HfO_2-HfO_x Based Memristor with Different Size Active Layers

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http://doi.org/10.29227/IM-2024-01-35

Submission date: *12.2.2023* | Review date: *3.4.2023*

Abstract

Memristore parameters are strongly depend on the size of active layers. In this paper is reported the outcomes of memristore created with different size active layers. There are considered 1μ, 5μ and 10μ diameter separated devices in the form of crossbar with HfO_2 + HfO_x active layer and tungsten top contact, titanium nitride botton contact and aluminum wiring contact. As substrate was used sapphire and active layers of memristore was deposited by reactive magnetron sputtering technology. With photolithography exposure system by new pothomask has been done 1μ, 5μ and 10μ diameter lithography for formation active layers and all contacts. Leakage currents dropped to 0.01mA, increased cicles of histeresis of I-V curves and dramatically increased R_{off}/R_{on} ratio to be 100000.

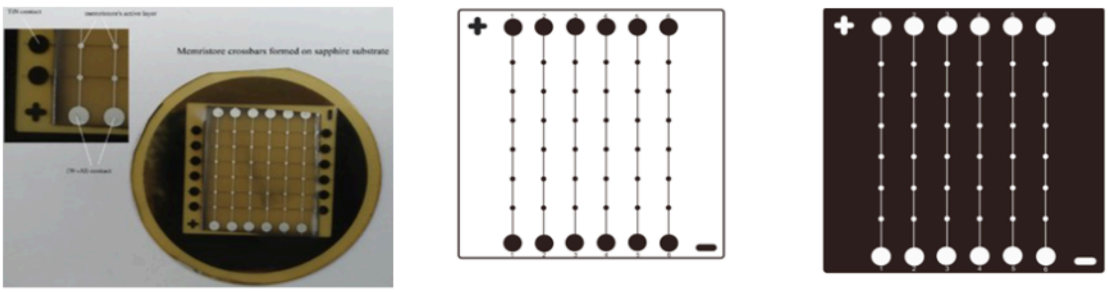
Keywords: electrical devices, memristor, active layer, photolithography

Introduction

In electrical devices and especially in electric circuit elements such as diodes, field effect transistors, memory storage elements, low energy consumption, long-term storage, high ON / OFF resistance ratio, multi-level operation cell and more, important parameter is leakage current and fast speed switching. Leakage current must be as low as possible in the level of micro amps. In this paper are given outcomes regarding to memristore R_{off}/R_{on} ratio and leakage current, which is proportional to R_{off}/R_{on}. Also is shown the stability and repeatability of electric parameters and I-V curve of the memristore [1-7].

Experimental

In the experiments were used 2 inch sapphire wafers 300μm thickness and surface orientation (0006). Prior to the experiments substrate surface was chemically cleaned using standard techniques. Technology forming memristore's active layers as well memristore's contacts was reactive magnetron sputtering. Sputtering target was made by 50mm diameter W (99.95%) and Hf (99.9%) materials. Rotary and turbo pump combination was used to get the desired vacuum in the vacuum chamber. The base pressure of the system was less than 10^{-6} torr. All the depositions were carried out at a total pressure of 5 x 10^{-5} torr. The distance between the target and substrates was kept at 45 mm and the substrate temperature was 400^0 C. Design and morphology of the memristors were made by UV photolithography and are designed in the form of „crossbar'' (Fig. 1), which allows us to individually investigate each memristor and create a database with the possibility of incorporating it into the microchip in the future. Isolation of individual memristore structures were made by photoresist AZ5214E, which is a good electrical isolation material (Fig. 2). Text will be written here by using the all rules related to the text, citation, tables, figures, equations, etc. as given above.



(a) (b) (c)

Fig. 1. a) Memristor crossbars made on supphire wafer; b) positive photomask of crossbars; c) negative photomask of crossbars.

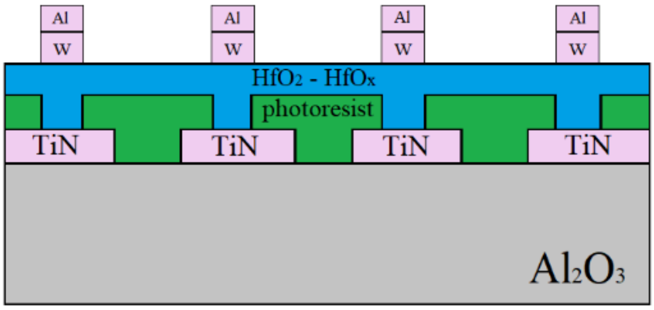


Fig. 2. Memristor crossection structure

Memristore structure was created in the following order: Al_2O_3 (substrate)+TiN (bottom contact) + (HfO_2- HfO_x) (active bilayer) +W (top contact) + Al (wiring contact) (Fig. 2). The electrical parameters of the obtained structure were measured by I-V characteristic. The photomask contains 6 lines with 2mm diameter circles in the both sides of the line for bottom contacts and between them are 100 µ diameter circles for active layer of memristore. Top contact also contains 6 lines. The first 2 lines contain 1µ holes, second 2 lines - 5µ holes and the last 2 lines – 10 µ holes. This configuration of the top contacts with different diameters give opportunity in the same substrate, in the same technological environment investigate the dependence of the active layer area of the memristore on electric parameters.

