Investigation of the electrode material influence on the titanium oxide nanosize structures memristor effect

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Abstract. The paper presents the investigation results of the titanium oxide nanosized structure memristor effect with various upper electrodes. It was shown that titanium oxide nanosized structures obtained by the local anodic oxidation method exhibit a memristor effect without carrying out an additional electroforming operation, and also the material of the upper electrode affects the structure memristor effect characteristics.

1. Introduction
Nanoscale structures demonstrating the memristor effect have broad prospects for using in the development and creation of resistive memory elements RRAM and synaptronics due to their ability to switch between high-resistance state (HRS) and low-resistance state (LRS) when switching voltage pulses are applied [1-3]. At the same time, the memristor structures based on titanium oxide are most preferable, since they have a high read/write speed, low power consumption, high reproducibility of parameters and stability of characteristics [4-5]. Analysis of modern methods of lithography has shown that classical technological processes based on the use of optical lithography have serious limitations in the production of memristor structures with dimensions less than 10 nm, in addition, the structures thus formed require an additional electroforming operation to implement the memristor switching mechanisms [6]. The method of local anodic oxidation (LAO) is one of the most promising methods for the oxides production, since it allows the electroforming-free memristor oxide nanosized structures (ONS) formation with high spatial resolution [7-13]. In the formation of memristor structure, in addition to the formation of titanium oxide, an important task is the upper contact electrodes precise formation, since the contact electrodes material has a significant effect on the memristor ONS characteristics. Precise contact formation can be realized by local ion-stimulated deposition methods by a focused ion beam from the gas phase [14-16]. Thus, it is important and relevant to study the upper electrode material influence on the memristor effect parameters on the basis of titanium oxide nanosized structures obtained using probe nanolithography methods.

2. Experiment
In the work, experimental studies were carried out on a thin titanium film 20 nm thick, formed by magnetron sputtering on the surface of the Si/SiO₂ structure. Titanium film local anodic oxidation was carried out on a raster graphic template using a scanning probe microscope (SPM) Solver P47 Pro (NT MDT, Russia). In the course of experimental studies, a titanium ONS with lateral dimensions of 2×2 μm and a thickness of 2.9±0.2 nm was formed (Figure. 1).

Figure 1(a, b). (a) AFM-image of titanium ONS; (b) profile along the line.

After that, on the formed oxide structure, the current-voltage characteristic were measured in the current mode of AFM spectroscopy, using various cantilevers with platinum, nitride-titanium and carbon coating as the upper contact electrode. In this case, the thin titanium film acted as the lower contact electrode (Figure. 2).

Figure 2. Scheme of measuring current-voltage characteristic

3. Results and discussion
Obtained dependences analysis showed that the formed titanium ONS exhibits a memristor effect without additional electroforming operation, in addition, it was shown that the use of cantilevers with different coatings as the upper electrode has a significant effect on the memristor effect parameters (Figure. 3).
3. **Conclusion**

Thus, the work showed the influence of the upper contact electrode material on the memristor effect of oxide nanoscale titanium structures. It is shown that the greatest ratio of resistances in the HRS and
LRS is observed when cantilevers with platinum coating are used as electrodes, and the lowest switching voltages are used with cantilevers with nitride-titanium coating. The obtained results can be used to develop technological processes for the formation of RRAM elements based on oxide nanoscale structures, as well as synaptronic elements in the development of architectures based on neuromorphic systems.

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