

Investigation of conductive properties of micro- and nanowires using scanning probe microscopy

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The investigation of ferromagnetic micro- and nanowires is of great interest in fundamental physics and nanotechnology. This is mainly due to the existence in them of giant magnetoresistance effect. In principle it is possible to investigate magnetoresistance effect in such objects using scanning probe microscope (SPM) with a conductive tip and an electromagnet mounted into the SPM. As a first step in this way, it is necessary to measure the resistance of single microwire. The measuring circuit presented in Fig.1a allows one to measure the conductivity of the single microwire (when the microwire was formed on the nonconductive substrate and has a rather big contact pad at one end of the microwire).

The conductive properties of permalloy microwires were investigated in this work. The microwires were formed as an interdigital structure on pyroceram substrate and were 1 mm long, 1.5 μm wide and 120 nm thick and the common contact pad (Fig. 1c). The measurements were carried out with Solver-P47 using a two-window measurement mode: a contact topography and a spreading resistance mode in order to obtain the AFM image and the current image from the same sample area at the same time. The conductive cantilevers coated by TiN were used.

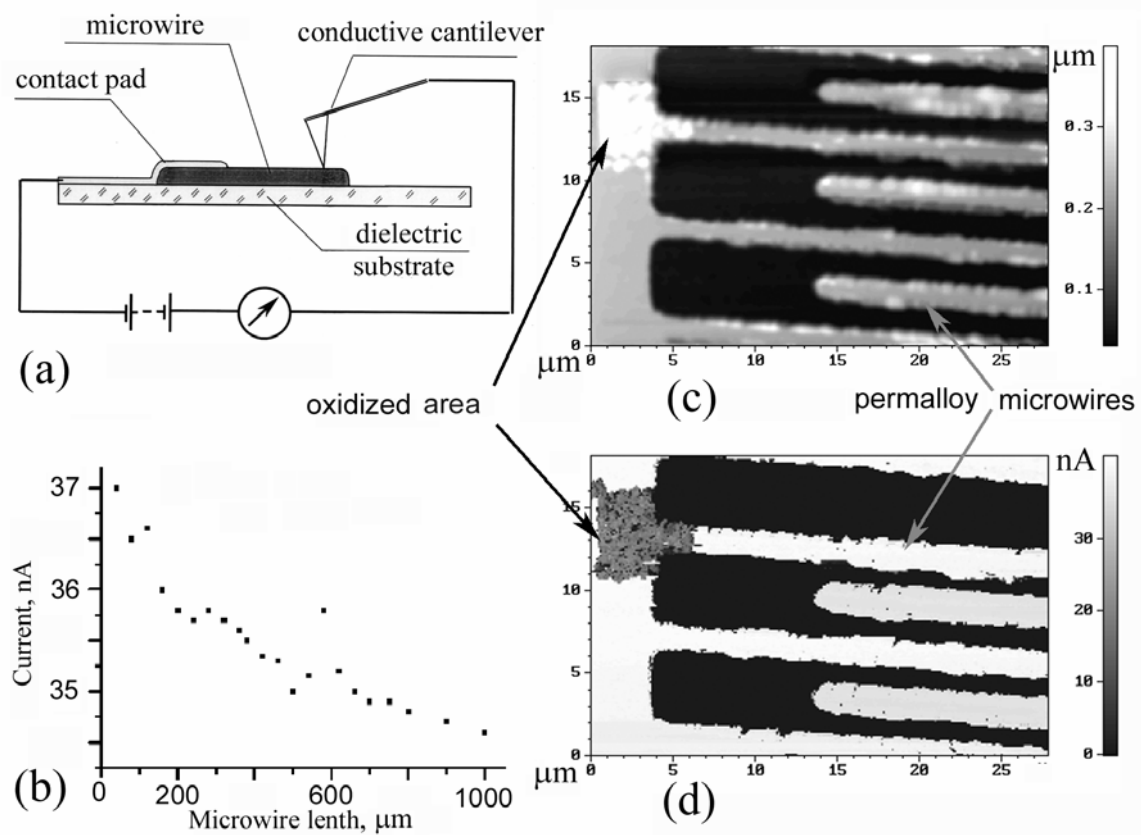


Fig.1. a – scheme for measuring of conductivity of the single microwire; b - the current dependence on the length of the single microwire; c – AFM image of interdigital permalloy structure on pyroceram substrate; d – corresponding current image.

