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The photovoltaic impact of atomic layer deposited TiO_2 interfacial layer on Si-based photodiodes

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ABSTRACT

In present work, photocurrent, current-voltage (*I-V*) and capacitance/conductance-voltage-frequency (*C/G-V-f*) measurements were analyzed for the photodiode and diode parameters of Al/TiO_2/*p*-Si structure. The TiO_2 thin film structure was deposited on *p*-Si by using atomic layer deposition technique (ALD) and its thickness was about 10 nm. The surface morphology of TiO_2 coated on *p*-Si structure was observed via atomic force microscope (AFM). Barrier height (Φ_b) and ideality factor (n) values of device were found to be 0.80 eV, 0.70 eV, 0.56 eV and 1.04, 2.24, 10.27 under dark, 10 and 100 mW/cm^2, respectively. Some photodiodes parameters such as fill factor (*FF*), power efficiency (%η), open circuit voltage (V_{oc}), short circuit current (I_{sc}) were obtained from *I-V* measurement under different light intensity. *FF* and η were accounted 49.2, 39,0 and 0.05, 0.45 under 10 and 100 mW/cm^2 light power intensity, respectively. C^{-2}-*V* graph was plotted from *C-V-f* measurements and zero bias voltage (V_0), donor concentration (N_d), Fermi energy (E_F), barrier height (Φ_b) and maximum electric field (E_m) were determined from C^{-2}-*V* data for different frequencies. The electrical and photocurrent values demonstrated that it can be used for photodiode, photo detector and photo sensing applications.

1. Introduction

Metal-semiconductor (MS) contacts used for rectification have a wide application area such as organic-based solar cells, photodiodes, thin film transistors (TFTs) and some integrated circuits elements [1–4]. The MS contact theory provides understanding semiconductor-based devices, and also it is the basis of the physics of semiconductor-based devices in advanced electronic applications [5–8]. The interface states play a crucial role on contact properties of a metal/ semiconductor rectifying devices. Therefore, the surface treatment can be affected by photovoltaic characteristics [9]. Thin film structures, which have device applications, have been consistently investigated by using various techniques. Optoelectronic devices [10], photodiodes [11], solar cells [12], transistors [13], etc. have been improved by researchers with developments of thin films synthesis technique. In recent years, the optoelectronic devices with thin films have attracted a great deal of attention. The photodiodes are one of the most important of these devices because of their features. Considerable number of researchers have studied them to improve the performance of photodiodes [14–17]. Electrical parameters of diodes such as n, Φ_b and series resistance (Rs) can be impressed from the oxide layer[18]. Dökme [19] has fabricated Al/SnO_2/*p*-Si/Al diode, and have found that ideality factor and barrier height 1.54 and 0.81 at room temperature, respectively. Aydın et al. [20] have prepared Al/*p*-Si/Al diode with 2.5 nm thickness of TiO_2 interfacial layer as dielectric materials. They have found 2.96 and 0.66 eV for ideality factor and barrier height values of structure under dark condition. Accordingly, ideal Schottky barrier diode (*SBD*) theory may not be sufficient to explain the characteristics of *SBD* with interfacial layer. The impact of interface states on the *I-V* characteristics have been investigated by many researchers [21–23]. There are different methods for the materials synthesis. Among them, the atomic layer deposition (ALD) technique occupies very important place thanks to its advantages. Some of its outstanding advantages are synthesis materials on substrate homogeneously, terrifically good thickness control, large area stability and uniformity, self-limiting feature in very good quality[24]. Additionally of these advantages, under low temperature synthesis of material is low cost than fabrications at high temperature. These advantages of the ALD show that the future of the ALD is so promising for desired materials synthesis [25]. Each ALD cycles occurs in the four steps, which are first precursor pulse, purging reaction chamber, second precursor pulse and purging reaction chamber again [26] (Fig. 1). This process is repeated until the desired

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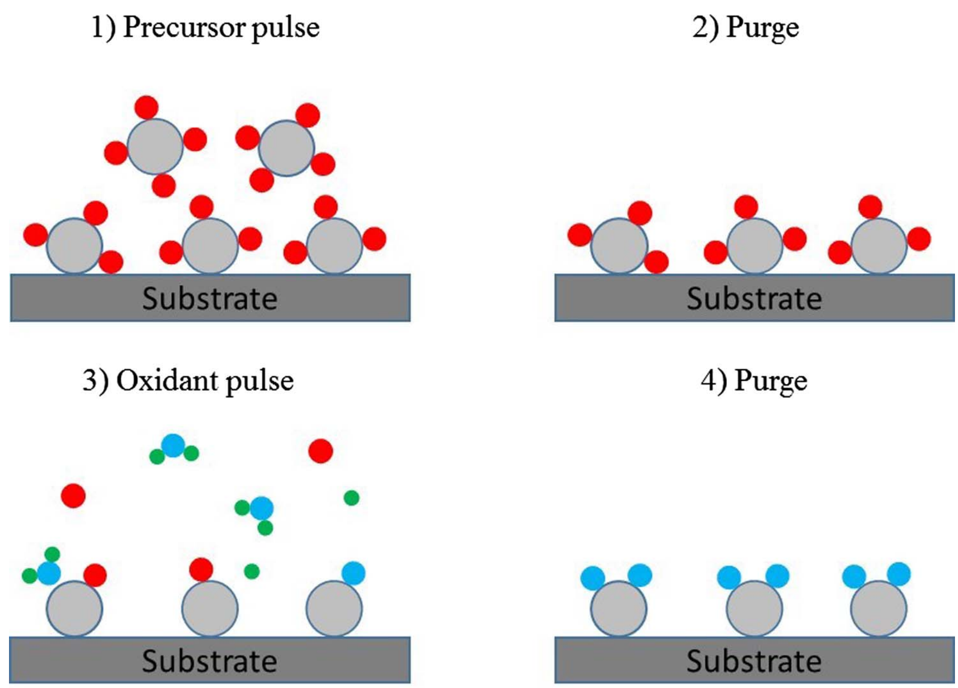

