Perpendicular magnetic tunnel junctions using ultra-thin strained MnGa electrode

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Mn-Ga alloy films have a large perpendicular magnetic anisotropy (PMA) and small damping constant[1)], thus it is potentially attractive for spin-transfer-torque (STT) applications, such as high density magnetoresistive random access memory (STT-MRAM) and sub-THz STT-oscillator/diode devices. Such STT applications requires growth of ultrathin Mn-Ga films with thickness below several nm, whereas no research groups have succeeded it yet.[2-5)] Recently, we succeeded the growth of ultrathin Mn-Ga films with thickness down to 1 nm by using CsCl type CoGa buffer layer.[5)] Here, we demonstrate the tunnel magnetoresistance (TMR) for perpendicular magnetic tunnel junction (p-MTJs) with the ultrathin MnGa free layer.[6)]

The device stacking structure of (100) single crystalline MgO substrate / Cr(40nm) /CoGa(30)/MnGa(1-5) /MgO(2) /CoFeB(1) / Ta(3) / Ru(5) was prepared by an ultra-high vacuum sputtering system. All the layers were deposited at room temperature and the heating treatments were performed only for the MgO substrate, Cr, and CoGa layer at 700, 700, and 500℃, respectively. The HAADF-STEM image of CoGa/MnGa/MgO layers is shown in Fig.1. 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. The TMR ratios of the MTJs are 12.8, 9.7, and 3.1% at 5, 100, and 300 K, respectively (Fig. 2). The TMR ratio is similar to that of the p-MTJ with thick-MnGa electrode. However, 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 is possible, like as Fe/MgO/Fe. This result is the important step to realize the advanced STT-devices.

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Reference: 1) S. Mizukami et al, Phys. Rev. Lett. 106, 117201 (2011). 2) F. Wu et al., IEEE Trans. Magn. 46, 1863 (2010). 3) A. Kohler et al., Appl. Phys. Lett. 103, 162406(2013). 4) M. Li, X. Jiang, et al., Appl. Phys. Lett. 103, 032410 (2013). 5) Y. H. Zheng et al., J. Appl. Phys. 115, 043902 (2014). 6) K.Z. Suzuki et al., Jpn. J. Appl. Phys. (RC) 55, 010305 (2016). 7) K.Z. Suzuki et al. submitted, 2016.

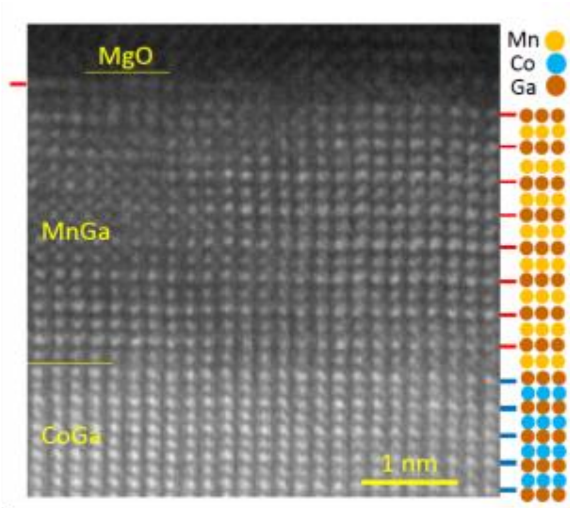

Fig.1 The HAADF-STEM image of the CoGa/MnGa/MgO layers.

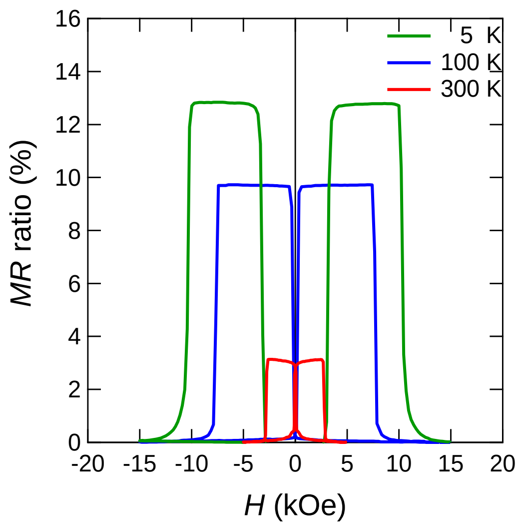

Fig.2 Out-of-plane TMR curves of the p-MTJs with the 3-nm-thick MnGa electrode measured at different temperatures.