Magnetization reversal induced by spin-orbit torque in a nanoscale Ta/CoFeB/MgO dot

Laboratory for Nanoelectronics and Spintronics, RIEC, Tohoku Univ.[1], CSIS, Tohoku Univ.[2], CIES, Tohoku Univ.[3], WPI-AIMR, Tohoku Univ.[4]

°C. Zhang[1], S. Fukami[2,3], H. Sato[2,3], F. Matsukura[1,2,4], and H. Ohno[1,2,3,4]

E-mail: zhang@riec.tohoku.ac.jp

Spin-orbit torque (SOT) induced magnetization reversal attracts increasing attention these years, because it offers a new magnetization switching scheme for spintronics devices [1]. For the development of SOT-spintronics devices, it is of particular importance to reveal factors in determining the threshold current density (J_{th}). According to our previous work [2], J_{th} in devices with the size down to 30 nm, to which a single-domain picture is expected to be applicable, is about 3-4 times smaller than that calculated from a macrospin model [3], suggesting some factors reducing J_{th} are missing. One possible missing factor is the field-like component τ_{FL} of SOT, which is not considered in the model studied so far. Here, we investigate the switching probability of a 40-nm Ta/CoFeB/MgO dot fabricated on a Hall-bar, and compare the result with the macrospin model including τ_{FL}.

Figure 1 shows the switching probability P_{sw} as a function of the pulse current density J_{pulse} under different external magnetic fields H_x applied along the current direction. From the fitting with a macrospin model without τ_{FL}, the spin Hall angle θ_{SH} and the effective anisotropy field $\mu_0 H_K^{eff}$ are determined to be 0.21 and 0.5 T, respectively. These values are deviated from θ_{SH} = 0.03 and $\mu_0 H_K^{eff}$ = 0.23 T determined from other methods [4]. We simulate SOT switching by a macrospin model with the Landau–Lifshitz–Gilbert equation including τ_{FL}, and compare the simulated results with the experimental ones. We find that the model without τ_{FL} overestimates both $\mu_0 H_K^{eff}$ and θ_{SH}, and the degree of discrepancy depends on the magnitude of effective damping constant α_{eff}. Assuming $\alpha_{eff} \approx 0.15$, the experimentally obtained J_{th} can be well reproduced by the simulation with θ_{SH} = 0.03 and $\mu_0 H_K^{eff}$ = 0.23 T, implying that τ_{FL} is one of the decisive factors for J_{th}.

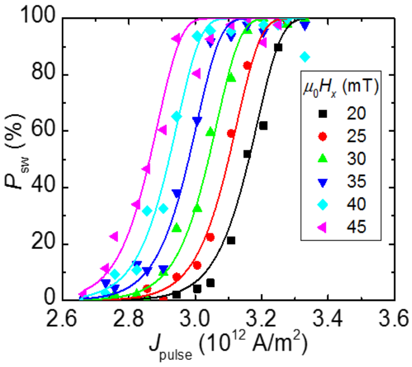

Fig. 1. J_{pulse} dependence of P_{sw} as a function of H_x.

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