Current induced magnetization switching of perpendicularly magnetized ultrathin $L1_0$ MnGa films

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Current induced spin-orbit-torque (SOT) for perpendicularly magnetized films attracted much attention as a writing technique for magnetoresistive random access memory (MRAM) with high recording density. We have studied perpendicular $L1_0$ MnGa ultrathin films for these application [1,2] and its magnetization switching by SOT has been investigated for CoGa/MnGa/Pt trilayer films [3]. However, this stacking structure is not desirable for practical applications based on tunnel magnetroresistive (TMR) device. In this presentation, we report the SOT switching for ultra-thin MnGa films where the pure spin current is injected from the CoGa buffer layer due to the spin-Hall effect [4]. The films were fabricated by an ultrahigh vacuum magnetron sputtering and the stacking structure was (001) MgO single-crystal substrate/MgO (10)/CoGa (15, 20, and 25)/ MnGa (2)/Mg (0.4)/MgO (2)/Ta (2) (thicknesses are in nanometers). The film was patterned into the 30×6 um-sized Hall bar by conventional ultraviolet photolithography and Ar ion milling. Figure 1 shows the current induced switching obtained from the Hall resistance (R_H) measurement with in-plane longitudinal magnetic field ($\mu_0 H_y$) of 200 mT. Here, the pulse duration of applied current (I_p) was 100 μs. The R_H changed sharply at about 22 mA and the magnitude of changes in R_H well corresponded to that observed in the R_H vs out-of-plane magnetic field measurement. Switching phase diagram is shown in Fig. 1(b). The I_c decreased with increasing $\mu_0 H_y$, implying that the damping-like torque resulting from the spin-Hall effect of CoGa buffer layer induces magnetization switching of MnGa layer [5]. This result suggests that the CoGa/MnGa/MgO structure serves as the bottom electrode for p-MTJs driven by SOT. This work was partially supported by KAKENHI (16H03846 and 17H14103), the ImPACT program, and the Sasakawa Foundation. [1] K.Z. Suzuki et al., Jpn. J. Appl. Phys. (RC) 55, 010305 (2016). [2] K. Z. Suzuki et al., Sci. Rep. 6, 30249 (2016). [3] R. Ranjbar et al.,Jpn. J. Appl. Phys. 55 120302 (2016), [4] M.Takikawa et al., Appl. Phys. Express. 10, 073004 (2017) [5] K.-S. Lee et al., Appl. Phys. Lett. 102, 112410 (2013)

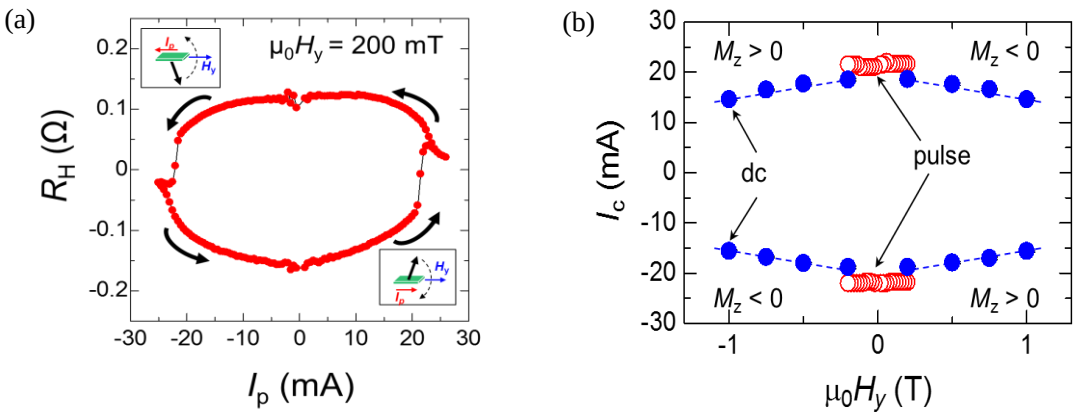

Fig.1 (a) R_H as a function of the pulsed current I_p with a pulse duration of 100 μs with $\mu_0 H_y$ of 200 mT. (b) Switching phase diagram of the switching current I_c vs $\mu_0 H_y$.