Enhancement of spin Hall angle in CuPt alloy systems

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Spin Hall effect (SHE) and inverse-SHE are considered as the promising ways to generate and to detect spin currents, respectively. The spin Hall angle (SHA) θ_{SH} is a parameter of the conversion efficiency between the charge current and the spin current. To develop future spintronics devices such as a spin-orbit torque (SOT) MRAM, it is crucial to enhance the value of SHA. Various heavy (spin-orbit) metals have been investigated such as Pt, Ta, W, Bi and so on. However, the maximum values of SHA are still not large enough for SOT-MRAM. Therefore, some of studies have been performed to explore new alloy systems to obtain larger SHA. In this study, we report the enhancement of the SHA in CuPt alloy thin films evaluated by spin-torque ferromagnetic resonance (ST-FMR).

The film stacks of CuPt(6 nm) /Py(2-10 nm)/ Al_2O_3(2 nm) for a cap layer on thermally oxidized silicon substrate was deposited by RF magnetron sputtering. The compositions of Cu and Pt were controlled by the RF power for each element. The thickness of Py was varied from 2 nm to 10 nm to separate the damping like (DL) torque from field like (FL) torque, respectively [1]. Then the ST-FMR devices were fabricated by microfabrication techniques using photolithography and Ar-ion milling. The ST-FMR measurement was conducted in a RF probe station equipped with an in-plane magnet at room temperature. The measurement circuit and fabricated device were shown in Fig. 1. To evaluate SHA precisely, it's very important to distinguish DL torque which contributes to the SHE from FL torque. The relationship between DL and FL torque is described based on Ref.1.

The spin torque efficiency ξ_{ST} is described as a function of Py thickness: t_{FM}. ξ_{DL}, ξ_{FL},

$$\frac{1}{\xi_{ST}} = \frac{1}{\xi_{DL}} \cdot \left(1 + \frac{\hbar}{e} \frac{\xi_{FL}}{4\pi M_S t_{SOM}} \frac{1}{t_{FM}}\right) \quad \cdots (*)$$

t_{SOM} ,M_s, are DL spin torque efficiency, FL spintorque efficiency, thickness of spin-orbit metal (SOM), saturation magnetization, respectively.

Then the result of the Py thickness dependence of ξ_{ST} in different compositions of CuPt was shown in Fig. 2. The contribution FL torque was negligible. ξ_{DL} in Eq. (*) is considered as SHA in this report. The SHA of $Cu_{75}Pt_{25}$ samples are evaluated to be less than 1% and those of $Cu_{50}Pt_{50}$ and $Cu_{30}Pt_{70}$ samples are 8.5 and 7.5%, respectively. To demonstrate the enhancement of SHA, the resistivity was controlled by the Ar-gas pressure for CuPt in each composition. The values of SHA are varied linearly depending on the resistivity as is reported in typical heavy metals, as shown in Fig. 3. The largest value of SHA was obtained for $Cu_{50}Pt_{50}$ samples. Further analysis to clarify the origin of this enhancement will be discussed in the presentation.

[1] C.-F. Pai *et al*,. Phys Rev B **92**, 064426 (2015)

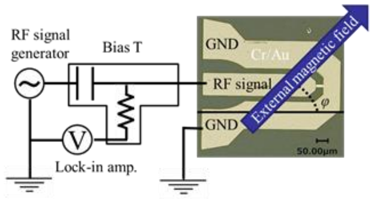

Fig. 1: Sample configuration of ST-FMR device.

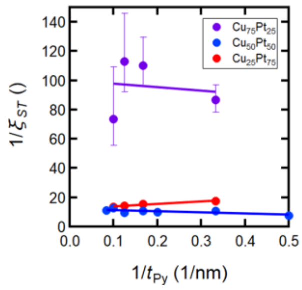

Fig. 2: Py thickness dependence of $1/\xi_{ST}$.

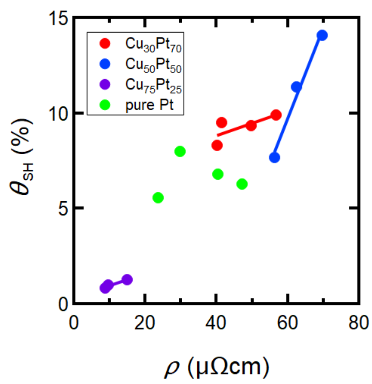

Fig. 3: Resistivity dependence of SHA in pure Pt for reference and CuPt, respectevely.