Euroasian Journal of Semiconductors Science and Engineering

Volume 2
Issue 5 *Issue 5*

Article 8

10-24-2020

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Recommended Citation

Abdullaev, Sh.; Sharipova, R.; and Yuldashev, Sh. (2020) "ZnMgO/SiO2/ p- Si MEMRISTOR WITH NEGATIVE DIFFERENTIAL RESISTANCE SWITCHING," *Euroasian Journal of Semiconductors Science and Engineering*: Vol. 2 : Iss. 5 , Article 8.
Available at: https://uzjournals.edu.uz/semiconductors/vol2/iss5/8

ZnMgO/SiO$_2$/ p- Si MEMRISTOR WITH NEGATIVE DIFFERENTIAL RESISTANCE SWITCHING

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Abstract. *Negative differential resistance switching was observed in ZnMgO crystalline thin films grown on the p-type Si with a thin native SiO$_2$ oxide layer by ultrasonic spray pyrolysis. The negative differential resistance switching was observed during the RESET cycle. This effect is explained by the resonant tunneling of electrons through the Ag nanoclusters in SiO$_2$ layer after rupture of conductive silver filaments.*

Keywords: *Zinc magnesium oxide, memristor, negative differential resistance switching.*

The resistive random access memory is seen as a potential candidate for next-generation non-volatile memory and neuromorphic computing [1]. The most common interest includes low power consumption, high scalability, multiple switching states and non-damaging readout. Long retention characteristics enable memristor to take over CMOS and also integrate with CMOS technology [2].

Resistive switching has been observed in many metal oxides. Among all oxides, ZnO is widely investigated and reported because of its remarkable properties such as reliability, non-toxic behaviour, inexpensive, superior retention time, and excellent endurance compared to other materials [3]. Recently Kadhim et al. demonstrated the negative differential resistance device in ZnO nano-rod array [4].

In this study, we investigate the effect of the negative differential resistance switching in ZnMgO thin films with 5% of Mg grown on SiO$_2$/p-Si substrates by using ultrasonic spray pyrolysis method.

ZnMgO thin films were deposited on p-type Si (111) substrates by ultrasonic spray pyrosis at temperature of 500 ^{0}C. Aqueous solutions of zinc acetate dehydrate with 5% of magnesium acetate tetrahydrate were used for the preparation of ZnMgO thin films. The precursor solution was sprayed using an ultrasonic nebulizer at a frequency of 2.5 MHz for atomization of the solution. Oxygen was used as the carrier gas. The substrate was not etched to protect the native oxide layer. Native oxide is usually 2 nm to 4 nm, but during the deposition in an oxygen-rich environment, there was further growth of silicon oxide. The Ag dots with the diameter of 100 μm were deposited by E-beam as top electodes at room temperature.

Figure 1 shows the scanning electron mycroscopy images of ZnMgO thin film grown on SiO$_2$/ p-Si substrate by ultrasonic spray pyrolysis method as descibed above. It is seen that the surface of deposited film is smooth and without any pinholes. The thickness of the ZnMgO film is about 35 nm as it is seen from the cross section image.

Fig. 2(a) shows the typical current-voltage (I-V) characteristics of Ag/ZnMgO/SiO$_2$/p-type Si device. I-V measurements were performed at room temperature by using a Keithley 4200 dc characterization system.

