Pinning potential of a perpendicular magnetic domain wall due to a point defect

Kyungmi Song[1]*, Kyung-Jin Lee[1,2]
[1]KU-KIST Graduate School of Converging Science and Technology, Korea University, Seoul 136-701, KOREA
[2]Dept. of Mater. Sci. and Eng., Korea University, Seoul 136-701, KOREA

1. Introduction

Dynamics of a magnetic domain wall in perpendicularly magnetized nanowires is of considerable interest due to its rich physics and potential for applications [1]. Perpendicular magnetic layers usually have lots of point defects where the magnetic properties would be different from their original values. Such point defects generate pinning potentials for a domain wall. It can result in relatively high depinning field that is important to understand domain wall creep phenomena and steady domain wall motion [2, 3].

In this work, we investigate the effect of a point defect on pinning potential for a perpendicular magnetic domain wall based on Nudged Elastic Band (NEB) method [4, 5]. It allows us to estimate the strength of the pinning potential and its dependence on various magnetic and geometrical properties.

2. Modeling Scheme

In Ref. [4], the authors reported a way to calculate minimum energy paths, called NEB method. This method allows to calculate the energy barrier between two local energy minima. We use Walker's ansatz [6] with varying the domain wall center position as the initial path. The final and equilibrium energy minimum path is obtained by minimizing the gradient of the energy.

We use the following parameters for numerical simulation: the perpendicular magnetic anisotropy density Ku is 10^7 erg/cm^3, the exchange stiffness constant is 10^{-6} erg/cm, the saturation magnetization is 1200 emu/cm^3, and the wire thickness is 1.2 nm. We place a point defect with the size of 1 nm in diameter at the center of nanowire. We vary the magnetic anisotropy at the point defect (K_{defect}) from 0 to 0.75 Ku and vary the width of the nanowire.

3. Result and Discussion

Figure 1(a) shows the energy (normalized by the thermal energy at room temperature) as a function of the average z component of magnetization ($\langle M_z \rangle$). An energy minimum is obtained at $\langle M_z \rangle = 0$, corresponding to that the domain wall is on the point defect. Two energy maxima are obtained on both sides of the local energy minimum. The difference between the energy maximum and minimum gives the pinning potential due to the point defect. Figure 1(b) shows effect of K_{defect} on the energy profile. The pinning potential as a function of K_{defect} is summarized in Fig. 1(c). When K_{defect} is zero (thus, the difference of the magnetic anisotropy from other region is Ku), the largest pinning potential is obtained. It is about 0.1 k_BT, corresponding to 4.4 ferg that is quite small. We attribute this small pinning potential to a small effective magnetic anisotropy (= Ku-2pMs ~ 9.5×10^5 erg/cm^3), resulting in the domain wall width of 10 nm, which is much larger than the size of a point defect. However, we expect that the pinning potential would increase as Ku increases because the domain width decreases.

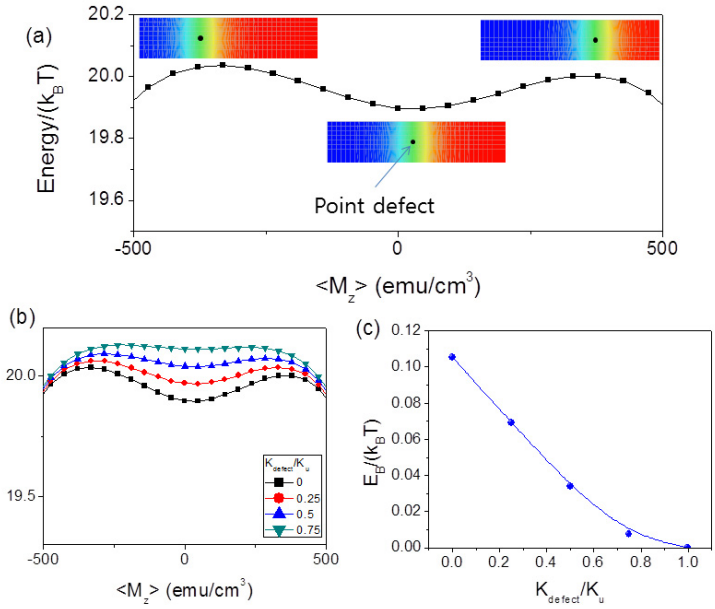

Fig. 1. (a) Pinning potential due to a point defect with $K_{defect} = 0$. (b) Pinning potential profile as a function of $K_{defect.}$ (c) Pinning potential versus $K_{defect.}$

4. Summary

We investigate effect of a point defect on the pinning potential for a perpendicular magnetic domain wall based on the NEB method. We find that this method can give a reasonable value for the pinning potential and allows us to study the effect of various geometrical and magnetic properties on the pinning potential. In the presentation, we will discuss the effect of Ku and wire width on the pinning potential in detail.

5. Acknowledgments

This work was supported by the KU-KIST School Joint Research Program.

6. References

[1] G.S.D. Beach, M. Tsoi, and J.L. Erskine, J. Magn. Magn. Mater. 320, 1272 (2008).

[2] K.-J. Kim et al., Nature 458, 740 (2009).

[3] J. Ryu, S.-B. Choe, and H.-W. Lee, Phys. Rev. B 84, 075469 (2011).

[4] G. Henkelman, B.P. Uberuaga, and H. Jonsson, J. Chem. Phys. 113, 9901 (2000).

[5] R. Dittrich, T. Schrefl, H. Forster, D. Suess, W. Scholz, and J. Fidler, IEEE Trans. Magn. 39, 2839 (2003).

[6] N.L. Schryer and L.R. Walker, J. Appl. Phys. 45, 5406 (1974).