Double Vortex Formation and its Effect on the Switching Field of Micron-sized Elliptical NiFe Elements

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Magnetic vortex states are often observed in patterned ferromagnetic thin films of micrometer size or smaller. These states are normally characterized by the magnetization adopting a circular configuration, with the spin orientation changing by 180 degrees over a very short path length. This behaviour arises from the competition between the magnetostatic energy and the exchange energy, which favors an in-plane, closed flux domain structure [1,2]. In the center of the vortex, at its core, this behavior forces the spins to turn out of the plane [3,4]. Magnetic vortices have been studied intensively in recent year by various techniques such as MFM, PEEM, and broadband microwave.

In this study, we have used full-field optical Kerr microscopy to study the double-vortex interaction in epitaxially grown micron-size elliptical ferromagnetic thin films by observing magnetization-switching behaviour. Both micromagnetic simulation and experimental measurements were carried out to determine the origin of the observed magnetization reversal process. It was found that the direction in which each vortex core rotates largely depends on the edge spins that are not saturated by an externally applied magnetic field. It was also found that the switching fields depend significantly on the relative direction in which the vortex cores rotate.

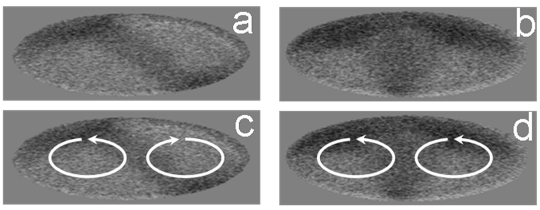


Fig. 1. (a), (b) Kerr microscope images of 20 μm × 6 μm elliptical elements at 0.9 mT with different magnetization states. Corresponding magnetization states (c) competing vortex cores (d) non-competing vortex cores.

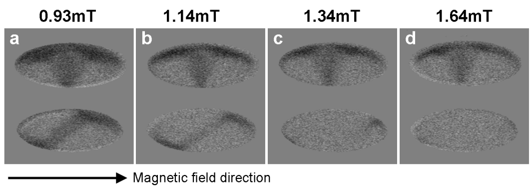
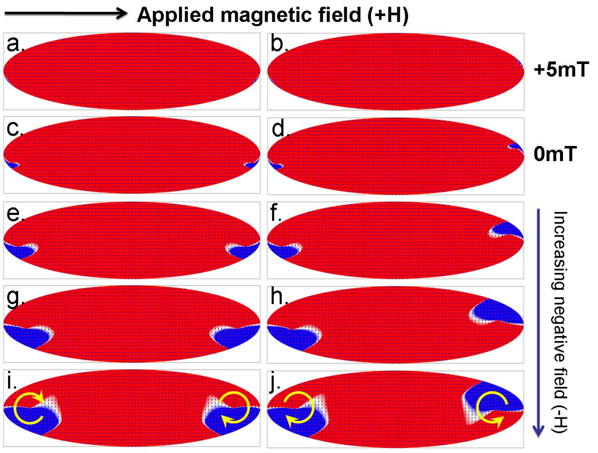


Fig. 2. Kerr microscope images of 20 μm×6 μm elliptical elements at an increasing magnetic field with two different magnetization states. (a) 0.93 mT, (b) 1.14 mT, (c) 1.34 mT, and (d) 1.64 mT.



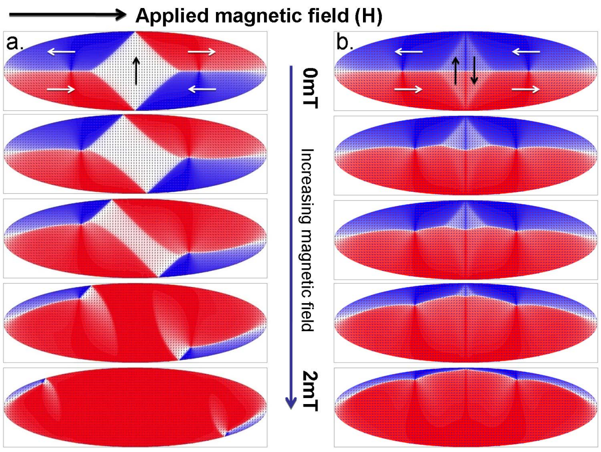


Fig. 3. OOMMF simulation results of 20 μm × 6 μm elliptical elements with two switching states. (a) Edge spins configured as "C" state (both in +y diection) under an applied field of 5 mT, the arrow show this position of edge spins. (b) Edge spins configured as "S" state (+y and -y directions) under an applied field of 5 mT. (c, e, g and i) Non-competing vortices state formed from "C" state. (d, f, h and j) Competing vortices state formed from "S" state.

Fig. 4. OOMMF results of 20 μm × 6 μm elliptical elements of two switching states with applied field from 0 mT to 2 mT in five steps, (a) two non-competing vortices (b) two competing vortices.

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