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

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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.

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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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Electrical transport properties of thermally stable n-ZnO/AlN/p-Si diode grown using RF sputtering

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Abstract

The temperature dependent electrical transport properties of n-ZnO/AlN/p-Si heterojunction diode fabricated by RF sputtering system have been investigated over a wide temperature range of 303 K–413 K. The AlN buffer layer in-between ZnO and Si lowers the mismatch in thermal expansion coefficient/lattice constant for improved electrical and structural characteristics. XRD pattern and FESEM confirm the crystalline nature and good quality of ZnO thin film with uniform grain size and crack free structure respectively. As measured from the temperature

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Effect of substrate temperature on the microstructural and optical properties of RF sputtered grown ZnO thin films

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ABSTRACT

This study investigates the effect of substrate temperature ranging from 30 ^{0}C to 150 ^{0}C on micro-structural and optical properties of ZnO thin films. RF sputtering method is used for the deposition of thin films on p- type Si substrate. The X-Ray Diffraction (XRD), Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) study is used for the investigation of different micro-structural and surface morphological properties of ZnO thin films. XRD results portrays hexagonal wurtzite structure, indices (0 0 2) preferred orientation thin films. UV–VIS-NIR spectroscopy and photoluminescence spectroscopy are employed to find the optical parameters of deposited ZnO thin films. It has been observed that the deposited thin films are highly transparent with the transmittance greater than 85% and their refractive index varying from1.75 to 2.75 as the substrate temperature changes from 30 ^{0}C to 150 ^{0}C. Various optical parameters like transmittance (T), absorption (A) and their outcomes are also examined and reported. The optical band gap shows a marginal variation from 3.22 eV to 3.26 eV.

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1. Introduction

Zinc Oxide (ZnO) has turned up as the most promising material among various II-VI group oxides, due to its excellent electronic, optical, magnetic and chemical properties and its potential device application in various fields. Its low cost, abundant availability in nature, wide band gap (3.37 eV), high absorption in UV region, non-toxic nature, high exciton binding energy (60 meV) [1–2], high mobility (2.5 cm^2 V^{-1} sec^{-1}), makes a solid platform for variety of applications like chemical sensors, Light Emitting Diode (LED), Thin Film Transistor (TFT), clear and flexible displays [3–5], piezo-electric nano-generators [6] and in solar cells.

Various deposition techniques like chemical vapor deposition (CVD), pulsed laser deposition, electro-deposition, sol–gel, and RF sputtering were earlier reported by researchers for depositing ZnO thin films [7–8]. In all the above methods some needs high temperature in order to prepare thin film, some other are toxic and some are complex processes. So among these all, RF sputtering is the most encouraging technique for depositing ZnO thin film because of its controlled growth process. The deposition process using RF sputtering also assures highly stable and repeatable films. Apart from this, it also ensures c-axis crystal growth and large grain size which improves carrier transport with good controllability and conformity [9].

Now a days, researchers giving considerable attention towards study and understanding of nano-dimension thin films. They are tracking the difference in the microstructural, optical and electrical behavior of the materials by switching substrate temperature. In past, researchers reported variation of functional ZnO thin film properties with thickness, pressure, substrate type and annealing temperature [10]. In order to ensure ZnO thin film compatibility for a variety of optoelectronic and piezoelectric device applications, effect of substrate temperature plays a vital role. The aim of present work is to report a systematic study about the influence of substrate temperature (30 ^{0}C, 50 ^{0}C, 100 ^{0}C, and 150 ^{0}C) on microstructural and optical parameters of Zinc Oxide thin films.

2. Experimental procedure

In first step, p-Si substrate was cleaned using standard RCA method [11]. The nano crystalline ZnO thin films were deposited

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