Crystal Structure Dependence of Spin-Orbit Fields in Pt/Co/AlO Trilayer Structures

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Backgrounds

Pt/Co/AlO[1] structure is gaining a lot of interests as a structure for current-induced spin-orbit torque devices, such as racetrack memory[2] or MRAM along with Ta/CoFeB/MgO structure[3][4]. Applying in-plane current into Pt/Co/AlO thin films, induces spin current due to spin Hall effect which is caused by the spin dependent scattering of conduction electrons in Pt. The scattered spins give torques to magnetization as spin transfer torque (so-called Slonczewski-like torque), enable magnetization switching. Most of researches are studying on Si substrate, however, precise discussion on crystal structure dependent spin-orbit torque of Pt is not reported yet. For understanding accurate mechanism of spin-orbit torque by spin Hall effect on Pt, we investigated different crystal structure dependence of spin-orbit torque in Pt/Co/AlO trilayers.

Methods

Pt 6 nm / Co 0.6 nm / AlO 2 nm films are fabricated on the AlO (0001) substrate and the thermally oxidized SiO_2 substrate. Each sample shows clear perpendicular magnetization anisotropy. Additional AlO cap was deposited by atomic layer deposition for protection from oxidation. Hall bar structures were fabricated by several steps of photo-lithography and HF/Ar etching. The crystal structures are determined by X-Ray diffraction and RHEED method. When AC current and in-plane magnetic field are applied, Hall voltage is oscillating as the sum of two sinusoidal waves of different frequencies. We can obtain spin-orbit torque as an effective magnetic effective field by applying in-plane external magnetic field in longitudinal direction ($\hat{y}$).

Results and discussions

Figure (1) shows RHEED patterns of Pt surfaces on different substrates. RHEED indicates that single and poly crystalline Pt were grown on the AlO(0001) and SiO_2 substrate, respectively.

We calculate the magnitudes of effective fields by spin Hall effect in harmonic measurement method (Figure 2). It is found that the effective field by spin Hall effect is greater in poly crystalline than single crystalline.

This result can be explained as the conduction electrons in poly crystalline Pt to be scattered more frequently than that in single crystalline Pt. For discussion of quantitative understanding, we need furthermore experiment about saturation magnetization and structures with other thickness.

Conclusions

We observed effective field due to the spin-orbit torque on magnetization by spin Hall effect in different Pt crystal structures. The larger effective fields are induced on the trilayer of poly crystalline Pt. This is because more frequent scattering takes place in poly crystalline and induces larger effective field. For the detail discussion, Pt thickness dependence will be discussed.

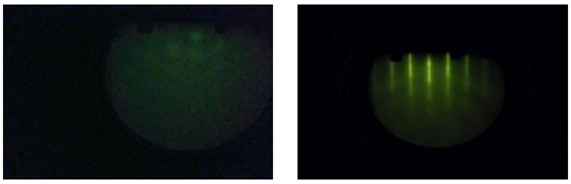

Fig. 1 RHEED patterns of deposited Pt on thermally oxidized SiO_2 substrate(left) and AlO(0001) substrate (right).

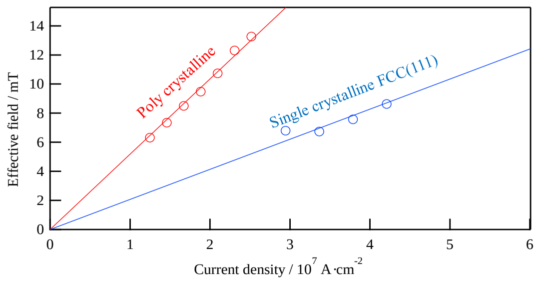

Fig. 2 Magnitudes of Slonczewski-like field along current densities. Pt of poly crystal structure induces larger Slonczewski-like field.

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