Spin-orbit torque efficiency in non-collinear antiferromagnet / heavy metal heterostructures

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Electrical manipulation of antiferromagnetic materials [1,2] is a representative outcome in antiferromagnetic spintronics, a newly established field attracting increasing attention. A recent study showed a novel spintronic phenomenon, that is, the rotation of chiral-spin structure by spin-orbit torque (SOT) in M-plane oriented non-collinear antiferromagnet Mn_3Sn film [3]. Of particular interest in the antiferromagnetic spintronics is a quantification of the efficiency of SOT acting on the antiferromagnetic ordering, which has never been addressed in any material systems. In this work, we report the determination of SOT efficiency in non-collinear antiferromagnet Mn_3Sn / heavy metal heterostructures.

We deposit W(2)/Ta(3)/Mn_3Sn(15)/MgO(1.3)/Ru(1) (in nm) on MgO(110) substrate by DC/RF magnetron sputtering [4], followed by annealing at 500 °C for an hour. The stack is then patterned into Hall bars, where the angle θ between the channel and kagome plane (0001) of Mn_3Sn is systematically varied. The efficiency of SOT acting on Mn_3Sn is measured by the phase diagram of the switching field (H_C) versus applied current (I).

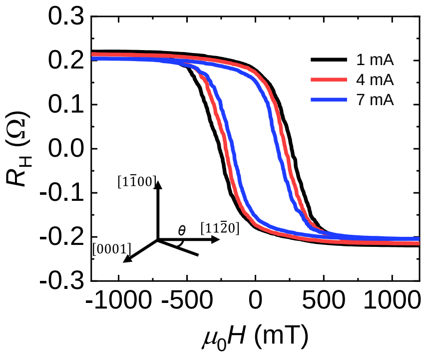

Fig.1 Applied current (I) dependence of R_H-H curve.

Figure 1 shows a Hall resistance (R_H) as a function of the magnetic field (H) with various applied currents for $\theta = 0°$, i.e., $I \perp (0001)$. H_C decreases with I as was seen in [3]. The switching phase diagrams for each θ are shown in Fig. 2. The linear relationship indicates a dominant contribution of SOT to the reduction of H_C. The slope of H_C-I decreases with increasing θ, which can be understood by considering the reduction of SOT contribution to the rotation of chiral-spin structure [3,5]. From the θ dependence of the slope with a reasonable macrospin approximation, the Slonczewski-like SOT efficiency is determined to be |0.15|, agreeing with previous reports of Ta / ferromagnetic system [6].

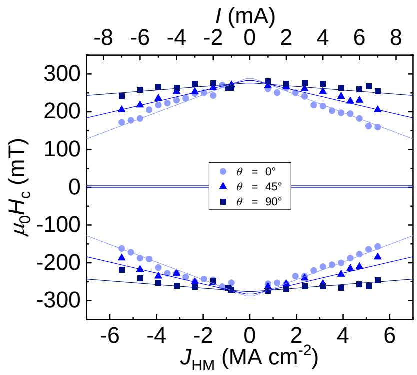

Fig. 2 Switching field (H_C) versus applied current I for various θ.

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[1] P. Wadley *et al.*, Science **351**, 587 (2016). [2] H. Tsai *et al.*, Nature **580**, 608 (2020). [3] Y. Takeuchi *et al.*, Nat. Mater. (2021). https://doi.org/10.1038/s41563-021-01005-3. [4] J.-Y. Yoon *et al.*, Appl. Phys. Express **13**, 013001 (2019). [5] Y. Yamane *et al.*, Phys. Rev. B **100**, 054415 (2019). [6] H. Gamou *et al.*, Phys. Rev. B **99**, 184408 (2019).