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Deposition of Different triplet layers of materials by using pulsed laser deposition on laser textured (p-type) silicon wafer solar cell

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Abstract

In this research, TiO_2/ZnO/CdS, TiO_2/ZnO/CdS-Se triplet-layers anti – reflective coatings were deposited on a glass and textured (p-type) silicon wafers by using pulsed laser deposition (PLD) technique. The average surface roughness (Ra) was measured using atomic force microscope (AFM) and ranged between 1.8 nm and 6.07 nm. Spectral absorbance was found to be 2.49eV and 2.47eV for these triple layers respectively..

Keywords: **TiO2, ZnO, CdS, Se:** thin films; pulse laser deposition (PLD); Heterostructure..

1. Introduction

Solar photovoltaic energy conversion is a one-step conversion process, which generate electrical energy from light energy (Anderson, 2001). Many studies have shown that the performance of a single layer coating is not satisfying due to its narrow working spectral range. Double-, triple-, or even multiple-layer ARCs have better performance when referring to broadband SCs (Richards, 2003). Semiconductor nanoparticles have attracted much attention in recent years due to novel optical, electrical, and mechanical properties that result from quantum confinement effects compared with their bulk counterparts (Chen et al., 2011). Titanium dioxide (TiO2) is non-toxic and has a high photo-stability, its large band gap (3.2 eV), and it works in the ultraviolet region of the solar spectrum (Stephan et al., 2015). Zinc Oxide (ZnO) is wide band gap semiconductor; Nanostructured ZnO materials have drawn broad attention due to its wide range of applications in ultraviolet (UV) solar cells (Jiang et al., 2007). Cadmium sulfide (CdS), direct transition II–VI semiconductor, is considered as one of the most promising materials for photonic devices (Gaewdang & Gaewdang, 2004).

The use of TiO2 is limited by its absorption wavelength that lies in the ultraviolet region. Therefore, in hetero-structure of this nature, electrons generated from the conduction band of the narrow band gap semiconductors after photo excitation are transferred into the conduction band of TiO2 (Jana et al, 2014). Selenium exhibits good photoelectrical properties, high photoconductivity (Ruyle, 2009).

2-Experimental Procedure

Pulsed laser deposition was used to fabricate TiO_2, ZnO, ZnO-Se and CdS, CdS-Se films on p-Si substrates as shown schematically in Fig.1.

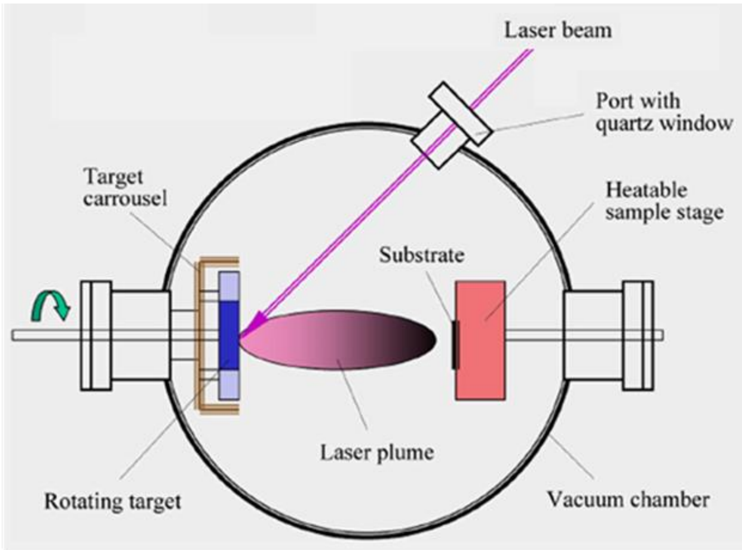

Figure 1. Schematic illustration of a pulsed laser deposition system.

