Effects of Capping Layers on the Dynamic Magnetic Properties of CoFeB

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Since the tunneling magnetoresistance ratios (TMRs) are significantly affected by the crystallization and interfacial compositions at $Co_{60}Fe_{20}B_{20}$/ MgO/ $Co_{60}Fe_{20}B_{20}$ interfaces, the interfacial compositions of annealed samples are studied by x-ray photoemission spectroscopy.[1] The formation of B, Fe, and Co oxides at the $Co_{60}Fe_{20}B_{20}$/ MgO interface was reported to be process-dependent. TMR of $Co_{40}Fe_{40}B_{20}$/ MgO/ $Co_{40}Fe_{40}B_{20}$ MTJs was increased after annealing at 275°C, which was ascribed to a thermally induced reduction of interfacial Fe-oxides. In addition to reduce the Co and Fe oxides, post-annealing may also incorporate B into the MgO to form a composite MgB_XO_Y layer.[2] In this work, we correlate the change of interfacial composition at CoFeB/ MgO with the variations of static and dynamic magnetic characteristics of CoFeB, in particular, the damping parameter α.

To clearly illustrate the interfacial characteristics, we deposited $Co_{40}Fe_{40}B_{20}$(5 nm)/ MgO(5 nm) multilayers (MLs) on oxidized Si substrate by using magnetron sputtering in the presence of a static magnetic field (~100 Oe) to induce the in-plane uniaxial anisotropy. The post-annealing was carried out in vacuum with a magnetic field of 1 kOe parallel to the direction of the deposition field for 2 hrs. The out-of-plane angular dependence of ferromagnetic resonance (FMR) measurements were performed to extract the damping parameter α.[3] The valance states at interfaces of the CoFeB/MgO MLs were obtained by x-ray photoemission spectroscopy (XPS), performed at the National Synchrotron Radiation Research Center, Taiwan. The energy resolution of synchrotron-based light source was 0.05 eV. The variations of $4\pi M_S$, H_C, and α of CoFeB/ MgO MLs with post-annealing temperature are shown in Fig. 1. Post-annealing monotonically increased the $4\pi M_S$; on the other hand, the reductions of H_C from 1.85 to 0.44 Oe and α from 0.0115 to 0.0054 were observed when the temperature was raised from room temperature to 275°C. The crystallization of CoFeB was triggered by annealing MLs at temperatures higher than or equal to 300°C. The crystallization of CoFeB resulted in increases in $4\pi M_S$, H_C, and α.

Figure 2 shows the XPS spectra of Fe 2p and B 1s from the $Co_{40}Fe_{40}B_{20}$(5 nm)/ MgO(5 nm) MLs. The spectra in Fig. 2 were obtained from the region corresponding to the top interface CoFeB/ MgO. Small amounts of Fe-oxides and B-oxides were found in the as-deposited samples due to the oxidation of the CoFeB by oxygen ions released by the rf sputtering of MgO. The Fe $2p_{3/2}$ peak was located at 711.0 eV, accompanying a distinguishable satellite peak, approximately 8 eV higher than the main Fe $2p_{3/2}$ peak. Based on this spectrum, we suggested that the Fe-oxide initially formed at the top interface was mainly composed of Fe_2O_3. After annealing at the temperatures higher than 275°C, the satellite peaks of Fe-oxide vanished. In addition, the Fe peaks shifted to lower binding energy as well, which indicated that the reduction of the Fe-oxide to metallic Fe.[1] On the other hand, the peak of initially formed B-oxide shifted to higher binding energy after post-annealing, which indicated that B was further incorporated into the MgO, and thus an intermixed MgB_XO_Y composite was formed.[2]

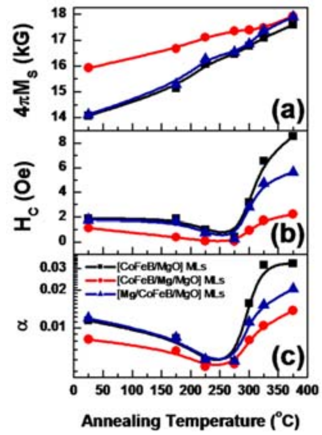

Fig. 1: Static/ dynamic magnetic properties of (a) 4πMs, (b) H_C, and (c) α as a function of annealing temperature for CoFeB(5 nm)/ MgO(5 nm), CoFeB(5 nm)/ Mg(1nm)/ MgO(5 nm), and Mg(1nm)/ CoFeB(5 nm)/ MgO(5 nm) MLs.

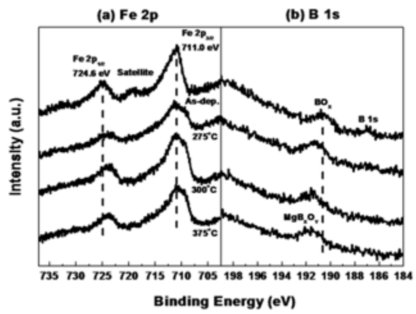

Fig. 2: Normalized XPS spectra of the (a) Fe 2p and (b) B 1s at the top interface in the CoFeB(5 nm)/ MgO(5 nm) MLs.

References

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