JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. 12 No 1, 01007(6pp) (2020)

ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том 12 № 1, 01007(6cc) (2020)

Effect of Top Electrode Materials on Switching Characteristics and Endurance Properties of Zinc Oxide Based RRAM Device

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(Received 18 November 2019; revised manuscript received 15 February 2020; published online 25 February 2020)

This work reports the effect of top electrode materials, i.e., Al, Ag, and Ti on the switching characteristics of resistive random access memory (RRAM) devices based on zinc oxide (ZnO) thin film. The RRAM devices with Si/Pt/Ti/ZnO/Top electrode (Al or Ag or Ti) structure were successfully fabricated, and their switching characteristics were measured. The structural properties of ZnO metal oxide thin film were studied using X-ray diffractometer (XRD), atomic force microscopy (AFM) and scanning electron microscope (SEM). The switching characteristics of the fabricated devices were measured with the help of *I-V* curves, which were measured using semiconductor parameter analyzer. It has been observed that the manufactured devices have exhibited bipolar properties. The Si/Pt/Ti/ZnO/Ag structure has shown the best endurance up to 10^3 cycles. Further, the measurement of retention properties at room temperature was also done for Si/Pt/Ti/ZnO/Ag structured device, which confirms the non-volatile properties of the obtained devices. The ratio of low resistance state (LRS) and high resistance state (HRS) was found maximum for Ag top electrode up to 10^2. It has been observed that LRS and HRS currents of the device do not degrade up to 10^4 s.

Keywords: RRAM, Switching characteristics, Top electrode, ZnO.

DOI: 10.21272/jnep.12(1).01007 PACS numbers: 85.25.Hv, 77.80.Fm, 81.15.Pq, 77.55.hf

1. INTRODUCTION

Due to the recent advancements in CMOS and other semiconductor devices, semiconductor memories are in huge demand. The memory occupies a significant portion in an IC, so it should be smaller in size, power efficient and stable. Due to the scaling in CMOS technology, the size of these conventional memories is reducing and now has reached a saturation point. The scaling has also increased the leakage power in CMOS circuits. To overcome the limitations of traditional memories and to bring advancement in new technologies like IoT and big data applications, the memories should be dense, power efficient and robust [1]. Existing non-volatile memory technologies like flash memories are charge storing memories and have now reached its physical limits [2]. Hence, nanoscale memories, which do not work on charge storing like FeRAM, MRAM, PCRAM, and RRAM, have drawn a significant interest of researchers for future non-volatile memories [3-6]. RRAM is a potential candidate for future memories due to its modest components, extraordinary compactness, low power, and exceptional scalability [7]. The device structure of RRAM is a capacitor like configuration with a metal-insulator-metal (M-I-M) structure. It is observed that the resistive switching occurring in the M-I-M structure can be changed by an electrical signal applied to it [8]. Recent reports on memory arrays are focused on the metal oxide-based RRAM due to the ease of the materials and exceptional compatibility with the fabrication procedure of CMOS.

The working principle of RRAM is established on the reversible resistive switching RS mechanism between two stable resistance states, which are low resistance state (LRS) and high resistance state (HRS). This reversible switching happens in transition metal oxides with the M-I-M configuration. There are two types of switching memories related to electrical polarity i.e. unipolar and bipolar [9]. The process, which brings variation in the resistance states of the device, i.e., from HRS to LRS is called SET process, while the variation from LRS to HRS is known as RESET process. An explicit resistive state (HRS or LRS) can be reserved after the cancellation of electric stress that specifies the non-volatile nature of RRAM. Generally, in the initial resistance state of a fresh sample, a higher voltage (more than the set voltage) is required to initiate the resistive switching behavior. This process is known as forming/electroforming process.

The mechanism of switching in the unipolar RRAM device is described as the formation of conductive filament when voltage is applied, which sets the device into a LRS. The Joule heating produced is responsible for rupture back to HRS. The polarity of the applied current does not affect the Joule heating effect, but its amplitude does. This type of devices shows unipolar switching behavior. Since switching direction is dependent on the applied voltage polarity in a bipolar RRAM, different polarity is used for erasing and writing the data. To circumvent the dielectric breakdown in every switching

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