Nonequilibrium long-range accumulations of skyrmions at Pt/Co interfaces

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Magnetic skyrmions are topological defects in magnetization mostly induced by the chiral interaction [1,2], attracting great interest for future device applications. The excellent characteristics of skyrmions is the ultralow threshold current density for driving [3], and their dynamics are usually described as kinds of steady particle motions [4]. We here report observations of different types of current-induced dynamics which show thermodynamic concepts beyond the scope of ongoing particle nature.

Figure 1 shows responses to current injections at (i) W/CoFeB/MgO and (ii) Pt/Co/Ir interfaces, respectively. For (i) W/CoFeB/MgO interfaces (Fig. 1(a)), skyrmion's trajectories can be described by the Thiele equation with spin-orbit torque terms [4]. On the contrary, dynamics at (ii) Pt/Co/Ir interfaces in Fig. 1(b) show accumulative phenomena along the Hall (y) direction prior to threshold current for longitudinal driving (~4.0×10^{10} A/m^2) [5]. The distribution of skyrmion shows linear profiles along the direction, which can be described by a phenomenological diffusion model with assumption of macroscopic intensive property, i.e., chemical potential.

Such thermodynamic concept can be applicable over ten of micrometers even where current is absent. We've demonstrated large scale of skyrmion pumping by tuning the chemical at nonlocal devices designed as analogies of "canal gates" of water control, where skyrmions are transferred between different canals though narrow junctions following profile of the chemical potential. This work provides a new methodologies of handling distributions of skyrmions over several tens of micrometers only by switching local currents.

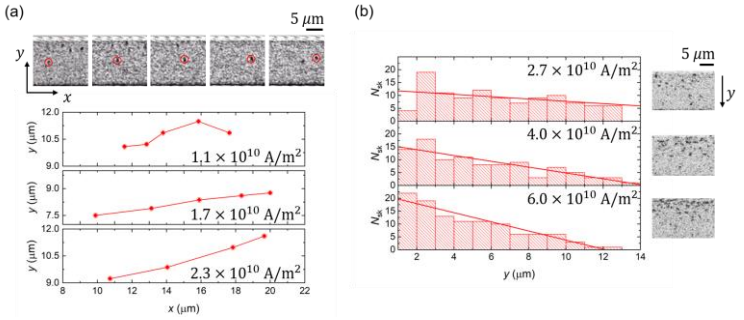

Fig. 1 Responses to current injection at (a) W/CoFeB/MgO, and (b) Pt/Co/Ir interfaces.

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