Composition dependence of spin-orbit torque in Pt$_{1-x}$Mn$_x$/CoFeB heterostructures

$^1$Lab. for Nanoelectronics and Spintronics, RIEC, Tohoku Univ., $^2$CSIS (Core Research Cluster), Tohoku Univ., $^3$CSR, Tohoku Univ., $^4$CIES, Tohoku Univ., $^5$WPI-AIMR, Tohoku Univ.

$^\circ$(M1) K.V. De Zoysa$^1$, R. Itoh$^1$, (D) Y. Takeuchi$^1$, S. DuttaGupta$^{1,3}$, S. Fukami$^{1,5}$ and H. Ohno$^{1,5}$

E-mail : v-zoysa@riec.tohoku.ac.jp

Spin-orbit torque (SOT) in antiferromagnet (AFM)/ ferromagnet (FM) heterostructures is prospective for digital and analogue spintronic devices [1-4]. The crucial requirements of co-existing large effective spin-Hall angle [5] and significant exchange-bias field [1] in a single material are satisfied in Mn-Y ($Y = 4d$ or $5d$ transition metal) metallic AFMs, making them promising candidate for AFM-based spintronic devices. Previous experimental results on polycrystalline Mn-Y/FM structures suggested the primary role of spin-orbit coupling of the $d$-transition element in determination of strength of SOTs [6], while subsequent results indicated an important role played by staggered magnetization of Mn [7]. Thus, systematic studies of SOTs in metallic Mn-Y/FM structures with the variation of composition are of necessity for better comprehension of SOT generation mechanism. Here, we quantify SOTs in AFM/FM PtMn/CoFeB heterostructures as a function of PtMn composition to obtain insights into the origin of SOT generation in AFM/FM structures.

We utilize Si/SiO$_2$ sub./Ta(3)/Ru(1.5)/Pt$_{1-x}$Mn$_x$(10)/(Co$_{25}$Fe$_{75}$)B$_{25}$(1.8)/MgO(1.5)/Ru(1) (in nm) structure, with various Mn-composition ($x$ at.%) We use extended harmonic Hall measurement technique for quantification of SOTs [8]. Slonczewski-like ($H_{\text{SL}}$) and field-like ($H_{\text{FL}}$) components of SOT effective fields are determined from fitting analysis of external magnetic field $H$ dependence of 1$\text{st}$ and 2$\text{nd}$ harmonic signals. Figure 1 shows the obtained $H_{\text{SL}}$ and $H_{\text{FL}}$ as a function of $x$. The results show a non-monotonic variation for $H_{\text{SL}}$ and $H_{\text{FL}}$ with $x$. We will discuss possible scenarios accounting for the observed composition dependence of SOT. The present results show the possibility for tuning SOTs in Mn-based AFMs for next generation AFM/FM structures.

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Figure 1: Slonczewski-like ($H_{\text{SL}}$) and field-like ($H_{\text{FL}}$) SOTs as a function of Mn composition x for Mn$_x$Pt$_{1-x}$/CoFeB structures.