CoFeB/酸化物界面へのフッ化物と窒化物導入による垂直磁気異方性の変化

Effects of nitride and fluoride introduction on perpendicular anisotropy at CoFeB/Oxides interfaces

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1. Introduction: CoFeB/oxide stack with perpendicular magnetic anisotropy (PMA) is one of the key technologies to realize high performance magnetoresistive random access memory. CoFeB/oxide PMA stacks with high interface anisotropy energy (K_{int}) have already been achieved by MgO deposition on CoFeB[1,2], but exploring the materials to induce higher K_{int} is still an issue. The formation of Fe-O bonds is considered to bring PMA of this stack due to the degeneracy lifting of Fe3d and hybridization of Fe3d and O2p orbitals [3]. Hence PMA enhancement is reasonably expected if we replace oxygen with anions with different electronegativity. In this study we introduce fluoride and nitride to the CoFeB/oxide interface, to investigate the possibility of manipulation of PMA.

2. Experimental: After thermal oxidation of Si substrate, Ta (2.9nm)/wedged $Co_{0.6}Fe_{0.2}B_{0.2}$ (0-2nm)/dielectric layer were sequentially deposited by sputtering. Three kinds of dielectric layers were investigated: **(i)** AlF_3 (0–0.6nm)/Al_2O_3 (4nm); **(ii)** AlN (0–0.5nm) /Al_2O_3 (4nm); **(iii)** MgF_2 (0–0.5nm)/MgO (1.5nm)/Al_2O_3 (4nm). Those stacks were annealed at 250°C or 300°C in N_2 for 10 minutes. Magneto-optical Kerr effect (MOKE) measurements showed the saturation magnetic field H_s at the different positions on each wedged structure. Saturation magnetization per area M_st_{eff} (M_s is saturation magnetization per volume and t_{eff} is effective thickness of ferromagnetic layer) at each point was determined by using superconducting quantum interference device (SQUID).

3. Results and Discussions: From the result of MOKE and SQUID, $k_{eff}t_{eff} \approx 1/2\ \mu_0 H_s M_s t_{eff}$ of each position d could be determined. Here, μ_0 is permeability of vacuum, k_{eff} represent effective magnetic anisotropy energy density of ferromagnetic layer. K_{int} also could be determined by considering the relationship: $k_{eff}t_{eff} = -1/2\mu_0 M_s^2\ t_{eff} + K_{int}$ as shown in **fig.1** for typical stacks. From the result shown in **fig.2**, the insertion of both 0.5-nm-thick MgF_2 for the MgO stack and 0.5-nm-thick AlF_3 for the Al_2O_3 stack brings around 50% increase of K_{int} in our experimental conditions, while the insertion of AlN at CoFeB/ Al_2O_3 decrease the K_{int}. Thus we can surmise that higher electronegativity anion introduction at the CoFeB/Oxides interface is beneficial for the enhancement of K_{int}, even though the maximum value of K_{int} achieved in this study was not so high as the reported value for MgO/CoFeB[1]. The physical origin of this observation is not yet fully understood, but we speculate that the transfer of more electrons from ferromagnetic to dielectric by higher electronegativity anion would enhance the PMA of CoFeB/oxide stacks.

[References][1] S. Ikeda, et al., Nature materials 9.9, 721-724 (2010). [2]D. C. Worledge, et al. Appl. Phys. Lett. 98, 022501 (2011). [3] H. X. Yang, et al., Physical Review B 84.5, 054401 (2011).

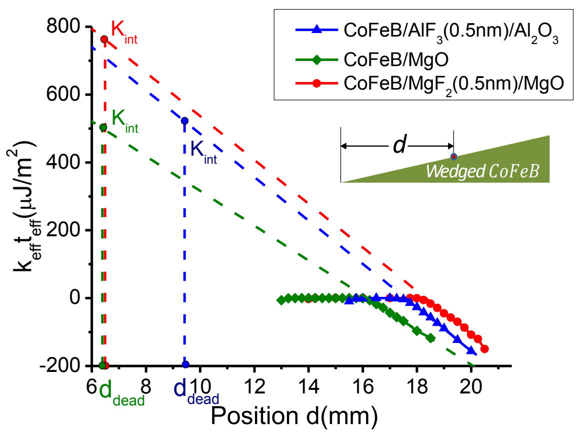

Fig.1 k_{int} values of typical stacks were estimated as the value of $K_{eff}t_{eff}$ at d_{dead}, here d_{dead} is the position that t_{eff} becomes zero, which determined by SQUID.

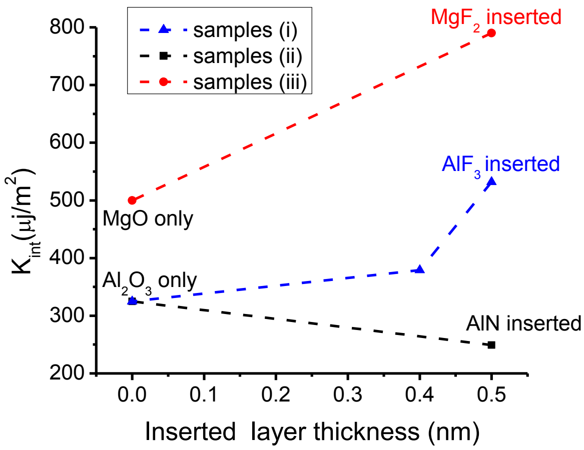

Fig.2 Comparison of k_{int} of samples **(i), (ii), and (iii)** with different inserted layer thickness. Annealing temperature of samples **(i)** and **(ii)** is optimized as 300℃ while samples **(iii)** annealed at 250℃.