# Photocurrent Efficiency of CdS/CdTe Based Inorganic Thin-Films Solar Cell

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*Abstract:* **Thin film solar cells contain multiple thin film layers of photo voltaic materials and having the advantages of low cost, high stability, good efficiency. Thin film solar cells have the potential to replace traditional Si p-n junction solar cells. In this paper, we have reported the use of CdS window layer (50 nm thickness) in CdTe based solar cell. The designed solar cell was fabricated using thermal evaporation technique on 2.5 x 2.5 cm$^2$ ITO coated glass substrate. The thickness of main absorbing layer of CdTe was kept at 1 µm. The Keithley electrometer was used for the measurement of current-voltage characteristics of the devices. The device was illuminated with solar simulator (Xe- source of light). The light intensity was adjusted to 100 mW/cm$^2$. Absorption spectra of CdS thin film was measured using UV-Vis-NIR spectrophotometer in the wavelength range of 200 nm to 1200 nm. The Efficiency of solar cell was observed about 13.16%**.

**Keywords:** Efficiency, UV-Vis-NIR Spectrometer, Solar Cell

## 1. INTRODUCTION

Nowadays, the compound semiconductor materials have been widely used in various fields like energy, environmental and biomedical. Among this widely used composite semiconductor, CdTe has attracted more attention compared to other materials due to its suitable direct-energy band-gap i.e.1.45 eV at room temperature, high absorption coefficient and higher chemical stability. CdTe is good for research purpose because it is low cost technologies for large area production of solar cells. Therefore, high quality CdTe thin films are presumed to be an ideal optical material and widely used in various electronic and large area optoelectronic devices like solar cells, infrared windows, photo detectors, LEDs, lasers etc. Photovoltaic cell converts photon input into current or voltage. It generates voltage or current when sunlight or photon is injected in it. We can use a photovoltaic solar cell in less calibrate exhilaration uses like computer, watches and remote power etc [1-5].

The photocurrent efficiency of the thin film solar cells significantly depends upon the quality and thickness of the window layer. The standard solar cell needs optimized thickness of window layer between the absorber layer and the transparent front contact layer to improve efficiency. It drives out the photo generated carriers with minimal losses while coupling light to the junction with minimum absorption losses, yielding a highly efficient solar cell. Thin film heterojunction solar cells provide more light towards the junction as it has wide band gap buffer layer in contrast with optimal low bandgap absorber layer. The lattice mismatching and difference of thermal expansion coefficient between absorption layer and window layer should also be less [6-13]. By analyzing all these aspects we have selected CdS as a window layer. This layer also works as electron transport layer in the designed solar cell structure. For hole transport layer we have selected $MoO_3$. The final designed solar cells have the structure of ITO/CdS/CdTe/$MoO_3$/Al.

## 2. EXPERIMENTAL DETAILS

The Schematic diagram of designed and fabricated solar cell is shown in fig. 1. Initially ITO coated glass substrate of size 2.5 x 2.5 cm2 was cleaned by sonication method and with acetone for 15 minute and then rinse it with DI water. The CdS thin film of 50 nm on indium tin oxide (ITO) coated glass substrate was deposited by the thermal evaporation technique (Model: BC-300 HHV) at room temperature. The absorber layer of CdTe of thickness 1 µm was deposited using thermal evaporation technique. Further, hole transport layer (MoO3 of thickness 50 nm) and Al metal contacts were deposited.

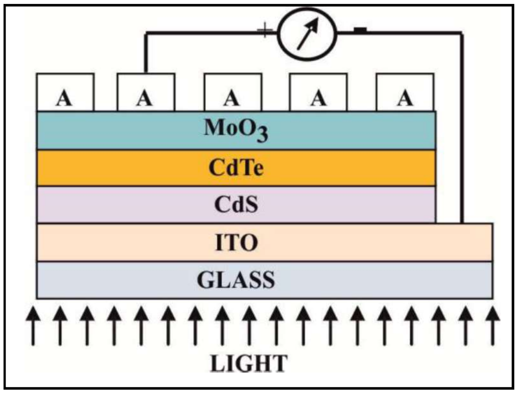


**Figure 1**: Schematic diagram of designed solar cell

The Keithley electrometer was used for the measurement of current -voltage characteristics of the devices. The device was illuminated with solar simulator (Xe- source of light). The light intensity was adjusted to $100 mW/cm^2$. Absorption spectra of CdS thin film was measured using UV-Vis-NIR spectrophotometer in the wavelength range of 200 nm to 1200 nm.

