Critical current of magnetization dynamics excited by spin-Hall torque in the presence of transverse magnetic field

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Spin-Hall torque switching in a heavy-metal-nonmagnetic/ferromagnetic multilayer has attracted much attention because of its potential application to magnetic memory devices. The absence of an applied voltage on the free layer at the switching is one advantage of spin-Hall torque switching, contrary to spin torque switching excited by an electric current flowing in a magnetic tunnel junction (MTJ). However, it has been argued that the critical current of the spin-Hall torque switching is independent of the Gilbert damping constant α [1], whereas that of the spin torque switching in an MTJ is proportional to α. Since the damping constant α is small (typically, on the order of $10^{-3} - 10^{-2}$), the critical current of the spin-Hall torque switching is relatively larger than that of the spin torque switching.

It should be noted that whether the critical current depends on the damping constant α is independent from whether the torque is excited by the spin-Hall effect or the spin-polarized electric current. The critical current is proportional to α when spin-Hall torque averaged over a precession of the magnetization remains finite, and thus, it can compete with the damping torque. In the previous works on spin-Hall torque switching, a longitudinal magnetic field (along the x-direction in Fig. **??** (a)) is applied along the direction of an electric field. In this case, the critical current is independent of α because the averaged spin-Hall torque is zero, and thus, the switching occurs as a result of a shift of the steady point of the magnetization, not a competition between the spin-Hall torque and damping. On the other hand, in this study, we found that the critical current is proportional to α when a transverse magnetic field along the y-direction is applied; see Fig. **??** (b), where the switching current obtained from the numerical simulation of the Landau-Lifshitz-Gilbert (LLG) equation shows good agreement with an analytical solution proportional to α. This is because the averaged spin-Hall torque remains finite in this case, and thus, the switching occurs as a result of a competition between the spin-Hall torque and damping. The details of this physical picture will be presented in the talk.

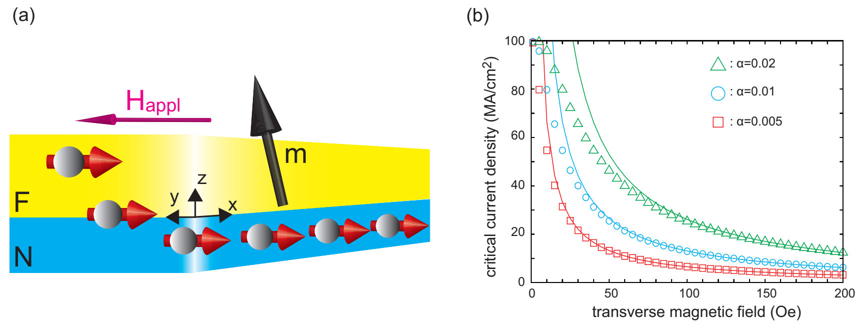

Figure 1: (a) Schematic view of system. The x-axis is parallel to the electrons' flow, whereas the z-axis is normal to the film-plane. The transverse magnetic field H_{appl} points to the y-direction. (b) Dependences of critical current on the transverse magnetic field for several damping parameters obtained from the LLG simulation (symbols). Solid lines are analytical solution of the critical current derived from a linearized LLG equation, which is proportional to α.

1. L. Liu *et al.*, Phys. Rev. Lett. **109**, 096602 (2012).