Magnetic junctions using a $Cu(In_{0.8}Ga_{0.2})Se_2$ semiconductor spacer and $Co_2Fe(Ga_{0.5}Ge_{0.5})$ electrodes for low-resistance devices

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The discovery of large magnetoresistance (MR) effect for the magnetic tunnel junctions (MTJs) using a MgO barrier[1)] and the current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) devices using Heusler alloy ferromagnetic electrodes[2)] enabled us to design the high-performance devices such as a read head sensor of the hard disk drive (HDD) over 2 Tbit/in^2 and a spin transfer torque magnetic random access memory (STT-MRAM) over gigabit class. For these applications, it is required to improve the MR ratio within an intermediate range of resistance-area-product (*RA*) from 0.1 to 1 Ω· μm^2. Therefore, many attempts have been made to reduce the *RA* values of MR devices, such as the optimization of deposition conditions of ultrathin MgO barriers in MTJs[1)] and the investigation of new metallic spacers in CPP-GMR devices[3)]. Another approach is to use a semiconducting spacer because semiconductors have smaller band gaps than the MgO (~7.8 eV). However, no promising results have been reported so far by using compound semiconductor spacers[4)]. In this study, we focused on $Cu(In_{0.8}Ga_{0.2})Se_2$ (hereafter, CIGS) compound semiconductor as a semiconductor spacer (or a barrier), the band gap of which ranges from 1.0 - 1.7 eV, having a good lattice matching with the Heusler alloys such as $Co_2Fe(Ga_{0.5}Ge_{0.5})$ (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, the film was patterned into pillars with ellipsoidal shape (0.3×0.1 μm^2) by means of electron beam lithography and Ar ion milling. Transport properties were measured by the dc-4-probe method at room temperature.

Fig. 1(a) 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 was 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. Fig. 1(b) shows the bias voltage (V_b) dependence of MR ratio and the output voltage ΔV (= MR ratio × V_b). At V_b ~ 0 mV, relatively large MR ratio of 30 % was observed. The *RA* and ΔRA values were 250 mΩ·μm^2 and 80 mΩ·μm^2, respectively. The MR ratio did not decrease obviously with increasing bias voltage. Large ΔV of 22 mV was observed at V_b = − 80 mV. These results suggest that a CIGS is a promising spacer (or barrier) material for spintronics devices where low *RA* are required.

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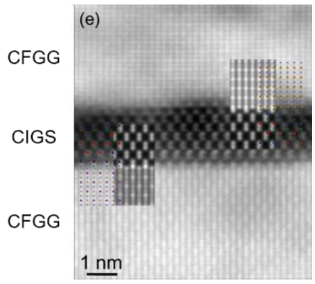
(a)



(b)

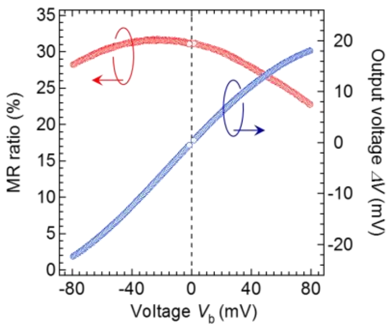


Fig.1(a) HAADF-STEM image of a CFGG/CIGS/CFGG film and (b) bias voltage dependence of MR ratio and output voltage (ΔV)

Reference

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