Cut-line Analysis and Parameters’ Extraction of Zinc Telluride Absorber Material based Multi-layer Solar Cell

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Abstract In present paper the ZnTe (Zinc Telluride) solar cell with heterojunction structure is developed and its electrical performance are explored. The ZnTe act as an absorber type layer, CdS (Cadmium-Sulphide) is the buffer layer and ZnO (Zinc-Oxide) is the window type layer in our solar cell. The numerical studies were done using Silvaco-Atlas which is a mathematical device-simulator. The ZnTe solar cell is simulated and various devices parameters such as open circuit voltage, fill factor etc. are extracted on different absorber-layer thickness sweeping from 0.5 to 2.5 µm keeping the thickness of other layers constant. This is followed by cutline investigation of the Zinc Telluride solar cell so as to comprehend the device’s physical science as photovoltaic cell. The solar cell is examined via a parallel (i.e. horizontal) cut-line drown inside ZnTe absorber type layer the of photovoltaic cell positioned at the junction of the absorber type and buffer type layer. The ZnTe solar cell shows good performance with 62.89% fill factor.

1. Introduction

The solar energy as of today is the best alternate renewable source of energy and the photovoltaic cells are the best for the capturing sunlight, an ecofriendly and renewable form of energy. The thin film photovoltaic cell built on semiconductor are enormously effective and affordable devices. The solar cells function is that of converting solar energy to electric current or electric form of energy. The photoelectrons produce light, photons contain energy that differs according to the wavelength of the light. In the semiconductor materials the photos are able to generate electric current when they are carrying enough energy so as to incite a loosely bound electron (after the electron acquires sufficient energy) present in the valence band to the conduction.

For designing a solar-cell the mathematical simulation models are tools of vital importance. Their importance can be understood from the fact that all the understanding of solar cell operation and all the needed solar cell improvements for future applications are very often contributed by these models [1]. Semiconductors solar cell based especially on group II-VI elements are leaders/best in the realization of affordable photovoltaic cells. Zinc telluride (ZnTe) shows a band-gap of 2.23eV to 2.28 eV [2] and the reported affinity of electron is at 3.73 eV [3] & zinc blend type of crystalline structure.

The first-generation solar cells are implemented using wafers. These cells are of single crystal structure. The thin films and semiconductor deposition with use of glass substrate characterised the second generation of the solar cell. In the solar cells which are based on semiconductors the photons which have energy lower than energy band gap of absorber layer material are not absorbed and are
lost, thus there is energy wastage. The third generation of solar cells are characterised by intermediate band solar cell. The intermediate band is created through alloying of the host and mismatched elements [4]. In the present work Zinc telluride solar cell is studied using the parameters [5-7], simulation is performed in silvaco atlas device simulator for the solar cell.

The present paper is arranged in four sections beginning with introduction as Section-1. Further, Section-2 represents structure of solar cell, materials utilised in diverse layers of cell, furthermore it (cell) is presented by analysing the of performance of Zinc Telluride based solar-cell and parameter extraction [8]. Afterward, the horizontal cutline internal analysis [9] is demonstrated in Section-3. Finally, significant results are briefed in Section-4.

2. Electrical characterization of Zinc Telluride Solar cell

The device characteristics are observed using Silvaco Atlas as device simulator. Silvaco being a 2-D simulator presents a very detailed device physics. In the simulator user defined materials are allowed, a variety of model parameters are also included for example SRH (Shockley-Read-Hall) model, Poole-Frenkel mobility model etc., for model calculations mesh is used. High density of meshing results in better accuracy with an extended run time.

The solar-cell can be simulated in the photovoltaic cell very efficiently. The accuracy of the solar cell simulation while modelling in Silvaco software attributes to the amalgamation of the availability of various types of optical propagation model [10] which are extremely accurate and capability of device simulator. The figure 1 represents the solar-cell simulated in the present paper. The nature and purpose of the solar cell are the two major factors according to which optical propagation models are selected and are absolutely dependent on it.

The figure 2 (a) below represents current-voltage graph of Zinc-Telluride/Cadmium-Sulphide/Zinc Oxide solar cell [11,12]. The photovoltaic cell is irradiated thru AM 1.5 (1 sun). The incident photon/s start to produce the charge carriers and the current starts to flow. The current voltage graph of a photovoltaic cell principally represents a graphic description amid photovoltaic device’s current and voltage at specific state of the illumination. The plot trails the universal current-voltage shape of any solar-cell.

