Interlayer exchange coupling between CoFeB/MgO and Co/Pd multilayer with perpendicular magnetic anisotropy

J. H. Jung*, S. H. Lim and S. -R. Lee
Department of Materials Science and Engineering, Korea University, Seoul 136-713, Korea

Since the antiferromagnetic (AF) interlayer coupling between two ferromagnetic layers with inplane anisotropy was reported, magnetic elements using this phenomenon have been widely used as pinned and free layer in magnetic tunnel junctions (MTJs). In these structures, the metallic spacer such as Ru forms the closed magnetic flux state, which is known as synthetic AF trilayer [1]. Recently, intensive research on the perpendicular MgO-MTJs have been performed using perpendicular magnetic anisotropy (PMA) material to achieve high thermal stability with a low critical current density for magnetization switching. Considering that MgO templated crystallization of CoFeB should occurs to obtain high tunneling magnetoresistance, the texture development of CoFeB should not be affected by other layers. Another requirement for the perpendicular MgO-MTJs can be a stable PMA of CoFeB. Recent study on perpendicular surface anisotropy in CoFeB/MgO interface is a one of approach to these issues [2]. The alternative solution can be an insertion of Ru spacer between CoFeB and PMA material. When this type of structure constitutes the pinned layer, MgO templated crystallization of CoFeB will be facilitated as proved well in the inplane MTJs. Also, another advantage of reduced stray field near the free layer is expected because magnetic moments of CoFeB and PMA material can be partially compensated by the AF interlayer coupling. In this study, AF interlayer coupling between CoFeB /MgO and Co/Pd multilayer with PMA was investigated as a function of Ru spacer thickness.

The unit structure investigated in this study is a thermally oxidized substrate of Si/Ta (5 nm)/Ru (15 nm)/[Co/Pd]x4/Ru spacer/Co/CoFeB/ MgO (2 nm)/ Ta (5 nm), which is relevant to a pinned layer structure of perpendicular MgO-MTJs. The thickness of Ru spacer was varied from 0.69 to 2 nm while those of Co and CoFeB were fixed to 0.3 and 0.7 nm, respectively. The stack was deposited using a magnetron sputtering system that had two separate chambers with different base pressures of 5×10-8 Torr and 1×10-8 Torr. During the deposition, the samples were transported from chamber to chamber with a UHV robotic system, so that the vacuum was not broken. Post annealing of the sample was carried out at 300^{o}C for 1 hour in a vacuum lower than 1×10-6 Torr.

The representative *M-H* loops which shows AF coupling between Co/Pd multilayer and CoFeB/MgO are shown in Fig. 1. Here, the thickness of Ru spacer is 0.77 nm and similar shape of *M-H* loop was observed for the samples with the Ru thickness of 0.69~0.95nm. Nearly zero remanence of in-plane *M-H* loop (dottedline) and plateau extended up to ~5000 Oe observed in out-of-plane *M-H* loop (solid line) indicate that the magnetization of CoFeB is AF coupled to Co/Pd multilayer with PMA. The coupling strength (*J*) is defined by the equation of $J=H_{ex}M_st$, where H_{ex}, M_s, and t are exchange field, saturation magnetization and thickness of CoFeB, respectively. The magnitude of H_{ex} can be determined in the out-of-plane *M-H* loop, indicated by arrow in the Fig. 1. The measured value of M_st of Co/CoFeB layer was about 80 μemu/cm^2 and this value was not highly dependent on the Ru thickness. The values of H_{ex} and J corresponded to H_{ex} are summarized in Fig. 2 where the left (right) vertical axis indicates Hex (*J*). As shown in the Fig. 2, AF coupling between CoFeB and Co/Pd multilayerwasobservedintheRuthicknessof 0.69~0.95 nm. The maximum strength of AF coupling was observed at Ru thickness of 0.77 nm. For the case of samples with Ru thicker than 0.95 nm, H_{ex} was not observed in the out of plane *M-H* loop, indicating ferromagnetic coupling between CoFeB and Co/P dmultilayer.

References

[1]. J. Hayakawa et al., Jpn. J. Appl. Phys. 45, L1059 (2006).

[2]. S. Ikeda et al., Nature Mater. 9, 721 (2010).

Fig. 1.

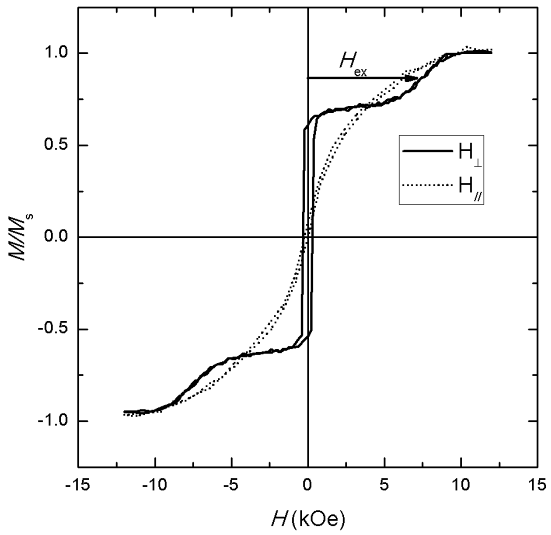

Fig. 2.