Evaluation of temperature-dependent spin Hall angle in CoFeB/MgO/Pt tunneling junctions by using Spin Hall effect tunneling spectroscopy

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Spin Hall effect (SHE) and its inverse effect (*i*-SHE) are promising ways to generate and to detect spin currents, respectively. The spin Hall angle θ_{SH} is the conversion efficiency between charge current and spin current. Various methods to evaluate θ_{SH} have been demonstrated, such as spin pumping [1], harmonic measurement [2] and lateral spin valve [3]. Recently, SHE tunneling spectroscopy (SHT) [4] has been proposed as an alternative way to evaluate θ_{SH}. In this method, *i*-SHE signal is obtained via tunneling spin polarized currents, which is applicable for not only metals but also topological insulators [5]. In this study, we explore the detailed spin dependent transport mechanism in spin Hall effect tunneling devices.

Film stack of Ru (8)/Ta (5)/CoFeB (4)/MgO (2)/Pt (7) (thickness in nm) was prepared by magnetron sputtering. The SHT device as shown in Fig. 1 was fabricated by using electron beam lithography and Ar ion milling. CoFeB/MgO junction was patterned into 4×4 μm^2 square - shaped element. The magneto-transport was measured by using AC resistance bridge by varying temperature. To evaluate θ_{SH}, following equation is used [4].

$$\theta_{SH} = \frac{w \cdot t \cdot \Delta R}{P \cdot \rho \cdot \lambda_{sf}} \cdot \frac{1}{\tanh\left(\dfrac{t}{2\lambda_{sf}}\right)} \quad \cdots (*)$$

Here ρ and λ_{sf} are the resistivity of Pt and spin relaxation length of Pt, respectively, P and ΔR indicate spin polarization of CoFeB and the amplitude of SHT signal. w and t are width of the bottom electrode and Pt thickness (w=8μm, t=7nm in this case).

To evaluate λ_{sf}, weak-anti localization was measured as shown Fig.2. As a result, λ_{sf} of Pt is determined to be 5 nm at 1.6K. To evaluate λ_{sf} at high temperature, further experiment is going on. Temperature-dependence of inverse spin Hall signal ΔR is also evaluated at various temperatures as shown in Fig.3.

To evaluate θ_{SH} precisely, further analysis is underway.

[1] E. Saitoh et al., Appl. Phys. Lett. 88, 182509 (2006). [2] L. Liu *et al*., Science 336, 555 (2012). [3] V. Laurent, *et al*., Phys. Rev. Lett. 99, 226604 (2007). [4] L. Liu *et al*., Nature Phys. 10, 561 (2014). [5] L. Liu *et al*., Phys. Rev. B 91, 235437 (2015).

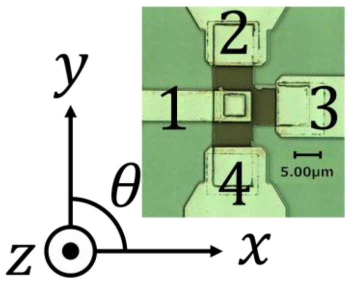

Fig. 1: Sample configuration of SHT device.

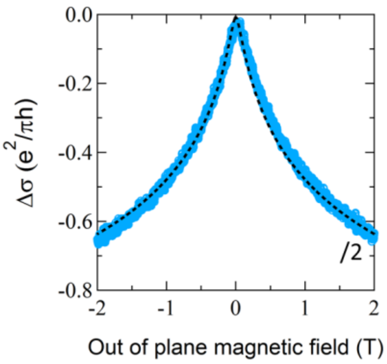

Fig. 2: Weal-anti localization and its analysis of 6 nm-thick Pt film at 1.6 K

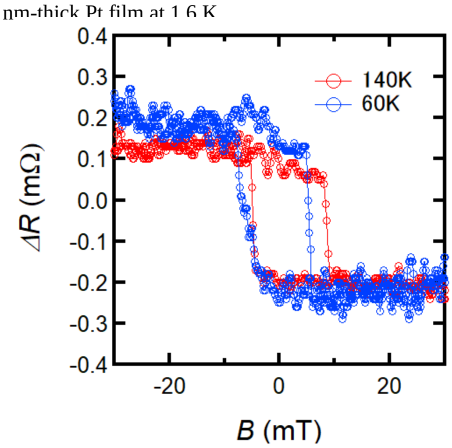

Fig. 3: field dependent ΔR.at each temperature