Perspective of spin-orbitronics

Junsaku Nitta
Department of Materials Science, Tohoku University, Sendai 980-8579

Center for Spintronics Research Network, Tohoku University, Sendai 980-8577

Spins of electrons had been so far manipulated by magnetic field since the magnetic moments of spins is strongly coupled with magnetic field. Spin-orbit interaction (SOI) originated from electric field is a relativistic effect, i.e. electrons feel an effective magnetic field when they move in an electric field. Much attention is now focused on spintronics based on SOI, the so-called *spin-orbitronics*, since generation, manipulation and detection of spins are realized by all electrical means via SOI[1].

Electrical control over the magnetization direction of small magnets is currently among the most active areas in *spin-orbitronics*, due to its interest for memory, logic and data-storage applications. This magnetization control has been achieved by transferring spin angular momentum working as a torque due to the SOI from heavy metals, antiferromagnets, oxide materials and topological insulators. Now, we call it spin-orbit torque (SOT), which is expected to be an innovative way towards energy-efficient applications such as fast domain wall motion and magnetization switching. The charge-spin conversion efficiency (or spin Hall angle) in these hetero-structures is the most crucial parameter for the SOT performance.

However, a major difficulty is clearly identifying the physical origin of the SOT. The spin Hall effect is believed to play a major role when the adjacent layer to magnet is dirty heavy metal[2]. An intrinsic (Berry phase-induced) SOT mechanism is proposed if the bulk inversion symmetry is broken in the adjacent layer[3]. It is also pointed out that the Rashba-Edelstein effect at the interface is not negligible[4]. It is required to enhance the charge-spin conversion efficiency by clarifying the origins and mechanisms.

When the spin Hall effect was discovered in bulk GaAs[5], no one could imagine that the spin Hall effect can be utilized for magnetization switching since the spin polarization accumulated at the edge of GaAs was extremely small, moreover, it was performed at low temperature. The tremendous progress in *spin-orbitronics* has been achieved and the concept has been extended to variety of systems in the last decade. In this symposium, I hope we can witness the recent progress of *spin-orbitronics* in different systems and discuss future perspective.

Reference

1) A. Manchon, *et al.*, Nature Materials, **14**, 817 (2015).
2) L. Liu, *et al.*, Science **336**, 555 (2012).
3) H. Kurebayashi, *et al.*, Nature Nanotech., **9**, 211 (2014).
4) I. M. Moron, *et al*., Nature, **476**, 189 (2011).
5) Y. K. Kato, *et al*., Science, **306**, 1910 (2004).