International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

Vol.4., S1., 2016

N C L A – 2016

ISSN: 2321-7758

STUDY OF PHOTOVOLTAIC CHARACTERIZATION OF SPRAY DEPOSITED CdTe THIN FILMS

D.M.Sapkal

S.I.C.E.S. Degree college of Arts, Commerce & Science, Ambernath(west)

ABSTRACT

CdTe thin films have been deposited onto amorphous glass substrates using spray pyrolysis technique. The preparative parameters such as substrate temperature, concentration, quantity of solution and Ph of solution have been optimized by photo-electrochemical (PEC) technique. The films were characterized by techniques such as X- ray diffraction and Scanning electron microscopy (SEM) and energy dispersive analysis by X-rays (EDAX) technique. The photo-electrochemical characterization shows that both short-circuit current (Isc) and open circuit voltage (V_{oc}) are at their optimum values at the optimized substrate temperature of 250 ^{0}C and solution concentration of 0.01M. The XRD pattern shows that films are polycrystalline with cubic structure. The optical absorption studies reveals that films are CdTe films exhibit a direct optical transaction with band gap of energy E_g to be 1.5 eV. The films at optimized temperature have well formed grains as evidence from SEM.

Keywords: Spray pyrolysis; Thin films; PEC Characterization; XRD; SEM; EDAX techniques;

1. INTRODUCTION

The cadmium telluride (CdTe) is one of the major promising semiconductor thin film materials for producing large area solar cells. The CdTe thin films have drawn considerable interest in recent years due to their wide use in the fabrication of photovoltaic devices, photoconductors, space charge limited diodes, transistors and infrared (IR) detectors [1-4]. A great part of these devices are schottky diodes. Their performance depends strongly on the CdTe surface preparation performed before schottky metallization. The technology of the CdTe/CdS thin films solar cells through intense studies at universities, institutes and industrial groups has reached a stage where the transfer into production is generally considered to be appropriate. This means that every single layer which form the device is almost completely understood both from the point of view of its chemi-physical behavior and from the point of view of deposition techniques. The CdTe has been found to be best suited material for thin film CdS heterojunction solar cells, and conversion efficiencies higher than 16% have been reported for CdTe/CdS solar cells prepared by several techniques. The increasing interest towards this material has lead to a large number of studies on (CdTe/CdS) solar cells during last years [5-11].

2. MATERIALS AND METHODS.

2.1 Preparation of solution

The spray solution was prepared from mixture of distilled water, ammonium hydroxide, hydrazine hydride, hydrochloric acid and appropriate amounts of ingredients cadmium and tellurium are added to this mixture in the form of cadmium chloride ($CdCl_2$) and tellurium oxide (TeO_2) with different concentration.

2.2 Deposition of CdTe thin films

In order to find optimized preparative parameters for deposition of CdTe thin films, initially the deposition was carried out by varying substrate temperature from 225 ^{0}C, at the interval of 25 ^{0}C to300^{0}C. and keeping other parameter at fixed value, for optimization of solution concentration, deposition was carried out by varying the solution concentration and keeping substrate temperature, quantity of solution at fixed values. In this way deposition parameter were optimized.

Table 1.1 Observed and standard *d* values for the CdTe thin films at various substrate temperature $T_{225°C}$, $T_{250°C}$, $T_{275°C}$ and $T_{300°C}$ at fixed solution concentration 10 mM.

Sr. No.	Standard d Values (A^0)	Observed d values (A^0)				Reflections (hkl)
		T_{225}	T_{250}	T_{275}	T_{300}	
1.	3.742	3.7415	3.7425	3.7441	3.7410	(111)
2.	3.270	3.2269	-	-	-	(200)
3.	2.290	2.2904	2.2913	2.2951	2.2872	(220)
4.	1.954	1.9538	1.9557	1.9561	1.9554	(311)

Table 1.2 Variation of crystallite size with substrate temperature

Sr. No.	Substrate Temperature (^0C)	Crystallite size (nm)
1.	**225 ± 5**	**41.68**
2.	**250 ± 5**	**55.36**
3.	**275 ± 5**	**36.41**
4.	**300 ± 5**	**27.14**

