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A Micromagnetic Study on the Motion of Double Domain Walls in a Perpendicular Magnetized Nano-wire Driven by Spin Polarized Current

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Recently much research has been focused on current induced domain wall motion which is applicable to a high density non-volatile memory. Conductive electrons passing through the domain wall in a ferromagnetic material, can cause the domain wall to propagate due to spin angular momentum transferred from the electrons to the magnetic moments in the domain wall.[1] The motion of a single domain wall in magnetic nanowires or nanostrips have been actively investigated. Particular attention has been paid to critical current and domain wall velocity or critical current in field or current-driven domain wall motions. [2~3]

In this work, we extend previous work to nanowires with double domain walls used to address the stability concern of memory devices. We performed micromagnetic simulations on double-domain wall motion by spin polarized current in a perpendicular magnetized nanowire. The double-domain wall motion with an injected current pulse shows less critical current density and larger domain wall velocity compared with single domain wall motion as shown in Fig. 1(a). Fig. 1(b) shows the terminal distance between double domain walls as function of current density. Below the critical current density of 24 MA/cm^2, the domain walls maintain a 300 nm distance between each other. After domain wall movement by current pulse, the equilibrium distance between the double domain walls decreases to about 50nm due to the magnetic interaction. Current-driven domain wall dynamics are discussed and the effect of double-domain wall interaction on domain wall velocity and position is analyzed.

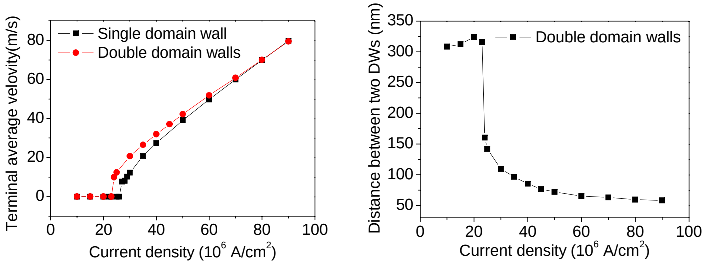

Fig. 1. Domain wall velocity and distance between double domain walls.

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Dynamics of Domain Walls via Collective Coordinates

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A quantitative description of the motion of domain walls in ferromagnetic nanowires under the influence of an applied magnetic field and spin current has been a long-standing problem [1]. Domain walls in nanowires exhibit at least two distinct dynamical regimes: steady viscous motion in low applied fields and oscillatory motion with a slow drift in higher fields. A complex internal structure of the domain walls [2], coupled with the presence of long-range dipolar forces, puts an exact solution out of reach. In the past, a successful treatment of similarly nontrivial dynamics of one-dimensional domain walls by Walker [3] focused on the softest modes of a magnetic texture described in terms of collective coordinates. Starting with the Landau-Lifshitz equations with Gilbert's damping term [4], we derived the equations of motion for an arbitrary set of collective coordinates parametrizing a magnetic texture [5], generalizing Thiele's result for simple translational motion [6]. The resulting set of equations is truncated by keeping the soft modes, whose relaxation time exceeds the characteristic time scale of the motion, and ignoring the hard ones.

The method was successfully applied to the dynamics of vortex domain walls both in the steady state and in the oscillatory regime using just two collective coordinates parametrizing the location of the vortex core [7]. The two-mode approximation works well up to the point where additional modes, associated with oscillations of topological edge defects [8], become soft and can no longer be ignored.

The theoretical framework is sufficiently general to allow the inclusion of additional soft modes, spin current and pinning forces. Incorporating "discontinuous" events, such as creation and annihilation of topological defects, is a problem that requires further work.

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