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Impact of annealing treatment on structural and dc electrical properties of spin coated tungsten trioxide thin films for Si/WO_3/Ag junction diode

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ABSTRACT

We report on the effect of the thermal annealing on structural and electrical properties of p-Si/n-WO_3/Ag junction diode. According to the XRD pattern, the WO_3 films exposed that the crystalline phase transformation of monoclinic to orthorhombic structure for an increasing annealing temperature. The SEM images show an abrupt change in the plate like grain growth and surface morphology. From the UV–visible analysis, the band gap energy decreases for the higher annealing temperature. The dc electrical characterization shows that the conductivity (σ_{dc}), activation energy (E_a) and pre-exponential factor (σ_0) values vary function of temperature. The Si/WO_3/Ag contact junction diode parameters of ideality factor (n), barrier height (Φ_B), leakage current density (J_0) and series resistance (R_s) were examined by the J-V method, Cheung's and Norde functions as a function of annealing temperature according to the thermionic emission method (TE). The values of n and Φ_B decrease with increasing annealing temperature and better the device performance on an optimized annealing temperature at 873 K. The temperature dependent of experimental n and Φ_B revealed the presence of inhomogeneity at WO_3-Ag interface. This behavior is modeled by assuming the existence of Gaussian distribution (GD) of barrier heights in temperature range 303–423 K.

1. Introduction

The p-n junction diode is an emerging technology that employs in industrial and academic fields of microelectronics and photovoltaic devices. In recent years, interest in research for the development of renewable technologies by eco-friendly and low cost n-type transition metal oxide semiconductor (TMOS) based p-n junction devices. The p-Si/n-TMO based diodes have attracted world for their better charge transport capabilities [1–5]. ZnO, TiO_2, SnO_2, MoO_3 and WO_3 are the most standard semiconductor metal oxides used in the optoelectronic devices. Among them, tungsten trioxide (WO_3) is used in many electronic devices owing to its tunable properties of chemical composition, surface morphological, optical absorption in visible range and high thermal stability [6,7]. To achieve a better film surface, porosity, crystal structure and phase modifications of WO_3 thin films, the various heat treatment (sintering, calcination and thermal annealing, etc.) processes are followed [8–10]. Predominantly, the annealing temperature influences on the electrical and optical properties of WO_3 owing to densification of the grains with higher packing density, subsequently minimize the lattice defects and other structural deformations [11–13]. Kumar et al. [14] reveals that the annealing temperature influence on the structural, electrical and optical properties of the thermally evaporated WO_3 thin films. Doucette et al. [15] grown multi-domained heteroepitaxial WO_3 films on Si (100) substrates using a (111)-oriented BaF_2 buffer layer at the WO_3-Si interface. Ahn group [16] improved crystallinity and enhanced light absorption in the long-wavelength region of the WO_3 thin films by varying annealing temperature and it was used for photo-electrochemical applications. The WO_3 films annealed at high temperature, exhibits structural and well developed grain size in the sol-gel process [17,18].

From the J-V characteristics of the p-n junction diode interface engineering process and charge transport mechanism usually deviate from the ideal thermionic emission (TE) model [19–22]. So that the main technological issue in the J-V characteristics at ambient temperature does not provide a detailed information about the conduction mechanism, charge transport mechanism across the p-n layers (Poole-Frenkel emission, hopping

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