Room-temperature spin-orbit torque magnetization switching induced by non-epitaxial BiSb topological insulator

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BiSb is a conductive topological insulator with a giant spin Hall effect (θ_{SH}~52) at room temperature [1,2], which is very promising for spin-orbit torque (SOT) magnetoresistive random-access memory (MRAM) and race-track memory. However, high quality single crystalline BiSb thin films require epitaxial growth by molecular beam epitaxy (MBE), which is not always available in realistic applications. Here, we study room-temperature SOT magnetization switching induced by a non-epitaxial BiSb thin film with poor crystal quality and low electrical conductivity to determine its lower-bound performance. We found that, even under this situation, BiSb still outperforms heavy metals by an order of magnitude in terms of the switching current density and spin Hall angle. We fabricated multilayers of CoTb(2.7 nm)/Pt(1 nm)/$Bi_{0.85}Sb_{0.15}$(20 nm) for SOT measurements. Here, the CoTb (2.7 nm)/Pt(1 nm) stack was first deposited by ion beam sputtering. The CoTb layer was formed by depositing 0.6 nm-thick Tb and 0.3 nm-thick Co layer alternatingly for three cycles. The stack was then exposed to air and transferred to a MBE chamber for deposition of the top BiSb layer. Reflection high energy electron diffraction and X-ray diffraction indicate the poor crystal quality of the BiSb layer. Indeed, the electrical conductivity of the BiSb layer is $9\times10^4\ \Omega^{-1}m^{-1}$, which is several times lower than that of epitaxial BiSb thin films. Figure 1(a) shows the Hall resistance curves of a 50 μm×25 μm Hall bar of the multilayers under a perpendicular magnetic field, indicating perpendicular magnetic anisotropy of the CoTb layer. Figure 1(b) shows SOT switching of the CoTb layer under various in-plane magnetic fields H_{in}. Although the BiSb thin film has poor crystal quality, full magnetization switching of the CoTb layer was confirmed by both DC and pulse currents at room temperature. Figure 1(c) shows the critical switching current density J_c as a function of H_{in}. J_c is as low as 0.5 MA/cm^2 (0.35 MA/cm^2 for BiSb) at H_{in} = 490 Oe, 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 [3]. We further demonstrate repeating SOT switching by 10 ms pulse currents of J_{Pulse} = ±2.5 MA/cm^2 under H_{in} = 90 Oe and H_{in} = -110 Oe, as shown in Fig. 2. Harmonic measurements indicate θ_{SH}~0.35 for the BiSb layer, which is still one order of magnitude larger than that of Ta (θ_{SH}~-0.03) and Pt (θ_{SH}~0.017) when in contact with CoTb [3]. Our results reconfirm the advantage of BiSb as the spin source for SOT-MRAM and race-track memory. **Acknowledgment**: this work is supported by JST CREST (JPMJCR18T5). **References:** [1] N. H. D. Khang, *et al*, Nature Mater. **17**, 808 (2018). [2] T. Shirokura, *et al*, preprint at arXiv:1810.10840. [3] L. Han *et al.*, Phys. Rev. Lett. **119**, 077702 (2017).

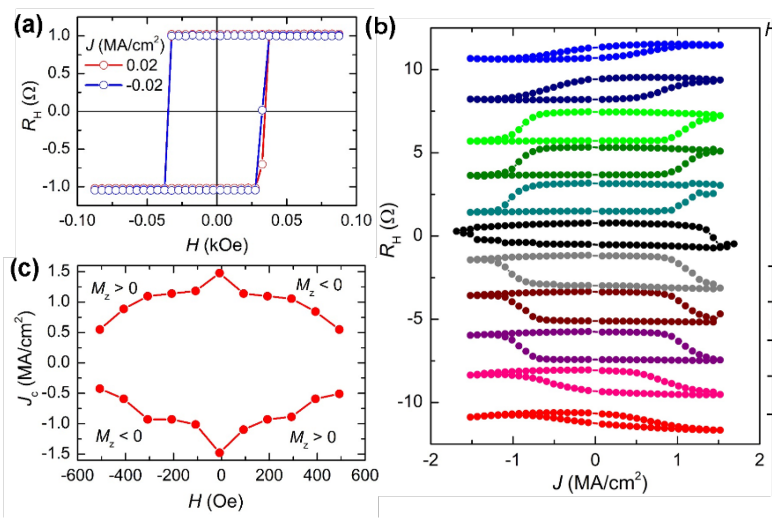

Fig. 1. (a) Hall resistance of a 50 μm×25 μm Hall bar of the CoTb (2.7 nm)/Pt(1 nm)/$Bi_{0.85}Sb_{0.15}$(20 nm) multilayers. (b) DC current-driven SOT switching at various in-plane magnetic field H_{in}. (c) Critical switching current density J_c as a function of H_{in}.

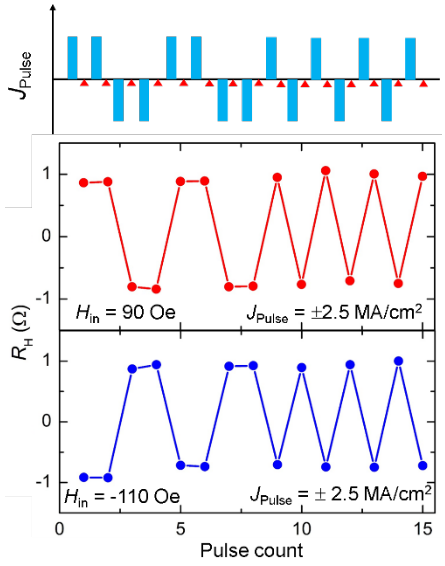

Fig. 2. Repeating SOT switching by 10 ms pulse currents of J_{Pulse} = ±2.5 MA/cm^2 under H_{in} = 90 Oe (red) and H_{in} = -110 Oe (blue).