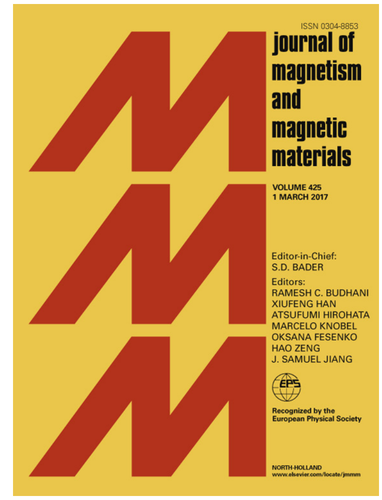
Accepted Manuscript



Research articles

Single array of magnetic vortex disks uses in-plane anisotropy to create different logic gates

H. Vigo-Cotrina, A.P. Guimarães

PII: S0304-8853(17)30787-4
DOI: http://dx.doi.org/10.1016/j.jmmm.2017.05.027
Reference: MAGMA 62731

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

Received Date: 3 March 2017
Accepted Date: 9 May 2017

Please cite this article as: H. Vigo-Cotrina, A.P. Guimarães, Single array of magnetic vortex disks uses in-plane anisotropy to create different logic gates, *Journal of Magnetism and Magnetic Materials* (2017), doi: http://dx.doi.org/10.1016/j.jmmm.2017.05.027

Single array of magnetic vortex disks uses in-plane anisotropy to create different logic gates

H. Vigo-Cotrina

Centro Brasileiro de Pesquisas Físicas, 22290-180, Rio de Janeiro, RJ, Brazil

A.P. Guimarães

Centro Brasileiro de Pesquisas Físicas, 22290-180, Rio de Janeiro, RJ, Brazil

Abstract

Using micromagnetic simulation, we show that in-plane uniaxial magnetic anisotropy (IPUA) can be used to obtain FAN-OUT, AND and OR gates in an array of coupled disks with magnetic vortex configuration. First, we studied the influence of the direction of application of the IPUA on the energy transfer time (τ) between two identical coupled nanodisks. We found that when the direction of the IPUA is along the x axis the magnetic interaction increases, allowing shorter values of τ, while the IPUA along the y direction has the opposite effect. The magnetic interactions between the nanodisks along x and y directions (the coupling integrals) as a function of the uniaxial anisotropy constant (K_σ) were obtained using a simple dipolar model. Next, we demonstrated that choosing a suitable direction of application of the IPUA, it is possible to create several different logic gates with a single array of coupled nanodisks.

Keywords: Magnetic vortex, Thiele's equation, uniaxial anisotropy, coupling integrals, logic gates

1. Introduction

The magnetic vortex configuration is a ground state characterized by a curling magnetization in the plane, and a small region (core vortex) in the center, where of magnetization is out the plane [1, 2]. From these characteristics, two properties are defined: the circulation C and the polarity p. The circulation is C = +1 when the curling direction is counterclockwise (CCW) and C = -1 when it is clockwise (CW). The polarity is p = +1 when the core points in the +z direction and p = -1 in the -z direction. The magnetic vortex dynamics is characterized by an eigenfrequency (gyrotropic frequency) in the sub-gigahertz range [1–4]. This frequency depends on the intrinsic parameters of the material and on the ratio β of the thickness to the radius of the disk (β = L/R) [1].

The use of the magnetic vortices in logic gates is one of the potential technological applications in spintronics [5–8]. Controlling parameters such as the polarity and circulation, different logical configurations can be obtained, as already demonstrated by Jung *et al.* [5], and controlling the magnetic interaction through the separation distance between the disks, it is possible to perform fan-out operations [7]. Therefore, the control of these parameters is of vital importance for the construction of logic gates. Both p as C can be controlled with rotating magnetic fields [5, 9], and the magnetic interaction can be modified without the need to change the separation distance between the disks.

One of the ways of obtaining this goal is by the application of perpendicular magnetic fields (PMF) to the plane of the disks [10]. This method may not be very effective, since the PMF distorts the core profile of the vortex, which is where the information bits are usually stored; therefore, the search for other mechanisms is an open topic. In this sense, the influence of the in-plane uniaxial anisotropy (IPUA) on the dynamics of magnetic vortices is gaining interest in recent years [11, 12]. Experimentally, the IPUA can be induced by voltage-induced strain via a piezoelectric transducer (PZT) [12, 13]. The advantage of using the IPUA, is that this does not alter the core profile of the vortex, making it a practical tool to control the dynamics of the magnetic vortex [11, 12].

When disks with magnetic vortex configuration are coupled, energy is transfered periodically between them [14]. The energy transfer is characterized by an energy transfer time parameter τ. Therefore, controlling this parameter is very important to affect this transfer. In a previous work, we have shown that applying the IPUA along the x axis allows obtaining shorter energy transfer times [12].

The goal of this work is to study the influence of changing the direction of application of the IPUA in a pair of identical nanodisks, and using the IPUA in order to obtain different logical configurations with an array of coupled nanodisks. We used micromagnetic simulations and a simple analytical dipolar model in order to obtain the interactions along the x and y directions (the coupling integrals). We used the open source software Mumax [15], with cell size of $2 \times 2 \times 7$ nm^3; the magnetostrictive material used was Galfenol (FeGa) with parameters [16, 17]: saturation magnetization $M_s = 1.360 \times 10^6$ A/m^2, exchange stiffness $A = 14 \times 10^{-12}$ J/m and a typical damping constant

Preprint submitted to Elsevier *April 26, 2017*