3D Skyrmionic configurations in soft magnetic nanodots with no Dzyaloshinskii-Moriya interactions

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Magnetic skyrmions are widely attracting researchers due to fascinating physics and novel applications related to their non-trivial topology [1]. Néel skyrmions have been extensively investigated in magnetic systems with Dzyaloshinkii-Moriya interaction (DMI) and Perpendicular Magnetic Anisotropy (PMA). However, so far, at least PMA is considered to be a necessary ingredient for skyrmion stabilization. In this work, Néel skyrmions were detected experimentally by using magnetic force microscopy techniques in Py sub-100 nm diameter nanoparticles (NP) [2]. This is a non-expected magnetization configuration in NP since the minimum energy configuration for these Py structures (without DMI and more remarkably, in absence of any magnetic anisotropy) is vortex state or single domain in plane magnetization [3]. In addition, we have used micromagnetic simulations to show that 3D quasi-skyrmions, spin textures with topological charge close to 1, can be stabilised in soft magnetic nanodots (planar disks and hemispheres) with no DMI. We have found that the range of geometrical parameters were the skyrmions are stabilized is wider in magnetic hemispheres than in planar circular nanodots [4]. We argue that the key factors responsible for the stabilization of DMI-free skyrmions are the magnetisation confinement and surface curvature. Besides, the curvature introduces chirality to the system, as the core magnetization direction and the radial magnetization component are coupled. We have calculated the state diagram for quasi-skyrmions as well as the 2D topological charges and gyrovector values, as a function of the geometrical parameters. Our results open the door for a new research line related to the nucleation and stabilization of magnetic skyrmions in a broad class of nanostructured soft magnetic materials.

References

[1] A. Fert, V. Cros, J. Sampaio. Nature Nanotech. 8 (2013) 152–156.

[2] E. Berganza, M. Jaafar, J. A. Fernandez-Roldan, M. Goiriena-Goikoetxea, J. Pablo-Navarro, A. García-Arribas, K. Guslienko, C. Magén, J. M. De Teresa, O. Chubykalo-Fesenko, A. Asenjo, Nanoscale, 12, (2020) 18646.

[3] M. Goiriena-Goikoetxea *et al*. Nanoscale 9, 11269–11278 (2017)

[4] E. Berganza, J.A. Fernandez-Roldan M. Jaafar, A. Asenjo, K. Guslienko and O. Chubykalo-Fesenko. Sci. Rep. 12, (2022) 3426.

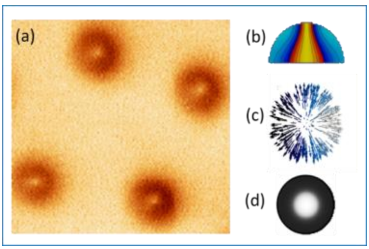

Figure 1:(a) MFM image of Py nanoparticles, (b) mz component of the magnetic configuration calculated by OOMMF (c) my component of the same simulation and (d) simulated MFM image corresponding to the same simulation.