Quantification of Dzyaloshinskii-Moriya interaction from thermally-activated and flow regime domain wall motion

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Spin-orbit torque (SOT) induced domain wall (DW) motion in non-magnet/ferromagnet/oxide systems is a promising concept for three terminal spintronics devices¹. The asymmetry of stack structure results in an interfacial Dzyaloshinskii-Moriya interaction (DMI) which plays a pivotal role for fast SOT-driven DW motion²-⁴. Thus, understanding the manifestation of DMI-induced effective field ($H_{DMI}$) is important.

Thermally-activated DW motion under magnetic fields ($H_Z$ and $H_X$) is proposed to offer quantitative information about $H_{DMI}$⁵. However, the role of $H_{DMI}$ from this regime is greatly debated and demands a quantitative comparison of $H_{DMI}$ between dynamically different regime of DW motion, i.e., flow regime⁶,⁷.

Multilayers utilized in this study are W(5)/CoFeB(1.1)/MgO(2)/Ta(1) (W/CoFeB) and Ta(4)/Pt(3)/Co(0.3)/Ni(0.6)/Co(0.3)/MgO(1.5)/Ru(1) (Pt/[Co/Ni]) (in nm). To evaluate DMI from thermally-activated regime, we investigate $H_X$ dependence of bubble expansion under $H_Z$. DW velocity (v) vs $H_X$ curve indicates $\mu_0 H_{DMI} = 14 \pm 5$ mT for W/CoFeB (Fig. 1(a)), whereas miniscule value ($\mu_0 H_{DMI} \approx 0 \pm 10$ mT) for Pt/[Co/Ni] (Fig. 1(b)). We also investigate $H_X$ dependence of current-driven DW motion in flow regime for both the samples. The results shown in Fig. 1(c) and (d) indicate non-zero DMI for both the structures ($\mu_0 H_{DMI} = 14 \pm 0.5$ mT for W/CoFeB and 176 $\pm 10$ mT for Pt/[Co/Ni]). Only the result for Pt/[Co/Ni] in thermally-activated regime does not agree with previous study. We find that an accurate determination of DMI strength is possible only when DW motion satisfies a creep scaling law for the thermally-activated regime, whereas the flow-regime experiment is versatile for quantification of DMI.

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Fig. 1: (a) v vs $H_X$ at constant $H_Z$ for W/CoFeB in TA regime. (b) v vs $H_X$ for Pt/Co/Ni system in TA regime. (c) Flow regime v vs $H_X$ curve at current ($J = 9.67 \times 10^{11}$ A/m² for W/CoFeB system. (d) v vs $H_X$ at $J = 1.04 \times 10^{12}$ A/m² for Pt/Co/Ni system.