Giant spin-orbit torque observed in a Py/W/Pt trilayer

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Spin-orbit torque (SOT) via spin Hall effect or Edelstein effect is key ingredient for spintronics devices from the perspective for inducing magnetization reversal which is central concept for MRAM. Therefore, many materials have been studied for generating SOT so far such as Pt, Ta, W. Although spin torque efficiency (STE) is determined by a just bulk materials parameter, we need to design new multilayered materials for more efficient or controllable SOT generation. From the view point of spin-orbit engineering, an artificial lattice has a possibility to emerge novel SOT due to variable Berry curvature, especially multilayer consisted of spin Hall materials which have opposite sign of spin Hall angle each other. Here we focus on W/Pt multilayers for extracting SOT such as damping-like (DL) and field-like (FL) torques.

At first, we prepared several Py/W/Pt multilayers by means of DC magnetron sputtering. After that, we fabricated conventional waveguide devices and performed spin-torque ferromagnetic resonance (ST-FMR) measurement with 6 dBm-power and 5 to 12 GHz-frequency. We compared different Pt thickness cases such as (a) Py(5nm)/W(2nm)/Pt(5nm) and (b) Py(5nm)/W(2nm)/Pt(1nm). The result for case (a) is shown in Fig. (a). The estimated efficiency is about -0.05. This means that the result comes from spin Hall effect in α-W whose efficiency is reported as below -0.07 [1]. So there is no interesting effect from the multilayer on the spin torque generation. While we found surprising behaviors in Py(5nm)/W(2nm)/Pt(1nm) as shown in Fig. (b). The ST-FMR signals consist of almost 100 % symmetric voltage V_{S} without any anti-symmetric one V_{AS}.

Here we discuss the reason why V_{AS} is almost zero in this Py(5nm)/W(2nm)/Pt(1nm) trilayer. Actually, the asymmetric signal V_{AS} is originated from a sum of torques generated by the Oersted field and the FL field described like $V_{\mathrm{AS}} \propto (H_{\mathrm{Oe}} + H_{\mathrm{FL}})\sqrt{1 + \mu_0 M_{\mathrm{eff}}/\mu_0 H_{\mathrm{R}}}$, where $H_{\mathrm{Oe}}, H_{\mathrm{FL}}, \mu_0 M_{\mathrm{eff}}, \mu_0 H_{\mathrm{R}}$ mean Oersted field, FL field, effective magnetization of Py, resonance field, respectively. Therefore, zero V_{AS} signal indicates that the FL torque and Oersted-field induced torque are cancelled out each other. So this comparable FL torque to Oersted-field induced torque is quite remarkable since the FL torque generated from W is usually negligible [2] and much smaller than Oersted-field induced torque [3].

In this conference, we discuss Py thickness dependence for extracting actual DL and FL torque quantitatively, and Pt thickness dependence for unveiling the origin of the large FL torque in this system.

Surprisingly large FL torque is revealed in a Py(5nm)/W(2nm)/Pt(1nm) multilayer. We find that the FL torque is drastically controlled by varying Pt thickness. This Py/W/Pt multilayered system has a key for understanding the origin of the novel FL torque by studying thickness dependence systematically.

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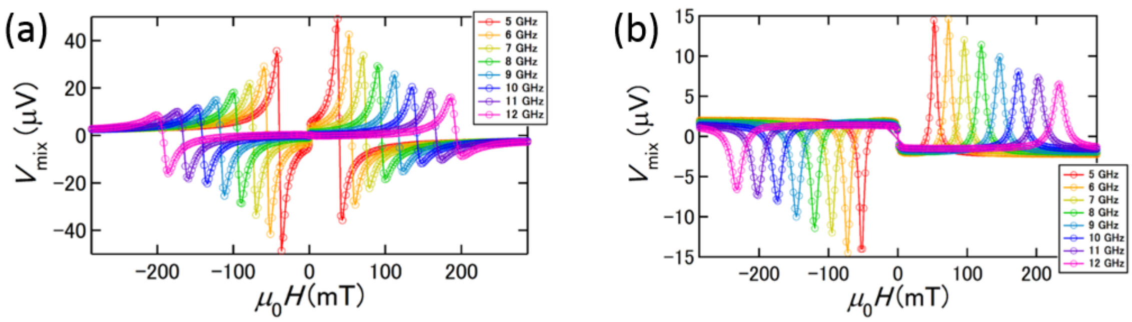

Fig. ST-FMR signals in (a) Py(5nm)/W(2nm)/Pt(5nm) and (b)Py(5nm)/W(2nm)/Pt(1nm) case.