrictive free layer with the sidewall of piezoelectric materials, piezoelectronic tunnel junctions (PE-MTJ) [1], is attractive MTJ since it can overcome the intrinsic problem of keeping high thermal stability and reducing critical current density for magnetization switching. We have been studied $SmFe_2$ thin films as a promising material for the free layer of PE-MTJ, and obtained $SmFe_2$ thin films with perpendicular magnetic anisotropy (PMA) and giant negative magnetostriction simultaneously. However, the origin of the anisotropy is not understood, since the $SmFe_2$ thin films have amorphous structure according to X-ray diffraction and transmission electron microscopy analysis. In this study, we analyzed short-range order in the $SmFe_2$ thin films with various magnetic anisotropy using polarized extended X-ray absorption fine structure (EXAFS) measurements.

The stack structure of the samples is Quartz-sub./W/$SmFe_2$/W. The substrate temperature T_S during sputtering was varied from 200 to 400°C so that easy axis of magnetic anisotropy changed from out-of-plane to in-plane directions. The post annealing temperature was fixed at 500°C. EXAFS measurements for the Sm-L3 edge were done at a beamline BL-9C in High Energy Accretor Research Organization (KEK).

The EXAFS signals were well fitted with a single Sm-Fe path using QFC model. Figure 1 shows the distance R between Sm and Fe atoms and the coordination number N of Sm as function of T_S. For the sample formed T_S = 200 and 300°C with PMA, R for out-of-plane and in-plane are different. On the other, the sample formed at 400°C with in-plane magnetic anisotropy, R was identical. The N of all the sample for both directions were identical which seems not to contributed to the magnetic anisotropy in this case.

The analysis implies that the $SmFe_2$ films with PMA have tensile stress, which strengthens magnetic anisotropy in the out-of-plane direction via the negative magnetostrictive effect, resulting in PMA.

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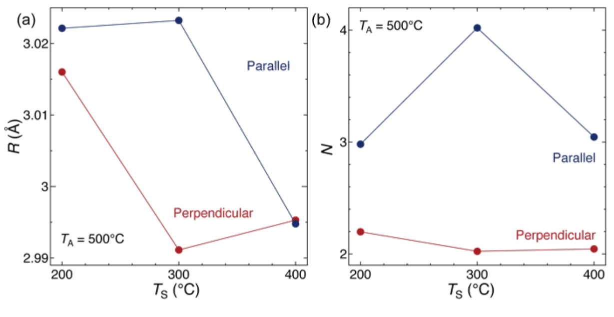

Fig. 1 EXAFS analysis. (a) the distance R between Sm and Fe atoms (b) the coordination number N around Sm atoms as a function of substrate temperature T_S.

References

[1] Y. Takamura, et al., Solid State Electron., **128**, 194 (2017).
[2] Y. Takamura, et al., “Perpendicular magnetic anisotropy of giant negative magnetostrictive $SmFe_2$ amorphous thin films,” to be submitted in 2020.