P02

Enhancement of Damping Caused by Spin-motive Force

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1. Introduction

The Landau-Lifshitz-Gilbert (LLG) equation is widely used to predict and understand magnetic systems: the domain wall motion, the magnetic vortex dynamics are examples. Although the phenomenological origin of Gilbert damping constant, it has been used to interpret the experimental results. However, Thiaville et al. showed the Gilbert damping constant is deeply connected with dynamics of domain wall. [1] Thus, in order to analyze domain wall motion correctly, it is needed to obtain the precise value of the damping.

Recently, it is proposed that the temporal and spatial variation of magnetization generate the electric-current and spin-current which act as a damping torque. [2] The damping term was described as a constant value in a form of a_0m X ∂_tm in the LLG equation. Damping is a tensor as a result of that moving magnetization creates spatially-nonuniform spin current which is related to damping torque. Damping tensor is described as Eq. (1) by Zhang et al.

$$\mathcal{D}_{\alpha\beta} = \alpha_0\delta_{\alpha\beta} + \eta\sum(\mathbf{m}\times\partial_i\mathbf{m})_\alpha(\mathbf{m}\times\partial_i\mathbf{m})_\beta \tag{1}$$

where d_{ab} is the unit matrix element, a_0 is the original damping parameter from all other sources, $\eta = g\mu_B\hbar G_0/(4e^2M_s)$, Ms is the saturation magnetization.

2. Micromagnetic modeling

We perform micromagnetic simulation with the Landau-Lifshitz-Gilbert (LLG) equation using damping tensor instead of using a constant damping. We assume a Permalloy nanowire with the thickness of 6 nm and the width of 40 nm. 1D and 2D modeling magnetic field-driven domain wall motion were performed in two ways: Fisrt, simulation using damping tensor, then simulation using constant damping. (Used cell size was 4 x 40 x 6 nm3 in 1D model and 4 x 4 x 6 nm3 in 2D model.)

3. Results and Discussions

Fig. 1 (a) shows 1D simulation result which shows the change of domain wall velocity (Dv_{DW}) when we introduce damping tensor. As predicted in the theory, Dv_{DW} linearly increased corresponding to applied magnetic field. But the simulation result of 2D is not identical to theoretical prediction (Fig. 1 (b)). A noticeable difference between 1D and 2D simulation is observed in a spatial distribution of damping. In the case of 2D simulation, a large spatial distribution of damping tensor is observed compare to 1D simulation.

Fig. 1 (a)

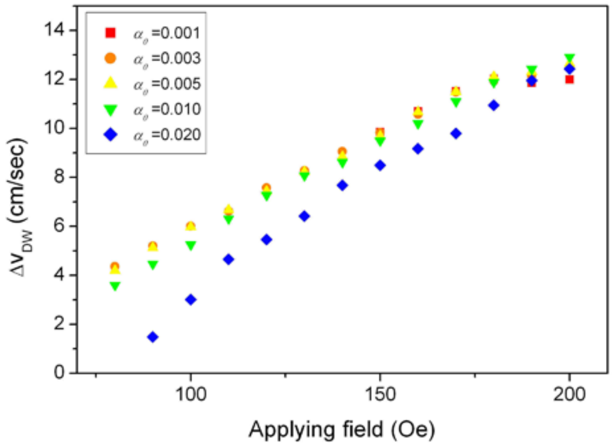
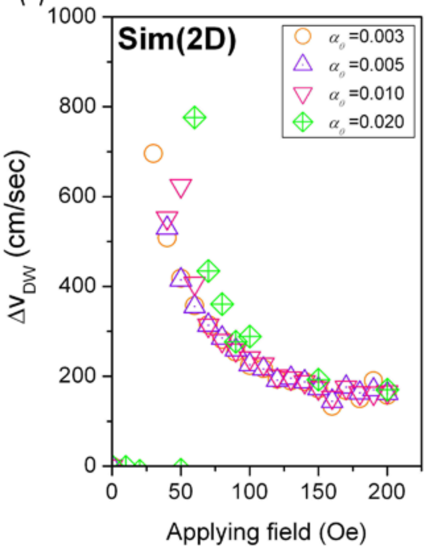


Fig. 1 (b)



4. Summary

To summarize, we observed a spatial distribution of damping tensor gives a different simulation result. When we use LLG equation, especially dealing with spatially-varying magnetization texture, it is expected that damping tensor should be considered instead of constant damping.

5. References

[1] A. Thiaville, Y. Nakatani, J. Miltat, and Y. Suzuki, Europhys. Lett. 69, 990 (2005)
[2] Shufeng Zhang and Steven S.-L. Zhang, Phys. Rev. Lett. 102, 086601 (2009).