Polycrystalline CPP-GMR devices using <001> textured $Co_2Fe(Ga_{0.5}Ge_{0.5})$ Heusler alloy layer and conductive $Mg_{0.5}Ti_{0.5}O_x$ buffer layer

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Current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) devices with Co-based Heusler alloys have recently drawn considerable attention due to their potential application as read sensors for ultrahigh density magnetic recording. With a non-magnetic Ag spacer layer, the resistance change-area product (Δ*RA*) of epitaxial pseudo spin valves (PSVs) on single crystalline (001) MgO substrates has exceeded 10 mΩ μm^2 by using quaternary ferromagnetic (FM) Heusler alloys such as $Co_2Fe(Ga_{0.5}Ge_{0.5})$ (CFGG) and $Co_2Fe_{0.4}Mn_{0.6}Si$ (CFMS). From a practical point of view, however, we need to develop CPP-GMR sensors with polycrystalline thin films at relatively low annealing temperatures (<400°C). Our previous work on <001> textured polycrystalline CPP-GMR using MgO buffer layer showed favorable device thermal stability and moderate Δ*RA* of 5.8 mΩ μm^2 at 400°C was obtained. Nevertheless, it is not industrially viable because MgO as an insulator cannot be used for the fabrication of the actual CPP-GMR sensors. In this work, we report the CPP-GMR properties and microstructure of PSV devices using <001> textured FM Heusler layer CFGG and Ag spacer with a conductive buffer layer $Mg_{0.5}Ti_{0.5}O_x$ (MTO) deposited on an chemically-mechanically polished (CMP) Ta/Cu/Ta electrode on thermally oxidized Si substrates. Relatively large Δ*RA* of 6.6 mΩ μm^2 and desirable interfacial smoothness make it a promising candidate for actual read head design.

All the thin film stacks were deposited at room temperature (RT) onto thermally oxidized Si (Si/*a*-SiO_2) substrates by magnetron sputtering with a base pressure better than 4×10^{-7} Pa. The thin films were characterized by x-ray diffraction (XRD), vibrating sample magnetometer (VSM) and atomic force microscope (AFM). For CPP-GMR properties, multilayer thin film stacks of *a*-NiTa(10)/MTO(2)/Cr(10)/CoFe(2)/CFGG(t_F)/Ag(7)/CFGG(t_F)/Ag(5)/Ru(8) (thickness in nm, t_F=3, 5, 10 nm) were deposited onto CMP Si/*a*-SiO_2//Ta(10)/Cu(250)/Ta(30) substrates. The multilayer stacks were examined by high-angle angular dark field (HAADF) scanning transmission electron microscopy (STEM). Conventional microfabrication process was done for CPP-GMR devices fabrication.

From the XRD results, 20 nm CFGG directly deposited on MTO buffer layer, i.e. Si/SiO_2//*a*-NiTa(10)/MTO(2)/CFGG(20)/Ru(2), is nano-crystalline or amorphous, while the insertion of Cr/CoFe nanolayers between MTO and CFGG layers results in observable (002) diffraction peak (B2 ordering) for the CFGG layers. For the CPP-GMR devices, Fig. 1 summarizes the Δ*RA* as a function of annealing temperature for <001> textured and (001) epitaxial devices with 10 nm CFGG. Δ*RA* results with <011> textured CFGG are also shown as reference. In this work, optimal annealing condition (~400°C) yields average Δ*RA* of 5.5 (6.4) mΩ μm^2 for 5 (10) nm CFGG layers with MR ratio of around 2.4%. The small MR ratio despite moderate Δ*RA* value is due to the large background resistance coming from the high resistive MTO layer. Properly tuning the Mg-Ti composition may decrease the parasitic resistance. As for the microstructure, Fig. 2 reveals the elemental distribution of Co, Fe, Ga, Ge, Ag, Mg and Ti. Relatively flat interfaces are observed up to the top CFGG layer. Little elemental diffusion could be seen and continuous Ag spacer excludes the existence of pin holes that will exert undesirable exchange couplings for the two FM layers through the Ag spacer. The merits of using MTO buffer layer in <001> textured PSVs are not only the favorable interfacial smoothness shown in Fig. 2, but also the slightly higher Δ*RA* value compared to the MgO-based <001> textured PSVs. Such increase is probably owing to the enhanced chemical ordering or improved interfacial flatness of the CPP-GMR multilayers.

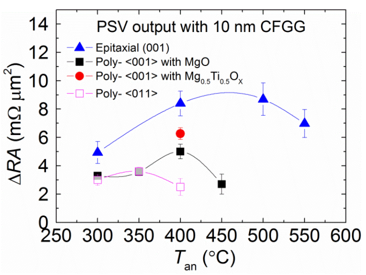

Fig. 1 Comparison of polycrystalline PSVs with <001> textured CFGG using MgO buffer (solid square) and MTO buffer (sphere). Results for epitaxial devices (triangle) and devices with <011> textured CFGG (void square) are also shown for reference

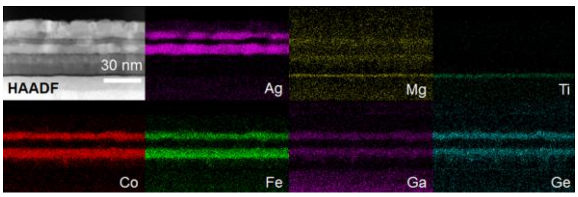

Fig. 2 HAADF-STEM image and EDS mappings of elements for the optimally annealed PSV multilayer