Formation, Phase Composition and Memristive Properties of Titanium Oxide Nanodots

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RELEVANCE

The increase in the modern electronics productivity is limited by the CMOS structure minimum. Furthermore, miniaturization is impossible due to an increased leakage power consumption, reduced reliability, and a more complex fabrication process. Therefore, increasingly attention is paid to the development and research of new nanoelectronic elements with small characterizing dimensions, as well as high performance and speed.

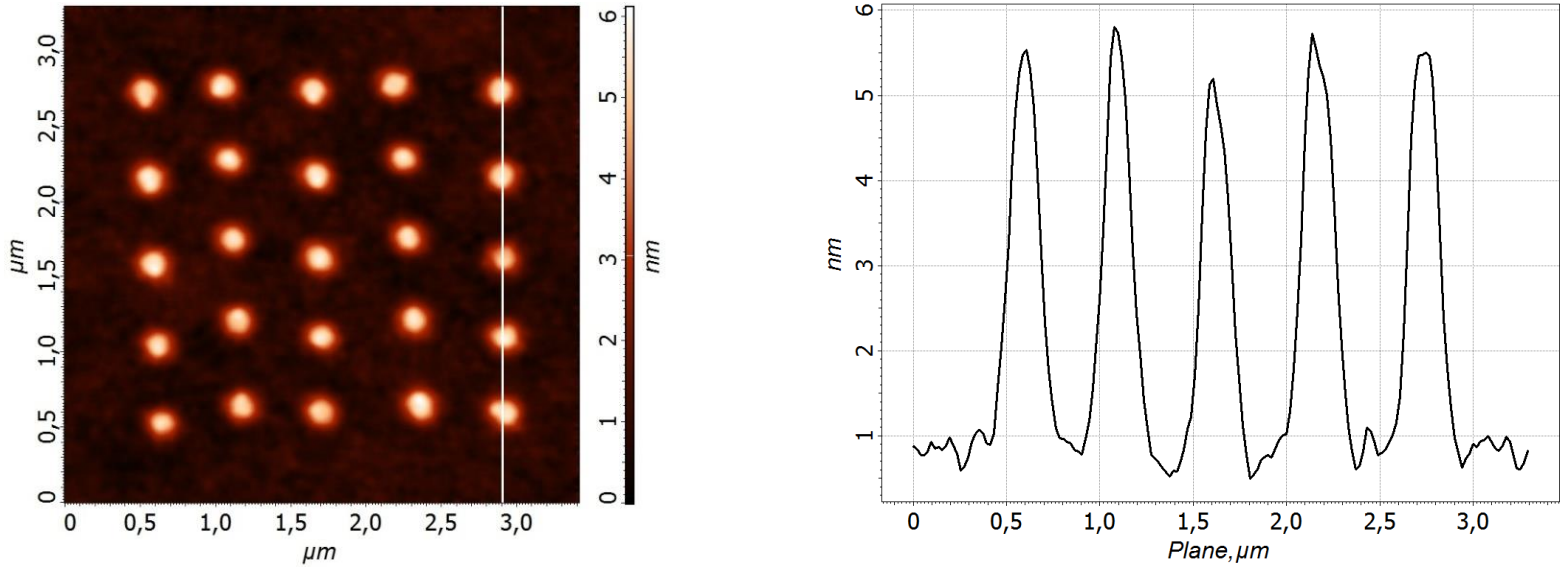
The recently discovered resistive switching effect has led to the development of memristor switching between high (HRS) and low (LRS) resistance states. Such structures can be used both in memory elements and in logical computation operations. In addition, there is an idea of computation-in-memory architecture that combines the functions of computing and data storage in one integrated circuit.

An analysis of the literature has shown that titanium oxide nanostructures are most preferable when creating memristors with good characteristics in terms of speed and energy efficiency, while the best characteristics are achieved when a nonuniform stoichiometric composition of titanium oxide is formed.

