Room-temperature field-free formation of stable skyrmions in BiSb/MnGa bi-layers

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Magnetic skyrmions, appearing as the consequence of Dzyaloshinskii-Moriya-Interaction (DMI) in magnetic structures with broken inversion symmetry, have emerged as a novel candidate for the next generation magnetic storage technology thank to their small size and ultra-low driving current density [1-3]. While skyrmions can be observed in various B20 compounds such as MnSi, FeGe and MnN with bulk DMI, they can be only formed at low temperatures and under the presence of a magnetic field. Recently, it is found that room-temperature skyrmions can also be generated in magnetic multi-layers, such as Ta/CoFeB or Pt/Co with interfacial DMI [4, 5]. However, skyrmions in those multi-layers are still meta-stable at zero-magnetic field. Furthermore, their topological Hall effect (THE) has not been observed. In this study, we demonstrate room-temperature field-free formation of *stable skyrmions* in BiSb topological insulator / MnGa bi-layers. By combining the strong spin-orbit-interaction of BiSb and the small magnetization of MnGa, we can obtain a huge interfacial DMI (D_s = 5.02 pJ/m) that could be tailored by controlling the annealing temperature (t_{an}) of the MnGa thin film with perpendicular magnetic anisotropy. Figure 1(a) and 1(b) show the THE resistivity (green line) extracted from the total Hall effect resistivity (blue line) and the anomalous Hall effect (AHE) resistivity derived from magnetic circular dichroism intensity-magnetic field measurements (red line) of BiSb(10 nm)/ MnGa(5 nm) bi-layers. At the annealing temperature of 400°C, THE can be observed at room temperature even under absence of an external magnetic field, demonstrating formation of stable skyrmions. Figure 1(c) shows the magnetic phase diagram of the BiSb/MnGa bi-layer with t_{an} = 400°C. We observe that thermodynamically stable skyrmions at zero-magnetic field can be formed down to 150 K. Our results show that BiSb topological insulator can generate not only colossal spin-orbit-torque [6], but also huge interfacial DMI for generation and manipulation of skyrmions.

References: [1] S. Mühlbauer, Science **323**, 915 (2009). [2] F. Jonietz, et al. Science **330**, 1648 (2010). [3] Yu, X. Z. et al. Nature **465**, 901 (2010). [4] S. Woo *et al.*, Nat. Mater. **15** 501 (2016). [5] C. Moreau-Luchaire *et al.*, Nat. Nanotech. **11** 444 (2016). [6] N. H. D. Khang, et al, Nat. Mater. in press.

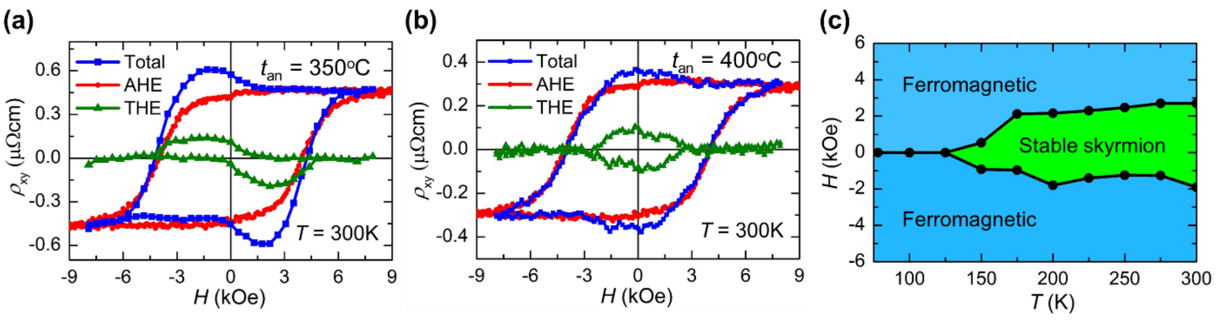

Fig. 1. (a)(b) Room-temperetarure topological Hall efffect (THE) (green line) extracted from the total Hall effect resistivity (blue line) and the anomalous Hall effect (AHE) resistivity derived from magnetic circular dichroism intensity-magnetic field measurements (red line) obsevered in BiSb(10 nm)/ MnGa(5 nm) bi-layers at different annealing temperature of MnGa (t_{an} = 350°C and t_{an} = 400°C). (c) Magnetic phase diagram of the BiSb(10 nm)/ MnGa(5 nm) bi-layer (t_{an} = 400°C).

