Pulse width dependence of spin-orbit torque switching in noncollinear antiferromagnetic Mn_3Sn nanodot

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Manipulating spins in antiferromagnets (AFMs) is crucial for the AFM-based technologies [1,2]. In a noncollinear AFM Mn_3Sn, bidirectional switching by spin-orbit torque (SOT) has been reported for epitaxial [3,4] and polycrystalline [5,6] films. In epitaxial films, a competition between the chiral-spin rotation driven by the current [3] and the reorientation of the uncompensated magnetization caused by the magnetic field has been attributed as the underlying mechanism of the switching [4]. Here, we report the unconventional current pulse-width τ_p dependence of the threshold currents in an Mn_3Sn nanodot.

We fabricate an epitaxial Mn_3Sn(20nm) nanodot [7] on the Ta(3nm)/W(2nm) channel grown on the MgO(110) substrate [Fig. 1(a) and (b)]. Figure 1(c) shows the switching probability (P) versus current density into the W/Ta layer (J_{HM}), with τ_p of 5 ms, under an in-plane field $\mu_0 H_{[11\bar{2}0]}$ of 100 mT. We find that, with a given τ_p, P initially increases with current density into the W/Ta layer J_{HM}, reaches the unity, and then starts decreasing upon further increasing J_{HM}. We define two threshold current densities: J_{c1} and J_{c2} at which P hits 0.5 in the switching process and 0.75 in the switching-back process, respectively. J_{c1} decreases with τ_p, which can be understood in a straightforward manner: the Mn_3Sn nanodot is exposed to the thermal fluctuation for a longer time with a longer τ_p, hence a better chance of completing the switching at a lower J_{HM} with the thermal assistance. In contrast, J_{c2} is insensitive to τ_p, which defies a simple interpretation with no similar phenomenon known in ferromagnets. The observed behavior is reproduced well by LLG simulations. In this presentation, we discuss potential mechanism of the unconventional switching behavior. Our findings provide new insights into the dynamics of noncollinear antiferromagnets and open up prospects for novel functionalities in SOT-driven AFM devices.

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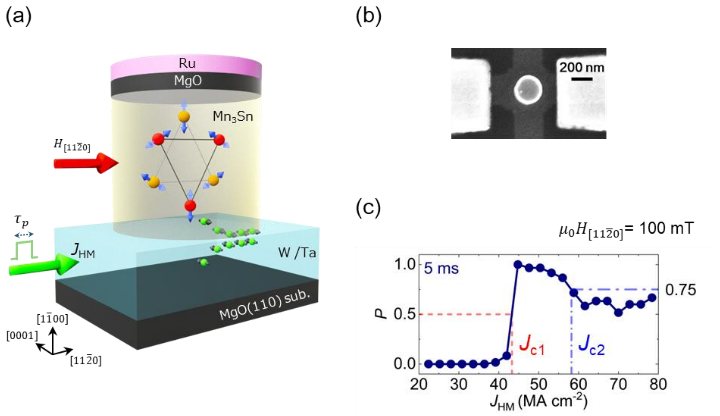

Fig.1 (a) Schematic of the switching measurement of Hall device with a Mn_3Sn nanodot. (b) The scanning electron microscope image of the fabricated device. The nominal dot diameter is 200 nm. (c) P versus J_{HM} for τ_p of 5 ms.

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