Magnetization switching using spin orbit torques in CoFeB|MgO magnetic heterostructures

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Spin orbit torques in ultrathin magnetic heterostructures are attracting great interest owing to the large spin orbit coupling of the elements constituting the heterostructure and from the interfaces. Magnetization switching[1, 2]and domain nucleation[3], fast current driven domain wall motion[4] have been observed using in-plane currents in ultrathin magnetic layer sandwiched between a heavy metal and an oxide. Most of the current (or voltage) induced effects in these systems can be represented by the "effective magnetic fields", which illustrate the strength and direction of the force exerted on the magnetic moments from the generated spin currents via the spin orbit effects.

We have studied the current induced effective field in Ta|CoFeB|MgO heterostructure[5] to reveal the underlying physics of the interaction between the magnetic moments and current in such structure. We find that the effective field is sensitive to the thickness of the Ta and CoFeB layers. The effective field even changes its direction when the Ta layer thickness is varied, indicating that there are competing effects, e.g. spin Hall and Rashba-like effects, that contribute to the effective field generation. The effective field has components parallel and transverse to current flow direction and the relative size between the two also varies with the thickness of Ta and CoFeB layers.

The effective field revealed in our experiments explains recent reports on magnetization switching of perpendicularly magnetized system using in-plane currents[1, 2], current induced domain nucleation[3] and current driven domain wall motion[4]. In addition, we find interesting aspects of magnetization switching and domain wall motion in CoFeB|MgO heterostructures with different underlayers, which will be discussed.

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[1] I. M. Miron *et al.*, Nature **476** (2011).
[2] L. Liu *et al.*, Science **336** (2012).
[3] I. M. Miron *et al.*, Nature Materials **9** (2010).
[4] I. M. Miron *et al.*, Nature Materials **10** (2011).
[5] J. Kim *et al.*, Nature Materials **12** (2013).

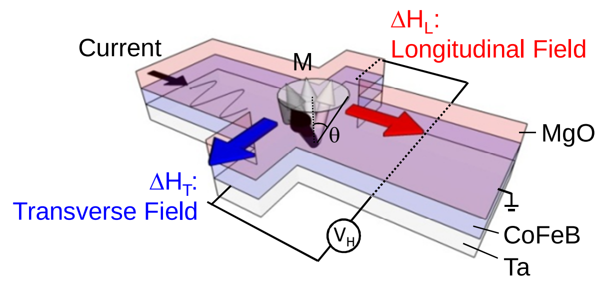

Fig. 1. Schematic illustration of the experimental setup used to measure current induced effective fields.

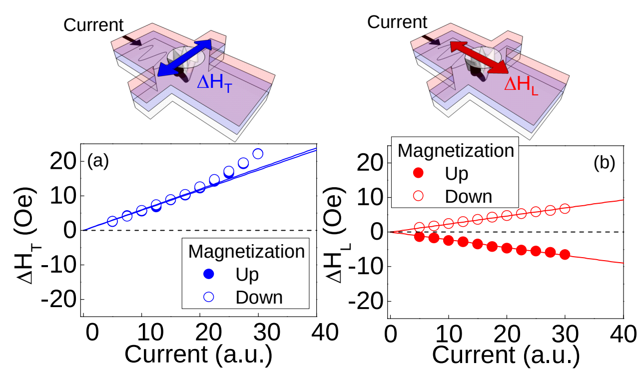

Fig. 2. Current induced effective field measured as a function of the input current[5]. Effective field transverse (ΔH_T) and along (ΔH_L) the current flow are measured for magnetization oriented normal to the film normal. Open and solid symbols indicate the magnetization direction.