## 3. RESULT AND DISCUSSION

### *3.1 Optical characterization*

Optical performance of CdS thin layer was examined using absorption spectra. The band gap was estimated using the transition rate equation for direct band gap semiconductor [14]. The absorption coefficient for direct transition is given by the Tauc's equation:

$$\alpha h\nu = A\,(h\nu - E_g)^n \qquad [1]$$

where hν= photon energy, α = absorption coefficient, $E_g$ is the band gap energy, A= constant, n= ½ for the allowed direct band. The exponent 'n' depends on the type of transition and it may have values 1/2, 2, 3/2 and 3 corresponding to the allowed direct, allowed indirect, forbidden direct and forbidden indirect transitions, respectively.

The absorption spectra and transmission spectra of CdS thin film (thickness = 50 nm) are shown in fig. 2 and fig. 3, respectively. The absorption spectra show the absorption edge near about 560 nm. The transmission spectra show that CdS film is transparent in visible (560 nm – 780 nm) and near IR region, which clearly shows the application of CdS thin film as a window layer in solar cell design. Optical band gap of CdS thin film was calculated using Tauc's relationship and the plots of hν vs. $(\alpha h\nu)^2$ are shown in fig. 4 . The value of band-gap is 2.38 eV for Cadmium Sulfide.

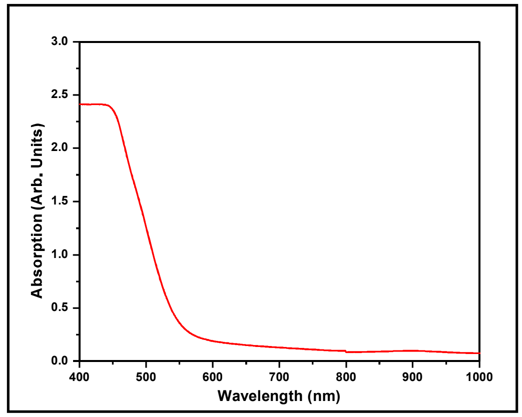


**Figure 2:** Absorption spectra of CdS thin layer (50 nm)

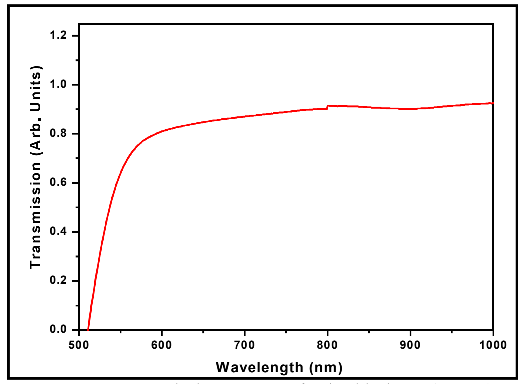


**Figure 3**: Transmission spectra of CdS thin layer (50 nm)

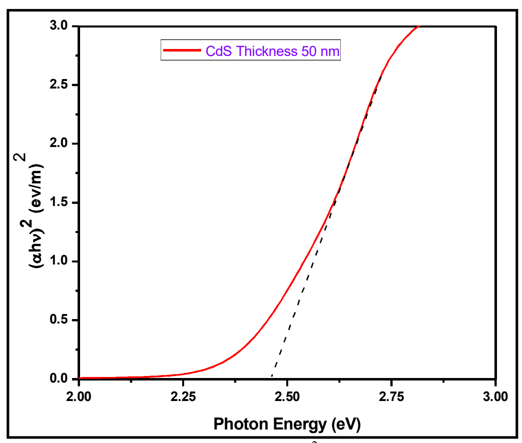


**Figure 4**: Photon energy versus $(\alpha h\nu)^2$ plot for CdS thin film of thickness 50 nm.

### *3.2. Photocurrent Efficiency*

J-V curves provide the information required to configure a solar system so that it can operate as close to its optimal peak power point as possible [15]. The J-V characteristic of the fabricated solar cells is shown in fig. 5.

