Perpendicular magnetic tunnel junctions using ultrathin Mn_xGa_{1-x} electrode with different compositions

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MnGa alloys are attractive materials applicable to spin-transfer-torque based devices, such as magnetoresistive random access memory and oscilltator/diode devices with operation frequency of THz range, because their large perpendicular anisotropy, small saturation magnetization, small damping factor are suited for these applications.[1] Recently we demonstrated the perpendicular magnetic tunnel junctions (p-MTs) with the 3-nm-thick $Mn_{61}Ga_{39}$ electrode formed on CoGa seed layer, and the first-principles calculations predicted epitaxial strain between CoGa and MnGa layer leads to a huge TMR.[2,3] However, the experimental TMR ratio was small, < 10%.[3] Here we investigated p-MTJs comprising ultrathin Mn_xGa_{1-x} electrodes with different compositions x. We also demonstrate, for the first time, p-MTJ with approximately stoichiometric MnGa and Mn_3Ga, which are not thermodynamically stable in bulk form.

Stacking structure of p-MTJs was MgO(001) substrate/Cr(40)/CoGa(30)/Mn_xGa_{1-x} (x=0.50, 0.61, 0.76) (3)/Mg(0.4)/Mg O(2)/CoFeB(1)/Ta(3)/Ru(5) (thickness is in nm). The MnGa layer was grown by the co-sputtering method using Mn and $Mn_{45}Ga_{55}$ alloy targets. The microfabrication of devices was performed by a conventional photolithography and Ar milling. The p-MTJs were annealed at T_a = 250℃ using the vacuum furnace.

Figure 1 shows out-of-plane TMR curves for p-MTJs with different x, measured at room temperature. The TMR ratios for x=0.50, 0.61, and 0.76 were 1.0, 6.7, and 13.7%, respectively. The TMR ratio and coercivity of Mn_xGa_{1-x} increased with increasing x. The p-MTJs with $Mn_{50}Ga_{50}$ electrodes was predicted to exhibit huge TMR ratio by our previous calculation. The small TMR ratio of MTJs with $Mn_{50}Ga_{50}$ electrode in this study may attribute the imperfection of the $L1_0$-ordering structure and MgO barrier, decreases of Curie temperature due to their thin thickness, or Ga termination. Further improvement of fabrication process, such as Mn atomic layer insertion technique, will be required.[4] This work was partially supported by ImPACT and KAKENHI (16K14244, 17K14103).

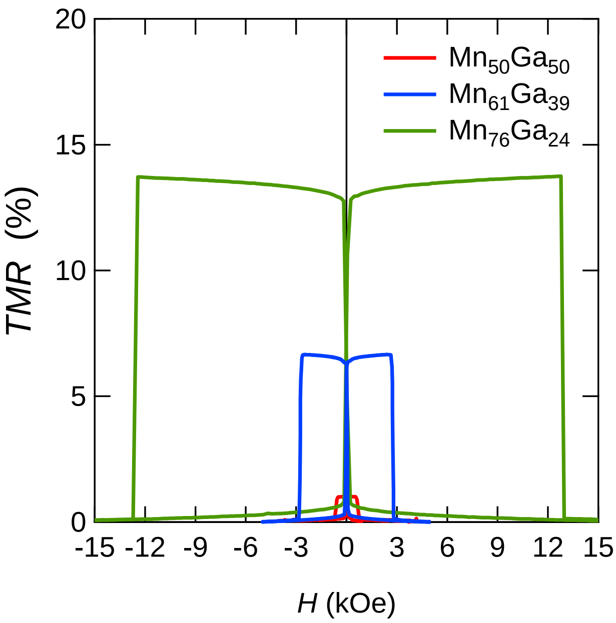

Fig.1 Room temperature TMR curves for different composition of MnGa electrode.

Reference:

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