Spin-orbit torque in a Ni-Fe single layer

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Spin-Hall effect (SHE) is the most promising way to convert from charge current (J_c) to spin current (J_s), and has been studied in a variety of nonmagnets (NMs). Exploiting the SHE-induced J_s, one can make a torque acting on a local spin of ferromagnet (FM), which is called spin-orbit torque (SOT). The stack structure frequently used for the SOT experiment is a NM / FM bilayer. It had been believed that the NM is essential to generate the SOT acting on the FM. After the pioneering works on the conversion from J_s to J_c in FM [1,2], however, the charge-spin conversion was reported for many kinds of FMs, and it has recently been revealed that the SOT generated in the FM can act on the magnetization of FM itself, *e.g.* $L1_0$-FePt [3,4], disordered CoPt [5], and Ni-Fe (permalloy, Py) [6]. In addition to the observation of self-induced SOT in the single ferromagnetic layer, the spin torque oscillation in the Py single layer has been demonstrated [7]. This demonstration opened a new avenue for SOT-based device applications although the mechanism of self-induced SOT is still under debate. In order to elucidate the mechanism of SOT in the single FM, it is indispensable to carry out the systematic study using a conventional spintronic material such as Py.

In this study, we examined the self-induced SOT in a Py single ferromagnetic layer. Spin-torque ferromagnetic resonance (ST-FMR) was measured for the very thin Py layers with and without structural inversion symmetry: “asymmetric” and “symmetric” Py layers. Thin films were prepared on a thermally oxidized Si (Si-O) substrate by employing the ion beam sputtering system. The asymmetric Py samples (Asym-Py) have the film stack of Si-O Subs. // Py(t) / Al-O(5) (in nanometer) while the symmetric Py samples (Sym-Py) are composed of Si-O Subs. // Al-O(5) / Py(t) / Al-O(5). For both structures, the field-like component coming from Oersted field clearly appeared. On the other hand, the damping-like component was observed only for the asymmetric Py with the thickness less than 3 nm. This damping-like torque is attributable to the significant spatial change in the properties of Py. We also propose a toy model to analyze the self-induced SOT.

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