

Abstract Submitted  
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**A critical comparison of electrical methods for measuring spin-orbit torques**<sup>1</sup> XUANZI ZHANG, YU-MING HUNG, LAURA REHM, ANDREW D. KENT, New York University — Direct (DC) and alternating current (AC) transport measurements of spin-orbit torques (SOTs) in heavy metal-ferromagnet heterostructure with perpendicular magnetic anisotropy have been proposed and demonstrated [1,2]. A DC method measures the change of perpendicular magnetization component while an AC method probes the first and second harmonic magnetization oscillation in responses to an AC current ( $\sim 1$  kHz). Here we conduct both types of measurements on  $\beta$ -Ta/CoFeB/MgO in the form of patterned Hall bars (20  $\mu\text{m}$  linewidth) and compare the results. Experiments results are qualitatively in agreement with a macro spin model including Slonzewski-like and a field-like SOTs. However, the effective field from the ac method is larger than that obtained from the DC method. We discuss the possible origins of the discrepancy and its implications for quantitatively determining SOTs. [1] L. Liu, C. Pai, Y. Li, H. Tseng, D. Ralph, and R. Buhrman, *Science* 336, 1126 (2012). [2] J. Kim, J. Sinha, M. Hayashi, M. Yamanouchi, S. Fukami, T. Szuki, S. Mitani, and H. Ohno, *Nature Mater.* 12, 3522 (2013).

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