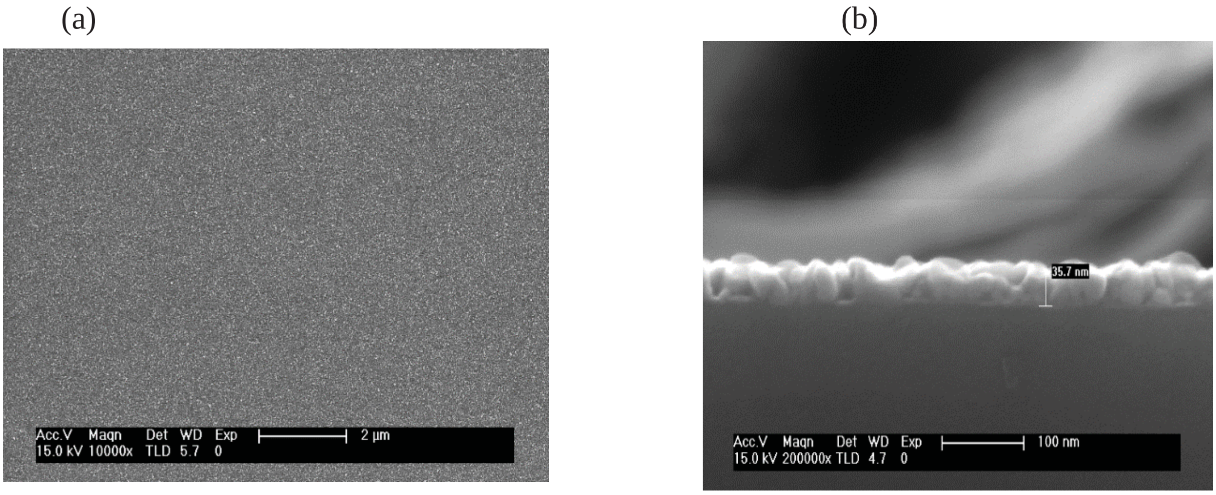

Fig.1. SEM images of the ZnMgO thin film: (a) the surface image and (b) the cross section image

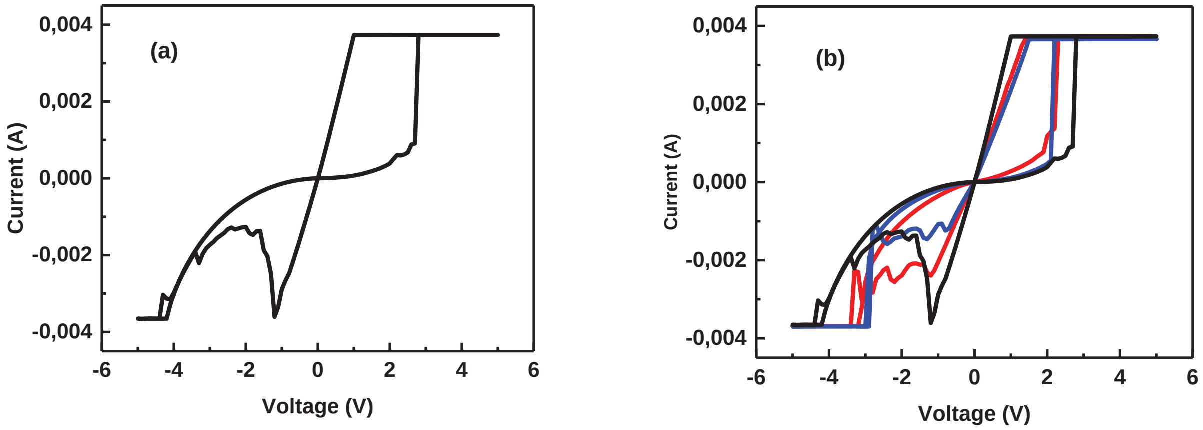

Fig.2. I-V characteristics of the Ag/ZnMgO/SiO_2/p-type Si device measured at (a) room temperature and (b) 300K, 350 K and 400 K

The device shows the resistive switching from the high resistance state to the low resistance state at about +3V when the positive voltage is applied across the top Ag electrode, which corresponds to the SET operation and the negative differential resistance effect during the negative bias changes from – 1V to -2V, which is the RESET operation. Figure 2 (b) shows the I-V curves measured at different temperatures such as 300 K, 350 K and 400 K, respectively. The resistive switching at positive bias is explained by the formation of Ag filaments due to migration of the Ag^+ ions during the SET operation.

The negative differential resistance effect and the current peaks at the negative bias were attributed to the resonant tunneling through the Ag nanoclusters (NCs).

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УДК 621.315.593