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# Study of Fabrication Process and Performance Analysis of the CdS/ CdTe Based Photovoltaic Cell

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***Abstract***
*Fabrication of CdS/CdTe based heterojunction photovoltaic cell has been undertaken to explore better light conversion efficiency. We have developed a photovoltaic cell using glass coated with Indium doped Tin Oxide (ITO) which works as transparent conducting oxide (TCO). ITO coated glass has promising prospects of enhancing the efficiency of the photovoltaic cell. ITO layers are known to be employed as anode terminal due to the negative polarity they possess compared to the whole PV cell; here, we have employed it for the same function as the front layer. During fabrication of the photovoltaic cell, the deposition of nanoparticles of CdS and CdTe layer is undertaken through doctor-blade method. We have employed pure CdS as window layer for its high band gap of 3.8 eV (particle size: 8 nm) and CdTe as absorber layer due to its high optical absorption coefficient with high mobility, good carrier lifetime and enhanced crystallographic properties. The CdS window layer and CdTe absorber layer together constitute a p-n junction where the CdS window layer captures high intensity photons and transmits the photo-excited electron to CdTe absorber layer, thereby leading to photo-current output, which serves as a base to explore and test its further applications. To obtain band gap of respective CdTe and CdS nanoparticles, optical characterization is used. Silver paste is used as rear contact to form anode terminal having good conductivity and providing better mechanical support to the photovoltaic cell.*
***Keywords:*** *Photovoltaics, Thin Film*

## 1. Introduction

Photovoltaic characteristics inherent in semiconductor materials have made it possible for the mankind to generate electricity from light energy sources i.e., sunlight. Crystalline Silicon based Solar Cells are much preferred in the current market due to the mechanical supportive properties it presents, although the cost of manufacturing high performance efficiency Solar Cells based on Crystalline Silicon is much higher owing to the fabrication machinery and the steps required for the same. The photovoltaic characteristic properties of crystalline silicon are quite fixed, and the scope of enhancement in its Power Conversion efficiency is limited, beyond the most accepted theoretical prediction of about 33% efficiency as reported by A.R. Zanatta in 2022 [1]. Meanwhile, the II-VI and III-V compound semiconductors have a variety of options to work with, based upon their different optical characteristics; this diversity makes these compound semiconductors an important topic of study for current as well as future research groups. The compound semiconductor industry is set to grow at a rate of 10.9% for the period 2023-2030 as forecast by the latest market reports [2]. The variety of options in compound semiconductors

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with different optical characteristics provides a better opportunity to manipulate their observed characteristics for the purpose of achieving better Power Conversion Efficiency (PCE). Moreover, the Technology of Solar Cells based on the compound semiconductors offers far lower cost on account of fabrication facilities as well as much less amount of time (approx. 4.5 hours), when compared to the Solar Cells based on the crystalline silicon [3]. Amongst the different options of compound-semiconductors-based Solar Cells, while the maximum Power Conversion efficiency of 68.9% has been achieved for the option of GAAS-based Solar Cell technology in 2022, the costs incurred for the GAAS technology option can be quite prohibitive for commercial use, whereas the CdTe -based solar cells are mostly used in commercial market owing to the distinctly lower costs with 22.1% Power Conversion efficiency in laboratory conditions and 18% efficiency for average commercial module [4,5]. Also, the latest predicted efficiency of CdTe -based Photovoltaic Solar Cell has been observed to be near 44% [6]. Overall, the Technology of CdTe-based photovoltaic Solar Cells offers the greater ease of fabrication at lower costs and more cost-effectiveness, in comparison with the technology of crystalline-silicon-based photovoltaic Solar Cells. The CdTe, as the absorption material in these photovoltaic Solar Cells, shows excellent absorption and conversion of sunlight into electrical energy due to its lower 'direct bandgap' value of 1.45 eV, closer to the ideal 'direct bandgap' value of 1.5 eV for photovoltaics, as well as distinctly better absorption coefficient as compared to crystalline silicon [7]. Due to the amount of focus on the CdTe-based Photovoltaics, it is quite crucial to identify the methods and practices which can enhance the overall performance efficiency of the CdTe -based solar cells for research as well as academic purposes. Hence, establishing a standard laboratory-based method for CdTe photovoltaic fabrication becomes quite important for the analytical study of physical fabrication. Also, since there is insufficiency of data for the used materials and ratios of the materials used in simple lab methods, we should have more focus towards the research over the quantitative perspective of fabrication. It is quite important to keep the particle size of layers used in photovoltaic cells up to nanoparticle level, since the nanostructure-based solar cells are expected to show better light conversion efficiency [8]. In this work, we have studied the fabrication steps of CdS/ CdTe -based PV and undertaken the analysis of open circuit Voltage performance based on it.