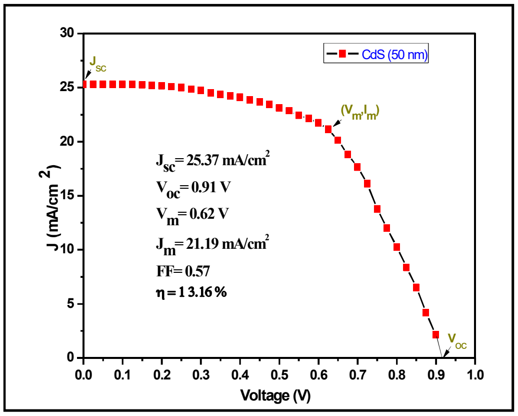


**Figure 5:** Current density and voltage curve for designed solar cell with 50 nm thicknesses of CdS layer

From the equivalent circuit of solar cell, the current produced by the solar cell can be expressed as:

$$I = I_L - I_D - I_{SH} \tag{2}$$

where $I$ is the output current of the solar cell, $I_L$ is the photo generated current, $I_D$ is the diode current and $I_{SH}$ is the shunt current. The current through these elements is governed by the voltage across them which can be expressed as:

$$V_j = V - IR_S \tag{3}$$

where $V_j$ is the voltage across both diode and resistor $R_{SH}$, $V$ is the voltage across the output terminals (volt), $I$ is the output current and $R_S$ is the series resistance (Ohm).

By the Shockley diode equation, the current diverted through the diode is:

$$I_D = I_O \left\{ exp \left[ \frac{V_j}{\eta V_T} \right] - 1 \right\} \tag{4}$$

where $I_0$ is the reverse Saturation current (ampere), $\eta$ is the diode ideality factor (1 for an ideal diode), $q$ is the Elementary charge, $k$ is the Boltzmann's constant, $T$ is the Absolute temperature, and $V_T = \frac{K_T}{q}$ is the Thermal voltage.

The value of solar current is dependent upon the physical size of the solar cell. If the junction size is larger than $I_L$ and $I_0$ will be large but same time Rs will be reduced, so it is not easy to predict the solar current with respect to physical size of solar cell since it will depend crucially on the grid design. To account for the dominance of the currents, the characteristic current density is expressed as follows:

$$J = J_L - J_O \left\{ exp \left[ \frac{q(V+J_{rs})}{\eta KT} \right] - 1 \right\} - \frac{V+J_{rs}}{r_{SH}} \tag{5}$$

where $J$ is the current density, $J_L$ is the photo generated current density, $J_0$ is the reverse saturation current density and $r_{SH}$ is the specific shunt resistance. It has been observed that the efficiency of the designed solar cell is 13.16% when the thickness of CdS layer was 50 nm.

## 4. CONCLUSION

CdTe based inorganic thin film solar cell with CdS window layer and $MoO_3$ hole transport layer was successfully fabricated. The thermal evaporation technique was used to deposit different layer of the designed solar cell. Optical properties of CdS layer thin film were also investigated. The band gap was measured using Tauc's relationship by plotting the curve between hν and $(\alpha h\nu)^2$. Photocurrent efficiency of the fabricated solar cell was investigated using solar simulated illuminating with light of $100 mW/cm^2$. Using the J-V characteristics, FF and efficiency were calculated. When the thickness of CdS layer was kept at 50 nm then we observed the efficiency  13.16 %. Thus CdS/CdTe based solar cell will be an important applicant for global low-cost solar cells market in future.

## 5. ACKNOWLEDGMENT

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