Overcoming the limits of vortex formation in magnetic nanodots

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Magnetic vortices are simplest topologically nontrivial magnetic states having promising applications in spin-torque oscillators, magnetic memory, etc. In the most of works common Bloch magnetic vortices in sub-micron soft ferromagnetic disks with thickness above 10-20 nm were studied.

We propose a way to achieve magnetic vortex state with unconventional structure in nanoscale soft ferromagnetic disks. Our approach is based on the application of hybrid nanostructure, in which a soft magnetic nanodot (thickness t_D) is placed within an antidot in a hard magnetic layer (thickness $t_{HL} > t_D$) with perpendicular magnetization. The diameter of dot is slightly smaller than the diameter of antidot, providing only dipolar coupling between subsystems. By means of micromagnetic simulations and analytical calculations we show that, depending on the strength of dipolar field form the hard layer, the ground state of the soft layer can be either radial (Neel) vortex, or a magnetic vortex with a complex structure, which is an intermediate (or mixture) between Neel and Bloch vortices.

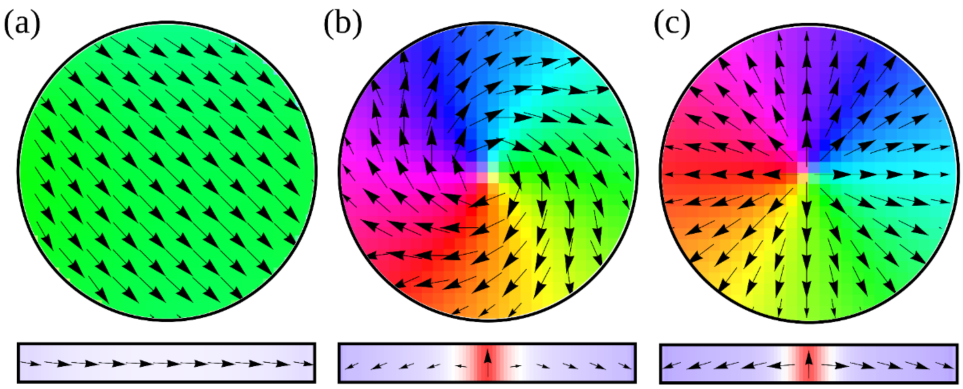

Fig. 1. Magnetization configuration of the 70-nm-diameter dot in a (a) single-domain state (hard layer thickness t_{HL}=6nm), (b) curled vortex state (t_{HL}=15nm), and (c) radial vortex state (t_{HL}=24nm). Top: Top view. Bottom: y−z cross section. The dot thickness t_D=3nm.

Moreover, dipolar coupling to a hard layer also reduce the characteristic sizes of a vortex. Therefore, vortex ground state in the studied nanostructure can be achieved in much smaller disks comparing to an isolated disk. For example, we observe formation of Neel vortices in Permalloy disks as small as 50 nm in diameter and 1-2 nm thickness, that is far beyond the limits of the vortex formation in an isolated disk.

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