The Influence Of Polyvinyl Alcohol (PVA) in the Electrical Properties of CZTS Thin Films Solar Cell

N. Ezukwoke*, O.U Oparaku, S. A Ugwu, N.E Ajimah, M. O Ezea
Department of Electronic Engineering, University of Nigeria, Nsukka .
Email: nnabuike.ezukwoke@unn.edu.ng*, ogbonna.oparaku@unn.edu.ng, aniezichukwu.ugwu@unn.edu.ng, nnabueze.ajimah.pg80983@unn.edu.ng michael.ezea@unn.edu.ng.
*Correspodning author

Abstract- For a few years now, thin films of Copper Zinc Tin Sulfide (CZTS) have attracted significant research attention due to its earth-abundant constituent elements, non-toxicity, and as material capable of driving the development of low-cost, high-performance photovoltaics solar cells. In this work, novel CZTS thin films were deposited on non-conducting transparent glass substrate materials using low- cost chemical bath deposition techniques. Chemical bath deposition was conducted in a water bath at a depositing temperature of 100^{0C} and depositing time of 12hours. The precursor solution used for the film's growth was prepared from the mixture of copper sulfate used as source of copper (Cu), Zinc Sulfate source of Zinc (Zn), Tin Chloride source of (Sn), thioacetamide as the source of sulfur (S) and conducting polymer or synthetic metal ie polyvinyl alcohol (PVA) used as capping agent and electrical stimulant. After the precursor preparation, water bath chemical deposition was used to grow films of CZTS material on non-conducting glass slides. The as-deposited films were further annealed to the temperature of 200^{0C} after which the films were characterized using UV-VIS spectrometer, and X-ray diffraction machine, (XRD) which confirmed the pure kesterite nature of CZTS. From the results, the presence of polyvinyl alcohol (PVA) in the deposited films yielded an absorption coefficient of $2*10^7 cm^{-1}$ at the photon energy of 4.5eV and PVA concentration of 0.07M. It was observed also that the films showed a zero reflectance as the wavelength increased from visible region through the infrared region of the solar spectrum.
Keywords: *CZTS, PVA, Reflectance, Low-Cost, Absorption Coefficient.*

INTRODUCTION

Thin films of low-cost and non-toxic materials are one of the growing sectors of most of the photovoltaic industry [1]. This is the major reason CZTS is drawing much research attention because of its low capital cost and less environmental damage characteristics [2][3]. From the past works, it has been mentioned that one of the challenges confronting solar cell industries is to develop materials composed of earth-abundant and non-toxic elements that can be used to manufacture efficient and scalable photovoltaic devices [4][5]. However, CZTS thin film has been recently studied intensively since its inception as earth-abundant and environmental-friendly thin films solar cells [3][7]. The CZTS absorber layer has a direct bandgap energy of 1.4-1.5 eV and high absorption coefficients ($\geq 10^4$ cm^{-1}) [5][8]. The semiconductor properties of CZTS make it a promising material than other thin-film technologies like CIGS, CdTe, and organic thin-film. Currently, the deployment of CZTS films in solar cell fabrication is rapidly increasing because the theoretical Shockley-Queisser limit for CZTS (e)-based thin-film solar cell is over 30 %. From reported record, conversion efficiency is still 12.6 %, which is far from the theoretical limit [8]. Several methods and techniques have been carried out in the deposition of CZTS thin films for solar cell applications [9]. From previous work, most of the techniques used in the growth of CZTS were vacuum process based [9]. This vacuum process has been proven to be equipment intensive and complicated evacuation systems methods. CZTS thin films have been prepared by different researchers using several chemical route techniques such as spray pyrolysis, dc magnetron sputtering, sol-gel sulfurization method, pulse laser deposition, and electron beam evaporation [10][11]. Significant effort has been geared towards improving the conversion efficiency of CZTS via variation of some chemical and physical properties of the depositing materials and methods. The use of buffer layers and doping techniques are some of the prominent attempts to improve the potentials of CZTS films for solar cell applications [12]. The role of the buffer layer is to provide band alignment between the CZTS and window layer and reduces defect and interfacial strain due to the window layer. Most times, Cadmium Sulfide is frequently used as buffer layers because it improves interface with the absorber CZTS and has high transmission in blue wavelength region. However, the performance of CZTS has not given a reasonable improvement despite these efforts, in this work; we used CBD to synthesized CZTS in the presence of PVA as a synthetic metal and capping material. The depositing process was conducted in a water bath at room temperature.

