Micromagnetic simulation of domain wall propagation along meandering magnetic strip with spatially modulated material parameters

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Introduction

Well controlled two-dimensional propagation of domain walls (DWs) enables sophisticated functional design in various DW based devices, including the race truck memory. The local modification of magnetic properties, fabricated with the ion irradiation for example [1], is a possible way without geometric constrictions to create pinning sites for DWs. In the present study we propose a meandering propagation truck for DWs by using magnetic strip with pinning sites (PSs) as above, and demonstrate possibility of high density integration exceeding 100 Gbit/cm^2 by micromagnetic simulations.

Numerical model

A schematic of a magnetic strip with periodic pinning sites (PS) is shown in Fig. 1. PSs were numerically modeled by the gradual parabolic reduction of the saturation magnetization M_s and the related perpendicular anisotropy K_u ($\propto M_s^2$). The modification coefficient r ($= (M_s - M_{s,min})/M_s$) was defined as a measure of pinning intensity. The following structural parameters were assumed in the simulation: thickness d = 5 nm, width W = 40 nm. Length of PS (L_1) and the value of r were preliminarily optimized as 20 nm and 0.3, respectively, so that the energy barrier height ΔE for the pinned DW satisfy the practical data stability requirement (> 60 k_BT). Standard material parameters for a Co/Ni multilayer were adopted: M_s= 600 emu/cm^3, K_u= 1.3×10^4 erg/cm^3, α=0.02. Magnetic strip was discretized into 2-D dipole array and the LLG equation was numerically integrated with a finite differential method.

Results and discussions

Snap shots of the propagating DW are shown in Fig. 2. The observed significant DW bending can be associated with the inhomogeneous current distribution and the geometrical local pinning at the corner. Fig.3 demonstrates successful bit-by-bit DW propagation along a meandering strip, where the DW is driven by pulsed currents with 1.0 ns width and 3.0 ns interval. The DW was stabilized inside the PS after the pulse end, accompanied with subtle positional fluctuation caused by the residual momentum dissipation. Typical error modes of excessive and delaying propagation are also shown in the figure. The current amplitude margin for the bit propagation along straight part and around corner can be well matched by optimizing the PS interval L_2 and the corner distance dL as 60 nm and 0 nm, respectively. The practical current amplitude margin is J = 2.4×10^8 A/cm^2 ± 37.5 % for the whole bit-by-bit propagation, as presented in Fig.4.

Reference

[1] A. Vogel et al., IEEE Trans. Mag., 46, 1708 (2010).

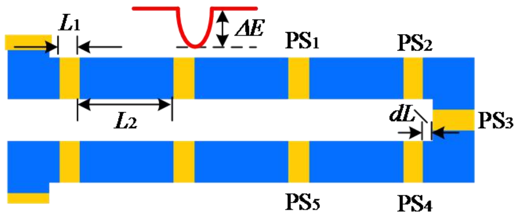

Fig.1. Schematic of numerical model for a DW propagation truck with pinning sites.

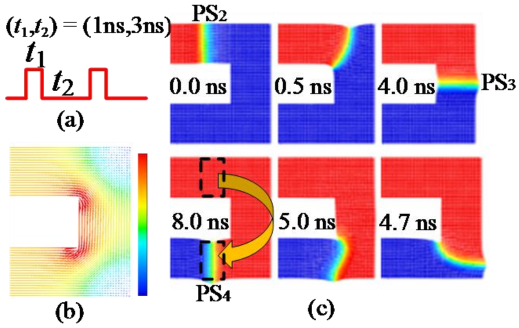

Fig.2 (a) Spin polarized currents pules. (b) Current density distribution at Corner. (c) DW propagation process at the corner.

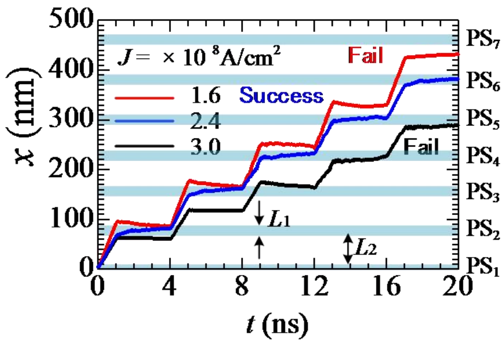

Fig.3 Time evolution of the propagating DW position along the magnetic stripe.

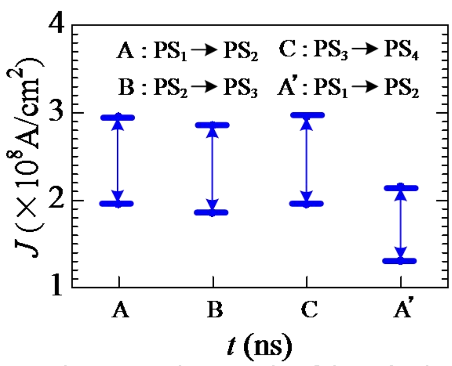

Fig.4 Bit propagation margin of the pulsed current density for DW motion (dL = 0 nm; L_1 = 20 nm, L_2 = 60 nm (A,B,C) , L_2 = 40 nm (A'))