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Resistive switching characteristics of ZnO/a-TiO_2 bilayer film fabricated on PET/ITO transparent and flexible substrates

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ABSTRACT

Resistance random access memory consisting of ZnO/TiO_2/Cu structure is demonstrated on a flexible and transparent PET/ITO substrate. To improve cell to cell uniformity, amorphous TiO_2 fabricated by atomic layer deposition is used for resistive switching material with ZnO film as a blocking layer. XRD, SEM and AFM measurements were used to analyze the composition and structure of the ZnO/TiO_2 films. XPS spectra and depth profile of the ZnO/TiO_2 structure were thoroughly investigated to verify the chemical composition of the films. Resistive switching characteristics were measured and conduction mechanism was analyzed according to above analysis.

1. Introduction

Recently, resistive random access memory (ReRAM) based on binary metal oxides has attracted great attention as next generation of nonvolatile memory. Among the large variety of binary oxides, titanium dioxide (TiO_2) is one of the most promising materials due to its simple composition, easy fabrication and high compatibility with complementary metal-oxide semiconductor [1,2]. Various models have been proposed to explain the resistance switching phenomena in TiO_2 film, but the popular one was the filamentary conduction mechanism [3–6].

Most of the papers were related to the TiO_2 thin films with crystalline phases such as anatase and rutile [7,8], which were fabricated at high substrate temperatures. However, it has some disadvantages, such as higher deposition temperature especially for the future flexible memory applications and difficulty in improving the stability of the devices based on the conducting filament model [9]. Instead, amorphous TiO_2 (a-TiO_2) films have advantages in low temperature fabrication process, excellent cell to cell uniformity and higher stability. Some groups have developed ReRAM devices based on the a-TiO_2 thin film grown by a plasma-enhanced atomic layer deposition (PEALD), whose device structure was Al/a-TiO_2/Al [10,11]. Stable bipolar resistive switching (BRS) from a-TiO_2 thin film has been achieved for Al metal electrodes, however there are severe problems like electromigration and breakdown in real applications, which can be a limiting factor for novel applications like transparent electronics. To solve this problem, it was suggested to insert an ultrathin metal layer in the top interface region or incorporate a thin blocking layer in the bottom interface to enhance resistance switching [12].

In this paper, we present TiO_2 based ReRAM devices on transparent and flexible PET/ITO substrates with ZnO as a blocking layer between TiO_2 and ITO bottom electrode. Based on existing semiconductor technology, it has the potential and realistic feasibility to support the real application of flexible ReRAM. What's more, research in electric switching in amorphous oxides with plenty of inherit defects may be helpful to further clarify switching processes.

2. Experimental details

The PET/ITO substrates were purchased from commercial suppliers. The thicknesses of PET and ITO are 0.175 mm and 185 nm, respectively. The substrate of PET/ITO was cleaned ultrasonically in acetone, ethanol and ionized water for 20 min, respectively. ZnO film was prepared by magnetron sputtering at room temperature by using ZnO ceramic target. The flow rate of Ar is 20 sccm, the sputtering power is 52W and the deposition time was 120 min. The thickness of sputtering ZnO film is about 60 nm.

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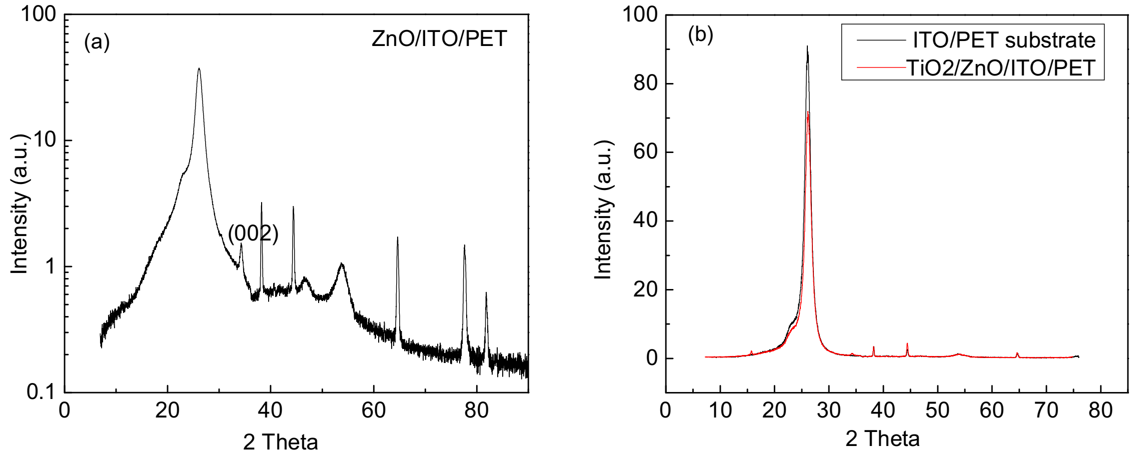

Fig. 1. (a) XRD pattern of Magnetron sputtering ZnO and (b) ALD TiO_2 films prepared on PET/ITO substrate.