2.3 Fabrication of photoelectrochemical (PEC) solar cell

The construction of practical photoelectro chemical cell (PEC) for the conversion of sunlight into electricity (or chemical energy), the most important fact is the long-term stability of cells that show reasonable conversion efficiency. PEC cell consists of a semiconductor photoelectrode, an redox electrolyte was 1M polysulphide (NaOH - Na_2S - S). and a counter electrode as shown in fig 1.1. The cell was illuminated with 500 W tungsten lamp for the measurement of short circuit current (I_{sc}) and open circuit voltage (V_{oc}). The distance between photoelectrode and counter electrode is 0.5cm. When both electrodes are immersed in the electrolyte, band bending of semiconductor photoelectrode may occur. The transfer of electrons from the electrolyte can takes place only in the energy region of conduction band, while hole transfer can take place in the region of the valance band. Such a transfer can occur between two states of the same energy, one empty and other filled. Under illumination, electron-hole pairs are generated in the depletion layer and separated by the electric field present at the interface. The incident energy of photon should be greater than the band gap energy of the semiconductor. The electron-hole pairs generated in the bulk of the semiconductor are essentially lost through recombination. If a positive potential is applied to the n-type semiconductor photoelectrode and illuminated, electron-hole pairs are generated and separated electrons rise to the top of the conduction band and holes in the valence band. This process sets up a counter field under open circuit conditions. The counter field is at its maximum and is the open circuit voltage; V_{oc} is given by the equation.

$$V_{oc} = \left(\frac{nKT}{e}\right)\ln\left[\frac{I_{ph}}{I_o}+1\right]$$

On the other hand, the counter electrode is being in the same electrolyte, the photovoltage acts as a driving force for electrons to move under short circuit conditions from semiconductor electrode to the counter electrode and a regenerative cell is formed and is shown in fig 1.2.

Short-circuit current is given by the equation.

$$I_{SC} = \int_0^{\infty} Q_C(1-R_n)(1-e^{-\alpha\omega})e \times n_{ph} E dE$$

where, *Qc* is collection efficiency of a semiconductor material, R_n is reflectance of a semiconductor photoelectrode, α is absorption coefficient of semiconductor photoelectrode, ω is thickness of semiconductor photoelectrode, *e* is electronic charge, n_{ph} - number of photons in the energy range *E* and *E+dE*

Thus I_{sc} is dependent on many semiconductor photo electrode parameters.

The electrons promoted to the conduction band drift towards the interior, while the holes, the minority carriers, come to the surface of semiconductor. Here, they encounter the reduced form of redox couple in the solution. The component is oxidized by holes, transported to the counter electrode and therefore gets reduced. This reduction is driven by the external connection from the semiconductor.

3. RESULTS AND DISCUSSION

3.1 Photoelectrochemical (PEC) studies.

The quantities such as short circuit current (I_{sc}) and open circuit voltage (V_{oc}) of the PEC cell obtained with each CdTe thin film at substrate temperature 225^0C - 300^0C. It is observed that the short circuit current (I_{sc}) and open circuit voltage (V_{oc}) relatively maximum at optimized temperature 250^0C as shown in Fig (1.3 and 1.4). The comparatively higher values of short circuit current (I_{sc} ~1.60 mA) and open circuit voltage (V_{oc} ~ 380 mV) obtained at optimized substrate temperature. The fig 1.5 shows short circuit current (I_{sc}) and open circuit voltage (V_{OC}) of the PEC cell obtained with each CdTe thin films deposited at various solution concentration observed that the I_{sc} and V_{OC} relatively maximum at optimized solution concentration of 10 mM. It is observed that CdTe thin films deposited at 250^0C and solution concentration of 10 mM only posses the right stoichiometry of the compound.

