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Local anodic oxidation by the probe method as a surface modification method for nanoscale profiling

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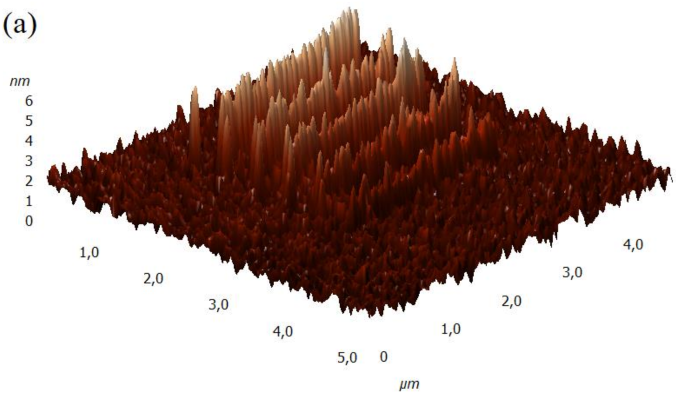
In connection with the miniaturization of electronic devices, as well as an increase in the density of base elements location on the crystal, it is quite natural that today there is a serious need for the development of new nanolithography methods. That would allow for precise profiling and surface treatment of structures whose linear dimensions are approximately tens nanometers [1-3].

Lithography with using of probe nanotechnology by the method of local anodic oxidation is a promising technology for formation of various kinds of electronic and mechanical nanoelectronics elements, starting form quantum dots and ending with one-electron transistors. This fact is confirmed by the main feature of this method is ability to control in real time electrical and topographic characteristics of the formed nanoscale structures Thus, it is relevant to study the application of local anodic oxidation with subsequent plasma chemical etching for nanoelectronic devices [4-6].

Plates of GaAs were used as the main material of the substrate. These plates were subjected to standard liquid polishing to improve the corresponding geometric parameters of structures surfaces. Using a probe of an atomic force microscope, a local anodic oxidation of GaAs structures surfaces was carried out in a noncontact mode. Oxide nanostructures of GaAs were formed in moist oxygen, the relative humidity of working medium of the microscope was 90%, with a probe displacement rate of 1.5-5 µm/sec. As the result, structures in subsequent plasma chemical etching processes will be used as masking layers [7-8].

For formation of nanoscale structures based on GaAs, selective parameters of plasma chemical etching processes were used for each mask. The samples were subjected to plasma chemical etching in high frequency inductively coupled plasma. As the chlorine containing gas, BCl3 was used, which has its own peculiarities in the etching of structures based on A3B5. The etching was carried out with the following parameters: the gases atmosphere pressure in the working chamber was 2 Pa; the power of the source of the capacitive plasma was W_{RIE} - 35 W, with a bias voltage U_{bias} - 10^2 V. In addition, the power of the inductively coupled plasma source was W_{ICP} - 400 W; the flow velocity of the intermediate carrier gas N_{Ar} - 100 cm^3/min and the chlorine-containing gas N_{BCl3} - 10 cm^3/min. The total etching time with these parameters ranged from 0.5 to 2 minutes.

The subsequent investigations of surfaces topology of structures obtained were carried out by scanning electron microscopy.



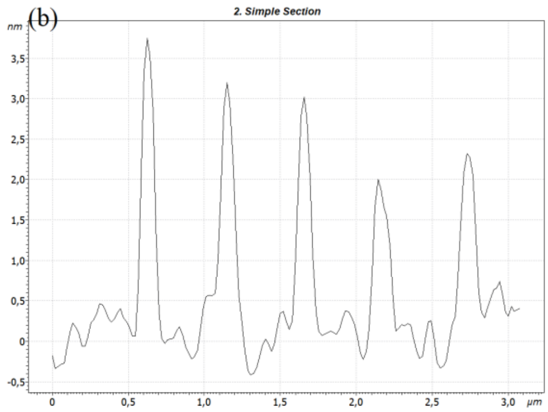


Figure 1. (a) The structures obtained by plasma chemical etching process and (b) profilogram across the structures.

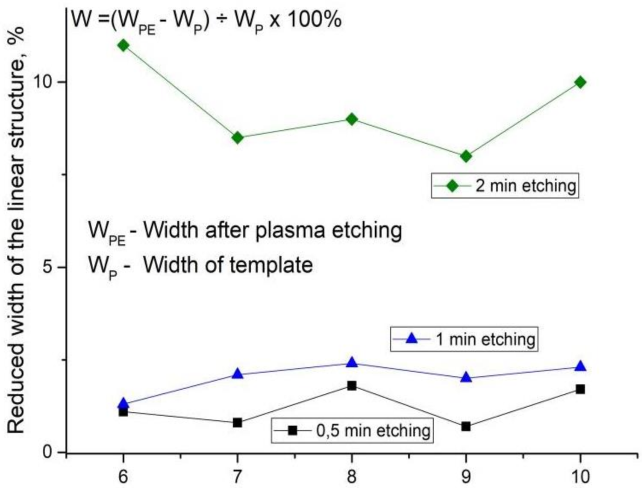


Figure 2. Dependence of the formation stress and etching time on the reduced width of the obtained nanostructures.

According to the experimental data, the geometrical parameters of formed structures were evaluated, at different stresses of LAO formation and etching time.

The obtained experimental dependences show that a combination of selective parameters of the local anodic oxidation method and plasma chemical etching makes it possible to modify the surface layer of GaAs structures with a specified degree of accuracy and roughness.

During the implementation of experimental studies, a technique for nanosized profiling of GaAs structures by a combination of local anodic oxidation and plasma chemical etching was developed and implemented. This work was carried out with support of the Southern Federal University (grant VnGr-07/2017-02). The results were obtained using the equipment of the Research and Education Center and Center for Collective Use "Nanotechnologies" of Southern Federal University.

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