INVESTIGATION OF MAGENTOTRANSPORT PROPERTIES OF HEUSLER-ALLOY-BASED MAGNETIC TUNNEL JUNCTIONS WITH A $Cu(In_{0.8}Ga_{0.2})Se_2$ SEMICONDUCTOR BARRIER WITH A LOW RESISTANCE-AREA PRODUCT

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The magnetoresistance (MR) effect is indispensable phenomenon for future device applications such as read head sensors of HDDs over 2 Tbit/in^2. In order to realize highly sensitive read head sensors, a large MR ratio at a low resistance-area product (*RA*) of ~ 0.1 Ω·μm^2 is required [1]. This requirement is a great challenge for conventional MR devices such as the magnetic tunnel junctions (MTJs) with MgO barriers and the current perpendicular to plane giant magnetoresistance devices with Heusler-alloy ferromagnetic electrodes devices, although many attempts have been made to obtain an adequate *RA* value of 0.1 Ω·μm^2, for example, the optimization of deposition conditions of ultrathin MgO barriers [2] and the investigation of new metallic spacers [3, 4]. Another interesting approach is to utilize semiconducting barriers, because their smaller band gaps may lead to an adequate *RA* without degrading MR ratios. In this study, we demonstrate a large MR ratio and a high output voltage at *RA* ~ 0.1 Ω·μm^2 by using the MTJs with a $Cu(In_{0.8}Ga_{0.2})Se_2$ (hereafter, CIGS) compound semiconductor barrier, having a good lattice matching with the Heusler alloys such as $Co_2Fe(Ga_{0.5}Ge_{0.5})$ (hereafter, CFGG).

A film consisting of Ru(8)/Ag(5)/CFGG(10)/CIGS(2)/CFGG(10)/Ag(100)/Cr(10) (unit :nm) was deposited on a MgO (001) substrate by magnetron sputtering. After ex-situ annealing at 300°C, Films were patterned into rectangular or elliptical pillars by electron beam lithography and Ar ion milling. The size of pillars was varied between 200 × 150 nm^2 and 800 × 300 nm^2. Transport properties were measured by the dc-4-probe method at room temperature.

Figure 1 shows the HAADF-STEM image taken from a CFGG/CIGS/CFGG tri-layer part. A well defined layered and crystalized structure with sharp interfaces is clearly observed. The CFGG and CIGS layers have the epitaxial relationship with $(001)[110]_{CFGG}$ // $(001)[110]_{CIGS}$. The CIGS layer is found to have the chalcopyrite structure, which is the low temperature phase. Moreover, the bottom and top CFGG layers were $L2_1$ and *B*2 structures, respectively. Figure 2 shows the bias voltage (V_{bias}) dependence of the (a) MR ratio and (b) output voltage ΔV (= MR ratio × V_{bias}) at 300 K. As shown in the inset of figure 2 (a), a large MR ratio of 47 % is observed at V_{bias} ~ 0 mV with a desired *RA* value of 0.14 Ωμm^2. First-principles calculation results have shown this is due to the Δ_1 electrons' coherent tunneling [5]. The MR ratio does not decrease significantly with increasing V_{bias}, resulting in a large ΔV of 24 mV at V_{bias} = 60 mV. These results suggest that CIGS is a promising barrier for read head sensors of HDDs over 2 Tbit/in^2.

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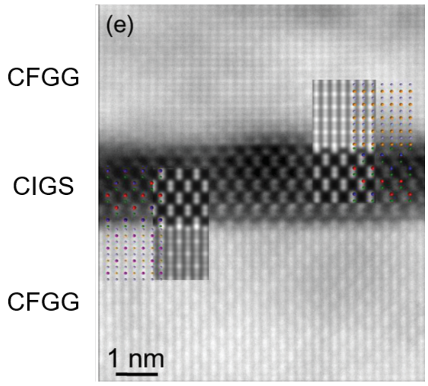

Figure1 HAADF-STEM images of CFGG/CIGS/CFGG films

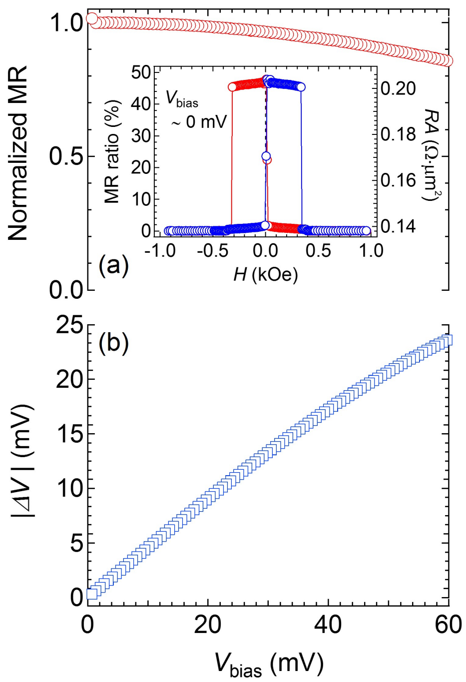

Figure 2 Bias voltage dependence of (a) normalized MR and (b) output voltage at 300 K.