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Photovoltaic Cell Prepared from Nanoparticles of CdS/CdTe on ITO Substrate and its Characterization

Aditi Priyadarshini[1], Kumar Nikhil[2], R.K. Mishra[3], K. P. Tiwary[4]
[1]UG- Department of Electrical and Electronics, Birla Institute of Technology Mesra, Patna campus, Bihar, India.
[2,3]Assistant Professor- Department of Electrical and Electronics, Birla Institute of Technology Mesra, Patna Campus, Bihar, India.
[4]Assistant Professor- Department of Physics, Birla Institute of Technology Mesra, Patna Campus, Bihar, India
Emails: *btech15086.20@bitmesra.ac.in[1], k.nikhil@bitmesra.ac.in[2], rajkumar.mishra@bitmesra.ac.in[3], kptiwary@bitmesra.ac.in[4]*

Abstract
CdS/CdTe based photovoltaic cell has shown the markable efficiency. The CdS/CdTe nanoparticles are being synthesized and deposited on the ITO glass plate. ITO glass has a large bandgap of about approximately 3.6 eV and is suitable to use in the fabrication of photovoltaic cell. As ITO behaves as negative terminal, it is used as front layer for capturing the light intensity. During fabrication of photovoltaic cell, the deposition of Cadmium sulphide and Cadmium telluride nanoparticles layer was done by brush painting technique. The CdS layer is used as window layer and CdTe acts as absorbing layer. The window layer's primary function is to absorb light particularly in the visible region of the spectrum to generate electricity. The CdS layer forms p-n junction with the CdTe layer. The nanoparticles of CdS and CdTe have been synthesized first and optical characterization was carried out using UV-visible spectroscopy to obtain bandgap of CdTe and CdS. Structural characterization was being obtained by XRD. The size of the nanocrystallites of CdS and CdTe have been obtained by Debye Scherrer equation and the result was 1.64 nm and 4.09 nm respectively. The CdTe layer which was used as absorbing layer consists of high optical absorption coefficient with high mobility, good carrier lifetime and an enhanced property of crystallographic. Silver paste was used as a back contact for good conduction.
Keywords: *Cds/Cdte; I-V Characteristic; Photovoltaic Cell; XRD Analysis.*

1. Introduction
Cadmium telluride (CdTe) is a crystalline compound. It is stable crystalline compound and it is formed by the combination of cadmium and tellurium. Cadmium telluride (CdTe) comes under II – VI group in a periodic table. It has direct band gap of ~1.45eV. It has very high optical absorption of value as $10^5 cm^{-1}$. It has p-type conductivity which makes it an ideal material in the use of PV application. Solar cells (thin filmed) are proved as the promising material and has the wide scope of device which designed in the terms of junction formation, types of substrates, sizes of substrate and the performance. [1] Cadmium telluride (CdTe) is the most common device used

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as the thin filmed solar cells. It is used as the semi-conducting material in photovoltaics. It forms a p-n junction in solar PV cell with cadmium sulfide material. It is cost effective. As we know in today's scenario the consumption of world's energy is growing drastically. This will lead to scarcity of the world's energy and because of this reason it encourages the world to find the alternative of it such as renewable energy sources (solar cell). As we can see that there are high demand of fossil fuel and is consumed by the world which brings the attention to use renewable energy instead. Fabrication of thin film solar cell is proved to be most prominent use, reliable, durable, cost-effective and widely accepted. CdS/CdTe is found to be most prominent solar cell among the all because of its advantage such as low cost, highly efficient and readily available. As we know the bandgap of CdTe is approximately 1.5 eV, they have the ability of wide range of absorption in solar spectrum and have high carrier mobility [2]. It has also entered into large scale manufacturing which is done by the First Solar Company. Experimentally when performed in laboratory [1993] the efficiency is found to be in the range of 15.8% - 16.5% [3]. In 2001 the efficiency is improved to 20.4% from 16.5% [3, 4]. During fabricating of CdTe thin film solar cell CdS layer act as n-type window layer which also helps in improving the efficiency. We can calculate the crystallite size, micro strain, interplanar spacing, etc using X-ray diffractometer. The J-V characteristics of CdTe based thin film photovoltaic cell can also be plotted. In J-V characteristics we can clearly see the short-circuit current (Jsc) and the open-circuit current (Voc). Protik Biswas *et al.*, 2015 has done the analytical approach to further enhance the Jsc value we can use the window layer which has large bandgap. The large bandgap can be obtained by oxygen incorporated into the CdS window layer [5]. When the desired current is achieved, we have to also improve the carrier collection in the long wavelength region [5]. It can be achieved by incorporating high S content in the alloy of $CdSe_xTe_{1-x}$. CdTe absorber uses a low bandgap (1.7 eV). CdSe window layer to enhance the current value. CdSe window layer make a heterojunction layer with CdTe in which Se was diffused. Fabrication of CdTe thin film solar cell can be synthesized by many methods such as chemical bath deposition (CBD), thermal evaporation, E-beam deposition technique, close space sublimation (CSS), electrodeposition and pyrolysis method [6,7]. The short-circuit current (Jsc) and open-circuit voltage (Voc) is also calculated [6]. The thin film CdTe based photovoltaic cell was also fabricated by using progressive method such as sputtering [7, 8], electrodeposition [9], which proves to be simple and less expensive. The CdS layer thickness was taken to be between 50- 110 nm as the layer should not be thick as well as not too thin. If the CdS layer is found to be too thin, upon applying the CdTe layer above CdS layer there was a high possibility of short-circuiting of the photovoltaic cell as the CdTe nanoparticles will get contact with ITO glass plate. The CdTe layer was taken as approximately 450 nm [10].

