Spin-orbit torque induced magnetization switching in W/CoFeB/MgO

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Spin-orbit torque (SOT) induced magnetization switching attracts great attention in these years as a new switching scheme for magnetic tunnel junction devices [1]. We previously studied the SOT-induced switching in perpendicularly magnetized Ta/CoFeB/MgO structure with various sizes down to single-domain scale, and found that the switching current density J_{th} strongly depends on the device size. When the size is less than about 100 nm, J_{th} is more than about 3×10^{12} A/m^2, which needs to be reduced for applications [2]. To achieve it, we here study the SOT-induced switching in W/CoFeB/MgO structure, in which a larger spin Hall angle θ_{SH} was reported in an in-plane magnetized geometry [3].

W(5)/CoFeB(1.3)/MgO(1.2)/Ta(1) film is patterned into a single CoFeB dot (diameter : 120 nm) on top of W Hall bars. Magnetization switching is induced by pulsed currents with various durations τ under an in-plane magnetic field (20 mT) along the current direction and is measured by anomalous Hall resistance measurement. We evaluate the switching probability P_{sw} and define J_{th} as the current density for P_{sw} = 50%.

Figure 1 shows J_{th} in W/CoFeB/MgO structure as a function of τ^{-1}. For comparison, the result for Ta/CoFeB/MgO is also shown. J_{th} of W/CoFeB/MgO is about half of that in Ta/CoFeB/MgO. While for Ta/CoFeB/MgO the switching cannot be observed at τ < 2 ns, the W/CoFeB/MgO shows switching at τ = 600 ps. This can be attributed to the larger θ_{SH} of W. We fit a linear function to J_{th}–τ^{-1} in the range of τ^{-1} > 0.2 GHz, and obtain the J_{th} at τ^{-1} = 0 to be 1.5×10^{12} A/m^2. Then, the effective θ_{SH} can be derived to be 0.6 [4], which is significantly larger than that in Ta in our previous work [2]. Note that actual θ_{SH}^{eff} should be smaller than the obtained value because the effects of incoherent reversal and field-like torque are neglected here.

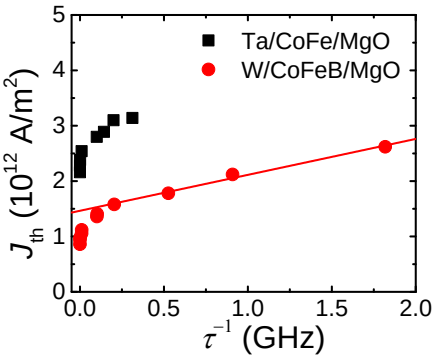

Fig. 1. τ^{1} dependence of J_{th} for W (Ta)/CoFeB/MgO structures.

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