Ultralow-power spin-orbit torque magnetization switching in all-sputtered BiSb topological insulator – ferromagnet multilayers

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Recently, we have shown that BiSb is a conductive topological insulator (TI) with a giant spin Hall angle (θ_{SH} ~ 52) at room temperature, which is very attractive for spintronics applications, especially in spin-orbit-torque (SOT) - magnetic random access memory (MRAM) [1]. However, high quality and single-crystalline BiSb thin films require epitaxial growth in ultra-high vacuum by molecular beam epitaxy (MBE). For mass production, however, BiSb has to be fabricated under industrial conditions by physical vapor deposition techniques, which may yield different crystal quality and spin-charge conversion efficiency. Therefore, evaluation of BiSb deposited by sputtering technique on Si substrates is required as a first step toward ultralow-power SOT-MRAM with BiSb as the spin current source.

In this study, we report ultralow-power SOT magnetization switching in all-sputtered CoTb(2.7 nm)/Pt(1 nm)/$Bi_{0.85}Sb_{0.15}$(10 nm)/Pt(1 nm) multilayer thin films (from bottom to top). Here, the CoTb(2.7 nm)/Pt(1 nm) stack was first deposited by ion-beam sputtering on oxidized Si substrates. The stack was then exposed to air and transferred to another chamber for deposition of the top $Bi_{0.85}Sb_{0.15}$(10 nm)/Pt(1 nm) layers by DC magnetron sputtering with different sputtering gas of Ar (0.6 Pa) (sample A), Ar (1 Pa) (sample B), and Kr (0.6 Pa) (sample C), respectively. Figure 1(a) shows the XRD spectra of these samples, which indicate that BiSb has poorer quality than MBE-grown films and crystallizes with the (001) orientation. Figure 1(b) shows the Hall resistance curves of 50 μm×25 μm Hall bars of these samples under a perpendicular magnetic field, confirming perpendicular magnetic anisotropy of the CoTb layers. Figure 1(c) shows SOT switching of the CoTb layer under various in-plane magnetic fields H_{in} for sample A. Despite the non-epitaxial nature of sputtered BiSb, full SOT magnetization switching was obtained. Figure 1(d) shows the critical switching current density J_c as a function of H_{in}. J_c is as low as 0.73 MA/cm^2 at H_{in} = 500 Oe in sample A, which is an order of magnitude smaller than J_c = 8 MA/cm^2 observed in a CoTb (1.7 nm) / Ta bilayer under the nearly same condition [2]. Similar results are obtained for sample B and C. Figure 1(e) shows the antidamping-like SOT field H_{AD} measured by the second harmonic technique as functions of current density J in sample A, B and C, respectively. The effective θ_{SH} is estimated to be 1.16, 0.73, and 0.87 for sample A, B, and C, respectively, which are at least an order of magnitude larger than that of Ta/CoTb (θ_{SH} ~ -0.03) and Pt/CoTb (θ_{SH} ~ 0.017) [2]. Taking into account the spin loss in the Pt (1 nm) middle layer and at the CoTb interface, the real θ_{SH} is estimated to be at least 8.7 for sample A. These results reconfirm the advantage of BiSb as a spin source for ultralow-power SOT-MRAM. **Acknowledgment**: this work is supported by JST CREST (JPMJCR18T5). **References:** [1] N. H. D. Khang, *et al*, Nature Mater. **17**, 808 (2018). [2] L. Han *et al.*, Phys. Rev. Lett. **119**, 077702 (2017).

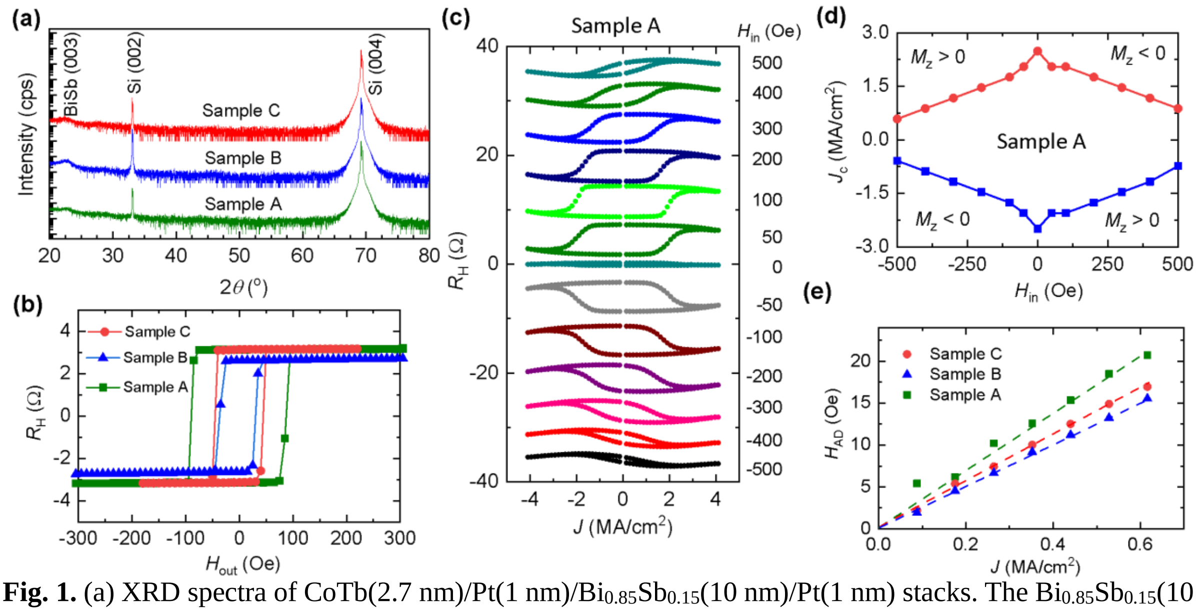

Fig. 1. (a) XRD spectra of CoTb(2.7 nm)/Pt(1 nm)/$Bi_{0.85}Sb_{0.15}$(10 nm)/Pt(1 nm) stacks. The $Bi_{0.85}Sb_{0.15}$(10 nm) layers are deposited by DC magnetron sputtering with different sputtering gases of Ar (0.6 Pa), Ar (1 Pa), and Kr (0.6 Pa) for sample A, B, and C, respectively. (b) Hall resistance curves of 50 μm×25 μm Hall bars of sample A, B, and C. (c) SOT switching of sample A at various in-plane magnetic fields H_{in}. (d) Critical switching current density J_c of sample A as a function of H_{in}. (e) Antidamping-like SOT field H_{AD} as functions of current density J in sample A, B and C, measured by the second harmonic technique.