Crystal orientation dependence of band matching in CPP-GMR pseudo spin-valves with $Co_2Fe(Ge_{0.5}Ga_{0.5})$ Heusler alloy and NiAl spacer

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According to the Valet–Fert model[1], the MR ratio depends not only upon the bulk spin polarization and the resistivity of ferromagnetic (FM) layers, but also upon the interfacial spin asymmetry that is a function of the lattice and band matching at the FM/non-magnetic metal (NM) interfaces[2]. It is highly relevant, therefore, to study whether or not the crystal orientation relationship between the Heusler layers and a spacer layer affects the interfacial spin scattering asymmetries or MR outputs. In our previous study of (001) and (110) epitaxial CPP-GMR devices, we found the change of crystal orientation in $Co_2FeGa_{0.5}Ge_{0.5}$(CFGG)/Ag system had introduced a different lattice mismatch at CFGG/Ag interface resulting in various MR outputs. The influence of lattice matching on the interfacial spin scattering asymmetry is considered to be the main reason for the ΔRA value difference[3]. However, how the band matching changes according to different crystal orientation is still unclear to us, because both lattice matching and band matching change when we alter the crystal orientation in CFGG/Ag system. To focus only on the band matching influence, we prepared CPP-GMR PSVs consisting of CFGG and B2 NiAl alloy for a spacer[4]. This combination is free of lattice matching influence depending on the crystal orientation because both alloys have the same bcc structure. The effects of the crystal orientation on band matching were examined by comparing with the devices' MR output in (001) and (110) orientations.

Pseudo spin valves (PSVs) in (110) orientation with the layer structure of sapphire/Ta(20)/W(100)/NiAl(10)/CFGG(10)/NiAl(2,5)/CFGG(10)/NiAl(5)/Ru(8) and (001) orientation with structure of MgO(001)/Cr10/Ag(100)/NiAl(10)/CFGG(10)/NiAl(2,5)/CFGG(10)/NiAl(5)/Ru(8) (unit: nm) were fabricated using an ultrahigh vacuum magnetron sputtering machine. The films were annealed at temperatures ranging from 300 to 600 ˚C after the deposition. The microstructure was characterized by XRD, HADDF-STEM and EDS mapping.

Figure 1 summarizes ΔRA against the annealing temperature T_a. At the T_a of 300 and 600 ˚C, Both (110) orientation and (001) orientation devices show similar ΔRA values. When the spacer thickness reduces form 5nm to 2nm, the MR outputs improve slightly. These results suggest that there is no or very small orientation dependence of band matching on MR output.

Figure 2 shows the plot of the saturation magnetization/unit film area (M_s/A) value as a function of t_F. The intercept of the t_F vs. M_s/A plot represents the thickness of the magnetic dead layer at CFGG/NiAl interface. Both films in two different orientations show negligibly small dead layer thickness, which indicates a good lattice matching between the CFGG and NiAl layers. This result proves that the films are comparable and free of lattice matching influence on MR output.

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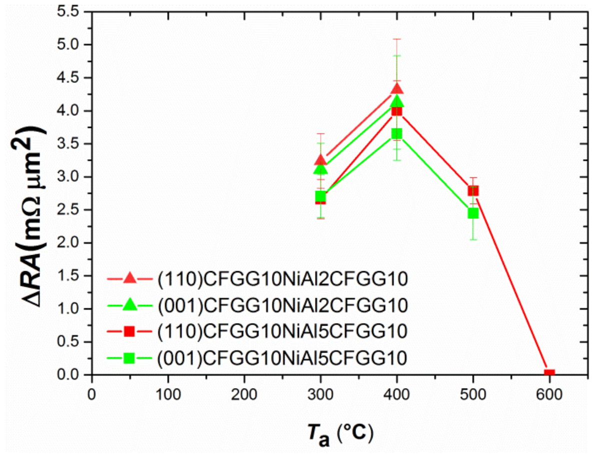

Fig.1 Annealing temperature dependence of ΔRA of the film stack in (110) and (100) orientation with NiAl spacer.

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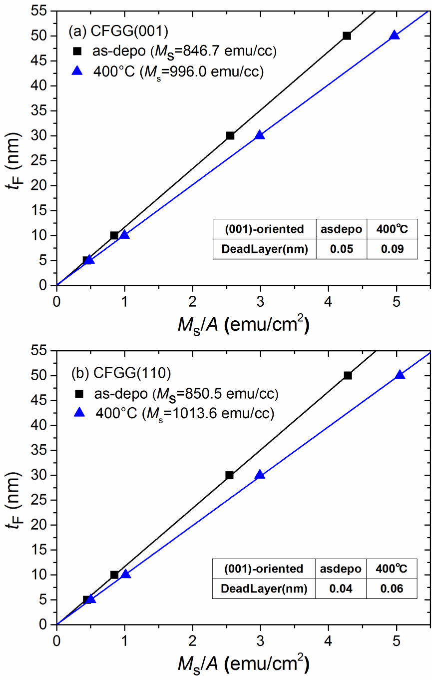

Fig.2 Plots of M_s/A versus CFGG layer thickness (t_F) (a) in an (001)-oriented CFGG film and (b) in a (110)-oriented CFGG film.