Spin-Orbit torque generated from perpendicularly magnetized ferromagnet

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Magnetization control using current-induced Spin-Orbit torque (SOT) is one of the promising writing technologies for next-generation spintronics devices. Previous studies have been achieved by using a heavy metal (HM) as a spin current source of SOT which mainly originates from Spin Hall effect (SHE) [1]. Although, the spin polarization vector of SHE in HM is restricted to a certain axis due to the symmetry point of view. Recently, ferromagnetic materials (FMs) have attracted attention as a candidate of new spin current source of SOT [2-4]. Additional symmetry breaking due to the magnetization leads to an additional spin current generator which could be a great advantage over HM. Here, we focused on the perpendicularly magnetized layer (PML) as a spin current source which few reports have been investigated so far. We revealed that two types of out-of-plane spin current with different spin polarization are generated from PML.

We prepared a tri-layer base structure as following; buffer-layer / [Co/Ni multilayers] (1.2 ~ 3.7 nm) / Cu (3.0 nm) / FeB (1.3 nm)/ MgO. In this structure, in-plane magnetized FeB layer acts as a detecting layer, and perpendicularly magnetized Co/Ni multilayers act as spin source layer. Harmonic Hall measurements were conducted using 10 μm wide Hall device [5]. We found sizable SOT acting on FeB layer even though there is no HM adjacent to FeB layer. In addition, the sign of the torque is reversed with the polarity of the PML ($+m_z^{Co/Ni}$ and $-m_z^{Co/Ni}$ state), which could not be explained by the conventional SHE mechanism. The in-plane angular dependence of torque efficiency of damping-like torque of two states (see figure) shows that that two spin currents are injected to the detecting layer, and the spin polarization of each spin current is estimated to be $\boldsymbol{z}\times\boldsymbol{I}_{ac}$ and $\boldsymbol{m}^{Co/Ni}\times(\boldsymbol{z}\times\boldsymbol{I}_{ac})$. The origin of present result can be explained by the combination of SHE [6] and spin-orbit precession effect [3,4] in Co/Ni multilayers. Our findings reveal the deeper understanding of the spin current generation in ferromagnetic materials and will promote the development of SOT-based applications.

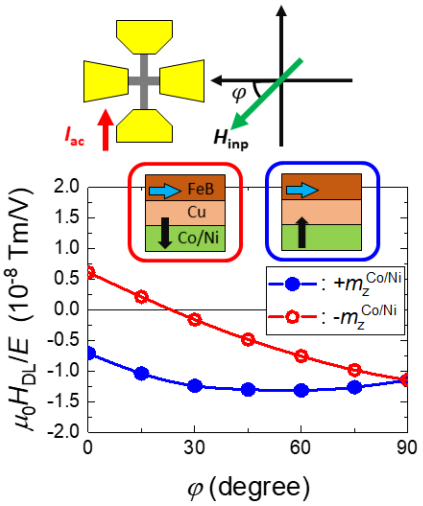

Figure: In-plane angular dependence of spin torque efficiency of damping-like torque ($\mu_0 H_{DL}/E$) in tri-layer structure. Upper panel shows the configuration of electrical current and in-plane field direction. The blue and red data shows the torque efficiency of Co/Ni multilayer magnetized along +z and -z direction.

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[References]

[1] L. Liu *et.al*, Science **336**, 555 (2012). [2] S. Iihama *et.al*, Nat. Electro. **1**, 120 (2018). [3] A. Humphries *et.al*, Nat. Comm. **8**, 911 (2017). [4] S. C. Baek *et.al*, Nat. Mater. **17**, 509 (2018). [5] M. Kawaguchi *et.al*, Appl. Phys. Express **6**, 113002 (2013). [6] W. Wang et.al, Nat. Nanotechnol. **14**, 819 (2019).