Large perpendicular magnetic anisotropy in Fe/$MgAl_2O_4$ heterostructures

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$MgAl_2O_4$ is promising to substitute barrier material of MgO for magnetic tunnel junctions (MTJs) due to its tunable lattice constant.[1)] It is crucial to obtain large interfacial perpendicular magnetic anisotropy (PMA) at an $MgAl_2O_4$ for applications of perpendicularly magnetized MTJs (p-MTJs). A recent theoretical calculation indicates that an areal PMA energy density of ~1.3 mJ/m^2 at an Fe/$MgAl_2O_4$(001) interface,[2)] which is nearly comparable to that at an Fe/MgO(001) interface (~1.5–1.7 mJ/m^2). However, a much smaller PMA energy density ~0.4 MJ/m^3,[3)] comparing with ~1.4 MJ/m^3 in Fe/MgO,[4)] has been experimentally reported in Fe/$MgAl_2O_4$(001) where the $MgAl_2O_4$ layers were prepared by post-oxidization of an Mg-Al alloy layer. Therefore, further improvement in the PMA energy of ultrathin-Fe/$MgAl_2O_4$(001) interfaces is expected if an optimized interface is obtained by suppressing atomic intermixing and over-oxidation through process optimization. In this study, we report the achievement of a large PMA at an Fe/$MgAl_2O_4$ by directly electron-beam deposition of $MgAl_2O_4$ instead of post-oxidation method.[5)]

Multilayers of Cr buffer (30)/Fe (0.7)/$MgAl_2O_4$ (t_{MAO} = 2 or 3 nm) (unit in nm) were epitaxially grown on an monocrystalline MgO(001) substrate by electron-beam evaporation technique. The $MgAl_2O_4$ used here has an enough high density compared to the bulk $MgAl_2O_4$ (~98% of bulk value). The Cr and Fe were post-annealed at 800°C and 250°C, respectively. The $MgAl_2O_4$, were post-annealed at various temperatures between 350°C and 500°C to modify the interface conditions, especially the oxidation conditions. Magnetic properties were investigated using a vibrating sample magnetometer (VSM) and VSM incorporated with superconducting quantum interference device (SQUID). The ultrafast magnetization dynamics property was measured by the time-resolved magneto-optical Kerr effect (TR-MOKE) method.

Figure 1 shows the effective anisotropy energy (K_{eff}) of an optimized Fe (0.7 nm)/$MgAl_2O_4$ (t_{MAO} = 2 or 3 nm) interface with a large K_{eff} up to ~1.0 MJ/m^3, comparable to the reported value for an Fe (0.7 nm)/MgO (~1.4 MJ/m^3).[4)] We also found that the PMA energy and saturation magnetization (M_s) were not very sensitive to measurement temperature, where from 100 K to 300 K, areal PMA energy (K_i) drops from ~2.0 mJ/m^2 to ~1.7 mJ/m^2. The effective damping constant was also evaluated to be ~0.02 by TR-MOKE under high magnetic fields. This study demonstrated robust interface PMA in ultrathin-Fe/$MgAl_2O_4$, which is useful for p-MTJ applications.

This study was partly supported by the ImPACT program of the Council for Science, Technology and Innovation (Cabinet Office, Government of Japan) and JSPS KAKENHI Grant Number 16H06332.

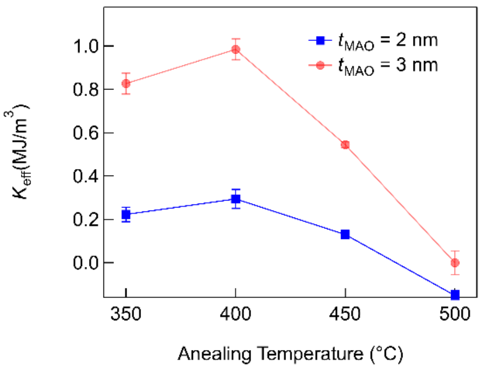

Fig. 1. Effective PMA energy K_{eff} for samples annealed at various temperatures with t_{MAO} = 2 and 3 nm.

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