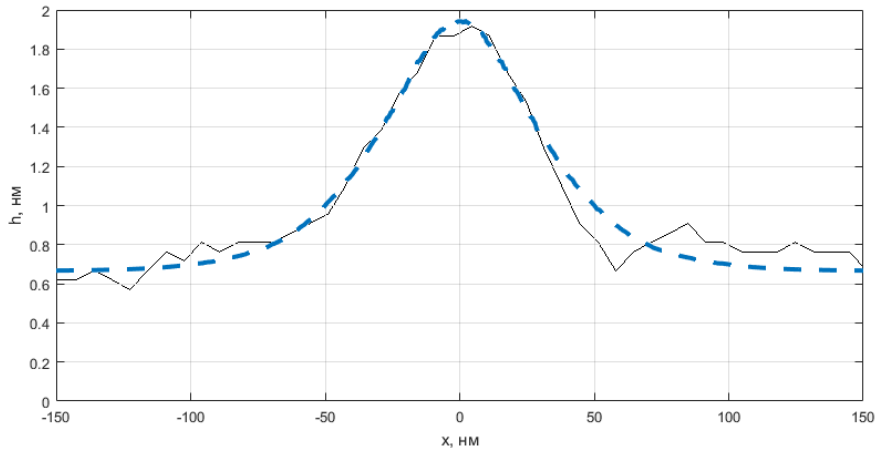
The method of local anodic oxidation is the most promising for the creation of memristors based on titanium oxide since the resulting structures exhibit a forming-free memristor effect and can be used to create memory elements or perform logical operations.

Therefore, the actual task and goal of this work is the experimental and theoretical study of the formation and resistive switching dependencies of titanium oxide nanodots obtained by the method of local anodic oxidation (LAO).

OXIDE NANODOTS FORMATION BY THE LAO METHOD

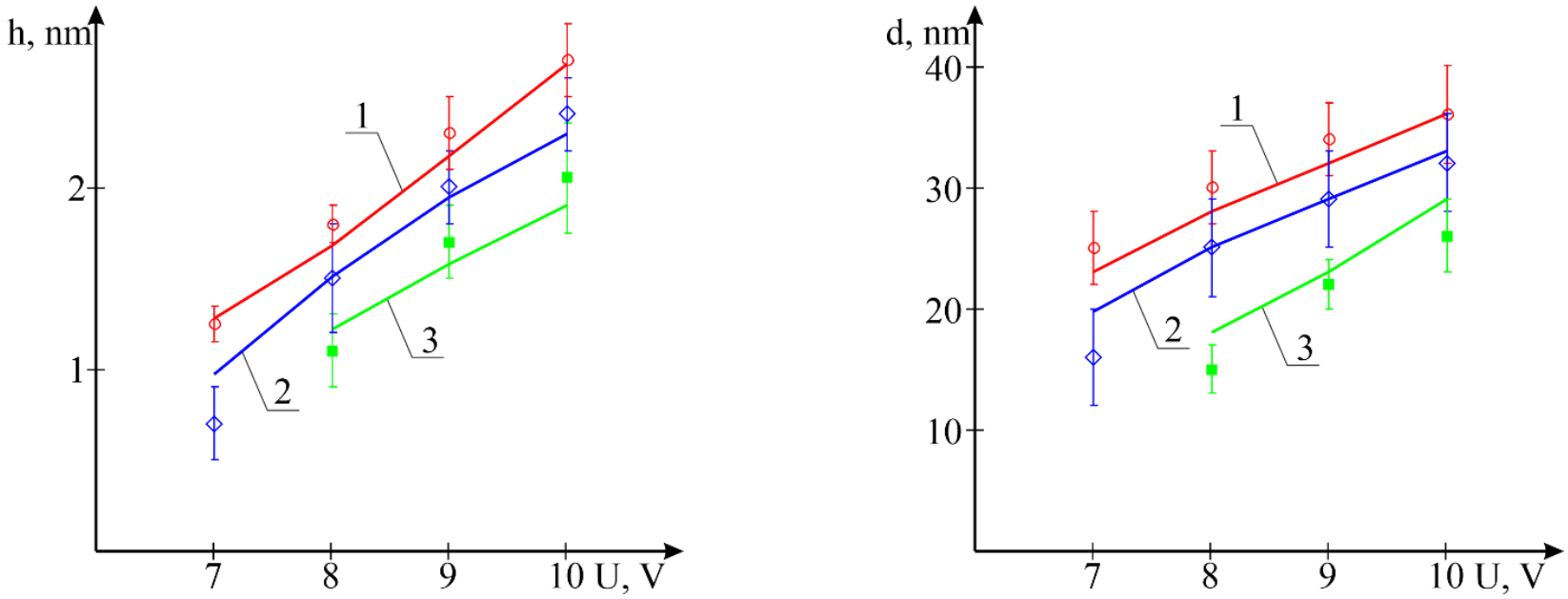


AFM image and profilogram of an array of titanium coside nanodots obtained by local anodic oxidation