3.2 Effect of substrate temperature on CdTe thin film

It was observed that the lower temperature (<225^0C) favours non-uniform and easily detachable film formation. The temperature might be insufficient to decompose sprayed droplets of the spraying solution for higher substrate temperature (>300^0C) film resulted with non-uniformity and pinholes. This could be due to higher evaporation rate of initial ingredients from surface of the preheated glass substrates. However, CdTe thin films deposited at intermediate substrate temperatures are uniform and well adherent to glass substrate. The other preparative parameters were optimized by photoelectrochemical (PEC) technique in order to achieve good quality films.

3.3 X- Ray diffraction (XRD)

The diffractograms of CdTe thin films are shown in Fig1.6. The XRD pattern of CdTe thin films exhibits sharp peaks at 2θ equal to 35.6^0, 59.9^0 and 71.6^0 which corresponds to diffraction from (111), (220) and (311) planes of the cubic phase respectively. Both the peak height and peak position are in good agreement with JCPDS data [12]. These are the prominent reflection occurs at optimize substrate temperature 250^0C. The plane (111) of CdTe appears with higher peak intensity. The (111) direction is close packing direction of zinc blende structure and this type of ordering is often observed in polycrystalline films [13,14] grown on heated amorphous substrates. Table 1.1 compares the'd' values of the CdTe thin films calculated from the x-ray diffractograms with the standard of the CdTe given in the JCPDS data card [12]. A matching of observed and standard 'd' values confirms that the films have cubic structure as reported by Vishwakarma et al. The calculated value of lattice constant (a) is found to be 6.4A^0 which is in well agreement with the standard single crystal CdTe value [12]. The crystallite size D can be obtained from Scherer equation for broadening due to particle size [15.16]

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

where k = 0.9, β is the full width at the half maximum of a peak (FWHM), θ is the diffraction angle and λ is the wavelength of the X ray radiation used (λ = 1.5406 A^0). Table 1.2 shows the relatively higher crystallite size has been observed for the CdTe thin films deposited at optimum substrate temperature 250 ±5 ^{0}C. All the films are nanocrystalline as crystallite size less than 100 nm.

3.4 Scanning Electron Microscopy (SEM) and Energy dispersive analysis by x -rays (EDAX)

The SEM micrographs (SEM model JEOL JSM 6360, Japan)of the spray deposited CdTe thin films on glass substrates at substrate temperature 250 respectively are shown in Fig 1.7. It is seen that the thin film prepared at optimized substrate temperature 250^{0}C with solution concentration 10 mM have better morphological parameters such as grain size, free of voids and close packed structure. It also shows periodically and continuously distributed well covered growth of film.

The compositional analysis of the CdTe thin films is carried out by EDAX technique for the films deposited at optimized substrate temperature and the material is found to be slightly rich in Tellurium. The elemental analysis of the CdTe thin film is shown in fig 1.8

The peaks other than Cd and Te are due to the elements present in the composition of glass substrate (Silica(SiO_2)) + Na + Mn + A_1)

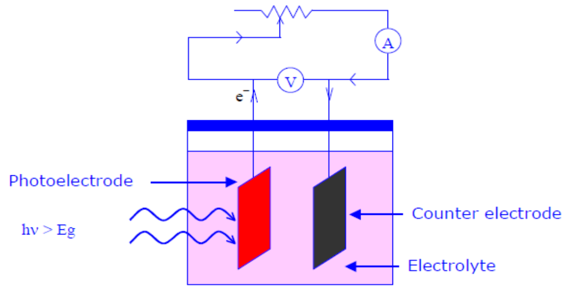

Fig. 1.1 A typical electrochemical photovoltaic cell

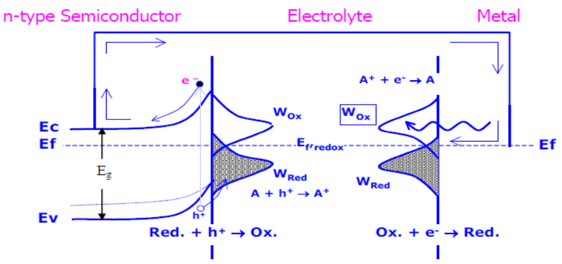

Fig. 1.2 Current flow and energy level diagram for n-semiconductor PEC cell

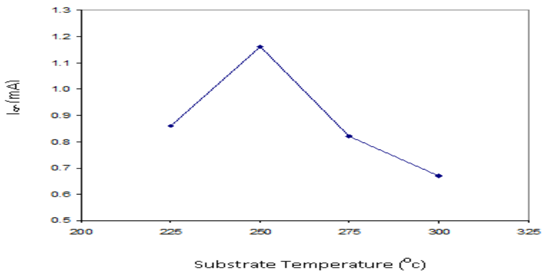

Fig 1.3 Variation of short circuit current (Isc mA) with substrate temperature (0c) for CdTe thin film