The PLD chamber comprises a rotate target holder and a substrate holder. Pulsed Nd-YAG laser beam (λ= 1064 nm, pulse width = 10 ns, repetition rate = 1-6 Hz) is incident on the target at an angle close to 45°. The distance between the target and substrate is 3 cm. The chamber is evacuated by mechanical rotary pump and diffusion pump to a pressure 10^{-5} bar. The silicon wafer substrates were textured and cleaned with distilled water and ethanol solution. Sprayed silicon wafer by 25M HF solution for (15-20) minutes to obtain freckled surface and loading the Si wafer and glass substrate into the chamber. The TiO_2, ZnO, CdS, CdS-Se, and ZnO-Se target were fabricated by pressing powders separately of 99.99% purity in to 4mm disk. The laser ablation energy was (140mJ), repetition rate of 6Hz and 200 pulses for each material. The films were deposited in the substrate at 250°C. Figure (2) shows the three layers of different materials deposited on two samples of silicon wafer (p-type).

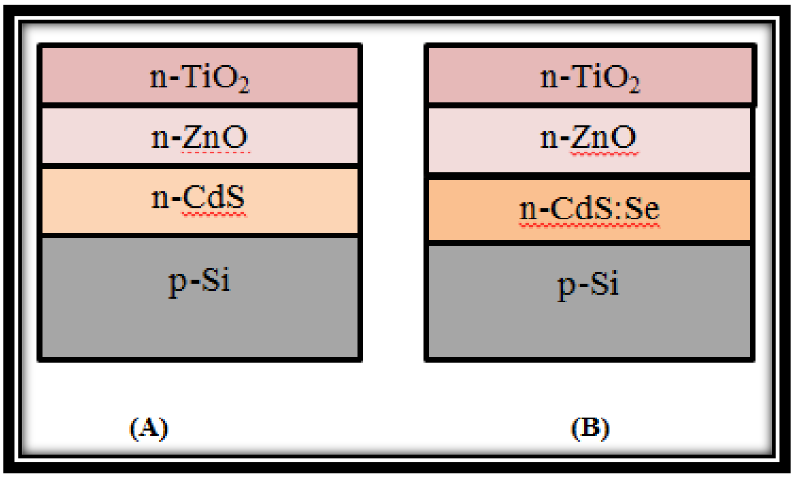

Figure 2. Schematic view of $TLARC_S$ (AR1, AR2 and AR3) on the Si (p-type) Solar cell.

3-Results and discussion

3.1 Optical properties

The optical characteristics of thin films give something about the physical properties such as absorbance, transmittance, and band gap energy determined by UV-VIS spectrometer (CECIL 2700). Absorbance spectra were recorded for TiO_2/ZnO/CdS and TiO_2/ZnO/CdS films as a function of wavelength ranged (280-880) nm. The absorbance increased after Se dopant, when the selenium was mixed with (CdS), as shown in figure (3).

