<001> textured polycrystalline current-perpendicular-to-plane pseudo spin-valves using full Heusler alloy Co$_2$Fe(Ga$_{0.5}$Ge$_{0.5}$)

Y. Du$^{1,2}$, B. S. D. Ch. S. Varaprasad$^2$, T. Furubayashi$^2$, Y. K. Takahashi$^2$, K. Hono$^{2,1}$

$^1$Graduate School of Pure and Applied Sciences, University of Tsukuba, Tsukuba 305-8571, Japan
$^2$National Institute for Materials Science, Tsukuba 305-0047, Japan

Current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) devices using a Co-based full Heusler alloy hold great potential to be utilized as the read sensors in ultrahigh density hard disk drives due to their intrinsically low resistance-area product ($RA$) (tens of mΩ μm$^2$) and the relatively high magnetoresistance of several tens percent. Recent investigations$^{1,2}$ have shown that fully epitaxial pseudo spin valves (PSVs) with L2$_1$ or B2 ordered Co-based Heusler alloys prepared on MgO (001) single-crystalline substrates exhibit MR ratio of more than 50% and the resistance-change area product ($ΔRA$) exceeding 12 mΩ μm$^2$ at room temperature. However, considering the industrial applicability, the CPP-GMR devices have to be developed on amorphous thermally oxidized Si substrates with polycrystalline film stack. In this work, we studied the <001> textured polycrystalline CPP-GMR PSVs using full Heusler alloy Co$_2$Fe(Ga$_{0.5}$Ge$_{0.5}$) (CFGG) and a MgO buffer layer.

Thin film structure of MgO(100)/Cr(20)/Ag(50)/CFGG(10)/Ag(7)/CFGG(10)/Ag(5)/Ru(8) was deposited on Si/SiO$_2$ substrate using magnetron sputtering with base pressure below $4 \times 10^{-7}$ Pa. All the film stacks were in-situ or ex-situ annealed at 300°C-450°C for 30 min. Magnetic properties were measured by VSM and the microstructure was characterized by XRD, HAADF-STEM and EDS mapping. The typical four-probe measurement was performed for magneto-transport properties after film stacks were micro-fabricated into PSV devices.

From XRD profile (data not shown) the Cr, Ag, CFGG layers all showed diffraction plane of (002) which indicated that the multilayer was <001> textured. Figure 1 exhibits the MR output of the <001> textured, <011> textured and (001) epitaxial PSVs at different annealing temperatures. At 400°C, the ex-situ annealed PSV (red curve in Figure 1) shows $ΔRA$ output of 4.6 mΩ μm$^2$. This value is further enhanced to 5.8 mΩ μm$^2$ by performing in-situ annealing for the PSV device at the same temperature shown in orange curve of Figure 1. HAADF-STEM and EDS images in Figure 2 shows the elemental diffusion of Ga and Ge into the Ag cap layer for the film stack ex-situ annealed at 400°C while reduced elemental diffusion for the in-situ annealed thin film multilayer, which indicated that the prevention of diffusion at the top CFGG layer accounted for the increase of $ΔRA$ at 400°C for the in-situ annealed PSV.

Reference

1) Ye Du et al., Appl. Phys. Lett. 103 (2013) 202401
2) S. Li et al., Appl. Phys. Lett. 103 (2013) 042405

Figure 1 MR output of (001)-textured, (011)-textured and (001)-epitaxial PSVs at different annealing temperatures.

Figure 2 HAADF-STEM and EDS images of (a) ex-situ annealed and (b) in-situ annealed thin film multilayer at 400°C.