Indirect excitation of self-oscillation in perpendicularly magnetized spin Hall nano-oscillator

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The spin Hall effect in nonmagnetic heavy metals generates pure spin current flowing in the direction perpendicular to an external voltage, and excites spin torque on a magnetization in an adjacent ferromagnet [1]. The spin torque induces the magnetization dynamics such as switching and self-oscillation. Substantial efforts have been made to develop practical devices based on the spin Hall effect, for example, magnetic random access memory, microwave generator, high sensitivity sensor, and new direction such as bio-inspired computing [2].

The spintronics devices based on the spin Hall effect, however, face a serious problem because of the geometrical restriction of the spin torque direction. Let us assume that an electric current flows in the nonmagnet along x direction, while the ferromagnet is set in z direction. Then, the direction of the spin polarization in the spin current generated by the spin Hall effect is fixed to y direction. The device designs and performances are subject to limitation due to such restriction of spin polarization. For example, the magnetization switching of a perpendicular ferromagnet solely by the spin Hall effect is impossible because the spin torque does not break the symmetry with respect to the film plane. Using external magnetic field, tilted anisotropy, or exchange bias has been proposed to overcome this issue [1,3]. It was also shown that an excitation of the self-oscillation in a perpendicular ferromagnet solely by the spin Hall effect is impossible due to the symmetry. Contrary to the case of the switching, this problem has not been solved yet.

In this work, we investigate the possibility to excite the self-oscillation in a perpendicular ferromagnet by the spin Hall effect. We are motivated by recent theoretical studies on the spin-orbit torque in the presence of an additional ferromagnet to the free layer [4]. These theories predict the existence of additional torques and/or enhancement of the spin accumulation. We consider adding another ferromagnet, referred to as the pinned layer, on the top of the free layer. The pinned layer provides an additional spin torque due to the reflection of the spin current at the interface and the diffusion in bulk. This additional torque has a different angular dependence from the conventional spin-orbit torque, and results in the excitation of the self-oscillation when the magnetization in the pinned layer is tilted from the film plane.

1. L. Liu *et al.*, Phys. Rev. Lett. **109**, 186602 (2012).
2. W. A. Borders *et al.*, Appl. Phys. Express **10**, 013007 (2017). K. Kudo and T. Morie, *ibid*, **10**, 043001 (2017).
3. L. You *et al.*, P. Natl. Acad. Sci. USA **112**, 10310 (2015). J. Torrejon *et al.*, Phys. Rev. B **91**, 214434 (2015). S. Fukami *et al.*, Nat. Mater. **15**, 535 (2016).
4. Y.-T. Chen *et al.*, Phys. Rev. B **87**, 144411 (2013). T. Taniguchi *et al.*, IEEE Trans. Magn. **52**, 1400204 (2015). G. Go *et al,*, Sci. Rep. **7**, 45669 (2017).