Experimentally obtained (solid line) and calculated (dashed line) profiles of nanodots obtained

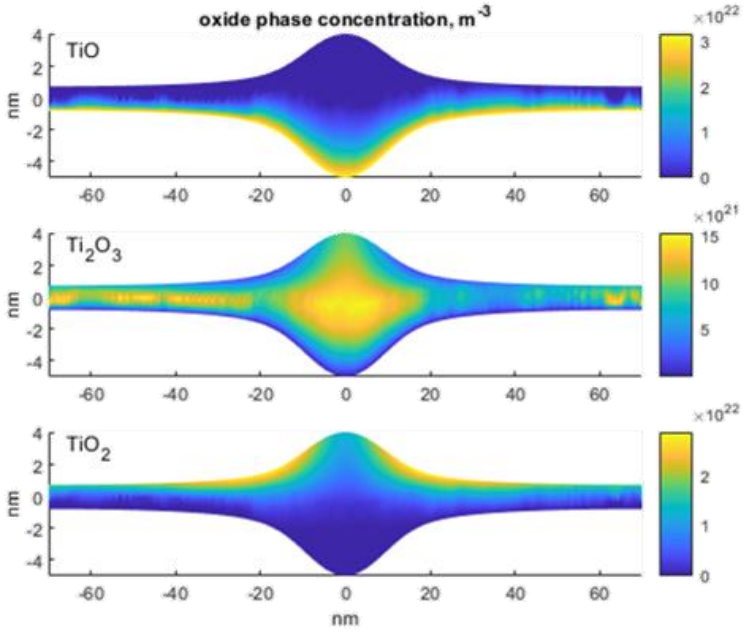
THEORETICAL AND EXPERIMENTAL STUDIES OF OXIDE NANODOTS FORMATION



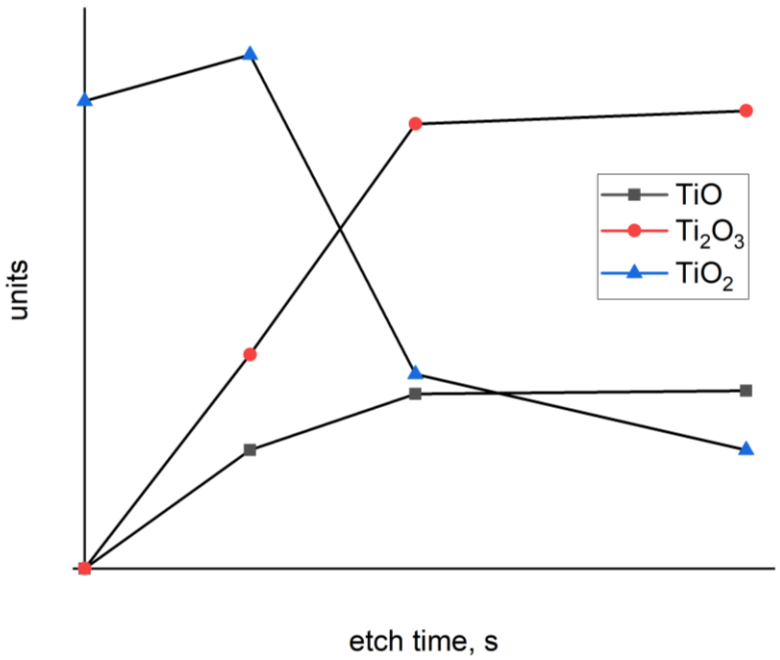
Experimental (points) and theoretical (lines) ONT height and diameter dependence on the applied voltage pulse amplitude at a relative humidity level of 1 - 90%, 2 - 70% and 3 - 50%

It was shown that the theoretical results are in good agreement with the experimental study results; an increase in the voltage pulse amplitude and air humidity in the technological chamber leads to an increase in the ONT height and diameter. This is explained by the increase in the ions number formed due to the decomposition of water molecules in the gap between the probe and the ONT surface.

