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Energy barrier of nanomagnet with perpendicular magnetic anisotropy

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

Examining the thermal stability of nano magnets with perpendicular magnetic anisotropy is important because the data retention time of magnetic random access memory(MRAM), the most promising next generation memory, is determined by the thermal stability.[1] In this work, based on the Nudged Elastic Band(NEB) method[2-5] we calculate the energy minimum state of the switching situation. [4, 5] Then we investigate the thermal stability of a non-uniform switching in these nanomagnet system for two type of cell geometry and various sizes.

We find that the energy barrier depends not only on the cell size but also on the shape of cell when the switching is governed by the domain wall nucleation. We will also show the field-dependence of the energy barrier for circular cell and then compare the energy barrier of the circular cell with that of square cell.

2. Modeling Scheme

Using the NEB method, we compute the energy barrier by tracing the energy minimum path that is obtained by minimizing the gradient of the energy [3]. We use the following parameters for NEB modeling: the perpendicular magnetic anisotropy density $K_u$is$7x10^6$erg/cm^{3i},the saturation magnetization is 1000emu/cm^3, and the free-layer thickness t is 1.5nm. We use the exchange stiffness constant A_{ex} of $1x10^{-6}$erg/cm. We also vary the shape and diameter L of the nanomagnet cell and applied external field. Commonly, STT-MRAM shows uniform single domain switching for a small cell and domain wall switching for a large cell. Figure 1(a) shows the NEB images of the domain wall switching (DWS) for $A_{ex}=1x10^{-6}$erg/cm, and cell size=40nm for two types of the cell geometry. A rainbow color section in the middle is a domain wall formed during the magnetization switching.

3. Result and Discussion

Figure 1(b) shows the field dependence of energy barrier E_B at $A_{ex}=1x10^{-6}$ erg/cm and various cell sizes for a circular cell. We find that the single domain switching occurs for the cell diameter smaller than 30nm whereas the domain wall switching occurs otherwise. An interesting feature is that the critical field vanishing E_B depends strongly on the cell diameter.

We also compare the energy barrier for various cell size according to the cell geometries(see the Fig1(c)). When the cell size is small, the energy barrier for square shaped cell is larger than that for the circular cell. However, as the cell size increases, the energy barrier of the square and circle cells becomes similar. We attribute this phenomenon to domain wall formation. When the domain wall switching occurs, the energy barrier is crucially affected by domain wall energyand thus domain wall length that is determined by the cell diameter. Therefore, when the system undergoes domain wall switching, the energy barrier should be proportional to the cell diameter regardless of the shape.

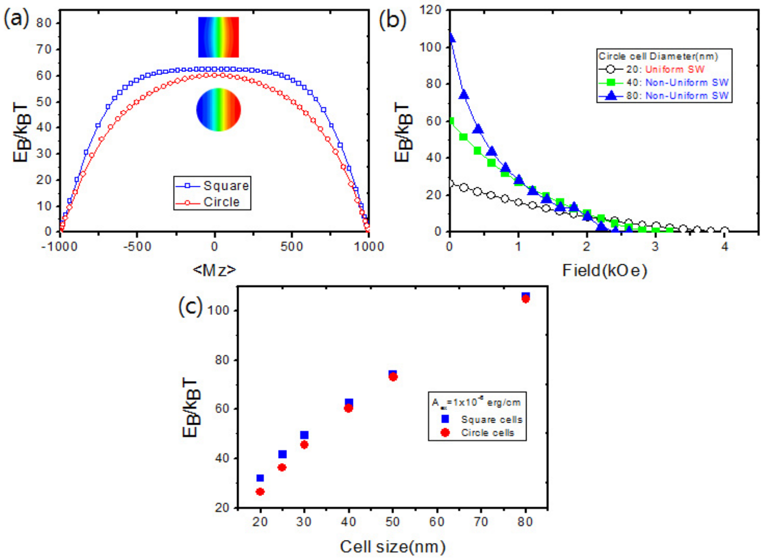

Fig 1 (a) NEB image of domain wall switching for $A_{ex}=10^{-6}$ erg/cm, cell size = 40nm for both of square and circular cell and external field is zero. (b) Field-dependence of energy barrier at various cell diameters for circular cell. (c) comparison of the energy barrier for square and circular cell when the cell size is 40nm.

4. Summary

We investigate the field-dependence of energy barrier for various cell diameters and two type of geometry through the NEB method. We find that the energy barrier can depend strongly on the cell size when the switching is governed by the domain wall motion. Moreover we also examine the cell size dependence of energy barrier for two type of cell geometry. In the presentation, we will discuss the effect of domain wall formation and more various cell size on the energy barrier in detail.

5. Acknowledgments

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6. References

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