Curvature effects of current-induced domain wall motion in a U-shaped nanowire

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The structural inhomogeneities of the magnetic media substantially affect the domain wall (DW) motion. Pioneer studies have theoretically revealed that the exchange term of the Hamiltonian for curved nanowires includes an effective Dzyaloshinskii-Moriya (DM)-like interaction [1, 2]. This interaction depends on the curvature of the wire, so that the curvature variation gives rise to a gradient of the potential energy, which pins the DW at the extreme point of curvature. Understanding the mechanisms of DW depinning in the inhomogeneous curved systems and evaluating the strength of DW pinning are helpful for the design of devices using DW motion, e.g. the race track memory [3].

We have studied the current-induced DW motion (CIDWM) in the U-shaped nanowire (USN) with perpendicular magnetic anisotropy, as an example of the curved magnetic media, using the analytical one-dimensional model (1DM). We derived the equation of DW motion in the presence of the spin transfer torque and the nonadiabatic torque, using similar methods as shown in previous studies [1]. The resultant equation reveals that an effective pinning-like field, induced by the spatial change of the effective DM-like interaction, emerges around the joint of the straight and the curved parts of USN. While the effective DM-like field, induced by the curvature itself and being parallel to the long axis of the nanowire, decreases abruptly. The numerical results of the DW dynamics indicate that CIDWM is obstructed at the joint, which agree qualitatively with the results of micromagnetics simulations (MMS). The Walker's rigid-body propagation is interrupted by the effective pinning-like field, and a current density above a certain value j_{th} is required for DW to go through the joint. The Fig. 1 shows that j_{th} decreases monotonically with increasing nonadiabatic torque parameter β and decreasing Gilbert damping constant α. The β dependence implies that the depinning occurs in the weak pinning regime, where the current exceeds the pinning force [4]. The α dependence may reflect the fact that the strength of the effective pinning-like field depends on the angle of DW magnetization, so that j_{th} is sensitive to the DW state.

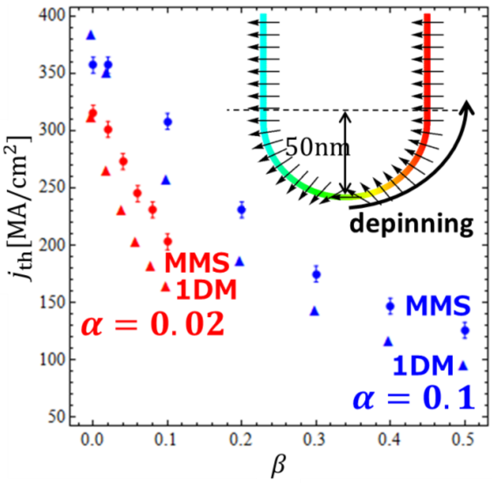

Fig. 1 Nonadiabatic torque dependence of threshold current densities for DW depinning of the USN, with the saturation magnetization and the exchange constant being 600 emu/cc and 1μA/cm, respectively.

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