Effect of damping and external field on current-induced skyrmion dynamics in a nanowire

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1. Introduction

When inversion asymmetry is present in magnetic system, the system has the antisymmetric exchange interaction called Dzyaloshinskii-Moriya (DM) interaction [1,2].

The DM interaction can make nano-sized skyrmions which are topological spin textures. It has been predicted that such nano-sized magnetic skyrmions can be used for information unit in ultrahigh density storage and logic devices [3]. In this respect, it is important to understand current-induced skyrmion dynamics for various magnetic properties. In this work, we investigate effect of the damping constant and the magnitude/direction of external field on current-induced skyrmion motion in a nanowire, based on micromagnetic simulations.

2. Simulation Scheme

In Ref. [3,4], skyrmion velocity is expected to be proportional to skyrmion diameter, current density and inversely proportional to the damping constant. Skyrmion diameter changes with perpendicular external field. [4]

We investigate skyrmion velocity using Landau-Lifshitz-Gilbert equation with an spin hall spin transfer torque with current density, damping constant, and external field as variables. We assume following parameters; nanowire width is 40 nm, thickness is 1 nm, cell size is $1\times1\times1$ nm^3, saturation magnetization is 800 emu/cm^3, exchange stiffness constant is 1.2×10^{-6} erg/cm, DM constant is -2 erg/cm^2, spin hall angle is 0.4, perpendicular magnetocrystalline anisotropy K_u is 0.8×10^7 erg/cm^3.

3. Result and Discussion

Figure 1 shows the velocity of skyrmion linearly increases with current density and 1/(damping constant) (=$1/\alpha$).

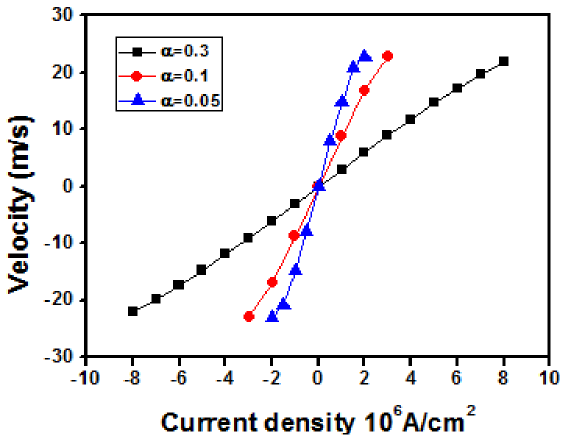

Fig. 1. Skyrmion velocity versus current density at the Gilbert damping constant of 0.3, 0.1 and 0.05.

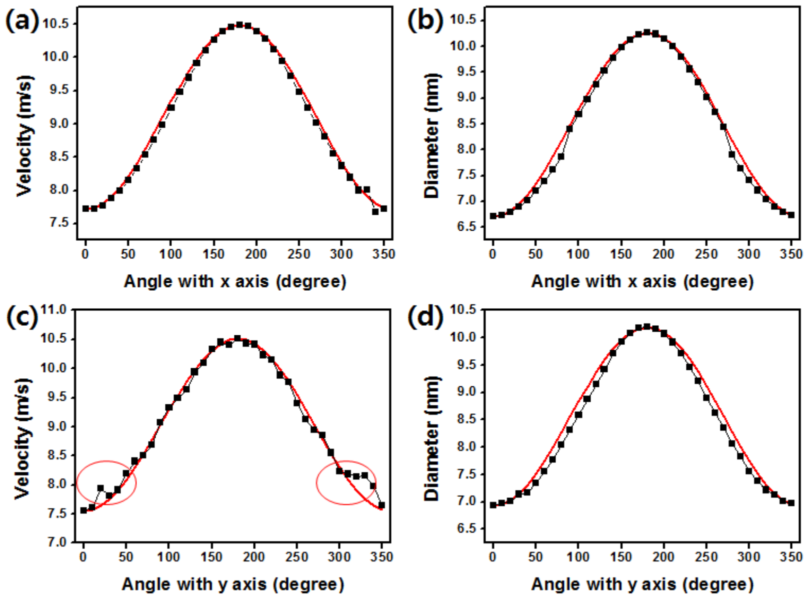

Fig. 2. Skyrmion diameter and velocity versus angle between $\overrightarrow{H}$ext with x(Fig. 2 a), y axis. H_{ext} is $400oe$ black squares are simulation result and red line is fitting curve using scaling sin function which indicate ratio of H_z to H_{ext}

Figure 2 shows the correlation between the skyrmion diameter and its velocity. Here the skyrmion diameter is modulated by applying an external field at a certain angle. We test two cases; the external field is in the x-z plane or in the y-z plane, where the x-axis, y-axis, and z-axis are collinear to the nanowire length, width, and thickness directions, respectively. The angle is measured from the z-axis. We find the skyrmion diameter is scaled with the z-component of the external field, that is, cosq (Fig. 2(a) and (c)). The skyrmion velocity is also scaled with the z-component of the external field (Fig. 2(b) and (d)), confirming the linear proportionality of the skyrmion velocity to the skyrmion diameter. We also find that this cosq – dependence of the skyrmion velocity is not obeyed strictly in some conditions (see circle in Fig. 2(c)). We attribute this discrepancy to the fact that the boundary effect becomes stronger when the external field is aligned along the width direction.

4. Reference

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