Fig. 1. Deposition process of ALD thecnique.

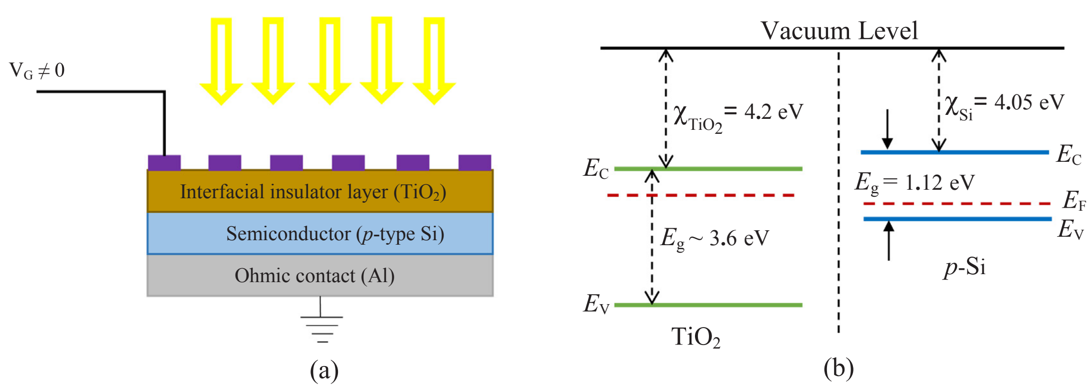

Fig. 2. (a) Schematical illustration and (b) energy band diagram before contact of the Al/TiO_2/p-type Si photodiode.

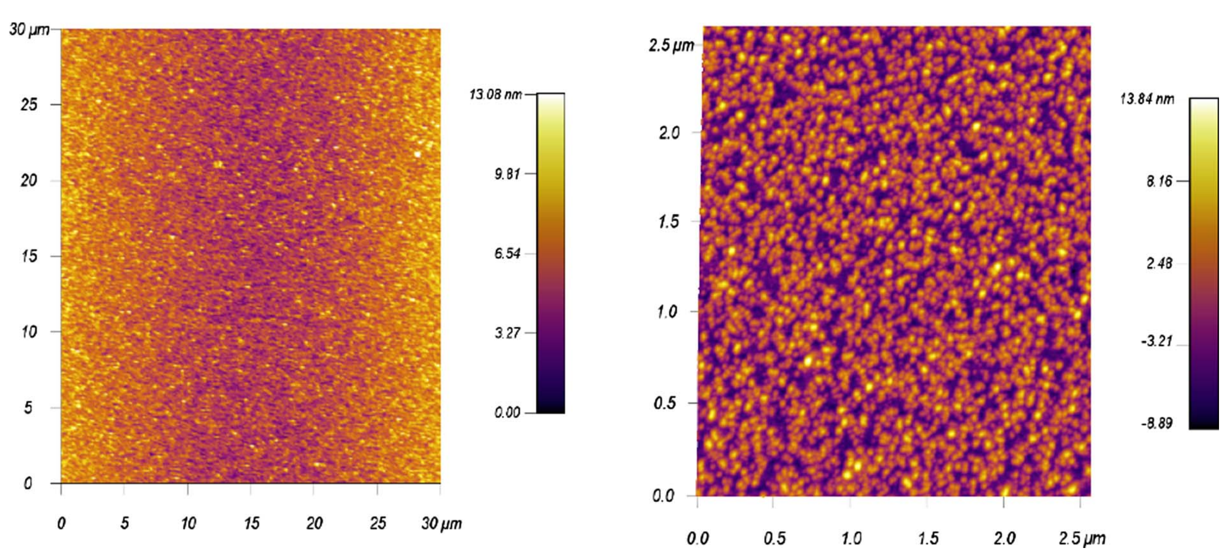

Fig. 3. 2D AFM surface images of the TiO_2 covered p-type Si.