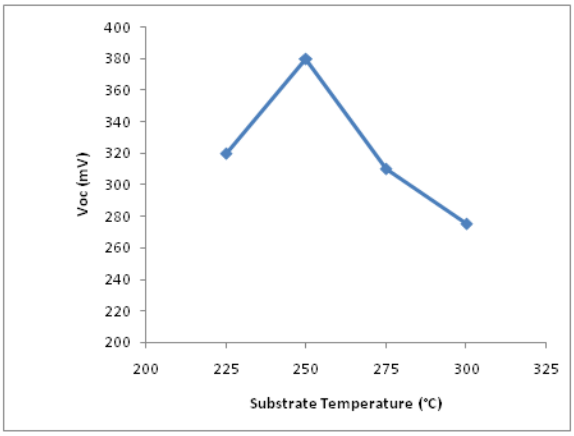

Fig 1.4 Variation of open circuit voltage (Voc. mV) with substrate temperature (0c) for CdTe thin film.

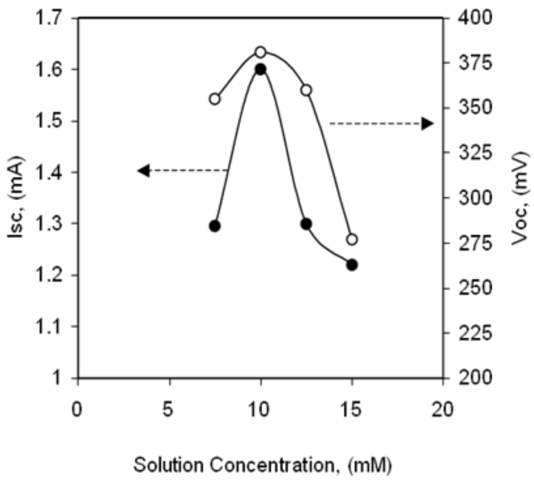

Fig 1.5 Variation of Short Circuit current (I_{sc}.) and open circuit voltage (V_{OC}) with solution concentration (mM) for CdTe thin film.

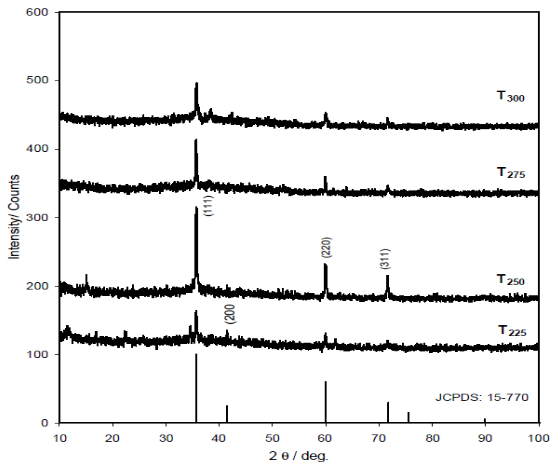

Fig. 1.6 X-ray diffraction patterns for CdTe thin films deposited at various substrates temperature.