Results and Discussion

Memristor With 1µ Active Layer

The I-V characteristic is shown in Fig. 3 Maximum applied voltage is around 1.3V.

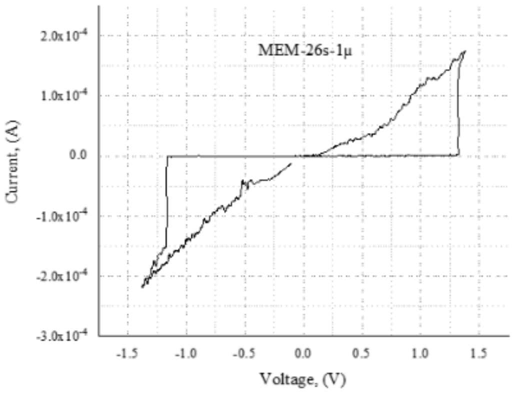


Fig. 3. I-V characterization of memristor with 1µ active layer.

As can be seen from Fig. 1, the behavior of the curve is promising to be good characteristic in the terms of resistance ratios, but R_{off} /R_{on} is about 140. The reason is that 1µ photolithography process is a difficult process and needs good exposure system to receive exact 1µ holes. Also, is not reached stability and repeatability of the parameters of the memristore.

Memristor With 5µ Active Layer

As previously was explained the photomask contains 5 µ holes for formation 5µ diameter active layer memristor. In Fig. 4 is shown I-V characterization of the memristore.

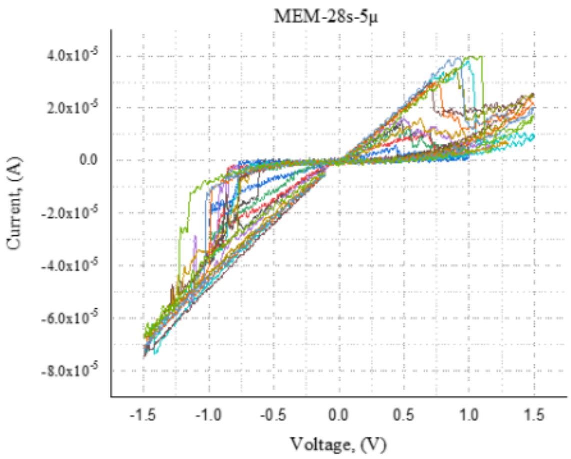


Fig. 4. I-V characterization of memristor with 5µ active layer.

The I-V characteristic shows output current is in the order of tens of microamperes. Ratio of high resistance state R_{off} (device is in the locked condition) and low resistant state R_{on} (switching mode) is equal to 20. As in the case of 1μ holes lithography, the reason is the same, but it seems more stable and repeatable parameters.

Memristor With 10μ Active Layer

Fig. 5 shows I-V curve of the memristore with 10 μ active layer.

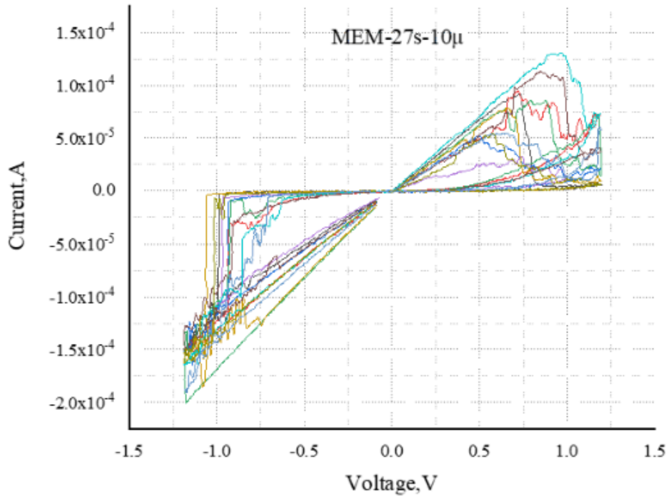


Fig. 5. I-V characterization of memristor with 10μ active layer.

Conclusion

To summarize received outcomes, the expectation from the experiments was to receive the best result in the case of 1μ diameter active layer. The reason is that, photolithography process is a bit difficult process for 1μ and 5μ by conventional photolithography exposure system. It needs more deep UV exposure system to get exact sizes of the objects. Also, in the process of deposition $HfO_2 + HfO_x$ active layer the substrate is heated around 400^0C. In this moment photoresist material loses ability to save form and size and after deposition we receive more less sizes than 1μ and 5μ holes. Because of this reason the deposition of active layers goes not properly and memristore I-V characterization gave not so good results. But the best results is shown in case of 10μ active layer of the memristore. The R_{off} / R_{on} is around 100000 and I-V characterization is stable.

In the future it is necessary to continue experimental work in the direction of improving photolithography exposure system and photoresist material quality to achieve good results for 1μ and 5μ diameter holes active layer of the memristore.

Acknowledgments

The work is implemented under the #YS-21-488 project of Shota Rustaveli National Science Foundation of Georgia.

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