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MAGNETISM

Magnetization Reversal of Permalloy Microparticles with the Configuration Anisotropy by Magnetic-Force Microscopy

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Abstract—Magnetic force microscopy has been used to study the distribution of the magnetization in permalloy microparticles with a configurational anisotropy. The triangular particles with different degrees of concavity of the lateral sides have been studied. An analysis of the results enables us to state that the particles can be in several quasi-homogeneous stable states. It is shown that the particle magnetization reversal can occur both stepwise and also via an intermediate state in the dependence on the particle orientation. It is demonstrated that the quasi-homogeneous magnetization orientation in a particle can be changed by a magnetic-force microscope probe.

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1. INTRODUCTION

Planar ferromagnetic particles are of interest as a patterned medium for high density magnetic data recording. Such particles usually have classical elliptic or rectangular shapes and are single-domain. Their magnetization direction is commonly changed by external magnetic field. However, the field strength necessary to carry out the switching between two stable states in such particles is quite high [1, 2]. To decrease the field value, various external factors such as temperature or mechanical stresses are often used [2–4].

The switching field of a particle can be decreased, retaining the stability of its state, using particles with configurational shape anisotropy [5–8], for example, triangular or multilobed ones. Such particles can be in several quasi-homogeneous stable states due to their more complex shapes and, thus, store several, not one, bits. The study of the switching of such particles from one magnetic state to another has a certain scientific interest.

In this work, we study the magnetization reversal processes in three types of permalloy (Py) particles exhibiting a configurational anisotropy. We studied planar triangular particles that have different degrees of concavity of lateral sides. The magnetization reversal of all formed array of the particles was carried out by external magnetic field, and that of an individual particle was carried out using an MFM probe.

2. EXPERIMENTAL

The Py particles studies in this work were prepared using scanning probe lithography (SPL) and the lift-off technique [9]. The prepared particles were placed on a silicon substrate surface. We used polymethylmethacrylate (PMMA) as a material of the formation of a protective mask. The polymer mask was formed on the substrate surface in a 100-nm-thick film the uniformity of which was attained by drying a PMMA chloroform solution (0.55%) drop during a continuous substrate rotation (so called spin-coating technique). SPL was carried out using a D300 (SCD-probes) cantilever with a diamond pyramidal single-crystal and a Solver P47Pro (NT-MDT) scanning probe microscope (SPM) operating in the atomic-force microscope (AFM) mode. An array of particles was formed on a 50 × 50 μm^2 area, and a special marker was made in this place to easily find these particles on the substrate surface by controlling position of the SPM tip using an optical microscope. The substrate sizes were 15 × 3 mm^2, and its thickness was 0.4 mm. The substrate was a polished low-ohmic silicon with the surface roughness 3 nm.

The permalloy layer (the 79NM alloy, the main components: 79% Ni, 16% Fe, and 4% Mo) was deposited by the electron-beam sputtering of a solid-state target. The deposition was carried out in an ultrahigh vacuum on an Omicron Multiprobe P setup. Then, the metal excesses and PMMA were removed in an ultrasound bath using chloroform, and the sample was washed out with distilled water and dried. The