Current-Induced Magnetization Switching of Exchange-Biased NiO Heterostructures Characterized by Spin-Orbit Torque

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Spin-orbit torque (SOT)-induced magnetization switching provides a potentially efficient alternative to spin-transfer torque switching in spin valves or magnetic tunnel junctions. Current induced SOT-switching of perpendicular magnetization is observed in an external magnetic field collinear with the current (but non-collinear with the magnetization), which, however, is impractical in device applications. In this work, we study magnetization switching induced by spin-orbit torque in W (Pt)/Co/NiO heterostructures with variable thickness of W and Pt heavy-metal layers, a perpendicularly magnetized Co layer, and an antiferromagnetic NiO layer [1]. Using current-driven switching, magnetoresistance and anomalous-Hall-effect (AHE) measurements, we determine the perpendicular and in-plane exchange-bias field. Several Hall-bar devices possessing in-plane exchange bias from both systems are selected and analyzed in relation to our analytical switching model of the critical current density as a function of Pt and W thickness, resulting in an estimation of the effective spin Hall angle and perpendicular effective magnetic anisotropy. We demonstrate in both the W(Pt)/Co/NiO systems deterministic Co magnetization switching without an external magnetic field, which is replaced by an in-plane exchange-bias field. Moreover, we show that due to a higher effective spin Hall angle in the W-based system than in Pt, the relative difference between the resistance states in the magnetization current switching to the difference between the resistance states in magnetic field switching determined by AHE ($\Delta R/\Delta R_{AHE}$) is about twice as high in W-based devices than in Pt, while the critical switching-current density in W-based devices is one order lower than in Pt. The current-switching stability and the training process are discussed in detail.

References:

[1] K.Grochot et al., Phys. Rev. Appl. 15, 014017 (2021)

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