The research of magnetic-contrast size-dependence in epitaxial iron nanostructures

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The spin-polarized electron transport in nanostructures and its revelations – giant magnetoresistance (GMR) are of great scientific interest nowadays. This is because of many technical applications of new magnetic-sensitive devices. The GMR effect was discovered in magnetic multilayer structures [1,2], and later it has been also observed in another systems such as heterogeneous granular alloys of AgCo and CuCo [3-5]. Magnetoresistance (MR) was also found in very thing Ni wires [6]. Recently the experiments on magnetoresistance of nanocontacts that is the contacts in ballistic regime with a few conductivity quanta were presented [7]. The MR effect was comparable to that observed in multilayer structures. It is smaller for larger contact area. This effect may be attributed to ballistic magnetoresistance (BMR). The theoretical explanation of BMR is based on the assumption that the atomic sharp domain walls are originated in point nanocontacts. The nonadiabatic spin-dependent scattering of electrons by these walls leads to BMR. Special interest is an observation of the effect in planar nanostructures. Spatial distribution of local magneticity in planar nanosructures may help to originate the desired domain structure useful for maximal magnetoresistance effect.

In this work the planar epitaxial iron nanostructures of a different shape and size were investigated using a magnetic force microscope imbedded into external magnetic field of controlled strength. Nanostructures were made of epitaxial 50 nm thick iron films by the electron lithography nanomask developing followed by ion etching. The iron films have been grown on r-plane sapphire by pulse laser deposition under ultra-high vacuum. The width of leads varied from 0.1 up to 2 micrometers. The scanning probe microscope (SPM) P47 Solver NTMDT, also operating in a magnetic force microscopy (MFM) mode was used in our investigations. An external magnetic field was supplied with the help of a magnetic coil and could be precisely changed in the range of ± 200 Oe.

In T-shaped nanostructures with a small lead width, the significant amplification of local magneticity near their ends and in the center of the cross was precisely observed. With increase of the lead width the spatial distribution of magneticity became more homogeneous along the structure length, and at 0.8 micrometers width the magnetic domains were similar to those observed in rectangular structures. The SPM images of the structures and their magnetic contrast are shown in the figures 1 and 2.

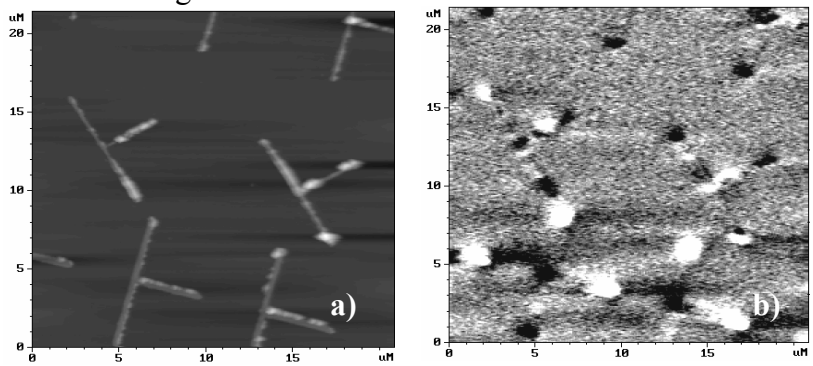

Fig.1. a). SPM image of T-shaped nanostructures of 0.1 μm width;
b). Magnetic contrast.

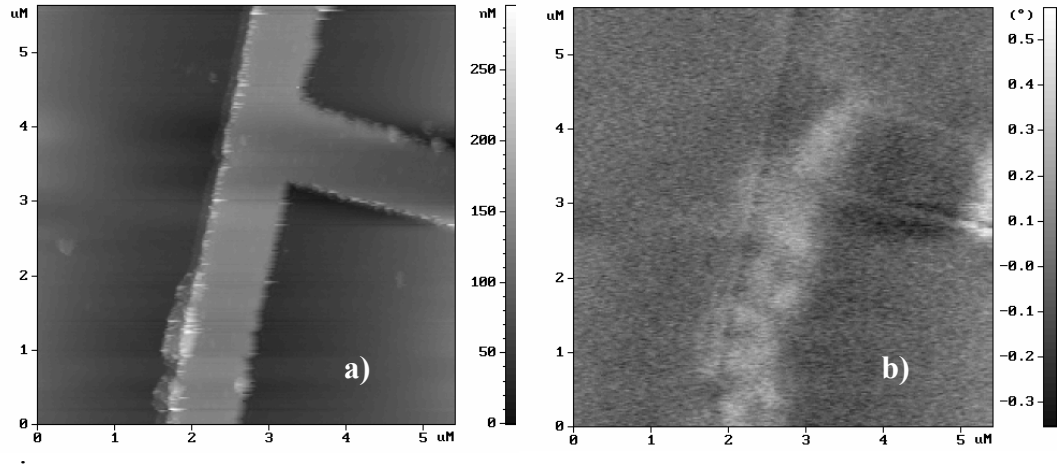

Fig.2. a). SPM image of T-shaped nanostructures of 0.1 μm width; b). Magnetic contrast.

The applied magnetic field was essentially affected on the spatial distribution of magnetic domains in the nanostructures. The magnetic contrast in the presence of an external in-plane magnetic field is shown in the figure 3.

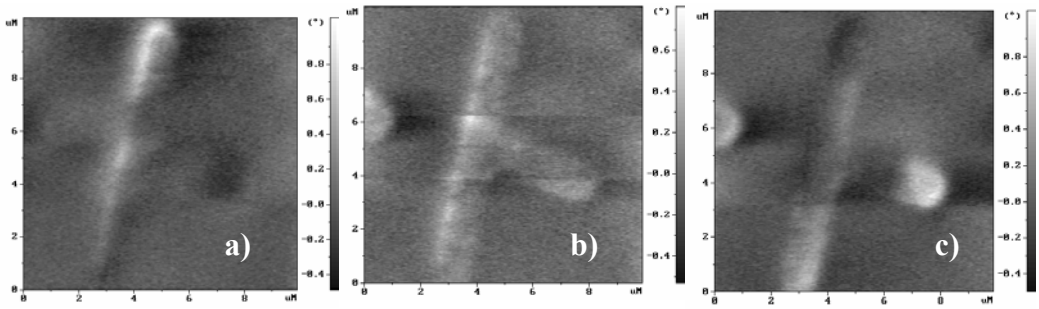

Fig.3. The magnetic contrast of one T-shaped nanostructure at different values of applied magnetic field. The direction of the magnetic field is in-plane and parallel to the x-axis direction. a). H = 100 Oe; b). H = 0; c). H= -100 Oe.

The results are pointed to size and shape dependence of spatial distribution of local magneticity in epitaxial iron nanostructures. The presence of magnetic amplification near the center of the cross allows to assume the domain-walls formation that may be useful for ballistic magnetoresistance effect if an electron mean free path becomes comparable to or exceeds a lead width of nanostructures.

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