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Device size dependence of magnetization switching by spin-orbit torque in Ta/CoFeB/MgO structure

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Recently in-plane current induced magnetization reversal by spin-orbit torque (SOT) in heavy metal/ferromagnetic metal/oxide heterostructures attracts great interest as a new switching scheme of magnetic tunnel junctions (MTJs).[1] In the previous work, we studied the SOT switching in Ta/CoFeB/MgO structures with perpendicular easy axis, and found that the switching current was much smaller than the calculated one based on a macrospin model.[2,3] One of the possible origins for this discrepancy is the domain nucleation during the magnetization reversal. To confirm it, we systematically investigate the device size dependence of SOT switching in Ta/CoFeB/MgO in this work.

A heterostructure of Ta(5 nm)/ CoFeB(1 nm)/ MgO(1.2 nm)/ Ta(1 nm) was deposited on Si/SiO_2 substrate by dc/rf magnetron sputtering and processed into dots (80–1000 nm) on the top of Ta Hall bars. In these devices, magnetization reversal was induced by pulsed current (50 μs) under an in-plane external magnetic field (H_{in}) pointing along the channel direction of the Hall bars. The direction of the magnetization is detected by dc Hall resistance measurement through anomalous Hall effect. We measured the threshold switching current density J_{th} as a function of H_{in}. We define J_{th}^0 as the intercept of a linear fit to H_{in} dependence of J_{th}. We also evaluate the effective anisotropy field H_K^{eff} in the same devices by measuring the Hall resistance as a function of in-plane magnetic field.[3]

According to the macrospin model, J_{th}^0 is proportional to H_K^{eff}. Figure 1(a) and (b), respectively, show the J_{th}^0 and H_K^{eff} as a function of the device size. As the device size decreases from 1000 nm to 100 nm, J_{th}^0 increases from 1.6 to 3.1×10^{11} A/m^2, whereas H_K^{eff} increases by only 5%. This suggests that the increase of J_{th}^0 in this range is related to the increasing difficulty of nucleation reversal with reducing device size. Also, from the parameters of our devices, the calculated J_{th}^0 is about 1.5×10^{13} A/m^2, indicating that the measured J_{th}^0 is still two orders smaller than the calculated result.

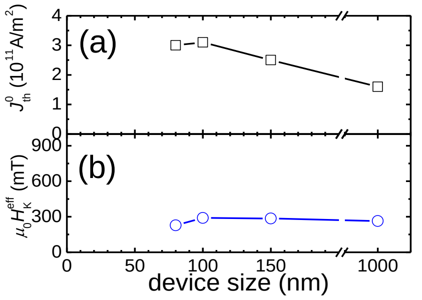

Fig.1. Device size dependence of (a)J_{th}^0 and (b)H_K^{eff}.

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