Magnetization switching combining spin-orbit torque and spin-transfer torque

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Magnetization switching using spin-transfer torque (STT) or spin-orbit torque (SOT) has been well studied in two-terminal or three-terminal magnetic tunnel junctions (MTJs), respectively[1-5]. In recent years, the switching combining STT and SOT has been predicted to be faster with lower power consumption compared to the conventional schemes by calculation studies and has attracted great interest[6,7]. Here, we experimentally investigate the combinational effect of SOT and STT on magnetization switching in both three-terminal and two-terminal MTJ devices. The devices in this work have elliptic CoFeB/MgO-based MTJs with major and minor axes of 400 and 100 nm formed on top of Ta(7 nm)/W(1.6 nm) channels. In these devices, STT is induced with an out-of-plane current flowing through MTJ, like the conventional STT-MTJs. Meanwhile, SOT is induced with an in-plane current (in three-terminal device) or the in-plane component of the current (in two-terminal device). The effective spin Hall angle of Ta/W channel is determined to be -0.19 from a separately-performed harmonic measurement. We design the device with the resistance-area product of MgO tunneling barrier to be 31 $\Omega\mu m^2$ and the channel resistance to be 2.6 kΩ, with which STT exerted on the switching layer is comparable in magnitude to SOT with a single input current. We first examine the effects of SOT and STT on magnetization switching from two different configurations of three-terminal devises. The easy axis of switching layer is design to be perpendicular to the channel in the film plane, leading to the anti-parallel ("STT−SOT" hereafter) or parallel ("STT+SOT" hereafter) directions of SOT and STT, depending on the channel current direction. We find that the switching direction depends on the channel current direction, indicating SOT > STT. The threshold switching voltage for "STT+SOT" configuration is smaller than "STT−SOT" configuration, evidencing an additive effect of STT and SOT. The switching characteristics for other configurations[5] in both two and three-terminal devices, allowing high-speed switching with pulsed current down to 200 ps, will be also discussed. This work demonstrates a scheme to reduce switching voltage/current at higher switching speed for the two- and three-terminal SOT devices in the absence of magnetic field.

A portion of this work was supported by the ImPACT Program of CSTI and JST-OPERA, and JSPS KAKENHI Grant Number 18K13796.

References

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