Effects of the Rashba spin-orbit coupling on a spin-transfer torque-driven domain wall motion

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According to the theory of the spin-transfer torque (STT), current pulses can directly generate a domain wall (DW) motion in ferromagnetic systems. Up to now, it is well-established that two orthogonal current-induced STTs (adiabatic and nonadiabatic STTs) are responsible for a DW motion. Recent experiments[1,2], however, suggests the existence of another type of current-induced STTs in a ferromagnetic system with a structural inversion asymmetry. When the structural inversion symmetry is broken, the Rashba spin-orbit coupling(RSOC), which affects conduction electrons spin and thus local magnetization via s-d exchange coupling, is induced. The RSOC affects the local magnetization as an effective in-plane magnetic field[3]. Here, we theoretically investigate the effects of the effective RSOC field on a STT-induced DW motion.

When the DW deformation is negligible during the DW motion, a DW motion can be well-approximated by collective coordinate approach in which a DW can be treated as a one-dimensional particle with two collective coordinates. Here, we derived equations of motion includes the effective RSOC field for two collective coordinates then numerically solve the equations.

Due to its property as a magnetic field, the effective RSOC field affects differently for different types of DWs. For metallic nanowires with perpendicular magnetic anisotropy (PMA), where the effective RSOC field is perpendicular to the magnetic easy axis, the effective RSOC affects a domain wall velocity via selective DW polarity reversal. Although this velocity modification due to the effective RSOC field cannot fully explain the experimental results, such as the DW motion in the current direction or anomalously high DW velocity in the presence of RSOC, it gives some insight on the issues. Another interesting result in PMA systems is the increasement of the Walker breakdown threshold current density due to the RSOC. Since the effective RSOC field is the in-plane magnetic field, it suppresses the DW precession during the motion and for a strong RSOC, no Walker breakdown occurs at all. This phenomenon is recently observed[2].

References

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