Micromagnetic studies of Fe/Co ellipses with competing anisotropy contributions


Published in:
Journal of Magnetism and Magnetic Materials

Document Version:
Peer reviewed version

Queen's University Belfast - Research Portal:
Link to publication record in Queen's University Belfast Research Portal

Publisher rights
© Elsevier Ltd. This manuscript version is made available under the CC-BY-NC-ND 4.0 license http://creativecommons.org/licenses/by-nc-nd/4.0/ which permits distribution and reproduction for non-commercial purposes, provided the author and source are cited.

General rights
Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and/or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy
The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.
Micromagnetic studies of Fe/Co ellipses with competing anisotropy contributions

S. Felton a,*, K. Gunnarsson a, P. Svedlindh a, M. Hanson b and O. Kazakova c

aDepartment of Materials Science, Uppsala University, Box 534, SE-751 21, Sweden
bDepartment of Solid State Physics, Chalmers University of Technology and Göteborg University, SE-412 96 Göteborg, Sweden
cNPL, Teddington, TW11 0LW, UK

Abstract

The effects of competing magneto-crystalline and shape anisotropies on magnetization reversal were studied in arrays of sub-micron Fe/Co ellipses of compositions Fe2/Co6 and Fe8/Co3 with magnetic force microscopy, MFM. A simple model assigning magnetization values to the different types of domain structures observed in the MFM images was used to estimate the field dependence of the total magnetization of a sample. The agreement with macroscopic magnetization measurements is discussed.

Key words: Fe/Co multilayers, competing anisotropies, MFM, domain structure

PACS: 75.50.Bb, 75.70.Kw

The process of magnetization reversal in arrays of sub-micron size ellipses made of bcc Fe/Co(001) multilayers was studied with MFM in applied magnetic fields up to 150 mT. Two different types of multilayer structures were used: a Fe2/Co6 film with high magneto-crystalline anisotropy and a Fe8/Co3 film with low magneto-crystalline anisotropy, where the figures stand for numbers of monolayers. For details of the samples see [1]. In both types of multilayers, the competition between magneto-crystalline and shape anisotropies was investigated in ellipses (nominal size 150 × 450 × 20 nm3) with their axes either along the easy or the hard magneto-crystalline directions, making a total of four different samples. Similar studies have been performed by others on e.g. Co [2] and permalloy [3].

First a saturating magnetic field, \(B_{sat}\), was applied parallel to the long axis of the ellipses and then removed. The domain structures of the ellipses were subsequently imaged in the MFM as a function of the field applied 180° to \(B_{sat}\).

Four different magnetic domain structures of the ellipses were identified during the switching process, as illustrated in Figs. 1 and 2. The structures are referred to as saturated, nearly saturated, equilibrium and distorted two domain structures.
Fig. 1. MFM-images of the Fe2/Co6 ellipses in an applied field of 60 mT. The scan size is 5 μm. The long axes of the ellipses are parallel to the magneto-crystalline (a) easy and (b) hard axis. The marked elements are in (a) saturated and in (b) a distorted two domain structure, see also Fig. 2(b).

Fig. 2. MFM-images of the Fe8/Co3 ellipses in an applied field of 45 mT. The scan size is 5 μm. The long axes of the ellipses are parallel to the magneto-crystalline (a) easy and (b) hard axis. The marked elements are in (a) a nearly saturated structure, and in (b) an equilibrium two domain structure, which consists of two domains of equal size but opposite magnetization direction.

For all the samples, at a low applied field, $B \leq 20$ mT, practically all the elements were in a saturated, or nearly saturated, state anti-parallel to the field. When a high enough field, $B \geq 100$ mT, was applied all the elements exhibited saturated, or nearly saturated, states parallel to the field. In intermediate fields, however, the relative occurrence of the magnetic structures was found to vary depending on the orientation of the ellipses and the strength of the magneto-crystalline anisotropy. In the case of co-operating shape and magneto-crystalline anisotropies, the magnetization of the elements was observed to switch almost directly from one saturated state to the other. However, for the ellipses with two different anisotropy axes multi-domain states were frequent prior to switching and the field interval where switching occurs was broader, see Figs. 1 and 2. For a detailed discussion of the differences between samples see [1].

Demagnetization curves were extracted from the MFM measurements by assigning magnetization values to the different types of domain structures observed in the MFM images. A comparison with the results from alternating gradient magnetometer measurements [1] gives a quantitative agreement between the MFM results and the magnetization curves. For the samples with high magneto-crystalline anisotropy, Fe2/Co6, the agreement is particularly striking, see Fig. 3. However, for the Fe8/Co3 elements the results of the MFM and macroscopic magnetization measurements are less compatible due to difficulty to distinguish between completely and nearly saturated states, possibly caused by the low magneto-crystalline anisotropy of the sample.

References