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 \(3 \times 10^{12} \text{ A/m}^2\), 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 \(\theta_{SH}\) 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 CoFe dot (diameter : 120 nm) on top of W Hall bars. Magnetization switching is induced by pulsed currents with various durations \(\tau\) 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 \(\tau^{-1}\). 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 \(\tau < 2 \text{ ns}\), the W/CoFeB/MgO shows switching at \(\tau = 600 \text{ ps}\). This can be attributed to the larger \(\theta_{SH}\) of W. We fit a linear function to \(J_{th} - \tau^{-1}\) in the range of \(\tau^{-1} > 0.2 \text{ GHz}\), and obtain the \(J_{th}\) at \(\tau^{-1} = 0\) to be \(1.5 \times 10^{12} \text{ A/m}^2\). Then, the effective \(\theta_{SH}\) can be derived to be 0.6 \(^4\), which is significantly larger than that in Ta in our previous work \(^2\). Note that actual \(\theta_{SH}^{\text{eff}}\) should be smaller than the obtained value because the effects of incoherent reversal and field-like torque are neglected here.

This work was supported by R&D project for ICT Key Technology of MEXT, ImPACT Program of CSTI, IIARE of Tohoku University, and JSPS KAKENHI Grant Number 15J04691.