Large spin Hall effect in BiSb topological insulator and perpendicularly magnetized CoFeB heterojunctions with oxide buffer and interfacial layers

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BiSb topological insulator has emerged as a promising candidate for the spin-orbit torque (SOT) layer in ultrafast [1] and ultralow power [2] SOT-MRAM devices thanks to its giant spin Hall angle (θ_{SH}) and high electrical conductivity σ [3]. Despite showing large θ_{SH} in BiSb/CoFeB heterojunctions deposited on sapphire substrates with a metallic Ti or Ru interlayer [4], BiSb can be lost during the high-temperature annealing due to its low melting point. Thus, an appropriate interfacial layer between BiSb and CoFeB that can prevent thickness loss during the high-temperature annealing process is necessary to reach the full potential of BiSb for practical SOT-MRAM applications.

In this study, we aim to realize BiSb / perpendicularly magnetized CoFeB heterojunctions with high θ_{SH} on thermally oxidized Si/SiO_2 substrate after 300°C high temperature post annealing by using oxide buffer and interfacial layers. Fig. 1(a) shows the full structure of our stacks and the annealing sequences. We first deposited TiO_x (25 nm)/TaO_x (5nm) buffer layers to suppress oxygen diffusion from the substrates and to enhance the crystallinity of BiSb. Then, a 10-nm thick BiSb was sputtered followed by a 1 nm TiO_x or TaO_x interfacial layer specially designed to prevent loss of BiSb during post-annealing at 300°C for 1 hour. Here, the oxide buffer and interfacial layers are insulating and thus helpful for reducing shunting currents. We then deposited Ta (1 nm)/CoFeB (1 nm)/MgO (2.5 nm)/Ta (2 nm) multilayers. Finally, the stacks underwent another annealing process at 250°C for 30 minutes to crystallize CoFeB and to achieve perpendicular magnetic anisotropy (PMA), as shown in Figs. 1(b) and 1(c). We found large $\theta_{SH}^{eff} > 4$ in the stacks from the second harmonic Hall measurements as shown in Figs. 1(d) and 1(e). By comparing X-ray fluorescence spectra of BiSb before and after annealing, we estimate that the BiSb thickness was reduced to approximately 9.3 nm, suggesting good protection of BiSb by the oxide interfacial layer. Thus, the combination of TiO_x/TaO_x buffer and TiO_x or TaO_x interfacial layers can prevent BiSb loss and current shunting, which are crucial for realizing high-performance SOT characteristics.

References:

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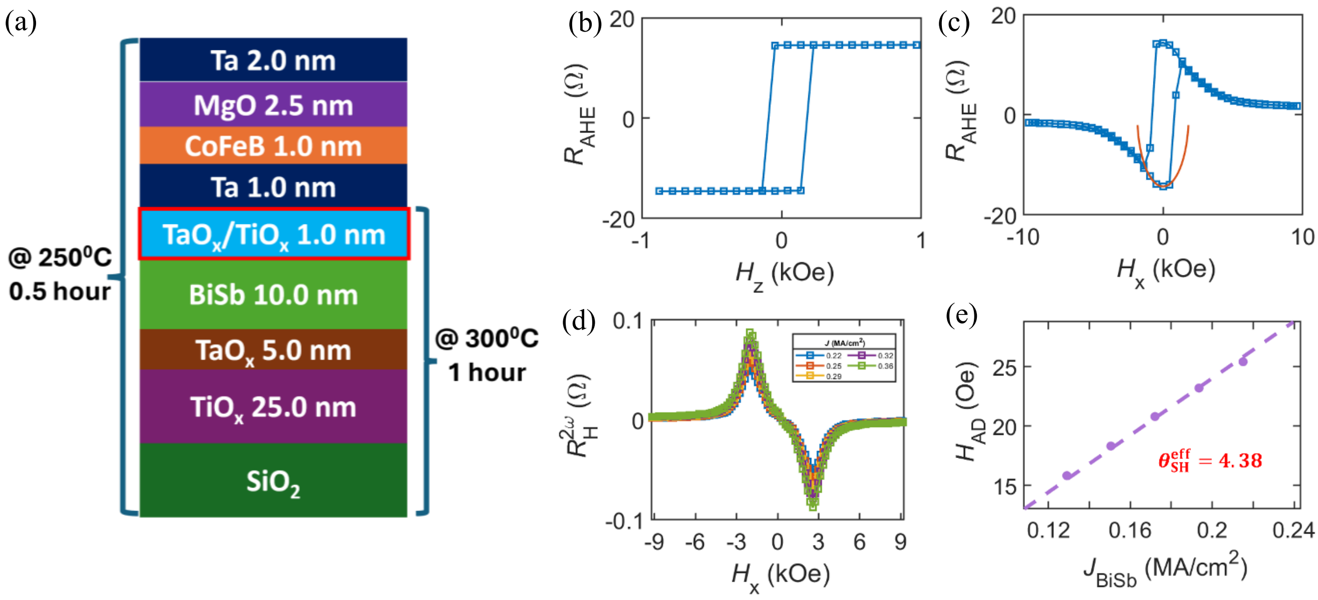

Fig. 1. (a) The schematic of our stacks. (b)(c) Anomalous Hall resistance measured in a 20×60 μm² Hall bar with a perpendicular and in-plane magnetic field, respectively. (d) Second harmonic Hall resistance and (e) antidampinglike SOT field as a function of BiSb current density.