Efficient spin current source using a half-Heusler alloy topological semimetal with Back-End-of-Line compatibility

Tokyo Tech. °Takanori Shirokura, Tuo Fan, Nguyen Huynh Duy Khang, Pham Nam Hai

E-mail: shirokura.t.aa@m.titech.ac.jp

Topological materials, such as topological insulators (TIs), have great potential for ultralow power spin-orbit torque (SOT) spintronic devices thanks to their giant spin Hall effect originated from their topological surface states (TSSs). However, the giant spin Hall angle (θ_{SH} > 1) is limited to a few chalcogenide-based TIs with toxic elements and low melting points, making them challenging for device integration during the silicon Back-End-of-Line (BEOL) process. Here, we focus on a half-Heusler alloy topological semimetal (HHA-TSM), YPtBi, to overcome this difficulty. We synthesized YPtBi thin films by using co-sputtering method with YPt and Bi targets while changing the substrate temperature. According to the X-ray diffraction and X-ray fluorescence measurements, YPtBi crystal is stable up to 600°C which is high enough for BEOL process. To evaluate the spin Hall effect of YPtBi, we conducted the second harmonic Hall effect measurement in CoPt/YPtBi heterostructures [1]. By controlling the electric conductivity of YPtBi and the spin transparency at the CoPt/YPtBi interface, we successfully realized a giant θ_{SH} up to 4.1. We found that θ_{SH} is inversely proportional to conductivity which can be explained by the intrinsic mechanism of the spin Hall effect. Furthermore, θ_{SH} disappeared when YPtBi thickness is thinner than 4 nm, indicating that the spin Hall effect was governed by TSS, which disappears below 4 nm due to interference of TSS on the top and bottom surface, as well known in other TIs [2]. We then demonstrate SOT magnetization switching in the CoPt/YPtBi heterostructure. Figure 1 shows SOT switching results by pulse current with pulse width of 50 μs to 10 ms under an external magnetic field of 0.5 kOe applied parallel to the current. Thanks to the giant spin Hall effect originated from TSS, small threshold current of about 1×10^{6} A/cm^{2} was observed, which is one order magnitude smaller than that in heavy metals [3]. Our work opens the door to the next generation spin Hall materials with both giant θ_{SH} and high thermal stability [4].

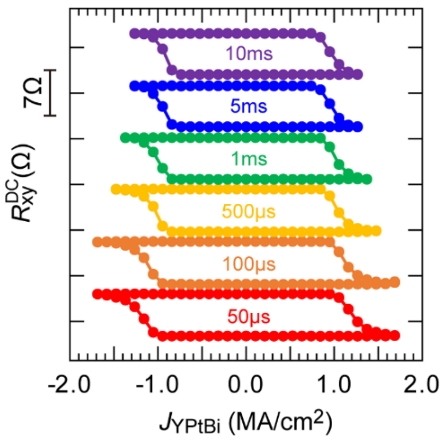

Figure 1. Magnetization switching by pulse currents with various pulse width ranging from 50 μs to 10 ms and magnetic field of 0.5 kOe in CoPt/YPtBi heterostructure.

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