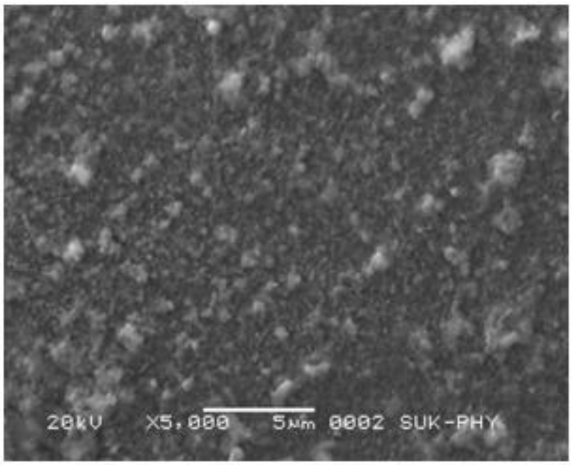

Fig. 1.7 The SEM micrograph T = 250^{0}C

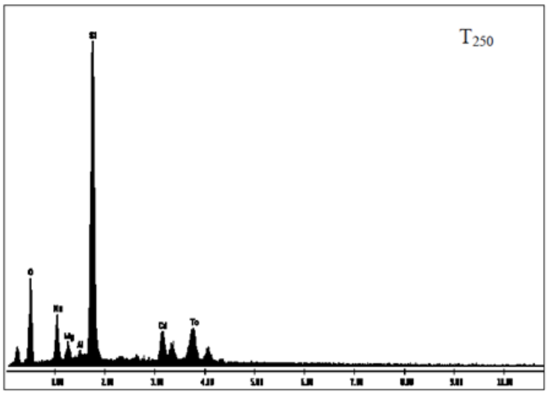

Fig. 1.8 Compositional analysis of CdTe thin film deposited at optimized substrate temperature

4. CONCLUSION

The short circuit current (I_{sc}) and open circuit voltage (V_{oc}) of the photoelectrochemical (PEC) cell obtained to be comparatively maximum at optimized substrate temperature of 250^{0}C with solution concentration of 10 mM. The comparatively higher values of short circuit current (I_{sc} ~1.60 mA) and open circuit voltage (V_{oc} ~ 380 mV) obtained at optimized substrate temperature. It is observed that CdTe thin films deposited at 250^{0}C only posses the right stoichiometry of the compound at that temperature with cubic structure

5. ACKNOWLEDGEMENT

Author Dr. D. M. Sapkal thankful to Principal and Management of S.I.C.E.S. Degree college of Arts, Commerce & Science, Ambernath (west),

6. REFERENCES

[1]. G. Entine, M.R. Sacillante, H.B.Serreze, E. Clarke IEEE Trans. Nucl. Sci. NS-28 (1981) 558.

[2]. A. L. Dawar, et al. 17 J. Phys. D: Appl. Phys. 14(1983) 2349.

[3]. G. Stollwerck, M.S. Thesis, Colorado State University, 1995.

[4]. P.K. Raychanduri, J. Appl. Phys. 62 (1987) 3025.

[5]. D. Bonnet, H. Rabenhorst, Proceedings of the 9th IEEE PVSC, New York, 1972, p. 129.

[6]. K.W. Mitchell, A.L. Fahrenbruch, R.H. Bube, J. Appl. Phys. 48 (1977) 1020.

[7]. B.M. Basol, S.S. Ou, O.M. Stafsudd, J. Appl. Phys. 58 (1985) 3809.

[8]. P.V. Meyers, 7th European PVSEC, Dordrecht, Netherlands, 1986, p. 1211.

[9]. N. Romeo, A. Bosio, V. Canevari, Int. J. Sol. Energy 12 (1992) 183.

[10]. C. Ferekides, J. Britt, Sol. Energy Mater. Sol. Clls 35 (1994) 255.

[11]. T.I. Chu, S.S. Chu, C.G. Ferekides, J. Cryst. Growth 117 (Nl-4) (1992) 1073.

[12]. JCPDS diffraction data File No. 15 -770, 1993.

[13]. S. Saha, U.pal, B.K. Samantaray, A.K. Chaudhari, Thin Solid Films 164 (1988) 85.

[14]. R. D. Gould, C. J. Bowler, Thin Solid Films 164 (1988) 281.

[15]. B.M. Basol, S.S. Ou, O.M. Stafsudd, J. Appl. Phys. 58 (1985) 3809.

[16]. P.V. Meyers, 7th European PVSEC, Dordrecht, Netherlands, 1986, p. 1211.