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

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 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_{0.4}B_{2}O_{3} (0-2nm)/dielectric layer were sequentially deposited by sputtering. Three kinds of dielectric layers were investigated: (i) AlF_{3} (0-0.6nm)/Al_{2}O_{3} (4nm); (ii) AlN (0-0.5nm)/Al_{2}O_{3} (4nm); (iii) MgF_{2} (0-0.5nm)/MgO (1.5nm)/Al_{2}O_{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 wedge structure. Saturation magnetization per area M_{sat} (M_{s} is saturation magnetization per volume and t_{ef} 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} ≈ 1/2 \mu_{0}M_{sat}t_{ef} of each position d could be determined. Here, \mu_{0} is permeability of vacuum, k_{ef} represent effective magnetic anisotropy energy density of ferromagnetic layer. K_{int} also could be determined by considering the relationship: k_{eff} = -1/2\mu_{0}M_{sat}^{2}t_{ef} + 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_{2}O_{3} stack brings around 50% increase of K_{int} in our experimental conditions, while the insertion of AlN at CoFeB/Al_{2}O_{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.