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Magnetic Skyrmions in Confined Geometries

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Abstract

Magnetic skyrmions are topologically stable whirlpool-like spin textures that offer great promise as information carriers for future ultra-dense memory and logic devices. To enable such applications, particular attention has been focused on the skyrmions in highly confined geometry such as nanodisks or one dimensional nanostripes or wires. Here, we systematically report the visualization of the magnetic skyrmions in FeGe nanostripes or nanodisks by high resolution Lorentz TEM and electron holography. We found the highly stable skyrmion chain originated from the termination of the spin helix at the edges of the nanostripes, the field-driven transition of skyrmion cluster states in nanodisks under the action of applied field, as well as the highly flexibility of skyrmion shape tuned by the size. These findings demonstrate that the geometry defects can be used to control the formation of topologically nontrivial magnetic objects.

1. Introduction

Chiral magnetic skyrmions are topological solitons appering in magnetic crystals with broken inversion symmetry. The stability or metastability of such particle like objects is provided by competition between Heisenberg exchange, Dzyaloshinskii-Moriya interaction(DMI) and interaction with applied field. Their small size, topological protection and high mobility make them hold great promise as data bit carriers or logical elements for future micro/nano spintronics devices[1-3]. For the applications as well as for fundamental research, one of the key question concerns the character of skyrmion skyrmion and skyrmion-edge interactions, which may place certain restrictions on the data capacity and ultimate operation speed. Therefore, the next important step is to develop approaches that can be used to control the fine structures of individual skyrmions and to nucleate them in a simple manner in a nanostripe, whose size is similar to that of the skyrmions themselves.

2. Experimental results

Nano stripes, Nanodisks and wedge-shaped nanostripe samples, whose width or diameters reaches only 40–150 nm were fabricated by focused ions beam (FIB) technique. Real space imaging of magnetic skyrmions was performed by use of Lorentz TEM and electron holography at various temperature. We observed the high flexibilities of the shape of individual skyrmions tuned by the width[4] and a unique field-driven helix-to-skyrmion cluster states transition [5,6,7] directly. Also, a new state, called target skyrmion[8,9] consisting of a central skyrmion surrounded by one or more concentric helical stripes was also identified.

- **Magnetic skyrmioins in wedge-shaped FeGe nanostripes**

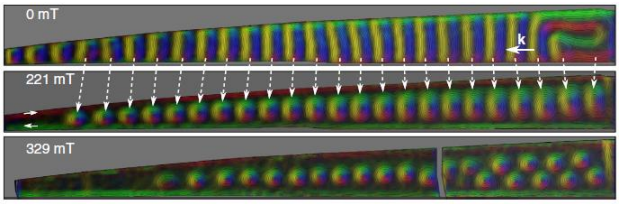

Fig.1. Magnetic induction maps recorded from a wedge-shaped FeGe nanostripe measured at a temperature of 95 K. At zero field, the ground state is helical with stripe domains perpendicular to the edge. Magnetic skyrmions chain is nucleated with skyrmions of different shape by application of a field. That is to say, compressed, circular and stretched skyrmions are obtained. Further increase of the field, zigzag chains appear and all of the skyrmions have same diameter.

- Magnetic skyrmions in FeGe nanodisks

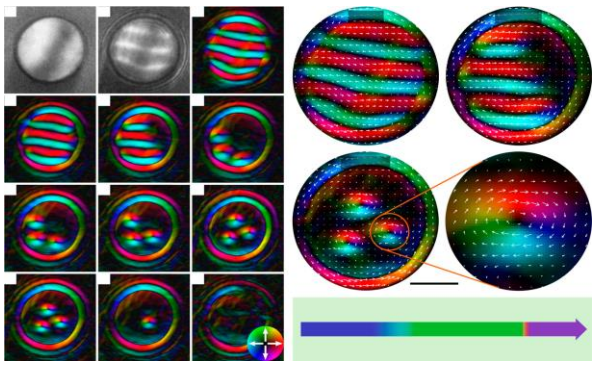

Fig.2. Variations of spin texture with magnetic field in a 270-nm FeGe nanodisk [2] at T = 100 K

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