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Growth and Characterization of PbTe Thin-film through Solvo Thermal Method

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Authors' contributions

This work was carried out in collaboration among all authors. Authors BAA and ANBK designed the study, performed the experiment, wrote the protocol and wrote the first draft of the manuscript. Authors MAA and IA managed the analyses of the study. Authors BAA, IA and MAA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The research considered the Solvo-Thermal method of growing PbTe on non-conducting glass substrate. Cadmium Sulphide thin-film was deposited and used as the n-type absorber layer. On the internal parameters studied, the PbTe nano-film has thickness of $0.143\ nm$ as measured through gravimetric analysis; the optical absorbance studied through the use of UV-750 Series spectrophotometer showed a stable absorbance within the visible wavelength (390 nm – 700 nm) and optical band gap energy of $0.22\ eV$ was obtained as extrapolated from the graph of $(\alpha h\nu)^2$ against $h\nu$. The I-V pattern were measured and plotted. The PbTe grown through this method therefore show a good Fill factor of 0.6755.

Keywords: Solvo thermal; PbTe; cadmium sulphide; optical band gap and fill-factor.

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1. INTRODUCTION

Among the technological material in thermo Photovoltaic energy conversion is Lead Telluride (PbTe) due to its low energy band gap of *0.27eV* [1]. The lead chalcogenide compounds have been the objects of numerous studies concerning thin film electro deposition from aqueous solutions. Recently, electro deposition has emerged as a simple, economical and viable technique to synthesize good quality films for device applications [2,3]. The strongly and non-degenerated carrier of PbTe wafers have proved its decrease resistivity with increase temperature [4]. This makes it a semiconducting thin film in nature. The nano-chalcogenide crystals which belongs to group IV-VI semiconductor [5] has many applications in nano-technology ranges from window coating, fibre optics (infrared lasers), thermoelectric materials and solar energy panels [6-10]. The low efficiency of ~5% has been recorded of thermoelectric generators. However other advantages, such as compactness, silent, reliability, long life, and long period of operation without attention, led to a wide range of its applications [11]. Among the absorber layers that show compactness with PbTe are TiO_2, *CdS*, e.t.c. Among these absorber layers, the CdS deposited through Ammonia-free CBD have shown a low resistivity and allow wide area deposition [12] of thin films. This research considered the growth of CdS/PbTe heterojunction solar cell through solvo-thermal method and studied its external parameters.

2. MATERIALS AND METHODS

The non-conducting glass substrates were wholly immersed in a clean beaker containing the mixture of concentrated H_2SO_4 and H_2O_2 in the ratio *3:1* (Piranha cleaning) for 30 minutes. They were rinsed with deionized water and dried through spinning. This is to clean the substrate, remove oxygen and ensures stickiness of the film layer to its surface during printing of *PbTe* film through drop casting. The tellurium powder obtained through C-Man labouratory was dissolved in the mixture of *NaOH* and Glycerol and heated to temperature of $150℃$ in a three neck conical flask as shown in Fig. 1.

The precursor $PbNO_3$ was injected into the flask and heated for 24 hours for formation and pulverization of *PbTe*. The pulverized *PbTe* was dispersed in deionized water, printed on the substrate through Drop Casting, dried through spinning and annealed at $200℃$ for 30 minutes.

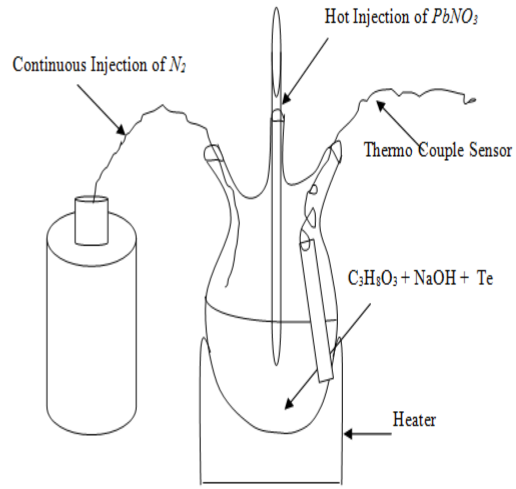

Fig. 1. Solvo-thermal preparation of PbTe

3. RESULTS AND DISCUSSION

3.1 Thickness

The thickness of the nano-layer was obtained through gravimetric method. The area covered by the layer was measured, followed by the mass difference, m between the empty substrate and the grown PbTe and used the expression:

$$Thickness = \frac{m}{\rho A} \quad (1)$$

Where ρ is the density of PbTe given as $8.164gcm^{-3}$ [13] and A is the area of substrate covered by the nano-layer. The thickness of the layer was found to be $1.43 \times 10^{-10}m$.