## 2. Experimental

In electronics, the photovoltaic effect is the outcome of the impact of photons on a photosensitive p-n junction maintained in reverse biasing circuit. The photons fall on the junction's n-side (i.e. n-doped CdS, in our experiment), where the excess of electrons is present; the photon-excited electrons then move (owing to the potential-difference between n-side and p-side) towards the junction's p-side (i.e. p-doped CdTe, in our experiment). In this process, the holes simultaneously emerge at the n-side, creating a vacancy (at the junction's n-side) to be filled by the photon-excited electrons carrying higher energy than the bandgap of the semiconductor. In sufficient sunlight, figure 1 the photons, which have higher energy than the semiconductor bandgap, will set off the migration of electrons out of the device to the circuit [9].

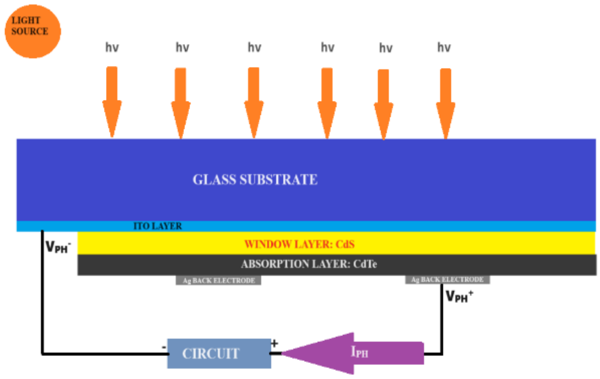


**Figure 1** **Shows the Structure of CdS/ CdTe Photovoltaic Structure for Representation Purpose**

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The CdS nanoparticles were synthesized in the laboratory, using precursors cadmium acetate (Cd(CH3COO)2.2H2O) and thioacetamide (CH3CSNH2). Cadmium acetate was stoichiometrically mixed with thioacetamide in distilled water to a volume of 800 ml and stirred in magnetic stirrer and later microwave irradiation was applied. Optical, structural and morphological characterization was done by S.K. Choubey et al [10]. Particle size was found to be around 6-8 nm and the optical bandgap was found to be 3.84 eV. CdTe nanoparticles were synthesized with microwave assisted irradiation using cadmium acetate (Cd (CH3COO)2.2H2O) and Tellurium (Te) as precursors. 0.5M cadmium acetate solution was mixed with Tellurium solution. Tellurium solution was made by mixing tellurium powder in distilled water, ethylene glycol and hydrazine hydrate in a ratio of 7:3:1. Structural and morphological characterization was done for the obtained nanoparticles. The crystalline size of the CdTe nanoparticles obtained was around 72 nm [11]. There are various methods by which the second-generation photovoltaics are fabricated like Vapor Evaporation, Vapor Deposition technique (VTD), Physical Vapor Deposition (PVD), Closed Space Sublimation (CSS), Sputtering, Spin Coating, Screen Printing, Spray Pyrolysis, Closed Space Vapor Transport, Metalorganic Chemical Vapor Deposition (MOCVD), RF sputtering and Electrodeposition [3,12]. Efficiency of CdTe based solar cells are known to be greatly dependent upon their quality of uniformity of deposited layers. Youn-Ok Choi et al. described the relation between optical absorption and thickness uniformity of the same showing that better thickness uniformity improves the overall performance for the CdTe based Solar Cells [12]. Process parameters such as temperature and pressure during deposition, annealing time and CdCl2 passivation treatments post deposition have significant out-turn to the layer surface uniformity and hence also performance of the solar cell [13,14]. To deposit the nanoparticles on the TCO, doctor-blade method was employed. For this purpose, a slurry or a colloidal paste was made by mixing small amount of the crushed nanoparticles with few drops of binder [15]. Annealing was performed for about 6 hours at temperature 150˚C in an oven. Later silver paste was used on the CdTe surface as contact layer and it works as cathode [16]. The flowchart shown in figure 2 is a representational pathway to summarise our methodology in more generalised manner.