Open circuit voltage (V_{oc}) is the highest value of voltage provided via a photovoltaic cell while its connection’s aren’t fixed at all to a external load. The curve in figure 2 (b) between the V_{oc} and absorber thickness represents that as the absorber thickness is increased open-circuit voltage increases simultaneously. The V_{oc} displays rectilinear increase as thickness of absorber layer is increased from 0.5-1.0 µm and 2.0-2.5 µm it remains constant between 1.0-1.5 µm. The highest magnitude obtained is 1.89 V at an thickness of 2.5 µm.
Figure 2. Characterisation plots of (a) Cathode Current v/s Anode Voltage at Zinc-Telluride layer of 1.5 µm, (b) $V_{oc}$, (c) Fill Factor & (d) $J_{sc}$ as a function of absorber layer thickness for Zinc-Telluride Photovoltaic cell.

The figure 2 (c) represents the $J_{sc}$ curve for the Zinc-Telluride based solar-cell. The curve shows the variation of $I_{sc}$ density with respect to variation in the Zinc telluride thickness i.e. absorber thickness. The above curve represents the fact that the $J_{sc}$ increases with the absorber thickness. As expected, current density ($J_{sc}$) increases as absorber thickness is increased. In the solar cell, we define current density to study how much current can be generated in photovoltaic cells because of it’s normalized by means of area of our active layer (including metal electrode).

The figure 2 (d) represents the curve between the FF (fill factor) and the absorber layer thickness. FF is an important parameter representing relation among real max. power delivered via a photovoltaic cell under steady operating settings & is equal to the product between $V_{ov}$ & $I_{sc}$. Values of fill-factor present quality of photovoltaic cell. The nearer is the magnitude of fill-factor to unity, means additional power could be delivered through photovoltaic cell making fill-factor a significant parameter for a solar cell. The typical values in general for the solar cells are in between 0.7 to 0.8, in the above graphical representation shows that the fill factor increases with the absorber thickness with fill factor values varying from 0.54 to 0.68 for a ZnTe cell when thickness is varied from 0.5 to 2.5 µm.

3. Internal Analysis

In the earlier section the ZnTe cell was simulated and its corresponding parameters such as Voc, FF etc. were extracted. Here in the present section the internal investigation of the solar-cell is made so as
to understand, explore and examine the internal developments linked to the architecture. This understanding and thoughtful investigation of the device physics help to analyse and appreciate the behaviour of the devices i.e. solar cells in depth. This analysis in turn helps to prove the influence or role of each layer in the solar cell specially with respect to the solar-cell performance.

Starting with the electric field, electric field variation in volt/cm of the device is shown in figure 3. The electric field is further more established between absorber type and buffer type layer (at junction) maximizing towards right near to the electrode and drops in value as the distance rises from junction which settles the fact that majority of carriers continue to be concentrated in the juxtaposition of electrode, at top of buffer layer. The valance band energy is represented in figure 4. The photons create electron hole pairs when light is incident of the device, the created electron move towards the conduction band (CB) from valance (VB) for the correct device operation.

![Figure 3. Variation of the applied electric field (V/cm) in layers of solar cell](image)

![Figure 4. Layer-wise valance band energies distribution for ZnTe cell.](image)

The figures 5 (a) & (b) below represents the variation of the electron concentration & the electron current variation. In the presented device the CdS layer is buffer layer and ZnTe is absorber layer. The maximum electron current density obtained is 1.4 A/cm².

![Figure 5 (a)](image) ![Figure 5 (b)](image)
The purpose of absorber type layer in the thin film photovoltaic cell is to capture incident photon/s and produce charge carriers. Whereas, function of buffer is to form a junction with absorber type layer & to transport the photoelectrons.

Conclusion

The present paper focuses on the study of the Zinc telluride solar. At first an already presented ZnTe based solar cell is simulated and its analytical and cutline analysis is also performed so as to explore, investigate and understand the internal device physics of the three solar cells. Parameter such as electric field, concentration etc. are also extracted for analysis and verification of the solar cell performance. Optimized results are achieved with a fill factor of 82.54%. From these fundamental outcomes, it’s established that enhanced performance can be comprehended from ZnTe solar-cell and can deliver a base for upcoming progress of Solar-cells which are based on Zinc Telluride materials.

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