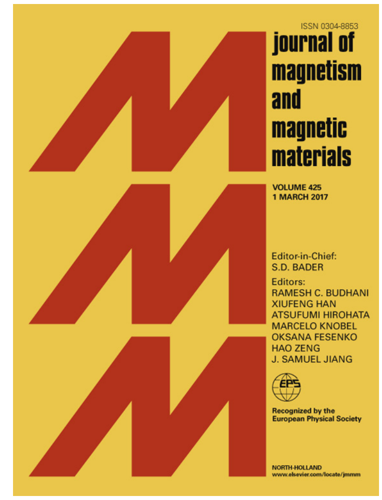

Research articles

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PII: S0304-8853(17)33358-9
DOI: https://doi.org/10.1016/j.jmmm.2018.01.075
Reference: MAGMA 63653

To appear in: *Journal of Magnetism and Magnetic Materials*

Please cite this article as: B. Sarma, F. Garcia-Sanchez, S.A. Nasseri, A. Casiraghi, G. Durin, Dynamics and morphology of chiral magnetic bubbles in perpendicularly magnetized ultra-thin films, *Journal of Magnetism and Magnetic Materials* (2018), doi: https://doi.org/10.1016/j.jmmm.2018.01.075

Dynamics and morphology of chiral magnetic bubbles in perpendicularly magnetized ultra-thin films

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Abstract

We study bubble domain wall dynamics using micromagnetic simulations in perpendicularly magnetized ultra-thin films with disorder and Dzyaloshinskii-Moriya interaction. Disorder is incorporated into the material as grains with randomly distributed sizes and varying exchange constant at the edges. As expected, magnetic bubbles expand asymmetrically along the axis of the in-plane field under the simultaneous application of out-of-plane and in-plane fields. Remarkably, the shape of the bubble has a ripple-like part which causes a kink-like (steep decrease) feature in the velocity versus in-plane field curve. We show that these ripples originate due to the nucleation and interaction of vertical Bloch lines. Furthermore, we show that the Dzyaloshinskii-Moriya interaction field is not constant but rather depends on the in-plane field. We also extend the collective coordinate model for domain wall motion to a magnetic bubble and compare it with the results of micromagnetic simulations.

Keywords: Chiral magnetic bubble, Domain wall, Perpendicularly magnetized ultra-thin films, Dzyaloshinskii-Moriya interaction and Vertical Bloch lines.

1. Introduction

The study of domain wall (DW) dynamics in ultra-thin films and nanowires has attracted significant attention in the spintronics research community due to its potential for applications in future memory [1, 2, 3], logic [4] and sensing [5, 6] devices. All these applications require moving multiple DWs precisely with applied spin-polarised currents or magnetic fields. Initially, DW dynamics in Permalloy with in-plane magnetic anisotropy were extensively studied [7, 8, 9, 10, 11]. Afterwards, perpendicularly magnetized ultra-thin films attracted particular interest due to narrower domain walls compared to their in-plane magnetized counterparts. It was found that current-driven DW motion provides higher efficiency due to the enhanced values of spin-torque efficiency [12, 13], with the DWs moving in the same direction as that of the electrons flow. On the contrary, in heterostructures composed of a magnetic ultra-thin film adjacent to a heavy metal layer, it was found that DWs move in the direction opposite to the flow of electrons. This behaviour was attributed to the spin Hall effect [14], which acts on the walls having a Néel configuration. In simultaneous