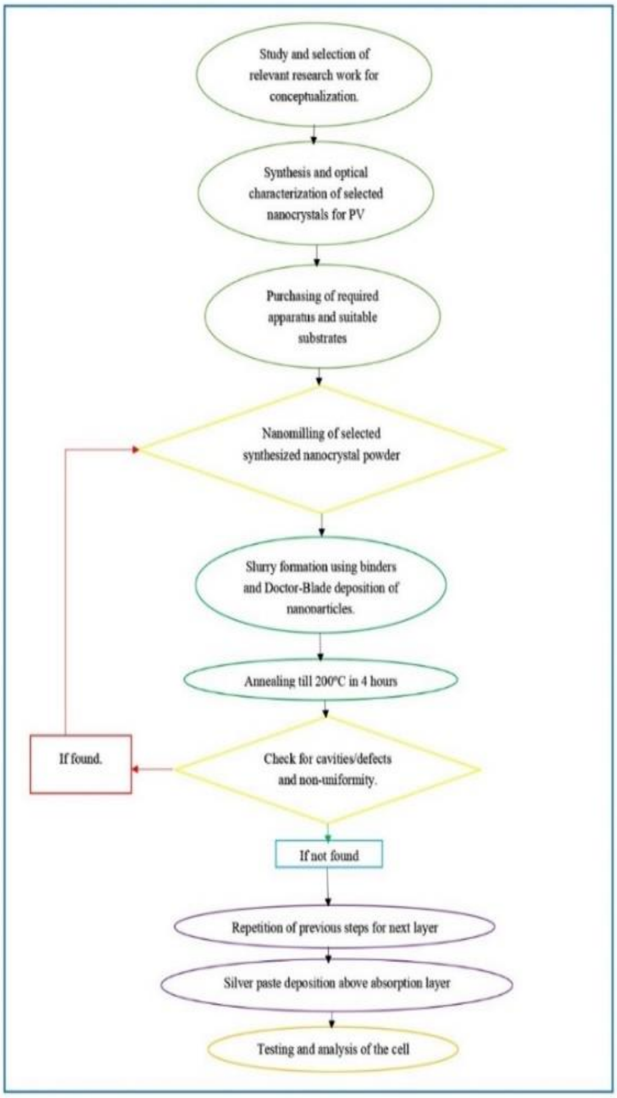


**Figure 2 Flowchart of CdS/ CdTe Based Photovoltaic Fabrication**

## 3. Results and Discussion

### 3.1 Nanoparticles

The CdTe and CdS nanoparticles were structurally, morphologically, and optically characterized after synthesis figure 3. XRD analyses of the nanoparticles were performed in the 2θ range from 10 to 800 using Rigaku X-ray diffractometer with CuKα radiation (λ = 1.5418 Å). The average nanoparticle size is calculated by the Debeye-Scherrer formula,

$$D = \frac{0.9\lambda}{\beta \cos \theta}$$

Where, θ is the Bragg's angle, μ is the incoming ray's wavelength, and β is the full width at half maximum. For the undoped CdS the average nanoparticle size was about 6-8nm and for the undoped CdTe nanoparticles, crystalline size was found to be 72 nm. [10,17] By plotting the graph for $(\alpha h\nu)2$ vs $h\nu$ and projecting the linear area of the curve to the energy axis, the energy band gap of the CdS nanoparticles was determined.

$$\alpha h\upsilon \propto A(h\upsilon - Eg)^{1/2}$$

Where A is a constant, hv is the photon energy, Eg is the direct band gap energy, and α is the absorption coefficient [18]. Using a UV-visible spectrophotometer (Rayleigh UV-2601), the absorption spectra of CdS nanoparticles is displayed in Fig. 3. The band gap value is indicated by the graph's X-axis intercept in Figure 4. It is determined that the optical bandgap is 3.84 eV [18].

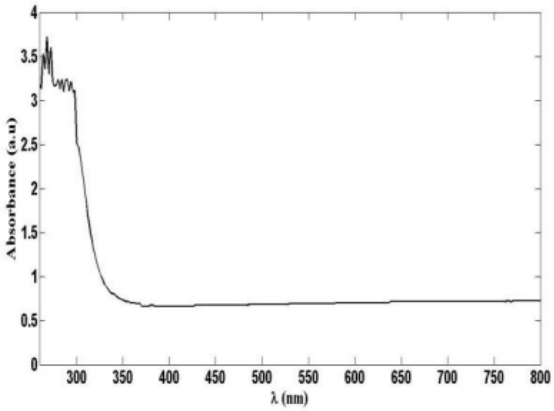


**Figure 3 Spectrum of Absorption for CdS Nanoparticles**

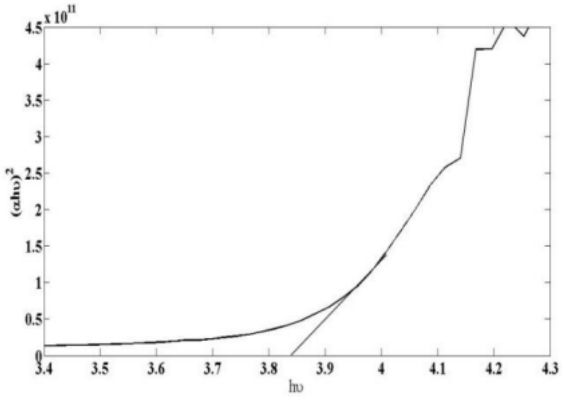


**Figure 4 The Optical Band Gap of CdS Nanoparticles**

### 3.2 Voltage Output (Voc)

The maximum open-circuited voltage reading was about 44.5 mV in the 100-Watt incandescent bulb light at a distance around 10 cm from the cell. The voltage reading was decreasing as the bulb was taken farther away from the cell and vice-versa.

## Conclusion

CdS and CdTe nanocrystals were synthesized using microwave assisted irradiation. The XRD patterns were analyzed for checking structure and optical characteristics of the obtained crystals. The average particle size of CdS nanoparticle was around 6-8 nm and for CdTe, it was around 72 nm. The CdS/ CdTe based photovoltaic was fabricated using doctor-blade method of deposition to deposit the thin films in a top-down approach of nanoparticle synthesis with Nano milling method for the miniaturization of crystals. The open-circuited voltage reading was obtained using a multimeter under a 100-watt incandescent bulb giving 44.5 mV in 10 cm distance.

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