1.1. Fabrication of Cds/Cdte Based Photovoltaic Cell

Fabrication of CdS/CdTe thin film photovoltaic cell was done by brush painting technique.[11] ITO coated glass plate was cleaned by acetone to eliminate the impurities or dust particles if present. Pure CdS and CdTe nanoparticles have been synthesized by microwave assisted method [12-17]. The nanoparticles are then mixed with few drops of polyvinyl alcohol as PVA works as a binding agent. The formed paste was then applied on top of the ITO glass plate by brush painting technique. The CdS coated ITO glass plate was then kept in to the oven for annealing purpose. The sample was kept at 140^{o}C for approximately 8 hours in the oven for annealing. Same way CdTe layer was also being deposited on the CdS coated ITO glass and annealed in the similar way. Silver paste was applied on the CdTe layer as a back contact. It helps in conduction process.

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1.2. Materials Used

The CdS and CdTe layer forms the heterojunction layer. The electron-hole pair is formed between the layer of CdS and CdTe which helps in the conduction process. The optical characterization was done by XRD. The ITO glass plate is taken as it is transparent and suitable to act as a front layer. The dimension of ITO is L-25mm, B-25mm, T-0.7mm. The resistivity was found to be 10 ohm/sq. Transmittance of ITO is ≥ 83%.

2. Method

The nanoparticles characterization was obtained by X- Ray diffraction (XRD) technique. While observing the spectra of XRD with the help of X-ray diffractometer, it has been seen that the samples were recorded in 2ϴ range from 20º to 80º and the value of lamda (λ) was 1.54Å. Fig 1 and fig 2 shows the XRD spectra of CdS and CdTe nanoparticles respectively. The peaks obtained in XRD studies was found to be against 2ϴ from which the ϴ has been calculated. The crystallite size of the nanoparticles has been calculated using Debye Scherrer equation as given by equation (1) where K is constant and its value was taken as 0.9.

Table 1 Structural parameters of pure CDS

Peak level	Crystallite size (nm)	Interplanar displacement (Å)	Micro strain (radians)
1st Peak	1.5181	6.683	0.9911
2nd peak	1.5931	4.1016	0.1232
3rd Peak	1.6446	3.4977	0.8348

Table 2 Structural Parameters of Pure CdTe

Peak level	Crystal lite size (nm)	Interplanar displacement (Å)	Micro strain (radians)
1st Peak	5.899	7.7829	0.2968
2nd peak	2.9757	6.5164	0.4928
3rd Peak	0.0857	4.7265	0.6157
4th Peak	7.420	4.4767	0.0136

Table 1 and 2 shows the calculated value of the structural characterization of the pure CdS and pure CdTe nanoparticles respectively. The Scherrer equation is considered for the calculation of the crystalline size which may be smaller or equal to the particle size in nm in Figure 1.

Scherrer Equation;

$$D = \frac{k\lambda}{\beta \cos\theta} - - - - - - (1)$$

The Bragg's Equation was taken for the calculation of the interplanar displacement of the nanoparticles in Å.

Bragg's Equation;

$$n\lambda = 2d\sin\theta - - - (2)$$

The micro strain (ε) as given by equation (3) is calculated using the full width at half maximum of the diffraction peak in radians.