MATERIALS AND METHOD

The CZTS films precursor preparation and deposition were carried out using 0.05M of Copper Sulphate for sources of copper (Cu), Zinc Sulphate for the sources of Zinc (Zn), and Tin Chloride for the sources of (Sn) all prepared in a 250ml glass beaker with distilled water. For the sulfide element, Thiacetamide salt was used. The thiacetamide was prepared in a 100ml glass beaker containing double distilled water, which was later, placed on a magnetic stirrer for 30minutes. In this case, the synthetic metal or conducting polymers used for capping was prepared from Polyvinyl Alcohol (PVA). This is an electronic plastic material which was prepared in a different concentration ranging from 0.04M, 0.05M, 0.06M, 0.07M to 0.08M in different 100ml beakers and was stirred for 30minute to obtain uniform solutions of PVA. Furthermore, the depositing solution was prepared by mixing the different concentrations of PVA solution in an equal volume ratio of 2:2:2:1:1 corresponding to Cu, Zn, Sn, S, and PVA respectively. After the mixture, CBD was used to grow the films on five different precleaned glass substrate materials. The precleaned glass substrate were inserted into a 250ml beaker containing the precursor solution, which was further placed in a water bath and allowed to deposit as shown in Fig.1 below. Before the deposition, the glass substrate surface went through surface engineering and preparation. This technique is a way to increase the absorption of films on the surface of the substrate. Finally, the as-deposited samples were annealed at an annealing temperature of 200^0C for an interval of sixty-minute to obtain a pure polycrystalline material.

Figure 1: Depositing Precursor Solution in a water bath during film growth.

RESULT AND DISCUSSION

X-Ray Diffraction Study

CZTS thin films were prepared by chemical bath deposition techniques. The quality of the grown films depends on parameters such as substrate temperature and concentration of the precursor solution. Another contributing factor to the ultimate quality of the films grown is the depositing time. Figure 1 below shows the XRD diffraction pattern of CZTS thin films deposited at different PVA concentrations. The most obvious diffraction peaks correspond to planes of (112), (220), and (312) which were observed at $2\Theta^0$ 28.05^0, $2\Theta^0$ 47.43^0, $2\Theta^0$ 62.50^0, respectively. The observed results are in alignment with polycrystalline CZTS with the kesterite structure phase[6]. The pure and clear formation from the XRD result showed the absence of impurity in the film. It was also observed that the diffraction peaks and the good quality of the films from the result is as a result of PVA in the CZTS deposition. The presence of PVA gave an improved pattern as shown by the peak intensity of the XRD result of fig.2.

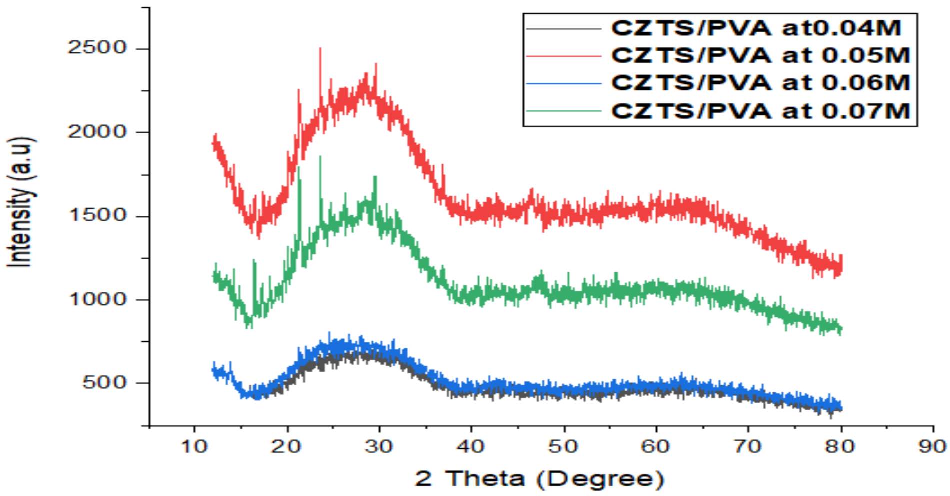
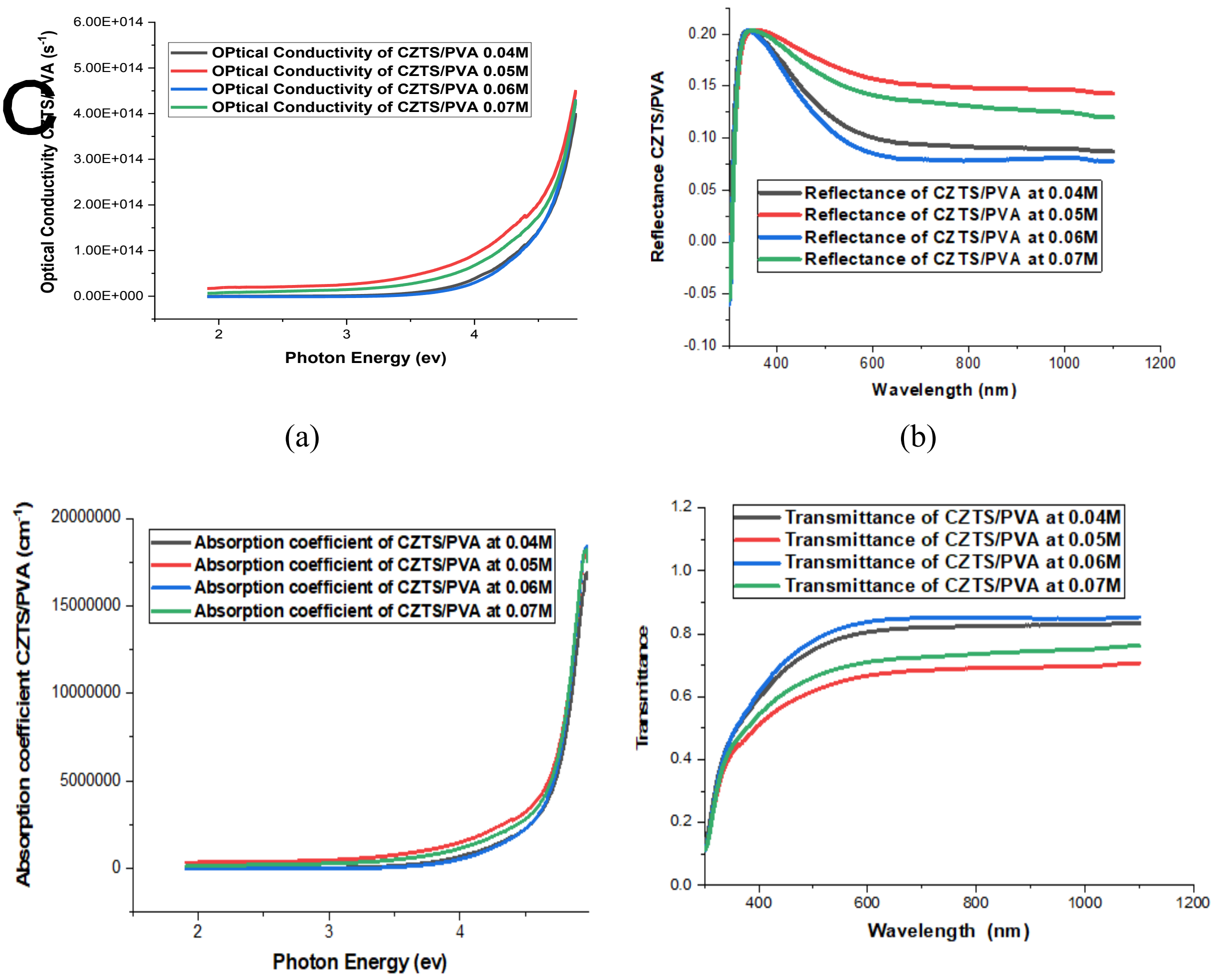


