PERPENDICULAR MAGNETIC TUNNEL JUNCTIONS USING ULTRATHIN MnGa ELECTRODES

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Ordered Mn-Ga alloy films have a large perpendicular magnetic anisotropy, small saturation magnetization and small damping constant, thus it is potentially attractive for spin-transfer-torque (STT) applications such as STT-MRAM and STT-oscillator/diode devices with sub-THz range.[1)] However, the fabrication process high quality ultrathin films with thickness below several nm have been not established yet.[2-5)] Recently, we have succeeded a highly-ordered ultra-thin MnGa films using paramagnetic B2 CoGa buffer layer. It showed the well perpendicular magnetic anisotropy with well magnetic squareness ratio even the thickness of 1 nm.[6,7)] In this presentation, we will report the structural and magnetic properties of the ultrathin L10-MnGa film grown on the paramagnetic B2-CoGa buffer layer, and demonstrate perpendicular magnetic tunnel junctions using the ultrathin MnGa films.

The device stacking structure of (001) single crystalline MgO substrate / Cr(40) /CoGa(30)/MnGa(t_{MnGa} 1-5) /MgO(2) /CoFeB(1) / Ta(3) / Ru(5) (thickness is in nm) were prepared by an ultra-high vacuum sputtering system. All the layers were deposited at room temperature (RT) and the heating treatments were performed only for the MgO substrate, Cr, and CoGa layer at 700, 700, and 500℃, respectively. The films were patterned into the micron-sized MTJs by a conventional ultraviolet photo-lithography and Ar ion milling.

Figure 1 shows the out-of-plane polar Kerr loops for these films without CoFeB/Ta/Ru layers. The loops with squareness close to unity are observed even at t_{MnGa}= 1 nm. The HAADF-STEM image of CoGa/MnGa/MgO layers is shown in Fig.2. The atomically flat interfaces and well-ordered crystalline structure of the MnGa layer was observed. In addition, it was clarified that the ultrathin MnGa layer has an in-plane lattice constant close to that of the CoGa layer owing to the epitaxial strain. XMCD measurement confirmed no diffusion of Co atoms into MnGa layer. Moreover, the first-principles calculations showed that the strained MnGa has a fully spin-polarized band structure along the c-axis, indicating that the huge TMR will be obtained.

Figure 3 shows annealing temperature (T_a) dependence of the room temperature TMR ratios for the p-MTJs with different MnGa thickness. The TMR ratios increase with increasing T_a, then those turn to decrease at T_a of about 250-300℃. The maximum TMR ratios at room temperature are 5-7% at T_a of 250℃. This annealing temperature dependences may originate from the diffusion of Mn or Ga atoms into the MgO or CoGa layer. Figure 4. Shows measurement temperature dependence of the p-MTJs with different MnGa thickness. Here, MTJs were annealed at 250℃. All the p-MTJs show the increase in the TMR ratio with decreasing the measurement temperature, which is similar to that reported in the p-MTJs with 30-nm-thick MnGa grown on Cr buffer layer in previous report.[8)] The maximum TMR ratios are almost independent of the MnGa thickness except for the p-MTJ with t_{MnGa}= 1 nm. However, the first principles calculations suggest that spin-polarized band structure is sensitive for epitaxial strain along the c-axis.[7)] This independent TMR may originate from the surface structure of MnGa and/or composition effect.[9,10)]

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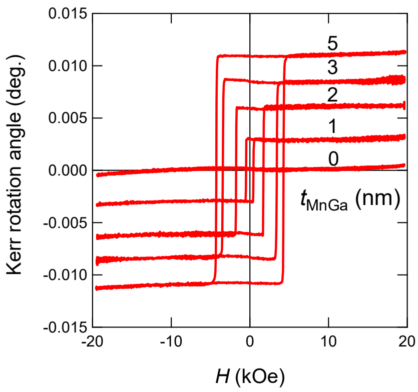

Fig. 1 Out-of-plane hysteresis curves measured by polar-MOKE

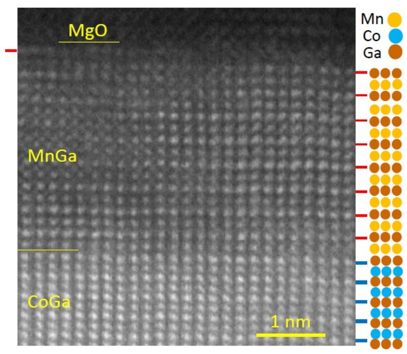

Fig.2 The HAADF-STEM image of the CoGa/MnGa/MgO layers.

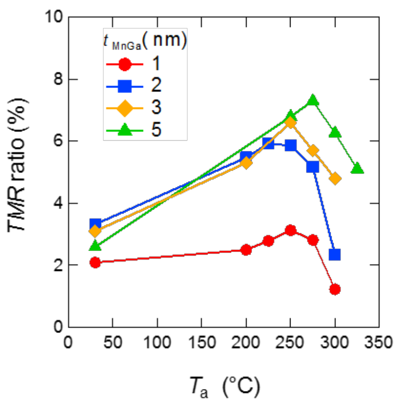

Fig.3 The TMR ratios measured at R.T. as a function of the T_a for p-MTJs with t_{MnGa}=1-5 nm.

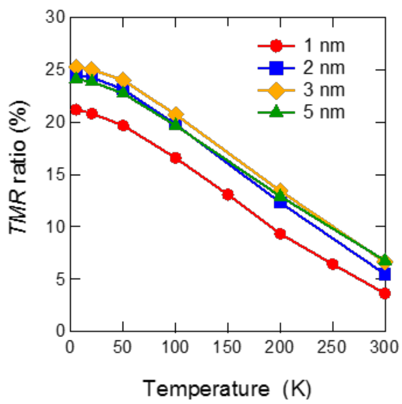

Fig. 4 The TMR ratios as a function of measurement temperature for p-MTJ with t_{MnGa}=1-5 nm.. All the MTJs were annealed at 250℃