Probe microscopy in the study of the process of template synthesis

A.S. Shatalov[1], D.L. Zagorsky[2], I.M. Doludenko[1,2]

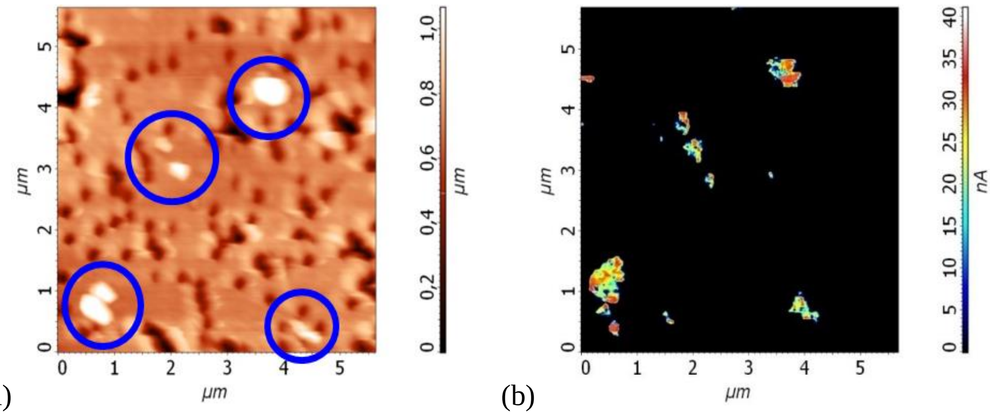
[1]*National Research University Higher School of Economics, 101000, Moscow, Russia*
e-mail: Shura_shatalov@inbox.ru

[2]*FSRC "Crystallography and Photonics" RAS, 119333, Moscow, Russia*

Template synthesis. The method of template synthesis is one of the promising methods for obtaining one-dimensional nanostructures [1]. The idea of the method is to fill the pores of a specially manufactured matrix with the required material. In this case, the manufacture of the matrix, its preparation and actual filling, represent separate processes, well-studied, controlled and reproducible. The method provides a unique opportunity to obtain identical nanosized structures with variable dimensional parameters from different materials. The cheapness and simplicity of the processes are also advantages of the method. There are several different variations of the method-as for the used templates (porous alumina, track membranes, etc.), and by the methods of filling them (galvanic, chemical, mechanical). In this work, polymer track membranes were used as templates (matrices), the pores in which were filled with various metals by an electrochemical (galvanic) method [2,3]. The result of the process was the production of an array of metallic filaments (nanowires, NWs) located within the polymer matrix. The purpose of this work is to assess the capabilities of probe microscopy and other microscopy methods when analyzing the various stages of obtaining NWs for the validation of the original matrices, NWs arrays within matrices, and isolated NW arrays.

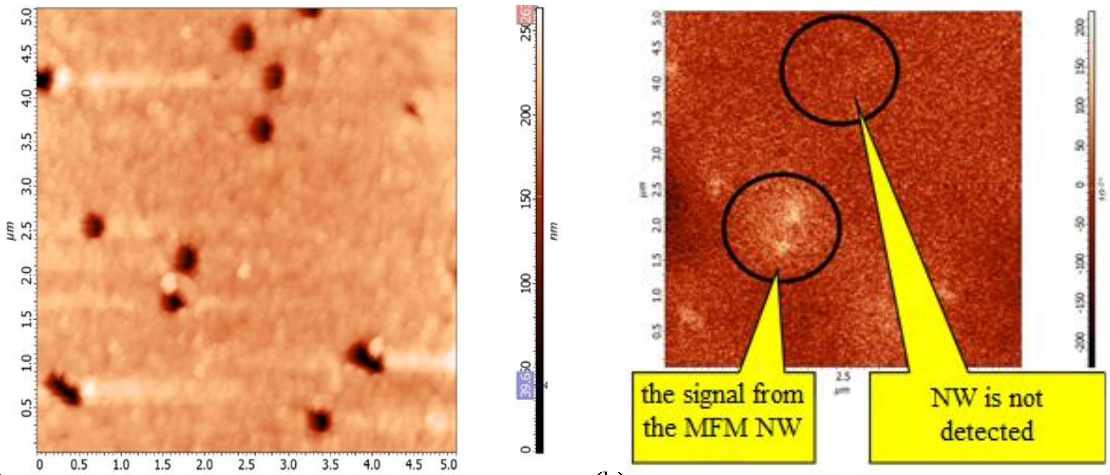
Optical microscopy was used for express analysis and for selecting areas for subsequent study at all stages of obtaining NW arrays. The wide range of problems was solved with the help of electron microscopy (SEM). The advantages of the latter include a large depth of field, the possibility of a more precise identification of pores (except for cases of diameters less than 50-70 nm), the possibility of changing the viewing angle. A great value in the study of multicomponent structures has the ability to conduct elemental analysis. The disadvantage of this approach include the relative complexity and duration of sample preparation; impossibility of subsequent use of the sample.

Probe microscopy from all of these methods gives the greatest resolution. When studying the matrix, this is the only way to see pores with dimensions less than 50-70 nm. In addition, it becomes possible to study the surface roughness of the matrix, which is important in evaluating the adhesion properties and pores, and the flat surface of the polymer matrix. The method is of greatest interest in the study of a polymer matrix filled with an NWs (a kind of "metal-polymer composite"). In this case, the SPM modes (spreading currents) and magnetic-force microscopy are used, the first one allows one to determine the electrical conductivity of individual NW. The image of the topography and a corresponding picture of the spreading current pattern for a membrane with pores 0.1 μm, some of which is filled with copper are given in Figure 1.



(a) (b)

Figure 1. SPM image of the TM surface with pores partially filled with copper: (a) surface topography, (b) the picture of the flow currents.



(a) (b)

Figure 2. SPM image of the TM surface with pores partially filled with cobalt: (a) surface topography, (b) the corresponding MFM image.

The results obtained make it possible to clearly distinguish the filled pores, and for the NPs themselves to estimate the electrical conductivity, it turned out to be much less than the corresponding values for bulk copper. Successful use of the method of magnetic force microscopy (MFM) for detecting NP from magnetic material (cobalt) growing into the pores of TM is demonstrated. Figure 2 shows the images of topography obtained in two-pass mode and the corresponding magnetic force picture.

The above results indicate the high sensitivity of the methods (detecting those that have not yet appeared on the surface of the NW) and the uneven growth of the NW (magnetic signal is observed only for a part of the pores). (Previously, the method has already been used to solve similar problems [4]).

Finally, the method was successfully used to study the topography of the surface of an NWs with a length (height) up to 1 μm (here the scale of determining the height was limited by the magnitude of the vertical displacement of the cantilever).

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