Non-equilibrium skyrmion dynamics under the direct current

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Magnetic skyrmion is a topological spin texture originated from the competition between the exchange interaction and Dzyaloshinskii-Moriya interaction [1-4]. Skyrmions in bulks can be driven by the electric current through the spin transfer torque with the extremely low threshold current density of 10^6 A/m^2 [5] compared to that for the domain walls of 10^{10}-10^{12} A/m^2 . This outstanding property, in addition to their small domain size ranging from several nm to 1 μm, offers new spintronics applications including the non-volatile magnetic memories and current-driven shift resistors.

From an application point of view, ultrathin magnetic heterostructures are favorable systems rather than bulk magnets because of their compatibility with existing spintronic technologies. Intensive studies related to the skyrmion observation, driving, and manipulation have been reported in Co-based and CoFeB-based heterostructures[6-8].

Here we demonstrate the current-driven skyrmion motion in Ir/Co/Pt tri-layer thin films. Skyrmions segregate in the transverse direction to the current flow via the skyrmion Hall effect, which shows scalability for current density and wire width [9]. We also demonstrate several new findings: the significant material dependence of skyrmion dynamics, multiplication of skyrmions at the non-linear regime, and non-local accumulation of nonequilibrium skyrmions over several tens μm. These results suggest the importance of the collective nature of skyrmions, while only the behaviors of a single skyrmion have been discussed in previous studies.

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