EFFECT OF SILICON ION IMPLANTATION IN SILICON OXIDE FILMS ON THE PARAMETERS OF RESISTIVE SWITCHING OF MEMRISTORS ON THEIR BASIS

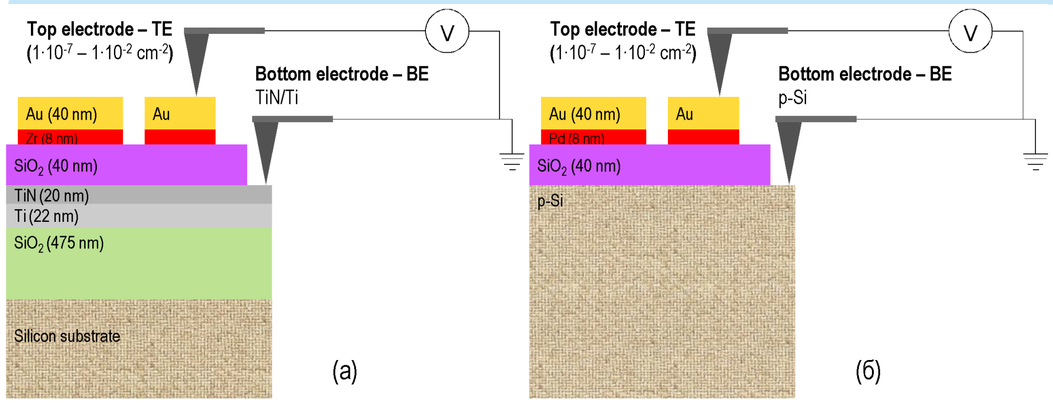
eokulich@nifti.unn.ru

E.V. Okulich, V.I. Okulich, D.I. Tetelbaum, A.N. Mikhaylov, A.V. Zdoroveishchev, V.L. Vorobyev

Abstract

The effect of ion irradiation on the characteristics of memristors based on silicon oxide films obtained by magnetron sputtering and electron-beam deposition has been studied. The results show the possibility of tailoring the characteristics of memristors using the developed technological processes.

Experiment



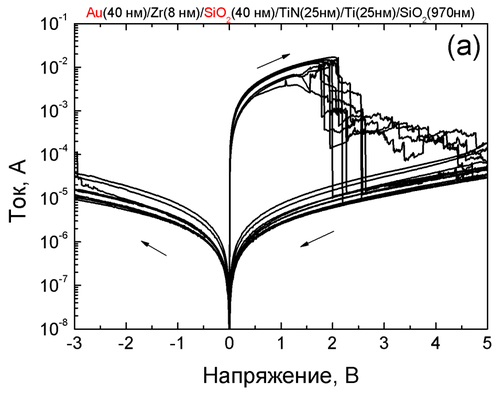
Schemes of the studied structures obtained: (a) by the method of magnetron sputtering; (b) by electron beam deposition.

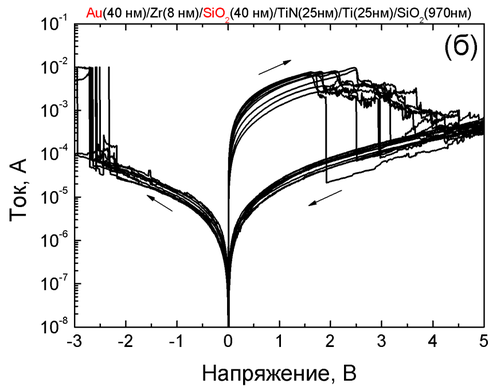
Before the deposition of the upper contacts, structures of both types were irradiated with a Si^+ ion beam. The dose (2×10^{15} cm^{-2}) and energy (20 keV) of ions were selected taking into account the thickness of the film so that the maximum of the embedded ions fell approximately in the middle of the film.

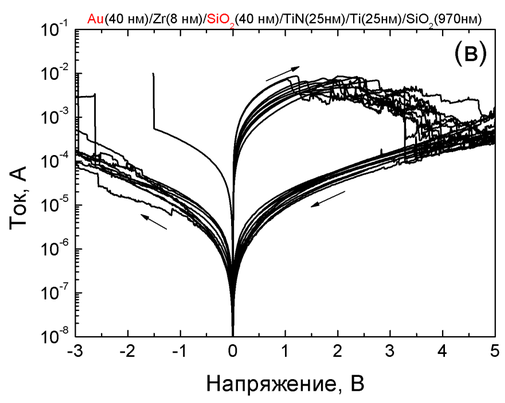
1. The method of magnetron sputtering (1 type)

Some of the samples were annealed at temperatures 600 °C, 800 °C, 1000 °C.