Micro strain Equation;

$$\beta = 4\epsilon\tan\theta - - - -(3)$$

2.1. XRD Characterization

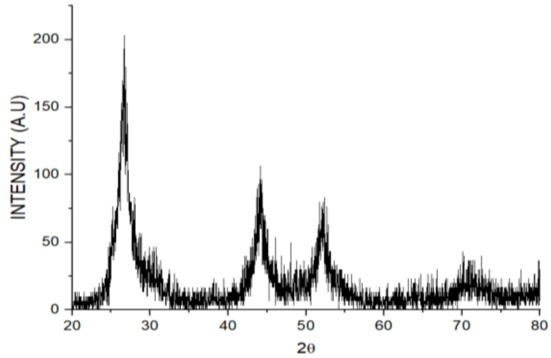

Figure 1 XRD of Pure CDS Nanoparticle

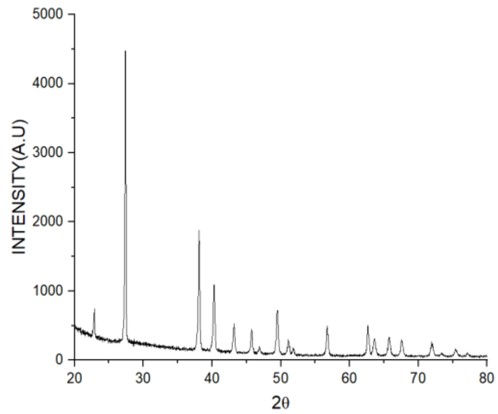

Figure 2 XRD of Pure CDTE Nanoparticle

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3. Results and Discussion

3.1. Results

The graph of XRD data for nanoparticles of CdTe and CdS have been plotted using Origin software. In the graph we observe the peaks which was obtained by the XRD characterization data is show in Figure 2.

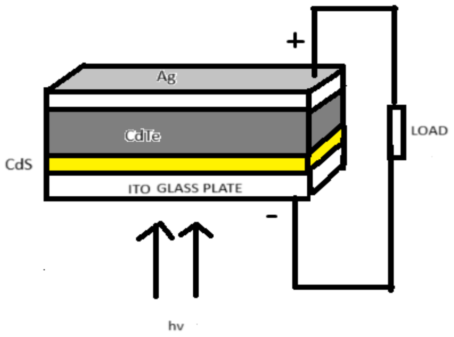

Figure 3 XRD Plot of CDTE - Hexagonal Structure

In each peak we can see its corresponding x and y values. The Intensity (A.U) vs 2ϴ graph is obtained. The three major peaks have been observed in CdS plot which confirms the crystallinity of the particles and also have the cubic phase. From this corresponding ϴ, we can calculate the value of other parameters as crystallite size, interplanar spacing, microstrain, dislocation density, etc. We have obtained the crystalline size of the material, lattice parameter. From XRD plot of CdTe it is confirmed that it has hexagonal structure Figure 3.

3.2. Discussion

The photovoltaic cell was fabricated as discussed earlier and the flow chart is as given in Figure 4. The silver paste was used on the top of the CdTe layer which act as anode terminal and the ITO glass act as cathode terminal. The CdS layer which acts as window layer absorbs the light of shorter wavelength as approximately 450 nm. The CdS layer should not be thinner as the CdTe layer get in contact with the ITO glass and increase the possibility of short-circuiting of the photovoltaic cell. This can hinder the performance analysis of the photovoltaic cell. The CdTe layer is thicker than CdS layer. The silver paste was applied on the CdTe layer carefully as it should not touch the ITO glass or else the cell gets short-circuit and required readings can't be obtained. With the help of multimeter, the open- circuit voltage was obtained. Load was attached between the two terminals and the short-circuit current was being measured. The short circuit current was being measured only when the voltage becomes zero. With the help of incandescent bulb of 100 watt, the voltage reading was obtained and Voc goes upto 105.5 mV.

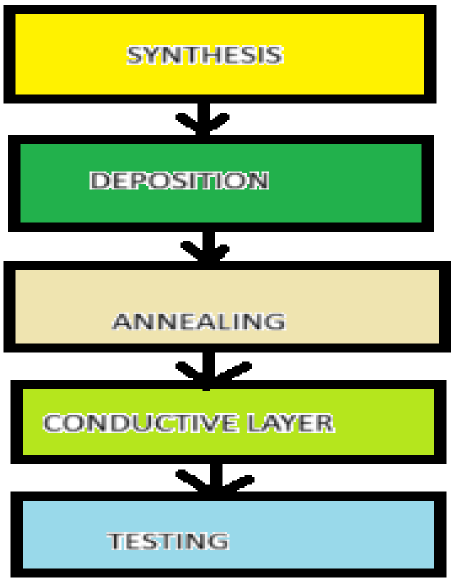

Figure 4 Process of Fabrication

Conclusion

The CdS/CdTe photovoltaic cell is being fabricated by brush painting technique. The thickness of CdTe layer was more than the thickness of CdS layer. Uniform layer of CdS and CdTe layer was being obtained. The silver paste was applied on top of the CdTe layer carefully. The open-circuit voltage Voc is found to be 105.8mV.

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