Figure 2: the XRD pattern of CZTS/PVA at different concentrations



(a) (b)

(c) (d)

Figure 3a shows the graph of optical conductivity with photon energy, 3b the graph of Reflectance with Wavelength, 3c Absorption coefficient CZTS/PVA with Photon Energy and 3d Transmittance with Wavelength.

The graph of the optical conductivity of CZTS/PVA against photon energy is presented in fig.3a. It was observed that CZTS/PVA optical conductivity at different concentration vary in the same manner as the photon energy in (eV). As the photon energy increases, the conductivity of the CZTS/PVA increases similarly. The optical conductivity increased from $0.00S^{-1}$ to $4.50*10^{16}S^{-1}$ for concentration of 0.05M PVA and $4.30*10^{16}S^{-1}$, $4.20*10^{16}S^{-1}$and $4.00*10^{16}S^{-1}$ for concentrations of 0.07M, 0.04M, and 0.06M respectively.

From Fig.3b, it shows that the reflectance of all the CZTS/PVA films is less than 0.1% in the wavelength range of 1—350nm. As the concentration of PVA increased from 0.04M through 0.07M at the wavelength of 400nm, the reflectance slightly increased to 0.05% of its initial value. It was observed that from the different concentrations 0.04M— 0.07M and wavelength 400nm—1000nm the reflectance of PVA decreased drastically to 0.002% of its former value. This low value of reflectance demonstrated that CZTS/PVA is a good absorber of the solar spectrum.

The graph of the absorption coefficient against photon energy was plotted as shown in fig.3c below. It was observed that the absorption coefficient of the sample similarly varied with the photon increasing from values of $0.00cm^{-1}$ to $2.0*10^7cm^{-1}$ at the photon energy range of 2eV to 4.5eV. The synthesized CZTS/PVA films of fig.3c demonstrated a very high absorption coefficient more than pure CZTS thin films. This has proved that the fabricated CZTS/PVA films are good for solar harvesting.

Fig. 3d, gives the transmittance (T) of the deposited CZTS/PVA thin films. From the transmittance graph, it was observed that the transmittance increased from the visible region to the infrared of the solar spectrum. The concentrations of PVA with 0.06M and 0.04M showed a significant increment in the transmittance more than other PVA concentration although varied in a similar manner.

CONCLUSION.

The CZTS/PVA thin films were synthesized by chemical bath deposition (CBD) method from Copper Sulfate, Zinc Sulfate, Tin Chloride, Thiacetamide, and synthetic metallic compound PVA. From the result analysis, the XRD confirmed that CZTS/PVA films obtained exhibited the kesterite structure of pure CZTS films. From Transmittance and Reflectance graphs against wavelength, it could be deduced that CZTS/PVA thin films are very suitable for solar cell applications. The optical conductivity plotted against photon energy demonstrated that there is a linear relationship between conductivity of the synthesized films and the photon energy.

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