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<001> textured polycrystalline current-perpendicular-to-plane pseudo spin-valves using full Heusler alloy $Co_2Fe(Ga_{0.5}Ge_{0.5})$

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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 (Δ*RA*) 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 $Co_2Fe(Ga_{0.5}Ge_{0.5})$ (CFGG) and a MgO buffer layer.

Thin film structure of MgO(10)/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 4×10^{-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 Δ*RA* 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 Δ*RA* at 400°C for the *in-situ* annealed PSV.

Reference
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2) S. Li *et al*, Appl. Phys. Lett. **103** (2013) 042405
3) Y. Sakuraba et al., Appl. Phys. Lett. **101** (2012) 252408

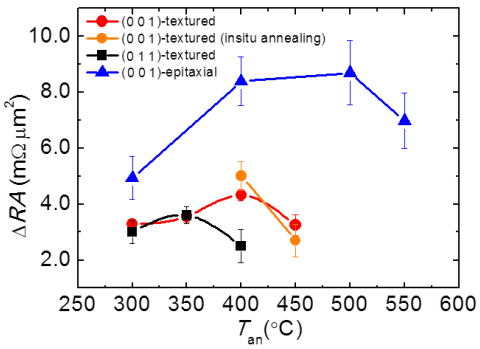

Figure 1 MR output of (001)-textured, (011)-textured and (001)-epitaxial PSVs at different annealing temperatures.

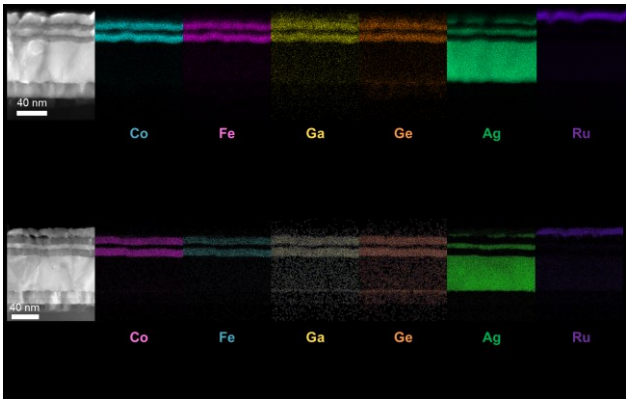

Figure 2 HAADF-STEM and EDS images of (a) ex-situ annealed and (b) in-situ annealed thin film multilayer at 400°C.