

Asymmetrical domain wall propagation in bifurcated PMA wire structure due to the Dzyaloshinskii-Moriya interaction

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1. Introduction

Domain wall (DW) propagation is one of the methods for local magnetization switching in memory and logic device applications.^{1,2)} The perpendicular magnetic anisotropy (PMA) materials are being investigated for utilizing the narrow DWs having Bloch and Neel configurations in higher density memory devices. The asymmetric film stack comprising of the PMA material has been caused to lead interfacial Dzyaloshinskii-Moriya interaction (DMI) wherein Néel DW configuration is favored.^{3,4)} DMI stabilized Neel DW has been reported to have higher speed as the Walker breakdown is shifted to higher external fields.^{5,6,7)} In addition, the DMI stabilized Neel DW configuration have been shown to propagate via a tilting of the DW surface. A tilt DW drives a dynamical effect of magnetization spin configuration in a bifurcated junction structure. The DW tilting leads to a field interval between DWs to arrive at Hall bar in the individual branch. Spin configuration and effective torques acting on the Neel DW play a decisive role in the motion of DW in the structure. Micromagnetic simulation results further reveal that control of DW dynamics in the PMA complex network structures can be achieved by tailoring the strength of DMI.

2. Experiments and Results

A thin film, multilayered Ta(5nm)/ Pt(5nm)/ [Ni (0.25nm)/ Co (0.5nm)]x4/ Co(0.5nm) with a Ta (5nm) capping layer were deposited on Si/SiO₂ substrate using sputtering deposition technique. The structure is asymmetric with respect to the spin Hall angle of the bottom Pt and top Ta layer.⁸⁾ A 2-μm-wide Y-shaped wire structure with a Hall bar at each branches has been fabricated using a combination of electron beam lithography and Ar ion milling techniques. Fig. 1 shows a Kerr microscopy images of the Y-shaped structure, which comprises of an 8-μm-long straight wire connected to a curved structure with an 8 μm radial curvature. The creation of DW via injection line has been investigated with a current pulse injection method. Anomalous Hall effect (AHE) measurements were further performed to detect the DW propagation and pinning in the structure. The effect of DMI on the DW splitting at the junction and its configuration changes were investigated using micromagnetic simulation. The results of micromagnetic simulation were compared with Kerr microscopy images. The measured SOT effective fields in the Hall bar structure was evaluated to be, $\sim \pm 25$ Oe at $J_{ac} \approx +5 \times 10^{10} \text{ A/m}^2$.

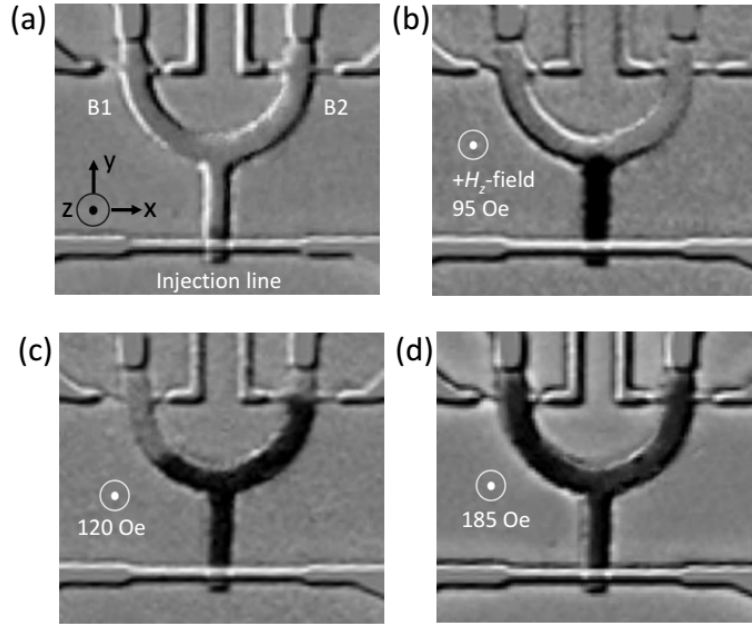


Fig. 1. Kerr images of field induced DW motion in a PMA network structure.

(a) A DW nucleated as a current pulse was applied via the injection line.

(b) The nucleated DW propagated to the junction of the network structure.

(c) and (d) The injected DW splits into two DWs and each propagated into separated branch, B1 or B2.

3. Summary

Direct observation of the DW dynamics in a bifurcated wire reveals that the propagation is via the splitting of DW at the junction, resulting in individual DW in each branch. The DMI induced DW tilting leads to quasi-selective propagation through the network structure, with favored branch determined by the tilting angle of the DW surface. This results in the DW in the individual branches having different depinning fields. Our work shows that by tuning the DMI constant in a material, selective DW motion through a network can be achieved.

4. References

- [1] D. A. Allwood, G. Xiong, C. C. Faulkner, D. Atkinson, D. Petit, and R. P. Cowburn, *Science* 309, 1688 (2005).
- [2] S. Parkin and S. H. Yang, *Nat. Nanotechnol.* 10, 195 (2015).
- [3] A. Fert, V. Cros, and J. Sampaio, *Nat. Nanotechnol.* 8, 152 (2013).
- [4] N. Perez, E. Martinez, L. Torres, S. H. Woo, S. Emori, and G. S. D. Beach, *Appl. Phys. Lett.* 104, 092403 (2014).
- [5] A. Thiaville, S. Rohart, É. Jué, V. Cros, and A. Fert, *EPL (Europhysics Letters)* 100, 57002 (2012).
- [6] I. M. Miron, T. Moore, H. Szambolics, L. D. Buda-Prejbeanu, S. Auffret, B. Rodmacq, S. Pizzini, J. Vogel, M. Bonfim, A. Schuhl, and G. Gaudin, *Nat. Mater.* 10, 419 (2011).
- [7] S. Emori, U. Bauer, S. M. Ahn, E. Martinez, and G. S. Beach, *Nat. Mater.* 12, 611 (2013).
- [8] C.-F. Pai, L. Liu, Y. Li, H. W. Tseng, D. C. Ralph, and R. A. Buhrman, *Appl. Phys. Lett.* 101, 122404 (2012).