Spreading resistance was measured in helium atmosphere in order to protect the sample metal surface from oxidation and to have a good electric contact between the cantilever tip apex and the metal sample surface during scanning. The nonconductive oxidized area on the metal surface was usually obtained on the metal surface during scanning in air, when the bias voltage between the conductive cantilever and sample was 2 V. This oxidized plot was observed as a protrusion with the height of about 150 nm on the AFM image (Fig.1c) and as a dark plot on the corresponding current image (Fig.1d). Moving the conductive tip along the microwire we can measure the current dependence on the length of a single microwire. Fig. 1b presents the corresponding experimental dependence. It is clear that this dependence is in rather good agreement with the Ohm's law.

We have also obtained the magnetic force microscopy images from the permalloy microwires using Solver-P47 with a homemade electromagnet mounted into the microscope. The stripe domain structure and their magnetization reversal were observed at different magnetic field. Our attempts to measure the magnetoresistance effect in single permalloy microwire using SPM conductive cantilever and external magnetic field was unsuccessful until now. The magnetoresistance effect was unusually large and very unstable. This is connected with an uncontrolled process in the contact between the conductive tip apex and the magnetic sample surface.

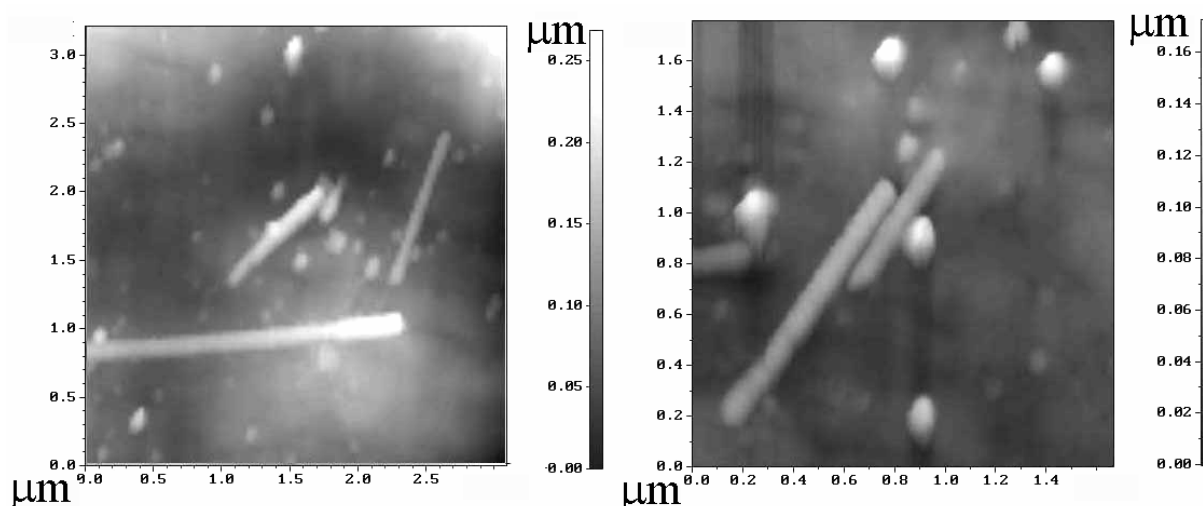


Fig.2. AFM images of ferromagnetic nanowires obtained at different magnifications.

The nanowires are obtained by dissolution of the polycarbonate membranes containing the ferromagnetic alloy in nanopores. The heterogeneous composite alloys containing Co, Ni, Ag or Cu were electrodeposited in the pores of polycarbonate membranes prepared by chemical etching of damage tracks previously created by high-energy particles. The typical diameter of nanopores was from 10 to 30 nm and their length was up to 60 μm. Figure 2 shows the AFM of such extracted nanowires. The apparent diameter of the single nanowires is of 60 nm and larger than the diameter of the nanopore due to the convolution effect between the tip apex and nanowires. Unfortunately we are not able yet to make a contact pad at the end of such a microwire in order to measure its conductivity using SPM.

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