Ultrahigh efficient spin-orbit-torque magnetization switching in sputtered BiSb topological insulator and Co/Pt ferromagnetic multilayers

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Topological insulator (TI) BiSb is a promising candidate for spin-orbit-torque (SOT) magnetoresistive random-access memory (MRAM), thanks to its giant spin Hall effect (spin Hall angle $\theta_{SH} \cong 52$ for the BiSb(012) surface) [1] and high electrical conductivity ($\sigma \sim 2.5 \times 10^5\ \Omega^{-1}m^{-1}$) at room temperature. Recently, we demonstrated that high-quality BiSb thin films with quasi single crystal structure could be grown by sputtering deposition, underlying its feasibility for mass production of SOT-MRAM [2]. In this work, we investigate the spin Hall effect and SOT magnetization switching characteristics of an all-sputtered BiSb–$(Co/Pt)_n$ multilayers deposited by direct current (DC) magnetron sputtering on sapphire substrates. We show that the sputtered BiSb thin films with the (110) surface have large spin Hall angle ($\theta_{SH} \cong 10$) and high electrical conductivity ($\sigma \sim 3 \times 10^5\ \Omega^{-1}m^{-1}$), which lead to ultrahigh efficient SOT magnetization switching of the $(Co/Pt)_n$ multilayers.

We deposited $(0.4\ nm\ Co/0.4\ nm\ Pt)_2$ – 10 nm BiSb multilayers, from bottom to top, on *c*-plane sapphire (0001) substrates at room temperature. The $(Co/Pt)_2$ multilayers are perpendicularly magnetized with a large anisotropy magnetic field of 5.6 kOe, which is the largest among TI/ferromagnet studied so far and similar to that of CoFeB/Ta/CoFeB free layer in perpendicular MRAM. We employed the second harmonic Hall measurement technique to evaluate θ_{SH} in 50 μm × 25 μm Hall bars. Figure 1(a) shows a representative second harmonic Hall resistance ($R_{2\omega}$) – in-plane magnetic field (H) characteristic and the corresponding fitting curve (red) for evaluation of the antidamping-like field H_{AD}. Figure 1(b) shows the estimated H_{AD} at various BiSb current density J^{BiSb}, which yields $\theta_{SH} \cong 10$. The magnetization of $(Co/Pt)_2$ can be efficiently switched with a small DC threshold current density $J_{th}^{BiSb} = 1.8 \times 10^6$ Acm^{-2} at H = 1.83 kOe. Figure 2 shows robust switching by 75 consecutive pulses ($J^{BiSb} = 4.4 \times 10^6$ Acm^{-2}, t_{pulse} = 100 μs). Our results demonstrate the feasibility of BiSb for ultralow power SOT-MRAM. **References:** [1] N. H. D. Khang *et al.*, Nat. Mater. 17, 808 (2018). [2] T. Fan *et al.*, Jpn. J. Appl. Phys. 59, 063001 (2020).

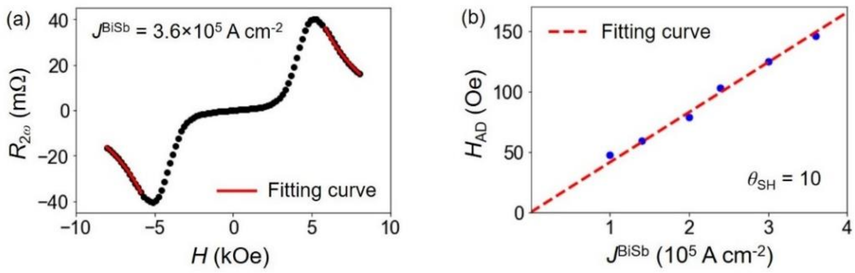

Fig. 1. (a) $R_{2\omega} - H$ characteristic of BiSb – $(Co/Pt)_n$ multilayers and the corresponding fitting curve (red). (b) H_{AD} at various J^{BiSb}.

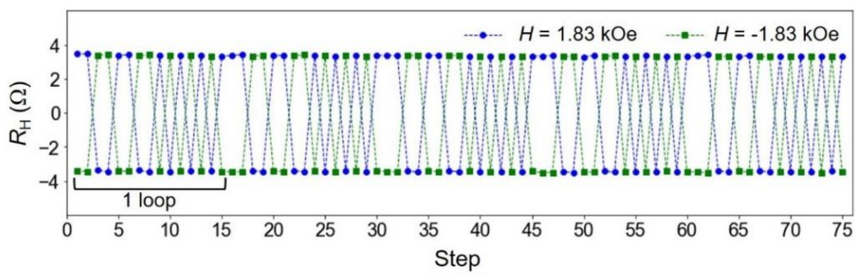

Fig. 2. Robust SOT magnetization switching by 75 consecutive pulses ($J^{BiSb} = 4.4 \times 10^6$ Acm^{-2}, t_{pulse} = 100 μs).