Investigation of spin-orbit torque induced magnetization switching in Ta-O/Co-Fe-B heterostructures

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Spin-orbit torque (SOT) induced magnetization switching in oxide/ferromagnetic heterostructures has attracted immense interest owing to its potential for the development of high-performance spintronics devices, realized by tuning the surface oxidization [1]. Since both of the Slonczewski-like (H_{SL}) and the field-like (H_{FL}) effective fields would contribute to the magnetization reversal, a detailed understanding and manipulation of H_{SL} and H_{FL} in these structures are important. Herein we selected typical Ta-O/Co-Fe-B heterostructures, and studied the change in H_{SL} and H_{FL} by controlling the thickness of Ta-O layer.

From the thermally oxidized Si substrate's side, Ta-O ($t_{Ta\text{-}O}$ nm)/$Co_{20}Fe_{60}B_{20}$ (1.2 nm)/MgO (1.3 nm)/Ta (1.0 nm) stacks with various values of Ta-O layer's thickness ($t_{Ta\text{-}O}$) were fabricated by DC/RF sputtering. Ta-O layer was formed by naturally oxidizing Ta layer at 0.3 Pa. The effective fields, H_{SL} and H_{FL} were evaluated using an extended harmonic Hall measurement for Hall bar devices.

The sign and absolute values ($|H_{SL(FL)}|$) of the effective fields are consistent with those in the previous work on Ta/Co-Fe-B/MgO stacks [2]. Figure 1 shows $t_{Ta\text{-}O}$ dependence of $|\mu_0 H_{SL(FL)}|/I$, where I is the total current applying to the device (a), and H_{FL}/H_{SL} in comparison with that of a non-oxidized stack (b). Both of $|\mu_0 H_{SL}|/I$ and $|\mu_0 H_{FL}|/I$ increase and converge to a certain value as $t_{Ta\text{-}O}$ increases, suggesting a bulk effect, such as the spin Hall effect, as an origin of SOT. On the other hand, $|H_{FL}|$ is larger than $|H_{SL}|$ and their ratio increases with $t_{Ta\text{-}O}$, as shown in Fig. 1 (b), suggesting an interfacial contribution such as the Rashba-Edelstein effect (REE), if one assumes that H_{FL} originates from REE [3]. These results are of importance to understand the SOT induced magnetization switching, and to design the spintronic devices using oxidized HM/FM systems.

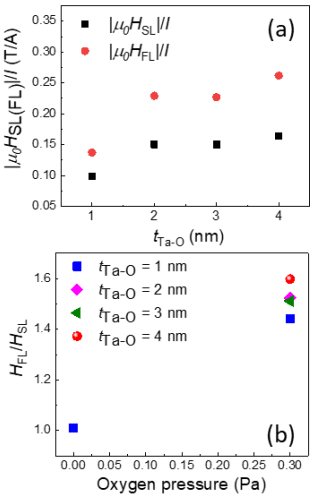

Fig. 1: $t_{Ta\text{-}O}$ dependence of $|\mu_0 H_{SL(FL)}|/I$ (a) and H_{FL}/H_{SL} in comparison with that of a non-oxidized stack (b).

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