3.2 Optical Band Gap

The optical absorbance of the film was observed through UV-750 Series. The absorbance as shown in Fig. 2, show that the film absorbs well within the visible range (390 nm – 700 nm).

The absorption coefficient, α was obtained through Beer Lambert equation [14];

$$\alpha = 2.303 \frac{\text{absorbance}}{\text{thickness}} \quad (2)$$

The point of intersection on $h\nu$-axis of extension of the straight line drawn from the most linear part of the curve of $(\alpha h\nu)^2$ against $h\nu$ graph gave the band gap energy of the deposited PbTe. Therefore, the band gap energy of 0.22eV was obtained.

3.3 I-V Characterizatioin

I-V characterization of the PdTe layer was studied through the use of a Solar Simulator; Model 4200-SCS (Semiconductor Characterization System) under irradiance of 1.5 AM (1000 Wm^{-2}) and the I-V graph in Fig. 4 was obtained.

The power produced by a cell in watts can be calculated from the I-V graph using;

$$P = IV \tag{3}$$

Equation (3) was used to obtain the maximum power, P_{MAX} through current, I_{MP} and voltage, V_{MP} and total power, P_T through I_{sc} and V_{OC} as obtained from the Fig. 4. Using:

$$FF = \frac{P_{MAX}}{P_T} = \frac{I_{MP} * V_{MP}}{I_{SC} * V_{OC}} \tag{4}$$

The fill factor of 0.6755 was obtained.
The efficiency of the cell was found to be 0.894% using;

$$\eta_{max} = \frac{P_{max}}{P_{in}} \tag{5}$$

Where P_{in} is taken as the product of irradiance of the incident light, measured in W/m^2, with the surface area of the solar cell (m^2).

