Large perpendicular magnetic anisotropy in sputter-deposited $Fe_{100-x}Al_x/MgAl_2O_4$ heterostructures

T. Scheike, °H. Sukegawa, X.D. Xu, T. Ohkubo, K. Hono and S. Mitani
(NIMS)

Large perpendicular magnetic anisotropy (PMA) at ferromagnet (FM)/oxide interfaces is of utmost importance for magnetic tunnel junctions (MTJ) based memory devices such as spin-transfer torque magnetoresistive random access memory (STT-MRAM) and magneto-electric RAM. In recent publications, Al diffusion from a Co_2FeAl FM layer into an $MgAl_2O_4$ layer was reported to induce large PMA energy K_{eff} = 0.4 MJ/m^3 in lattice-matched $Co_2FeAl/MgAl_2O_4(001)$ epitaxial heterostructures.[1,2] It was suggested that the element diffusion resulted in strong hybridization of Fe- with O-orbitals at their interface, assisting the PMA contribution.[2] In order to improve K_{eff} further, we examined the bcc Fe-Al with Fe rich compositions as an FM layer. Here, we report larger PMA energy K_{eff} over 1 MJ/m^3 using ultrathin $Fe_{100-x}Al_x/MgAl_2O_4$ heterostructures for various x.

The following stack structures were deposited on MgO(001) single crystal substrates using an ultrahigh vacuum magnetron sputtering system: MgO substrate/Cr (40)/$Fe_{100-x}Al_x$ (t_{FeAl})/Mg (0.2)/$Mg_{40}Al_{60}$ (0.7)/plasma oxidation/Ru (2) (thickness in nm). The MgO substrate/Cr layer was annealed at 750°C for 1 h. $Fe_{100-x}Al_x$ was deposited by co-sputtering of Fe and Al. An $MgAl_2O_4$ layer was formed by the plasma oxidation of the $Mg/Mg_{40}Al_{60}$ bilayer. The stacks were post-annealed *ex-situ* at temperatures of T_{ann}. Magnetic properties including K_{eff} were evaluated using a vibrating sample magnetometer at room temperature.

As shown in Fig. 1, large K_{eff} above 1 MJ/m^3 was obtained for x = 11, 20, and 28, which was nearly the same value observed in $Fe/MgAl_2O_4$ fabricated by electron-beam deposition.[3] For T_{ann} < 300°C, K_{eff} increases with x. K_{eff} values show a strong T_{ann} dependence above 300°C ($x \leq 20$), showing possible tunability of PMA properties with Al concentration and T_{ann}. Scanning transmission electron microscope analysis showed a lattice-matched interface with Al diffusion from the Fe-Al layer into the barrier. Above 300°C, diffusion of Cr was also confirmed; however, we observed no significant change in the saturation magnetization and negligible magnetic dead-layer. The results show very large interfacial PMA can be achieved by atomically-controlling element diffusion in sputter-deposited heterostructures. Therefore, the $Fe_{100-x}Al_x/MgAl_2O_4$ is a good candidate for future spintronic applications. This study was supported by the ImPACT Program, and JSPS KAKENHI Grant Nos. 16H06332 and 16H03852.

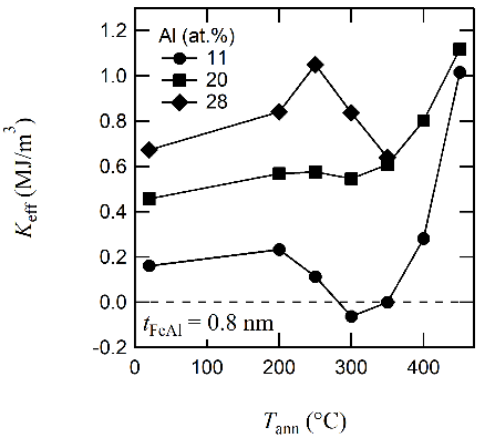

Fig. 1. T_{ann} dependence of K_{eff} of various Al concentration (x) in $Fe_{100-x}Al_x$ (t_{FeAl} = 0.8 nm)/ $MgAl_2O_4$ heterostructures.

Reference

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3) Q. Xiang *et al.*, Appl. Phys. Express **11**, 063008 (2018).