Hysteresis asymmetry in domain wall trap memory

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I. Introduction

Domain wall trap (DWT) magnetic random access memory (MRAM) aims to address some of the issues associated with traditional MRAM designs, for instance high switching fields and irreproducible switching mechanisms [1]. In DWT MRAM a domain wall is moved between two stable positions in order to switch the magnetization in only the central region of a permalloy nanowire (Fig. 1a).

II. Method

We use hybrid finite element/boundary element micromagnetics [2] to calculate the minimum de-pinning, switching and expulsion fields, for clock-wise (CW) and anticlock-wise (ACW) vortex domain walls (VDWs) at a domain wall trap in a DWT MRAM cell previously suggested by Brownlie and co-workers [3]. The 10 nm thin-film $Ni_{80}Fe_{20}$ permalloy cell is 100 nm wide in its narrowest portion.

For ***M-H*** hysteresis loop measurement an applied field is ramped slowly along the positive and negative direction along the long axis. The magnetization of the total memory cell volume is measured.

III. Results & Discussion

We observe asymmetric switching fields for different vortex domain wall chiralities (Fig. 1a), confirming experimental results obtained by Brownlie *et. al.* [3]. The domain walls experience a pinning potential at the traps due to a reduction in exchange energy, which is a result of the local reduction in the domain wall angle. At the left hand trap position, the CW vortex experiences a larger exchange energy reduction due to similar alignment and subsequent growth of the left hand portion of its internal magnetization structure with the magnetization of the neighboring side region of the memory cell. In contrast, the internal region of the ACW has un-like alignment with the neighbouring part of the wire and so the internal domain wall region shrinks and the exchange energy reduction is less significant.

The hysteresis loop is asymmetric around the origin (Fig. 2) due to the lower de-pinning field and different remanence position of the ACW VDW and is further complicated by a central magnetostatic pinning potential which originates from the side sections of the memory cell. This potential inhibits particularly the motion of the ACW VDW so that the switching field is higher than the de-pinning field (Fig. 1b). Similar asymmetric switching behavior is observed in a number of other DWT memory cell designs.

IV. Summary

The switching mechanism in the DWT memory is subject to an asymmetric ***M-H*** loop and varying switching fields depending on the direction of switching. This is due to a symmetry in the cell structure and an asymmetry in the vortex chirality. We find that the memory can be designed so that practical margins between switching field and domain wall expulsion field exist.

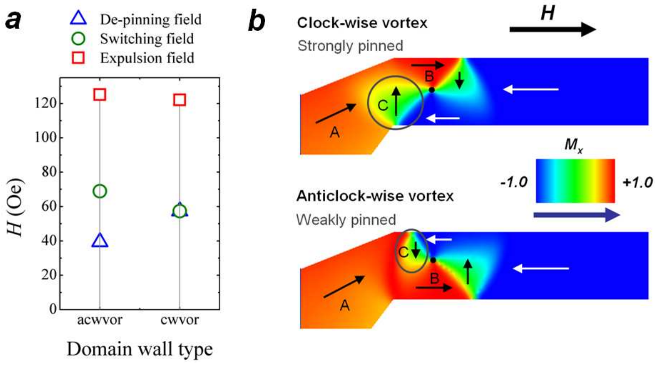

Fig. 1 Data confirming an asymmetry in the switching behavior of domain wall trap memory due to vortex domain wall chirality (a) The minimum de-pinning, switching and expulsion fields for both CW and ACW VDWs are given, showing practical margins between switching and expulsion. (b) The difference in de-pinning fields is explained as a product of the side region ("A") of the memory cell influencing the internal structure of the domain wall (particularly "C") and altering the exchange energy reduction at the trap site. Magnetization is indicated using arrows. (Color online).

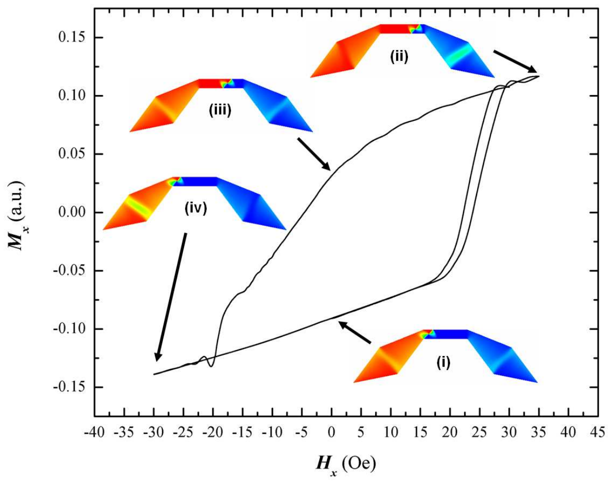

Fig. 2 The hysteresis plot shows an asymmetric loop, due to a larger pinning potential for the CW VDW at the left hand trap. A central pinning potential inhibits the motion in the –***x*** direction. (Color online).

References

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3. Brownlie, C., et al., *Lorentz microscopy studies of domain wall trap structures.* Journal of Applied Physics, 2006. **100**(3): p. 033902-9.

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