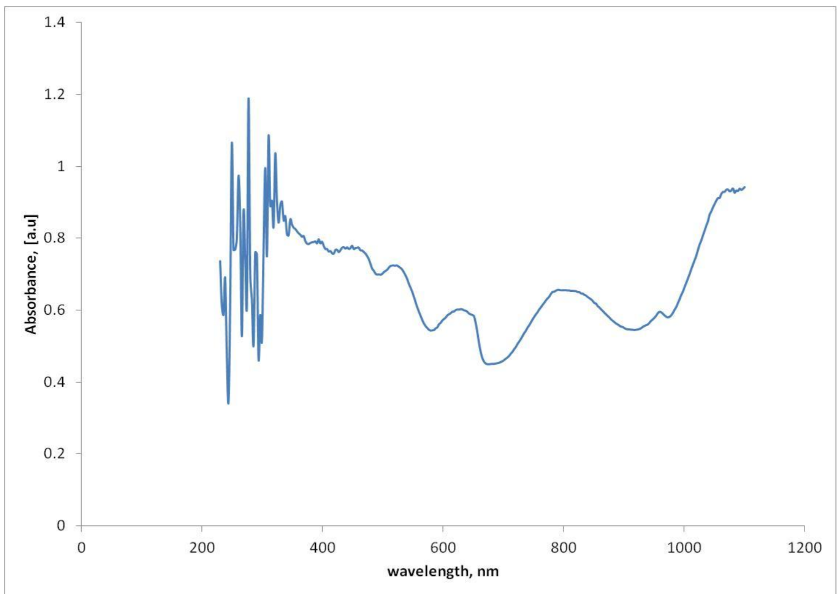

Fig. 2. Optical absorbance of PbTe from ultra-visible analysis

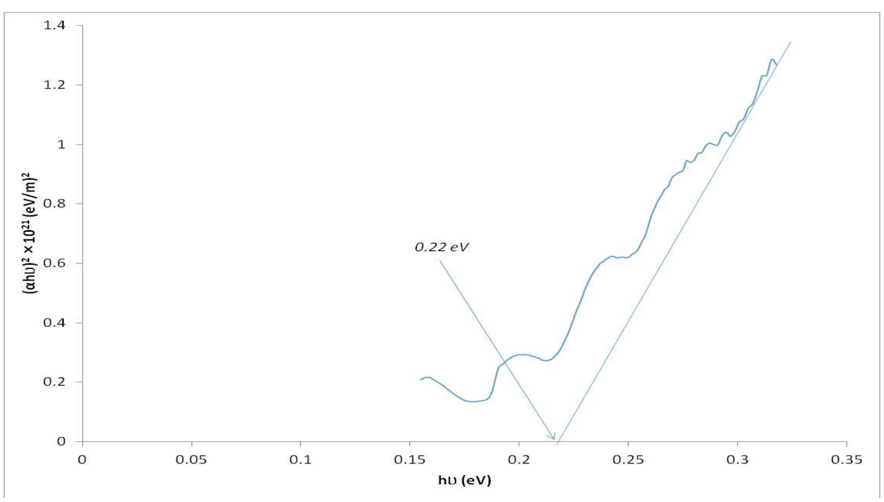

Fig. 3. Band gap energy

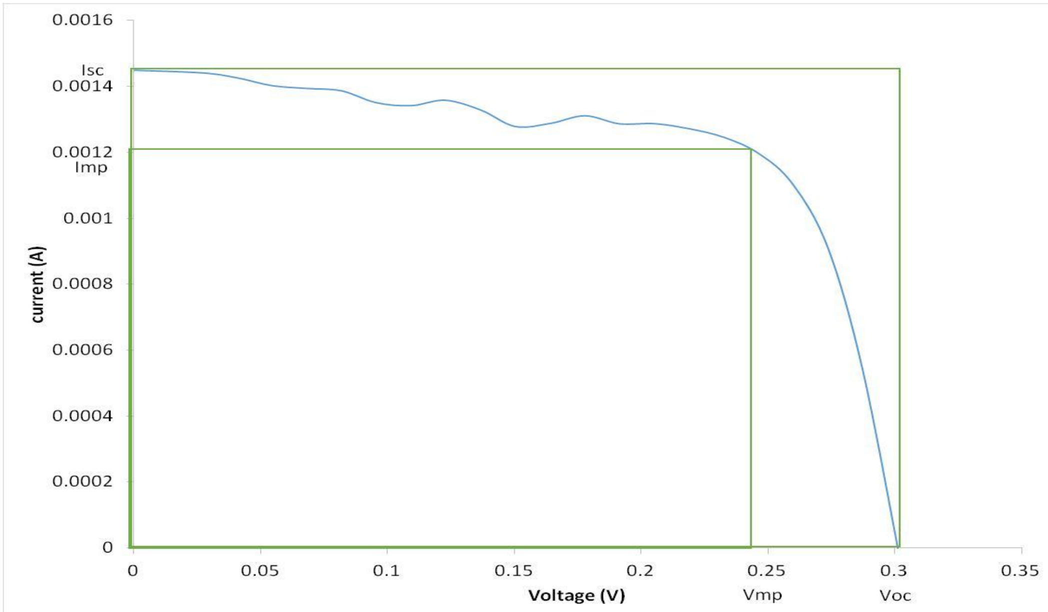

Fig.4. I-V characteristics under illumination

4. CONCLUSION

The PbTe films deposited through solvo-thermal method shows a film thickness of $1.43 \times 10^{-10} m$ and the band gap energy of $0.22eV$. These explain the nano structure of the film with the optical band gap energy in the neighborhood of values reported by other researchers, $0.25eV$ to $0.30eV$ [1]. The solar cell has a fill factor of 0.6755. This value is above 0.5 and thus proves the CdS/PbTe solar cell deposited through this method to be a good one.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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