Switching mode of nanomagnet with perpendicular magnetic anisotropy

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1. Introduction

Examining the thermal stability(∆) of nanomagnets 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] Based on the Nudged Elastic Band (NEB) method [1-4], it has been reported that the magnetization switching and thus E_B are governed by the single domain switching for MRAM cells having diameter smaller than the domain wall width, where as it is governed by the domain wall switching otherwise.[4, 5] Then we investigate the thermal stability(∆), the switching current(Jsw) and the STT-efficiency(∆/Jsw) of a non-uniform switching in these nanopillar magnet system for various sizes.

We find that the thermal stability(∆), the switching current(Jsw) and the STT-efficiency(∆/Jsw) depend on the cell size. when the switching is governed by the domain wall nucleation.

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 $1x10^7$erg/cm^3, the saturation magnetization is 1000emu/cm^3, and the free-layer thickness t is 1nm. We use the exchange stiffness constant A_{ex} of $1x10^{-6}$erg/cm. We also vary diameter L of the nanomagnet cell. Commonly, STT-MRAM shows uniform single domain switching for a small cell and domain wall switching for a large cell.

3. Result and Discussion

Figure 1(a) shows the thermal stability ∆ 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. We also compare the energy barrier for various cell size according to the cell geometries.

When the cell size is small, the thermal stability for the circular cell is also significantly small.. However, as the cell size increases, the thermal stability of becomes larger and larger. We attribute this phenomenon to domain wall formation. When the domain wall switching occurs, the energy barrier is crucially affected by domain wall energy and 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. Furthermore, Figure1 (b) shows current density and then we calculate the switching current from the switching current density. Then we obtain the STT-efficiency(∆/Isw, Isw: switching current) using the thermal stability and switching current. The results are in Figure1 (c).

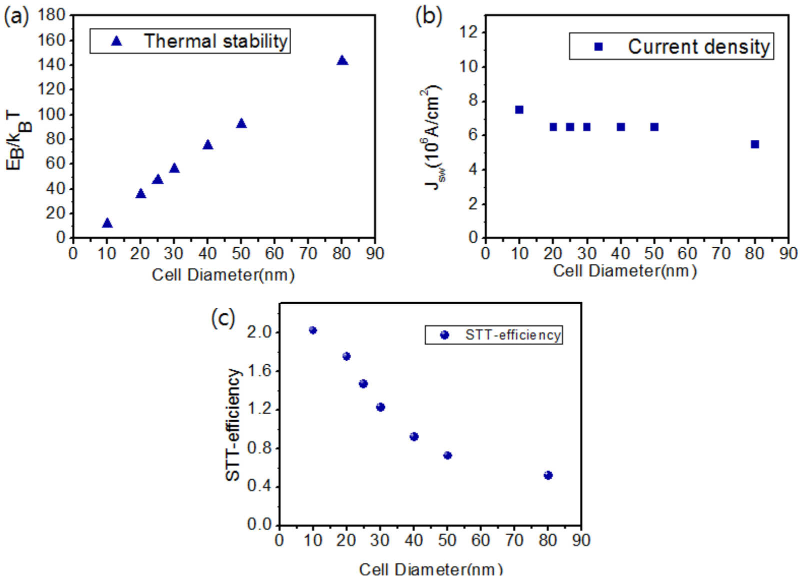

Fig. 1. (a) NEB image of domain wall switching for $A_{ex}=10^{-6}$ erg/cm, cell size = 40nm for both of square and circular cell and external field is zero. (b) Field-dependence of energy barrier at various cell diameters for circular cell. (c) comparison of the energy barrier for square and circular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

4. Summary

We investigate the thermal stability for various cell diameters and the current density and STT-efficiency also. 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 the thermal stability. 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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