Switching current density for spin transfer torque magnetic random access memory with Dzaloshinskii-Moriya Interaction

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1. Introduction

The Dzyaloshinskii-Moriya(DM) interaction [1],[2] has been attracted a lot of attention because of its interesting chiral physics. It is especially strong at the interface between a ferromagnet and a metal with strong spin-orbit coupling.

Examining the critical current density of magnetization switching in nanofilm magnets with perpendicular magnetic anisotropy is also important because current consumption of magnetic random access memory(MRAM), the most promising next generation memory[3], is determined by this critical current density.

In this work, we calculate the critical current density based on numerical work using the Landau-Lifshitz-Gilbert(LLG) equation. We estimate two cases (with and without DM interaction). Then we investigate the switching current density of a non-uniform switching in these nanomagnets for various cell diameter and DM interactions.

We find that the switching current density depends not only on the cell size but also on the DMI when the switching is governed by the domain wall nucleation.

2. Modeling Scheme

Using the LLG equation, we numerically calculate the switching current density. We use the following parameters for numerical calculation : the perpendicular magnetic anisotropy density K_u is $1x10^7 erg/cm^3$, the saturation magnetization is 1000 emu/cm^3, and the free-layer thickness t is 1.0nm. We use the exchange stiffness constant A_{ex} of $1x10^{-6} erg/cm$. We also vary the DMI constant D, the cell diameter L and an applied current density. We also assume that there is no external field and zero temperature. Commonly, STT-MRAM shows uniform single domain switching for a small cell and domain wall switching for a large cell. We find a clear formation of a domain wall for large cells during the switching.

3. Result and Discussion

We obtain results that the switching current changes with the cell size and DMI constants. We find that the single domain switching occurs for the cell diameter smaller than 20nm whereas the domain wall switching occurs otherwise. An interesting feature is that the critical current is increased with decreasing the cell size.

We also compare the switching current density not only for the cell size but also DMI constant. When the cell size is small, the current density for switching is increased. Moreover, for non-zero DMI case, the switching current density increases for large DMI constants. We attribute this phenomenon to the chiral symmetry and

stability for the cases with non-zero DMI.

We will show more detail all about the switching current at the system with DM interaction.

4. Summary

We investigate the switching current for various cell diameters and DM interaction. We find that the current density for switching can depend strongly on the cell size when the switching is governed by the domain wall motion. Moreover the switching current density is also strongly influenced by DM interaction . In the presentation, we will discuss the effect of domain wall formation and more various DMI constant on the switching current desity in detail.

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6. References

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