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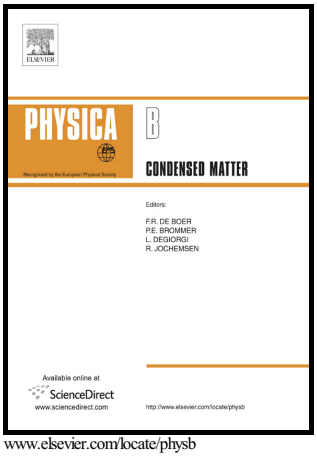

www.elsevier.com/locate/physb

PII: S0921-4526(16)30583-X
DOI: http://dx.doi.org/10.1016/j.physb.2016.12.015
Reference: PHYSB309756

To appear in: *Physica B: Physics of Condensed Matter*

Received date: 8 October 2015
Revised date: 28 October 2016
Accepted date: 9 December 2016

Cite this article as: S.V. Kozhevnikov, F. Ott and E. Semenova, Neutron Zeeman beam-splitting for the investigation of magnetic nanostructures, *Physica B Physics of Condensed Matter,* http://dx.doi.org/10.1016/j.physb.2016.12.015

Neutron Zeeman beam-splitting for the investigation of magnetic nanostructures

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Abstract

Zeeman spatial splitting of a neutron beam takes place during a neutron spin-flip in magnetically non-collinear systems at grazing incidence geometry. We apply the neutron beam-splitting method for the investigation of magnetically non-collinear clusters of submicron size in a thin film. The experimental results are compared with ones obtained by other methods.

Keywords: polarized neutrons; Zeeman; beam-splitting; thin films; magnetism

1. Introduction

Achievements in nanotechnologies require new methods of nanostructures characterization. Neutron scattering is a powerful tool for the investigation of biological objects, polymers and magnetic systems. Polarized neutron reflectometry (PNR) is routinely used to probe magnetic structures in thin films (at scales in the range of 3-100 nm) [1]. Off-specular scattering [2] appears when the film contains in-plane microscopic structures in the direction along the beam propagation (for length-scales in the range 600 nm - 60 μm). Grazing Incidence Small-Angle Neutron Scattering (GISANS) can be used when the film has nanometric in-plane structures with length-scales in the 3-100 nm range.

Using together the methods of PNR, off-specular scattering and GISANS opens the way towards the investigations of magnetic nanostructures in three dimensions. However, there are essential restrictions. These methods are model-dependent, average information over a surface and need periodicity or spatial coherence of inhomogeneities. Therefore, complementary application of direct methods may increase the data accuracy. Neutron methods for direct determination of the magnetic induction in thick films (thickness > 100 nm) are Larmor precession [7], neutron magnetic resonance [8] and the Zeeman spatial splitting of the neutron beam [9,10]. A review on these three methods can be found in [11].

In this communication, the beam-splitting method is applied for the direct determination of the magnetic induction inside non-collinear magnetic clusters in a Fe-Gd thin film. We present experimental data and compare it with other ones obtained by complementary methods such as PNR, Magneto-Optical Kerr Effect (MOKE), Vibrating Sample Magnetometry (VSM).

2. Zeeman spatial beam-splitting method

The phenomenon of Zeeman spatial beam-splitting at the boundary of two magnetically non-collinear media was predicted theoretically in [12] and observed experimentally in the geometry of reflection [13-15] and refraction [16-19]. The beam-splitting was registered in thin magnetically anisotropic films with domains [20-22], internal anisotropy in super-lattices [23,24] and clusters [25,26].

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