Charge to spin conversion in ferromagnet detected by ferromagnetic resonance technique

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Current induced spin-orbit torque (SOT) is one of the promising writing methods for spin-based memory device due to its high writing endurance and ultra-fast switching rate [1]. The driving force of the SOT is a charge to spin conversion (CSC) phenomena. Previous works on SOT havebeen achieved by using CSC in non-magnetic materials (NMs), which originates from spin Hall effect [1-2]. Recently, CSC in ferromagnetic materials (FMs) [3-5] has attracted attention because additional symmetry breaking due to the magnetization leads to an unconventional CSC which could be a great advantage as a spin source of field-free SOT switching [4,5]. Here, we focused on the perpendicularly magnetized ferromagnet (PFM) as a spin current source.

We prepared a tri-layer base structure as following; buffer-layer / PFM / Cu (3.0 nm) / FeB (1.3 nm)/ MgO. In this structure in-plane magnetized FeB layer acts as a detecting layer, and PFM acts as spin source. We chose Co/Ni multilayers and Co/Pt multilayers as a PFM in this research. The ferromagnetic resonance (FMR) in FeB is investigated through spin-torque FMR method [2]. High magnetoresistance of the system and the low anisotropy field enable highly sensitive detection of the FMR. The SOT acting on FeB is quantitatively estimated thorough modulation of resonance linewidth under DC bias current (Figure). We found that the modulation efficiency significantly changes by the polarity of the magnetization of PFM, indicating magnetization dependent CSC phenomena. The in-plane angular dependence revealed that two CSC mechanisms coexist in PFM, and the symmetry of each spin polarization to be $\boldsymbol{z}\times\boldsymbol{j}_e$ and $\boldsymbol{m}\times(\boldsymbol{z}\times\boldsymbol{j}_e)$ where $\boldsymbol{m}$ stands for magnetization of PFM [6]. Our findings show the deeper understanding of the spin current generation in ferromagnetic materials and will promote the development of SOT-based applications.

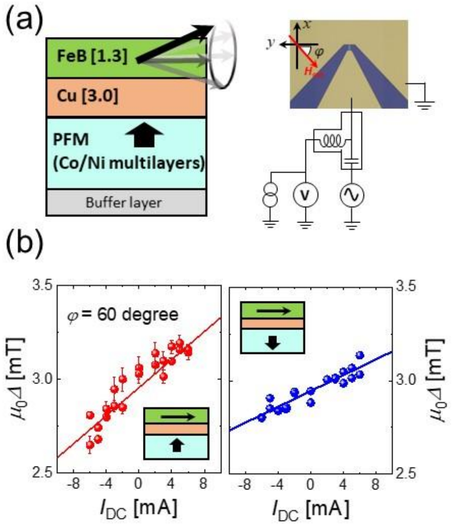

Figure: (a) Schematic of tri-layer structure with Co/Ni multilayers and setup of FMR measurement. The black arrows show the magnetization of each layer. (b) DC-bias current dependence of resonance linewidth. The blue and red data show measurements of PFM magnetized along +z and -z direction, respectively.

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[References]

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