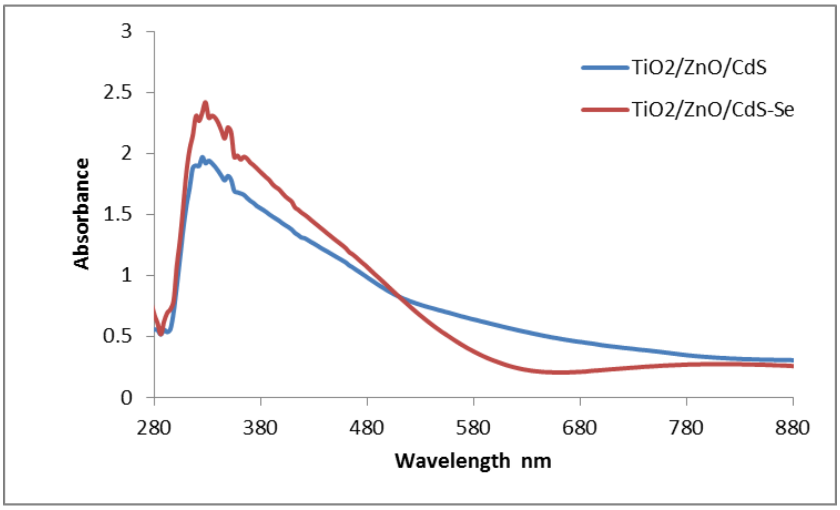

Fig.3. Absorbance spectra of TiO_2/ZnO/CdS & TiO_2/ZnO/CdS-Se thin films

This property of high absorbance makes it a good material for preparation solar cell when deposited this materials on silicon wafer (p-type). The optical band gaps of the films were calculated from the absorbance spectra. The absorption coefficient (α) is calculated using the equation (Clark& Kazmerski, 1980):

$$\alpha = 2.303\frac{A}{t} \;\ldots\ldots\ldots\ldots (1)$$

Where A is absorbance and t is the film thickness. The absorption coefficient (α) and the incident photon energy (hν) are related by (Shinde, et al., 2006):

$$(\alpha h\nu)^2 = A(h\nu - E_g) \;\ldots\ldots\ldots. (2)$$

Figure (4) shows the films transmittance. The optical transmittance of all films decreased when thickness was increased.

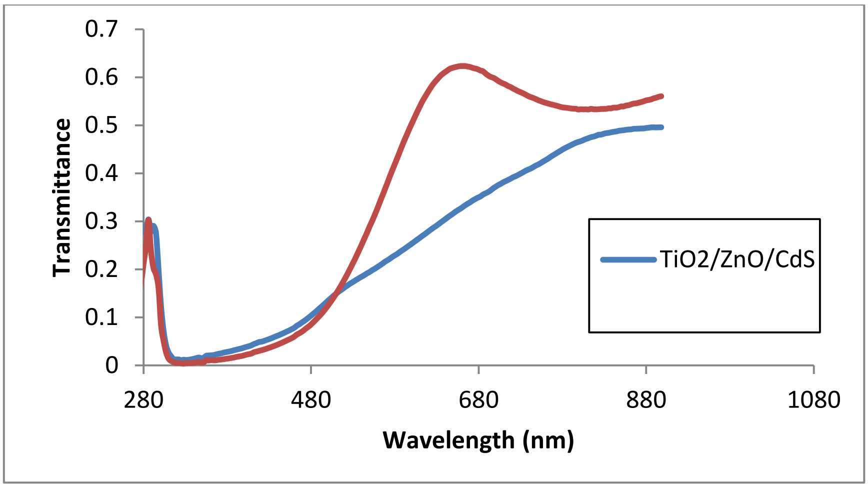

Figure (4) Transmittance Spectra of TiO_2/ZnO/CdS & TiO_2/ZnO/CdS-Se thin films

The typical plots of $(\alpha h\nu)^2$ versus hν for (TiO_2/ZnO/CdS) and (TiO_2/ZnO/CdS-Se) thin films deposited on glass substrate are shown in figure (5). Adding Se to the materials lead to decrease in optical band gap from 2.49 eV to 2.47 eV

