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

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 UV-750 Series spectrophotometer showed a stable absorbance within the visible wavelength (390nm – 700nm) 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.

KEY WORDS:

Solvo Thermal, PbTe, Cadmium Sulphide, Optical Band Gap and Fill-factor.

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.

Materials and Method

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

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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 figure 1.

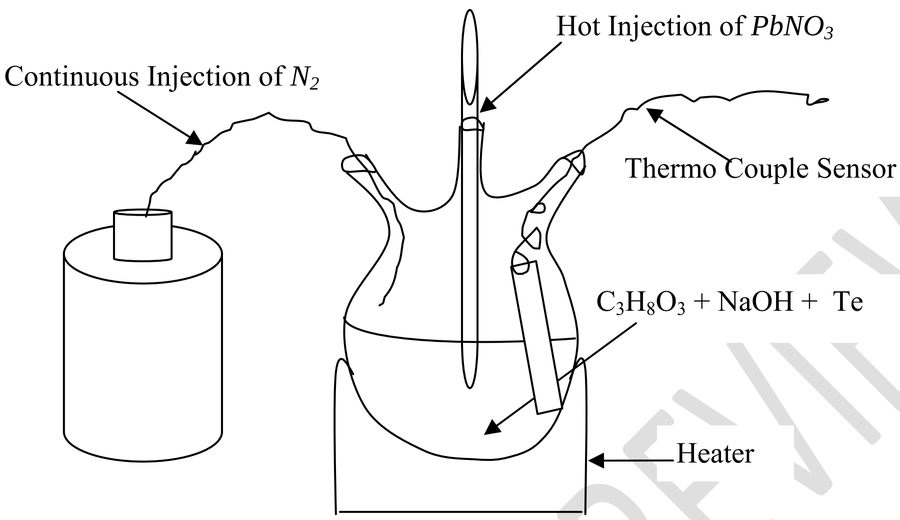

Figure 1: Solvo-Thermal Preparation of PbTe

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.

Results and Discussion

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:

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

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

Optical Band Gap

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

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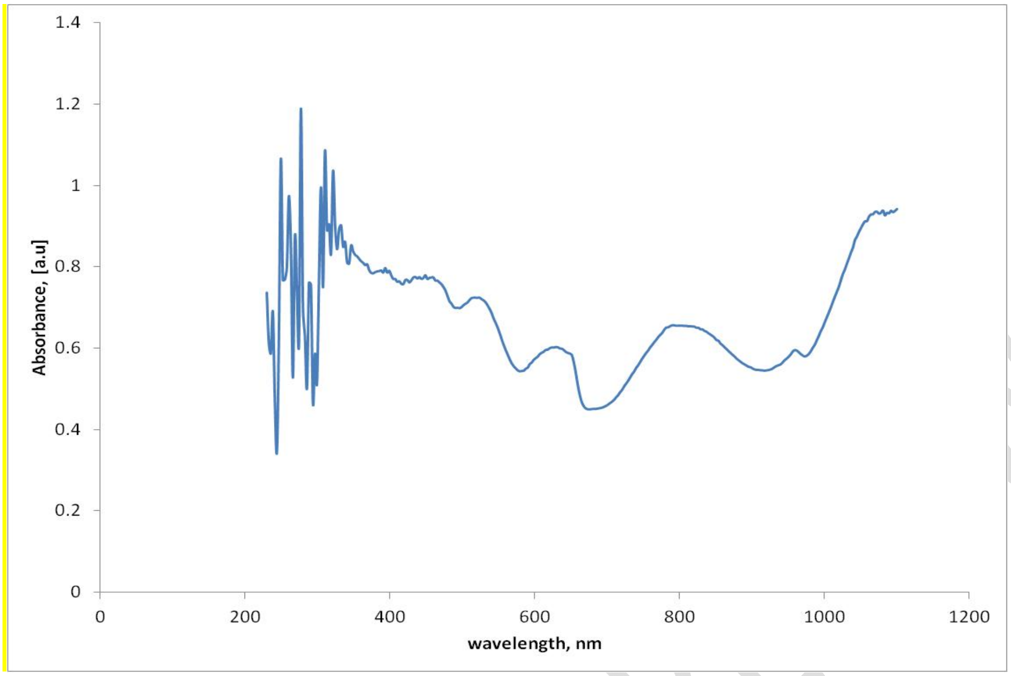

Figure 2: Optical Absorbance of PbTe from Ultra-Visible Analysis

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

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

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.

