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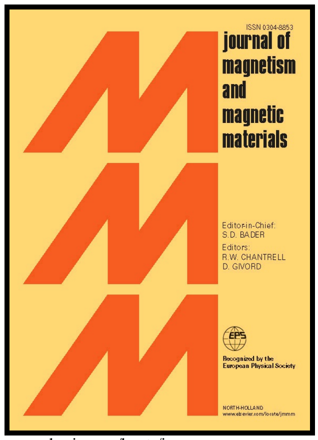

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Self-organization of the magnetization in ferromagnetic nanowires

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Abstract

In this work we demonstrate the occurrence of the characteristic spatial scale in the distribution of magnetization unrelated to the domain wall or crystallite size with using computer simulation of magnetization in a polycrystalline ferromagnetic nanowire. This is the stochastic domain size. We show that this length is included in the spectral density of the pinning force of domain wall on inhomogeneities of the crystallographic anisotropy. The constant and distribution of easy axes directions of the effective anisotropy of stochastic domain, are analytically calculated.

Keywords: Domain wall, nanowire, magnetic inhomogeneities, stochastic domains
PACS: 75.30 Gw, 75.50 Tt

1. Introduction

Recently, there has been a keen interest in studying relatively new magnetic objects - ferromagnetic nanowires - with self-organization elements in the structure. In particular, the authors of [1, 2] demonstrated the simplest case of magnetization self-organization in a nanowire bunch under the action of demagnetizing fields. The result observed was quite expected: neighboring nanowires appeared oppositely magnetized. The phenomenon of self-organization of the structures was observed in many systems containing the factor responsible for ordering: in the electric systems [3], the system of magnetic dipoles [4], superconductors [5], and thin ferromagnetic films [6, 7, 8]. In addition, it is interesting to consider the magnetization self-organization processes in 1D systems (nanowires and nanoribbons) [9, 10]. In particular, Rougemaille et al. [9] studied the formation of an ordered domain structure in wires with a diameter of a few atomic layers depending on the fabrication technique used.

In this work, we investigate the unusual self-organization type, specifically, the occurrence of the stochastic magnetization superstructure in a polycrystalline 1D ferromagnet. We consider a polycrystalline wire as a one-dimensional chain of crystallites with a linear size somewhat smaller than the domain wall (DW) thickness $\delta_0 = \sqrt{A/K}$, (A and K are the exchange and anisotropy constants, respectively). The crystallite easy magnetization directions are randomly distributed over a sphere. The exchange coupling between neighboring crystallites and crystallographic anisotropy of individual crystallites compete in the magnetic structure formation. If there is no uniform macroscopic anisotropy the magnetization field is a conglomerate of the so-called stochastic domains (SDs) or magnetic blocks (MBs) [11, 12, 13, 14, 15]. New length δ_S corresponding the SD size was detected in real experiments by different authors using different experimental tools [16, 17, 18]. But magnetostatics defines favorable direction of magnetization along the long axis of the crystallites chain.

2. Induced stochastic anisotropy

It is know the SDs exhibit the pronounced uniaxial anisotropy [15] with its effective constant and effective axis direction. To calculate the effective anisotropy constant for a block, we write the torque from the side of the random anisotropy field of an ensemble of crystallites contained in the SD:

$$M_\vartheta = \frac{\partial}{\partial\vartheta}\sum_{n=1}^{N} v_n K_n \left(\mathbf{m}_n \mathbf{e}_n\right)^2 . \qquad (1)$$

Here, v_n and K_n is the volume and local anisotropy constant for the n^{th} crystallite, $\mathbf{e}_n$ are the EMA direction orts, and N the number of crystallites in a SD, ϑ - polar angle of the magnetization. The same torque should be induced by the effective anisotropy of the SD that involves the block crystallites. We can write the effective anisotropy torque as

$$M_{\vartheta_{ef}} = \frac{\partial}{\partial\vartheta} V K_{ef} \left(\mathbf{m}\mathbf{e}_{ef}\right)^2 . \qquad (2)$$

Here, K_{ef} and $\mathbf{e}_{ef}$ are the effective anisotropy constant and effective anisotropy axis (EAA) direction vector of