Determination of spin-orbit torque by spin-torque ferromagnetic resonance free from spin-pumping

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Spin torque ferromagnetic resonance (ST-FMR) provides useful tool to investigate various magnetic properties in spintronic systems, where one excites FMR by applying rf current and detects dc voltage generated through rectification effects.[1,2] While this scheme has been used to characterize spin-orbit torques (SOTs) that attract much attention recently,[3-5] it is known that one needs to care about dc voltage arisen by spin pumping that overlaps with the signal by the rectification effects.[6] Here we show a method to determine the SOT generation efficiency by ST-FMR free from the spin pumping, using two representative material systems, W/CoFeB/MgO and Pt/Co/MgO.

Stacks, from substrate side, W(5)/CoFeB(1.75)/MgO(1.3)/Ta(1), Ta(3)/Pt(3)/Co(1)/MgO(1.3)/Ta(1) (in nm) are deposited by sputtering and are processed into strip lines in coplanar waveguides. Figure 1 shows a schematic illustration of the setup for ST-FMR. We apply rf signal with amplitude modulation into the strip lines under external magnetic field. While the magnetic field have been applied in in-plane in previous reports,[2,6] we rotate the magnetic field in XZ plane, by which dc voltages from spin-pumping vanishes. Magnitude of Slonczewski-like (SL) spin-orbit torque can be determined from magnetic field angle dependence of anti-symmetric component of Lorentzian. The SL torque efficiency (ξ_{SL}) is obtained to be -0.25 (0.08) for W/CoFeB/MgO (Pt/Co/MgO) system, which are confirmed to agree well with the values determined by an extended Harmonic Hall technique.[7] We also find that analysis of ST-FMR spectra obtained from a conventional setup without considering the spin pumping leads to a significant overestimation (ξ_{SL} = -0.56) for W/CoFeB/MgO. The present finding offers a useful insight to obtain a reliable value of SOT efficiency using ST-FMR particularly for systems that exhibit large SOT, which accompanies large spin pumping.

A portion of this work was supported by the ImPACT Program of CSTI, JST-OPERA, and JSPS KAKENHI Grant Number 18K13796.

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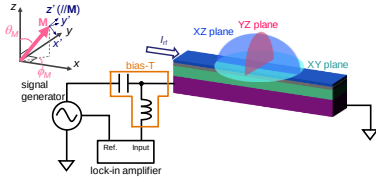

Fig.1 Schematic illustration of the experimental setup for spin-torque ferromagnetic resonance.