The I - V characteristic was analyzed for the following samples: control samples (unirradiated and unannealed), annealed at 600°C, and also irradiated and annealed at 600°C samples.







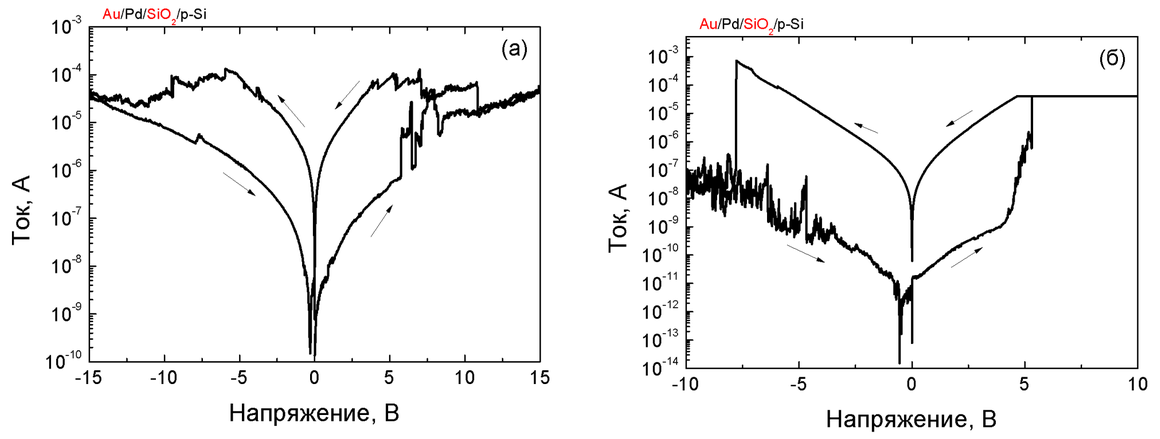
Typical I – V characteristics of SiO_2-based samples prepared by magnetron sputtering: (a) control (unirradiated and unannealed), (b) annealed at 600°C, (c) irradiated and annealed at 600°C.

1. Experimental findings

It was found that memristive structures annealed at 800-1000°C were initially in a conducting state and electroforming was not possible on them (the process in which filaments are formed under the action of an applied electric field). It can be seen that both annealing and ion irradiation improve the I – V characteristics of memristors.

2. Electron beam deposition (2 type)

Memristive structures based on silicon dioxide films obtained by electron beam deposition were annealed at a temperature of 400 ° C before measuring the I – V characteristics.



Typical I - V characteristics of samples based on SiO_2 prepared by electron beam deposition: (a) unirradiated, (b) irradiated.

2. Experimental findings

A change in the polarity of resistive switching processes (transitions from HRS to LRS and vice versa) was found.

This is consistent with the results presented in [1]. It can be seen that in this case, an improvement in the I – V characteristic is observed as a result of irradiation: the ratio of the resistances in the HRS and LRS increases significantly.

3. Additional research and results

For structures of the first type, the effect of high-temperature annealing on the state of the surface of the SiO_2 film was studied by atomic force microscopy. As a result of this study, a significant pitting of the surface of the oxide layer was found, the greater the higher the annealing temperature, which may be associated with intense evaporation.

A study of the quantitative composition and chemical state of elements in silicon dioxide (type 1) by the method of X-ray photoelectron spectroscopy has been carried out. The most significant result was the discovery of deep (almost to the middle of the oxide layer) incorporation of Ti and N atoms into the SiO_2 film with the formation of new chemical compounds of these elements with oxygen and silicon with the probable diffusion of oxygen and silicon into the TiN film during the deposition of a silicon dioxide film.

We also measured the C-V characteristics on structures of both types 1 and 2. It was found that type 2 film-based memristive devices exhibit significantly higher repeatability from contact to contact both before and after irradiation.

Conclusions

1. The results of the study have shown the fundamental possibility of controlling the properties of memristors based on amorphous silicon dioxide films by introducing excess Si atoms into them by the method of ion implantation.
2. The method of electron-beam sputtering is more preferable in the technology of creating memristive devices based on SiO_2 films.

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Literature

1. A. Mehonic, A.L. Shluger, D. Gao. Adv. Mat. 2018, 1801187.

If you have any questions or comments:
My e-mail: eokulich@nifti.unn.ru
My phone: +79307060757 (all messengers)