Visualization of mechanical stress of near-surface layer by analyze of MFM images of planar permalloy microparticles formed on surface

N.I Nurgazizov, D.A. Biziyaev, A.A. Bukharaev, I.V. Russkikh, Yu.V. Sadchikov

Zavoisky Physical-Technical Institute, FRC Kazan Scientific Center of RAS, 420029 Kazan, Russia
e-mail: niazn@mail.ru

The possibility of using the Villari effect (or the magnetoelastic effect, in which the magnetic properties of a solid change under mechanical action) has been intensively studied by scientists for application with changing of magnetization of micro- and nanostructures [1,2]. Moreover a change in the magnetization of particles can be used for detection of mechanical stresses that arise in the particle. By detecting the changes of a magnetization of planar particles located on a solid surface one can register the mechanical stresses in the near-surface layer of the substrate. In this case, the lateral resolution of this technique will be comparable with the lateral sizes of the particle.

The studies were carried out on samples representing an array of the planar Py (Ni79%, Fe16%, Mo4%) particles (with the size of 25×25 μm^2) located on a glass substrate. Heights of particles were varied for different samples in range 10−50 nm. Particles were fabricated by electron beam evaporation under ultrahigh vacuum conditions by using a “Multiprobe P” device (Omicron). An array of identical particles was formed by sputtering through a metal grid placed on the surface of the substrate.

To create stressed particles, the substrate was elastically bent. For this purpose the flat holder was used. The thin metal wire was placed under the center of a sample and the edges of a sample were clamped. Different tension of substrate and particles on it was carried out by changing of diameter of the wire. At the same time it was possible to investigate the same particle always by using of the system of optical positioning of a SPM tip.

A scanning probe microscope (SPM) Solver P47 (NT-MDT) and a magnetic cantilever of the model “N18 Co-Cr” (MikroSience) were used to perform MFM studies. MFM was used for visualization of particles domain structure. The obtained MFM images were compared with results of computer modeling of a particle magnetic structure. Its calculations were carried out by the OOMMF [3] and “Virtual MFM” [4] software. The size and the form of particles obtained by MFM were used for modeling. A modeling of distribution of a tension tensor in a substrate surface depending on its bend was carried out.

It has been shown that uncompressed particles have classical four-domain structure, with domains equal by the sizes. At one axe tension of particles is resulted to an increasing of the sizes of domains with direction of magnetization perpendicular to a tension. Increase of the size of domains with direction perpendicular to the tension caused by a negative sign of a magnetostriction constant of the used permalloy. Increasing of a domain size leads to form a characteristic bridge between them, which is clear observed on the MFM images.

Based on the experimental MFM results and the executed calculations for an each characteristic length of the observed bridge were got of a value of the tension tensor of a near-surface layer calculated for a curved substrate. It has been shown the direction of a bridge observed on the MFM image of Py particle is give possibility to find of a direction of the particle stretch. Thus, the planar ferromagnetic particles may be used for visualizing of mechanical stress in the substrate.

The work was support by RFBR 17-08-00915.

1. G. Dai, Q. Zhan, H. Yang et al., *J. Appl. Phys.* **114**, 173913 (2013).
2. S. Finizio, M. Foerster, M. Buzzi et al., *Phys. Rev. Applied* **1**, 021001 (2014).
3. M.J. Donahue, D.G. Porter: (http://math.nist.gov/oommf/).
4. D.V. Ovchinnikov, A.A. Bukharaev, *Technical Physics* **46,** 1014 (2001).