TiO_2 film was prepared by atomic layer deposition (ALD). The substrate temperature was 80 °C. The reactive sources were diethylzinc and H_2O with pulse time of 0.5 s and 0.5 s, respectively. Carrier gas was N_2 and the purging time was 60s. The top electrode of Cu with diameter of 100 μm was fabricated by E-beam evaporation and the Cu film thickness is about 100 nm. So the device structure was PET/ITO/ZnO/TiO_2/Cu.

The crystal structure was characterized by X-ray diffractometer (XRD, Bruker D8 Discovery, Billerica, MA, Cu Kα). The surface morphology of ZnO thin films were measured by scanning electron microscopy (SEM LEO GEMINI 1530 (Zeiss, Oberkochen, Germany)) and atomic force microscopy (AFM Agilent 5500AFM/SPM), respectively. The cross sectional image of PET/ITO/ZnO/TiO_2 was analyzed by SEM. XPS surface and depth profile measurements were carried out to identify the chemical state of Ti, O and their ratio by using a Thermo K-alpha XPS (Thermo scientific, Waltham, MA). Depth profiling was carried out using 4 keV Ar^+ bombardments with an etching rate of approximately 0.7 nm/s. 4 level cycles were totally conducted and etch time was 10 s for each level cycle. The XPS analysis chamber was at a pressure of about 1×10^{-7} Pa. The energy resolution of the XPS was 1.17 eV (FWHM). I–V characteristics of the PET/ITO/ZnO/TiO_2/Cu structure were measured using a potentiostat system (Metrohm Inc., Riverview, FL). During the I–V measurements, a voltage bias was applied to the Cu top electrode while the ITO was grounded.

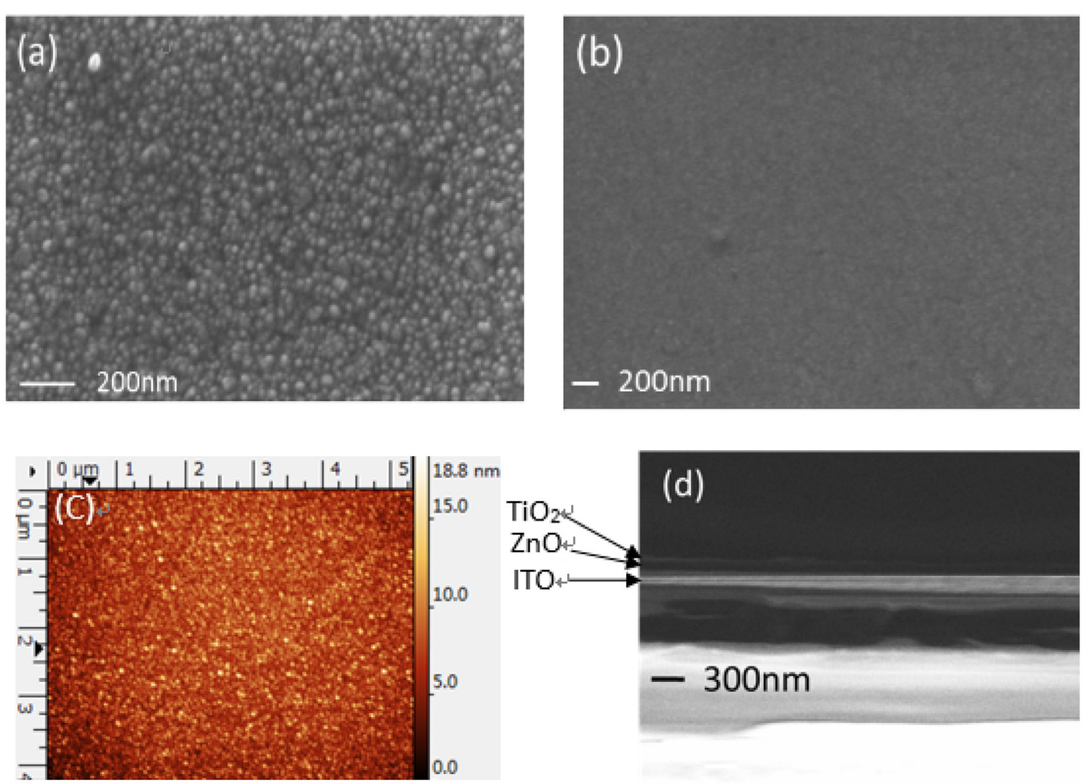

Fig. 2. Surface morphology of (a) ZnO film by SEM, (b) TiO_2 film by SEM, (c) ZnO film by AFM and (d) Cross sectional image of PET/ITO/ZnO/TiO_2 structure by SEM.