Spin-orbit torque in ionic crystal ReO_X

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Spin-orbit torque (SOT) generated by spin Hall effect (SHE) or Edelstein effect has a possibility to efficiently perform magnetization switching of ferromagnets for spintronic devices [1]. The generation of the SOT (spin current) via the SHE are attributed to electron scattering in materials. Especially phonon scattering plays an important role for the generation at room temperature [2]. SHE has been energetically studied in heavy metals such as Ta, Pt and W in which acoustic phonon induces the scattering so far. While optical phonon would also cause it in the same way. It is important to investigate the contribution of optical phonon scattering for unveiling the SOT generation mechanism.

Based on the background, we studied the generation of the SOT in ionic crystal ReO_X which is conductive and would have the contribution of the optical phonon by means of spin-torque ferromagnetic resonance (ST-FMR). First of all, we prepared 10 nm-thick ReO_X and pure Re as a reference by DC magnetron sputtering, especially with 1 sccm-oxygen flow and 400 ℃ substrate annealing for only the oxide. 5 nm-thick $Ni_{80}Fe_{20}$(Py) and 2 nm-thick Al_2O_3 were also deposited in-situ by same way for detecting the SOT and oxidation protection. After that, devices which consist of strip and GSG-type waveguide were fabricated for the ST-FMR measurement by using e-beam lithography and Ar ion milling.

The detected ST-FMR signals by application of 6 dBm-power with several different frequencies are shown for Re in Fig. (a) and for ReO_X in Fig. (b). A resonant field for the ReOx case is slightly shifted to higher field because effective magnetization of Py is affected by an interface oxidation. We analyzed the data for extracting the SOT efficiency by using conventional line-shape analysis as shown in Fig. (c). Averaged values on several frequencies are -0.2 ± 0.1 and 7.4 ± 0.4 % for pure Re and ReO_X cases, respectively. The value of SOT efficiency for Re is in good agreement with both of theoretical [3] and experimental reports [4]. The enhancement of SOT efficiency observed in ReOx suggests that Re can get a function of the SO material by the oxidation or the ionic crystallization. We will discuss the contribution of the expected optical phonon for the enhancement of the SOT in this presentation.

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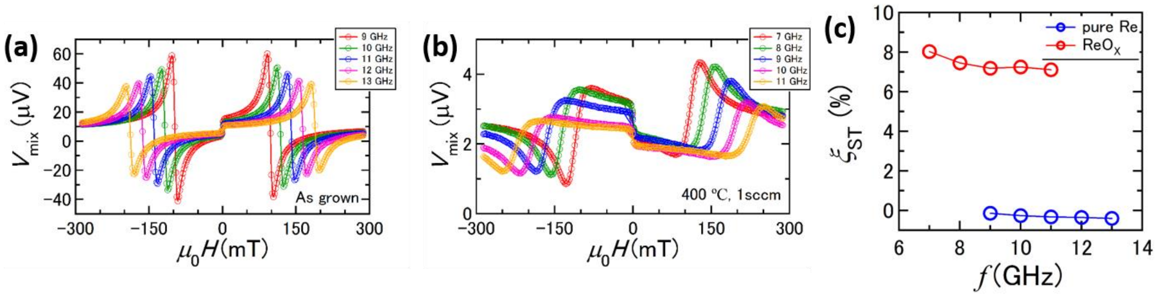

Fig. ST-FMR signals in (a) Re(10mn)/Py(5nm)/Al_2O_3(2nm) and (b)ReO_X(10mn)/Py(5nm)/Al_2O_3(2nm) case.

(c)SOT efficiencies as a function of frequency for Re and ReO_X.