Study on SOTs in Pt/CoFeB/MgO and Ta/CoFeB/MgO and their interfacial effects by Ti insertion

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1. 서론

Manipulation of the magnetization by electric field or current has been great interest for realization of spintronic memory and logic devices. Conventionally, spin transfer torques (STTs) were used to control the magnetization especially for STT-MRAM. However, there were numerous disadvantages; perpendicular current that flows across the tunnel barrier causes damage to the barrier, and it shows slow operation speed due to the precessional switching. Recently, new types of torques named spin-orbit torques (SOTs) have been robustly studied as a promising breakthrough, which enables to reduce writing power and to improve reliability of devices.[1]

A number of studies on SOTs have been reported based on heavy metal (HM)/ ferromagnet (FM)/ Oxide (OX) trilayer structure such as Pt/Co/AlO_χ and Ta (W)/CoFeB/ MgO.[2,3] From those early studies, it is known that SOTs are generated by both of two mechanisms: spin Hall effect, which mostly contributes to <u>damping like torque (DLT)</u> and Rashba effect, which mostly contributes to field like torque (FLT). However, it is ambiguous to study each mechanism and its contribution due to the coexistence of interfacial and bulk effects.

In this research, interfacial and bulk effects on SOTs of both Ta/CoFeB/MgO and Pt/ CoFeB/MgO layers were studied by inserting Ti layers with different thicknesses between HM and FM layers. The behaviors of DLT and FLT according to the thickness of Ti were conspicuously different in Ta/Ti(t)/CoFeB/MgO samples and Pt/Ti(t)/ CoFeB/MgO samples. Moreover, switching behaviors of each sample were also studied.

2. 실험방법과 결과

Two different sets of ferromagnetic layers of Ta(5)/Ti(t)/CoFeB(1)/MgO(1.6) (Ta set) and Pt(5)/Ti(t)/CoFeB(1)/ MgO(1.6) (Pt set) were fabricated on Si/SiO_2 substrates by magnetron sputtering where the values of t vary from 0 to 7 (0, 1, 3, 5, 7). Here the numbers in the parenthesis represent the film thickness in nanometers. After adequate annealing for each sample, it became perpendicularly magnetized; Pt(5)/CoFeB(1)/MgO(1.6) sample was annealed at 300 ℃ with out-of-plane magnetic field cooling and the rest of the samples was annealed at 150 ℃ without magnetic field.

All samples were patterned to 5μm-width hall cross bar structure by photolithography to measure SOTs. Both DLT and FLT of samples were measured using 2^{nd} harmonic lock-in technique with polar angle 86°. To study switching behavior, the Hall resistance was measured applying longitudinal current pulses, which is parallel to the direction of magnetic field sweeping.

As a result, Ta set showed negative 2^{nd} signals of DLT and FLT in contrast to Pt set, which showed positive SLT and FLT corresponding to the sign of spin Hall angles of Ta and Pt. The magnitude of both SLT and FLT decreased when Ti layer was inserted between HM (Ta, Pt) and FM layers but the two sets show different decaying behaviors. In Ta set, two torwues, SLT and FLT, were gradually decreased maintaining their relative ratio as Ti thickness increases. In Pt set, both two torques were drastically decayed when Ti is inserted compared to Ta set. Moreover, the magnitude of SLT was significantly larger than that of FLT when there is no Ti insertion. When Ti layer was inserted, the magnitude of FLT exceeded that of SLT. In addition, switching experiment supported the behavior of decreasing SLT.

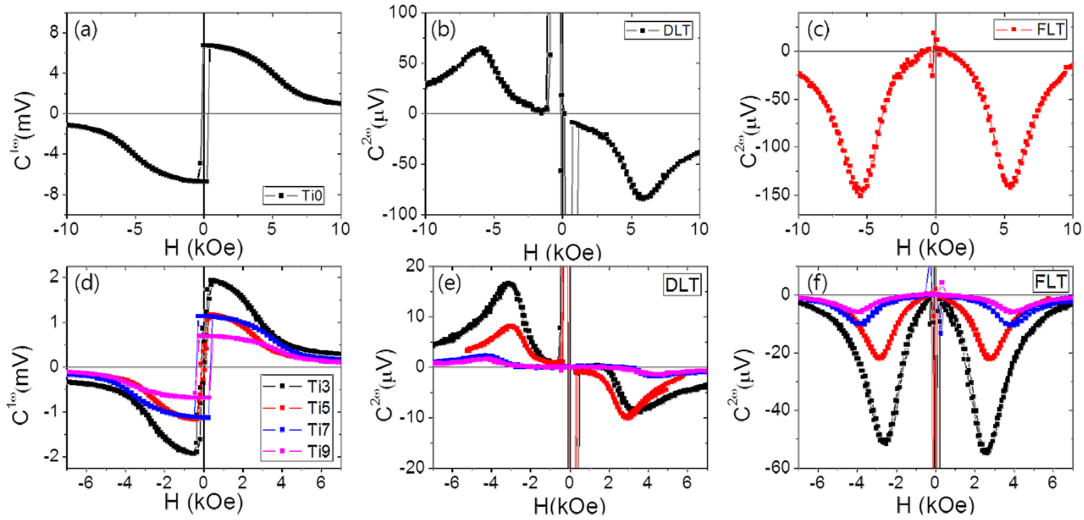

Fig. 1ω and 2ω signals of Ta set samples were measured at 5 mA. It can be known that the 2ω signals gradually decreases as Ti thickness increases.

3. 결론

We have studied interfacial effect on the SOT in the NM/FM/oxide structures by introduction of Ti layer in-between NM and FM layer. Different behaviors were observed between Ta set and Pt set when Ti is inserted, which indicates that there would not be a single mechanism that determines the magnitude of SOTs.

4. 참고문헌

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