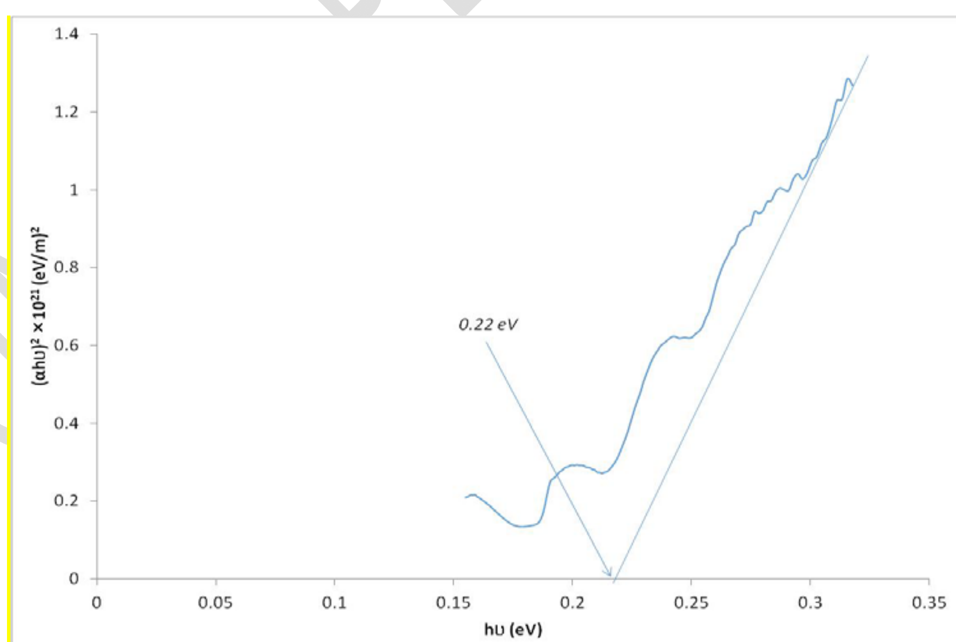

Figure 3: Band Gap Energy

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 figure 4 was obtained.

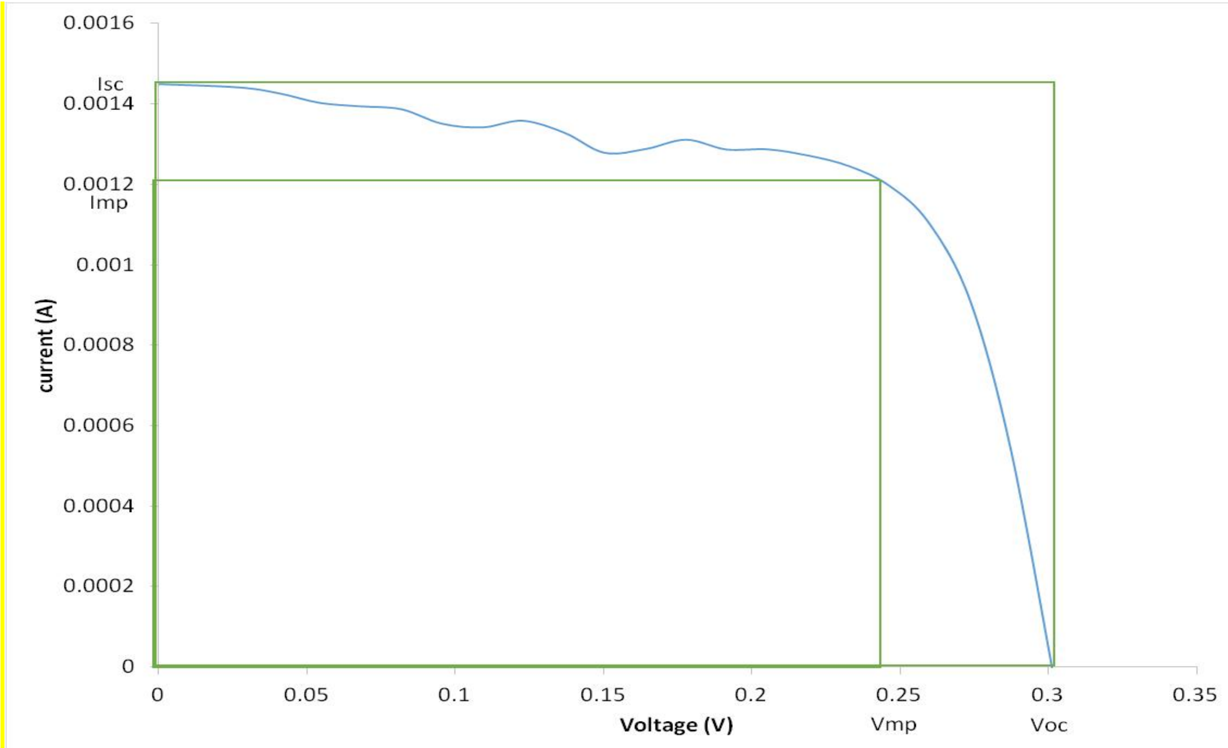

Figure 4: I-V characteristics under Illumination

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

$$P = IV \qquad (3)$$

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 figure 4. Using:

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

The fill factor of 0.6755 was obtained.

The efficiency of the cell was found to be 0.894% using;

$$\eta_{max} = \frac{P_{max}}{P_{in}} \qquad (5)$$

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).

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 $0.22 eV$. These explain the nano structure of the film with the optical band gap energy in the neighborhood of values reported by other researchers, $0.25 eV$ to $0.30 eV$ [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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