Measurement of spin-orbit torque switching in in-plane nanomagnet array using planar Hall geometry

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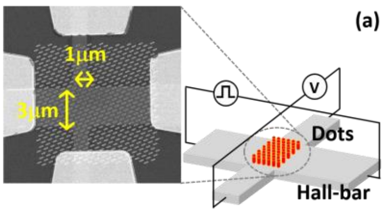
Spin-orbit torque (SOT) induced magnetization switching has attracted great attention as a new writing method of magnetoresistive random access memories (MRAMs) [1-3]. SOT-MRAMs using in-plane easy axis schemes allow for sub-ns and field-free switching depending on the easy axis direction [4], and it is of high importance to systematically and statistically investigate the dependence of switching properties with the design of nanomagnet towards low-power and reliable operations. Here we develop a procedure to statistically measure the SOT switching of in-plane nanomagnet array, where the planar Hall effect (PHE) is utilized to detect the magnetization direction. Using the procedure, we systematically evaluate the SOT switching properties of in-plane nanomagnets as a function of their size, aspect ratio, and easy axis angle.

A stack, Ta/W/CoFeB/MgO/Ta, is deposited by sputtering on a Si substrate. CoFeB/MgO layer is patterned into an array of elliptic nanodots with various designs on top of a micrometer-scaled Hall cross consisting of Ta/W (Fig. 1(a)). This structure allows for a short turn-around time, sufficient signal-to-noise ratio (S/N), and statistical information. To detect the magnetization state, Hall resistance due to PHE is measured under an application of an off-axis in-plane field that slightly rotates the magnetization and gives rise to a different Hall resistance depending on the initial magnetization direction [5]. A typical Hall resistance difference ΔR versus applied current density J is shown in Fig. 1(b). Clear hysteresis loop with high S/N is observed for all the designs. We systematically evaluate threshold current density for samples with various designs using current pulses with various widths. Based on the obtained results along with macrospin and micromagnetic simulations, we discuss the favorable design for SOT-MRAM applications.



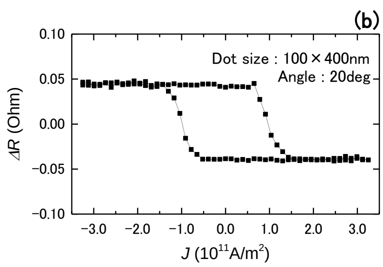


Fig.1: (a) Sample structure and (b) Typical ΔR-J loop.

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[1] I. M. Miron, *et al.*, Nature **476**, 189 (2011).
[2] L. Liu, *et al.*, Science **336**, 555 (2012).
[3] S. Fukami, *et al.*, Nature Nanotech **11**, 621 (2016).
[4] S. Fukami, *et al.*, 2016 Symp. On VLSI Tech, T06-05 (2016).
[5] G. Mihajlović, *et al.*, Appl. Phys Lett **109**, 192404 (2016).