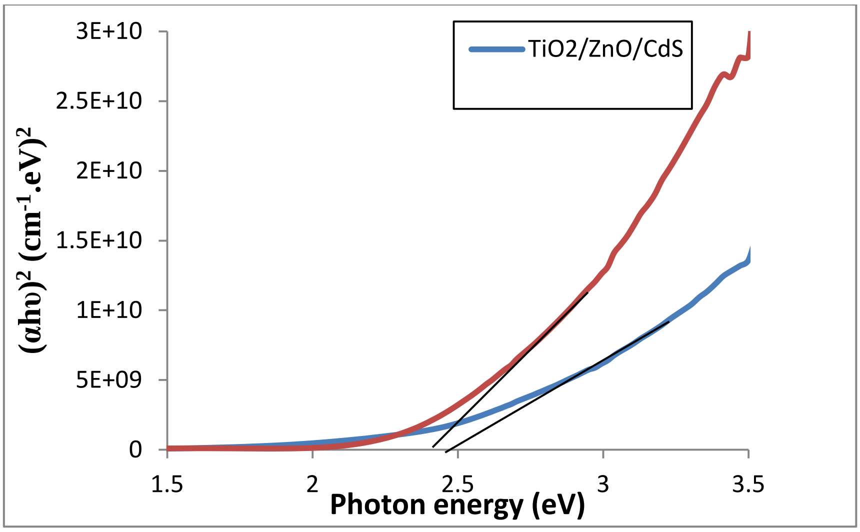

Figure (5): Allowed direct electronic transitions of (TiO2/ZnO/CdS) & (TiO2/ZnO/CdS-Se)

3.2 Solar Cell Morphology

The surface morphology of thin films is obtained by using an (AFM) image shown in figure (6). The image illustrates contrast in inhomogeneity of grains' surface of films graded three or four regions. The white regions in this figure represent the formation of agglomerated grains on the top of the other.

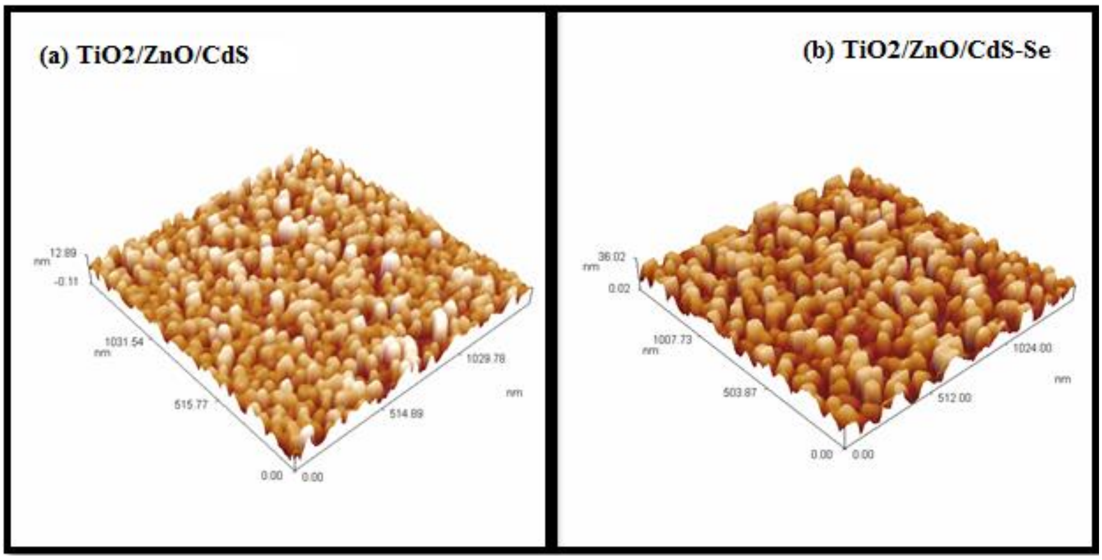

Figure (6) Image AFM of (a) TiO2/ZnO/CdS, (b) TiO2/ZnO/CdS-Se. On (p-type) silicon wafer.

Form the images; it can be observed that the surface of the films exhibit a confirmed degree of coarseness and the film became rougher when the selenium (Se) was doped.

4. Conclusions

The TiO2/ZnO/CdS and TiO2/ZnO/CdS-Se thin films had been successfully deposited by (PLD) method on glass and silicon wafer (p-type) substrate. The absorbance increased when selenium (Se) mixed at ratio 20% with Cadmium sulfide (CdS). AFM images also support the growth of grain size for the as-grown films and inhomogeneity films were observed.These thin films are highly absorbance in the ultra violet range and the absorption edge is in the visible range.

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