Efficient full spin-orbit torque switching in a single layer of a perpendicularly-magnetized ferromagnetic semiconductor GaMnAs

○(D) Miao Jiang[1], Hirokatsu Asahara[1], Shoichi Sato[1], Toshiki Kanaki[1], Hiroki Yamasaki[1], Shinobu Ohya[1,2,3] and Masaaki Tanaka[1,2]

[1]*Department of Electrical Engineering and Information Systems, The Univ. of Tokyo*

[2]*Center for Spintronics Research Network (CSRN), Graduate School of Engineering, The Univ. of Tokyo*

[3]*Institute of Engineering Innovation, Graduate School of Engineering, The Univ. of Tokyo*

Email: miao@cryst.t.u-tokyo.ac.jp

Spin-orbit torque (SOT) magnetization switching has been proposed to optimize the performance of magnetoresistive random access memory (MRAM) devices on the readability, access latency, and energy consumption. In the conventional SOT systems, there basically are two functional layers, one of which is the ferromagnetic layer and the other one is the paramagnetic layer with a large spin Hall angle to generate spin current and inject it into the adjacent ferromagnetic layer. Then the spin current exerts a torque on the magnetization of the ferromagnetic layer and reverses it[1, 2]. Therefore, the switching efficiency should be strongly limited by the interface quality and the spin injection process across the interface.

Here, we report a highly efficient full SOT switching by applying a current with a density of J_C = 3.4×10^5 A/cm^2 in a *single* layer of perpendicularly magnetized ferromagnetic semiconductor GaMnAs, as shown in Fig. 1. With the intrinsic bulk inversion asymmetry of the zinc-blende crystal structure, the intrinsic spin-orbit interactions couple the hole spin with its momentum and generate the Dresselhaus effective magnetic field[3], which contributes to induce an in-plane component of hole's spin in the GaMnAs thin film. Then the in-plane spin component exerts a torque on the magnetic moment of GaMnAs thin film itself. We have achieved the magnetization reversal just by driving a current in a single ferromagnetic GaMnAs layer, with much smaller J_C by two orders of magnitude than the J_C values reported so far in metallic bilayer systems. Our finding will provide a new possibility of more efficient SOT switching by using a single-crystalline ferromagnet with intrinsic bulk-inversion asymmetry, large spin-orbit interactions, and spin polarization.

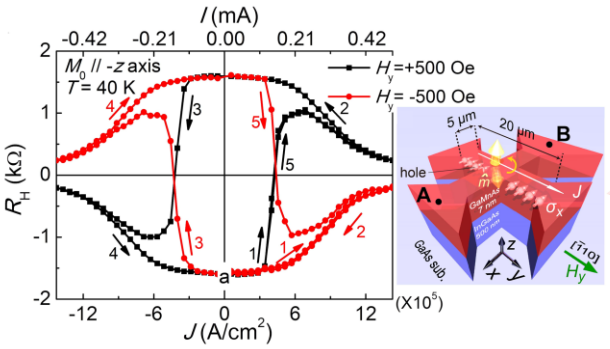

Fig. 1 SOT switching with H_y = ±500 Oe at 40 K and schematic illustration of the device structure.

This work was partly supported by Grants-in-Aid for Scientific Research (No. 16H02095, No. 18H03860), CREST program of Japan Science and Technology Agency (JPMJCR1777), and Spintronics Research Network of Japan (Spin-RNJ).

1. L. Liu *et al.*, Phys. Rev. Lett. **109**, 096602 (2012).
2. L. Liu *et al.*, Science **336**, 555 (2012).
3. D. Fang *et al.*, Nat. Nanotechnol. **6**, 413 (2011).