Measurement of spin-orbit torques in Pt/Co/AlOx heterostructures depending on Pt thickness

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1. Introduction

Recently, it has drawn a great attention that magnetization in a heterostructure of heavy metal-ferromagnet-insulator can be controlled by in-plane current because of its potential application in magnetic random access memories or domain wall devices [1, 2]. The mechanism involves the coupling of electron's spin and its orbital motion, resulting in non-equilibrium spin accumulation which ultimately gives rise to a torque on the magnetization, so-called spin-orbit torques (SOTs). This effect can be explained by spin Hall effect of heavy element and/or Rashba effect of asymmetric structure. However, there is still no consensus of the origin or dominant effect of the SOTs. So in order to elucidate the origin of the SOTs, we measured the SOTs in Pt/Co/AlOx hetorostructures with different Pt thickness.

2. Experiment

The samples of Pt(t)/Co(1.4nm)/AlO_x(2nm) were deposited by magnetron sputtering on a thermally oxidized Si substrate, where Pt thicknesses are 2, 3, 5, and 7nm. All samples were annealed at 300℃ for 30min in a vacuum chamber after the film deposition. Photo-lithography and ion etching were used to make Hall bar structure. We injected the AC current while sweeping the in-plane longitudinal and transverse magnetic field to current direction. The first (C_{1w}) and second (C_{2w}) harmonics Hall voltage were measured simultaneously with two lock in amplifiers. We can obtain longitudinal effective field (spin transfer-like torque) and transverse effective filed (field-like torque) by using the way described in Ref. [2].

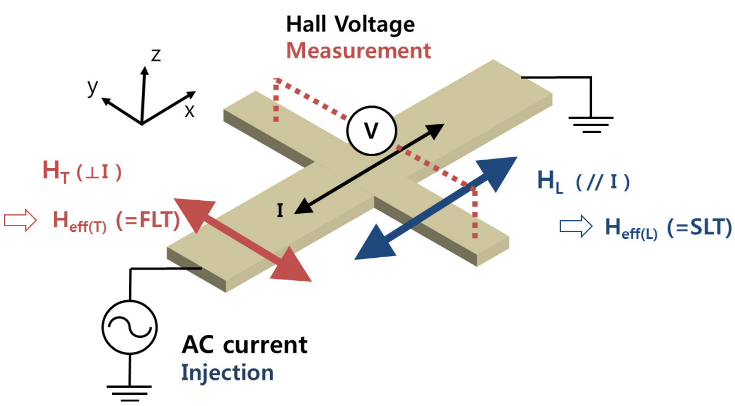

Figure 1. Schematics of the SOTs measurement

3. Results and discussion

Figure 2 shows the first and second harmonic Hall voltage for Pt 3nm samples under different field direction. The first harmonic signal (C_{1w}) is almost same, but the second harmonic signal (C_{2w}) depends on the applied field. From measured signal, we calculated the SOTs(Effective field). The FLT(SLT) has even(odd) symmetry with respect to the inversion of the magnetization as shown in Figure 3. Moreover, FLT decreases as Pt thicknesses increases, whereas SLT increases. This results can be explained by the origin of SOTs, spin Hall effect and Rashba effect. The SLT, which mainly originates from spin Hall effect, is bulk effect so, it increases with increasing Pt thickness. However, FLT related to Rashba effect decreases due to the relatively reduced interface effect.

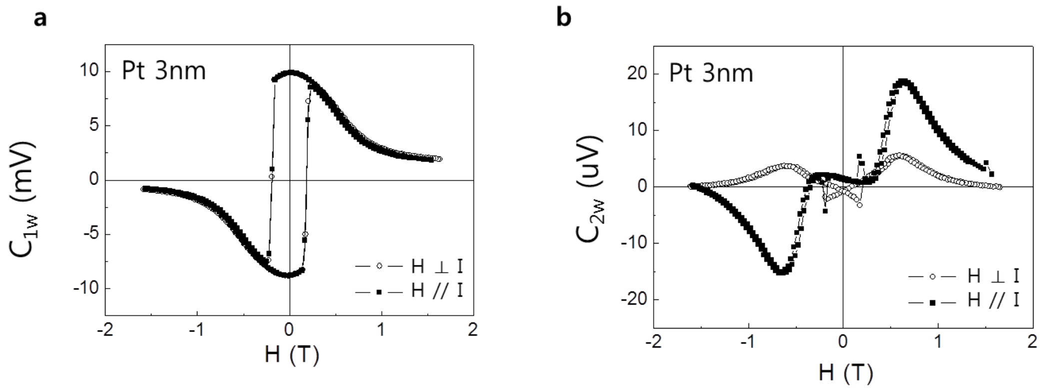

Figure 2. **(a)**First and **(b)**second harmonic Hall voltage. Open and solid symbols correspond to transverse and longitudinal field direction to current flow.

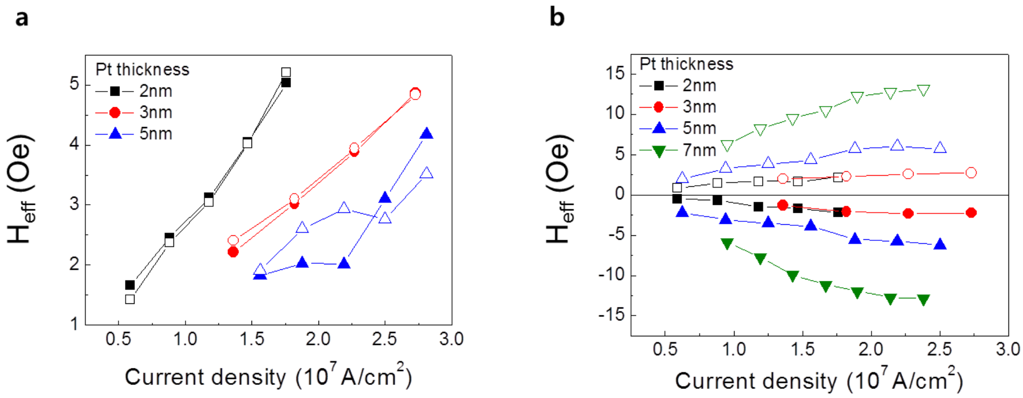

Figure 3. Pt thickness dependence of **(a)**transverse(FLT) and **(b)**longitudinal(SLT) effective field. Open and solid symbols correspond to magnetization pointing along -Z and +Z, respectively.

4. Reference

[1] Kevin, Garello et al., Nature nanotechnology **8,** 587 (2013)

[2] J. Y. Kim et al., Nature Materials. **12,** 240 (2013)