PHASE COMPOSITION STUDIES OF OXIDE NANODOTS



Titanium oxide phases distribution in the nanodot volume by numerical model

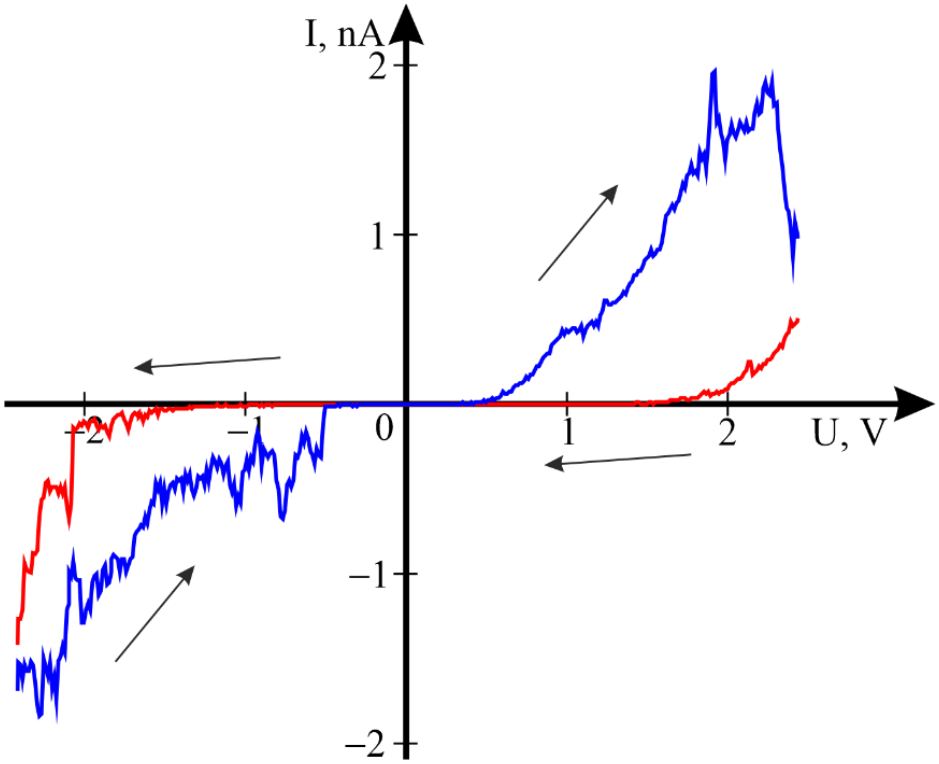


Titanium oxide phases distribution in the nanodot volume by XPS

During LAO oxidizer ions move in an external electric field through the oxide volume to the metal surface. In this case, the oxygen concentration is highest near the oxide surface, the TiO_2 phase is formed, and near the surface of the metal, the oxygen ions concentration is the lowest, and the TiO phase is formed.

To confirm the obtained experimental results, a titanium oxide nanodots array XPS was carried out (Figure 3), which showed good correlation with the obtained theoretical results.

THE CURRENT-VOLTAGE CHARACTERISTICS STUDY



Titanium oxide nanodots current-voltage characteristics

The current-voltage characteristics study of the ONT showed that they exhibit a memristor effect and switch between the HRS state (140 GΩ) and the LRS state (1.7 GΩ) (Figure 4) without additional forming operation.

CONCLUSION

Thus, in this work, titanium oxide nanodots formation theoretical and experimental studies by the local anodic oxidation method and phase composition were carried out. The electrical characteristics study showed that the resulting structures exhibit a forming-free memristor effect.

The results can be used in the development of technological processes for the formation of elements of nanoelectronics, as well as elements of resistive memory based on oxide nanoscale structures.

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THANKS FOR ATTENTION