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

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1. Introduction

In magnetic systems with an inversion asymmetry and large spin-orbit coupling, the antisymmetric exchange interaction called the DM interaction is arisen [1,2]. It was predicted theoretically that the Dzyaloshinskii-Moriya (DM) interaction is partially responsible for the magnetic skyrmion [3].

The DM interaction contributes to make nano-sized skyrmions which are topological spin textures. It has been expected to have higher potential as information unit in ultrahigh density storage and logic devices [4]. Up to now, most studies have focused on current-driven case, but case in the presence of both field and current has lacked. In this work, we investigate effect of the magnitude/direction of external field on current-induced skyrmion motion in a nanowire, based on micromagnetic simulations.

2. Simulation Scheme

We investigate skyrmion velocity using Landau-Lifshitz-Gilbert equation with an spin hall spin transfer torque with current density 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 1000 emu/cm^3, exchange stiffness constant is 1.2×10^{-6} erg/cm, DM constant is 2 erg/cm^2, spin hall angle is 0.3, perpendicular magnetocrystalline anisotropy K_u is 1×10^7 erg/cm^3.

3. Result and Discussion

Figure 1(a) shows the velocity of skyrmion is quasi-linear function of current density at various values of external perpendicular magnetic field $\mathbf{H}_z$. This behavior can be understood by skyrmion size [4,5], which depending on magnitude/direction of $\mathbf{H}_z$ field and current density, as shows in Fig. 1(b).

Figure 2 shows the maximum velocity of skyrmion, which is obtained before the annihilation of skyrmion at nanowire edge, can change by in-plane magnetic field $\mathbf{H}_x$ and $\mathbf{H}_y$, and change more sensitively by $\mathbf{H}_y$ rather than $\mathbf{H}_x$. In contrast to $\mathbf{H}_z$, the external magnetic field $\mathbf{H}_y$ shifts skyrmion core to –y direction. This shift of skyrmion core may be seemed that $\mathbf{H}_y$ acts like a force acting along –y direction. By this force, the maximum velocity of skyrmion can be increase with higher critical velocity.

Our results show that not only spin-orbit spin tranfer torque but also external field can affect skyrmion motion in a different way.

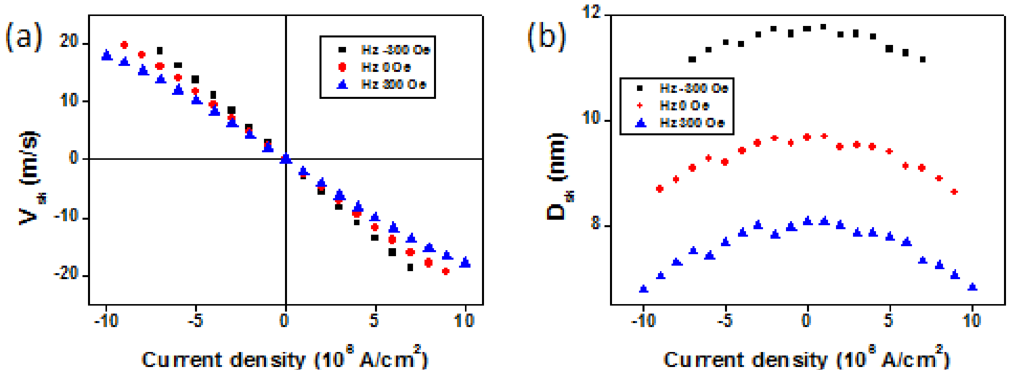

Fig. 1. (a) Skyrmion velocity (V_{sk}) versus current density for different $\mathbf{H}_z$, **(b)** Skyrmion diameter (D_{sk}) versus current density for different $\mathbf{H}_z$.

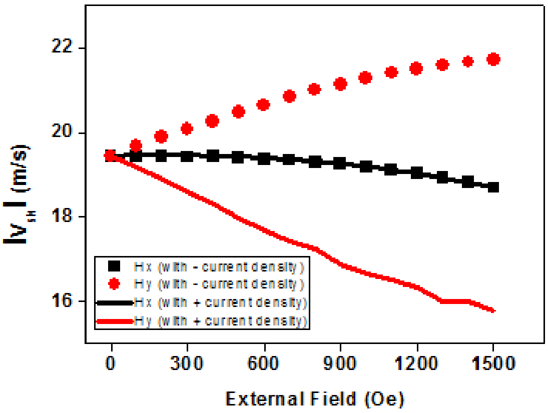

Fig. 2. Maximum speed of skyrmion ($|V_{sk}|$) as a function of magnitude of external magnetic field, in cases of external magnetic field direction is $+\hat{x}$ (black line and symbols), and external magnetic field direction is $+\hat{y}$ (red line and symbols).

4. References

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