THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Influence of Deposition Time on Performance of Nanocrystalline CdTe Thin Films Used as Photoelectrode in Photoelectrochemical Solar Cell

Preeti Pathak
Assistant Professor and Head, Department of Physics, Mata Gujri Women's College, Jabalpur, (MP), India
Kavita Gour
Assistant Professor and Head, Department of Electronics, Mata Gujri Women's College, Jabalpur, (MP), India
Dr. Meera Ramrakhiani
Professor and Head, Department of Physics and Electronics,
Department of Physics and Electronics, Rani Durgawati University, Jabalpur, (MP), India
Dr. Prashant Mor
Scientific Officer, Department of Physics and Electronics,
Department of Physics and Electronics, Rani Durgawati University, Jabalpur, (MP), India

Abstract:
In order to overcome the energy deficit in the future, a number of alternative energy sources are considered. Solar energy is renewable and carbon-free and is the most abundant energy source. Currently the solar cells are considered as a potential energy source for the future. Among them the photo electrochemical cells are low cast solar cells. The new and emerging technology is 'nanocrystalline thin film technology'. Nanocrystalline CdTe thin film was synthesized by a wet chemical route at pH 11.2 using cadmium chloride and potassium telluride as starting materials. The reaction was carried out by the refluxing the mixture of starting materials at 90^0 C for 5 hrs. Addition of 2-propanol to the solution produced suspension of CdTe nanocrystals. Nanocrystalline thin films of cadmium telluride have been grown on glass and indium tin oxide (ITO) substrates by rotating them in the solution At ambient temperature, transparent films have been synthesized and annealed at 200 ºC for 2hrs. The prepared thin films were characterized using X-ray diffractogram (XRD), and Atomic Force Microscopy (AFM). X-ray diffractogram reveals the presence of tetragonal phase. The thickness, crystallite size and grain size were observed to increase with increase in deposition time while optical band gap energy slightly decreases. Effect of deposition time on physical, structural, microstructural, and electrical properties of these films and photovoltaic effect was studied. Prepared thin films shows good response towards photoconduction in presence and absent of light.

Keywords: *Cadmium telluride thin films, chemical bath deposition (CBD) method Photoelectrochemical cells, XRD, Surface morphology, photovoltaic effect*

1. Introduction

Solar energy source is only long term natural source of energy and are considered as potential energy source for future. Photovoltaic cell can convert sunlight directly into electricity. It can provide nearly permanent power and is virtually free of pollution. The photo electrochemical cell (PEC) is an attractive means of converting solar energy into electricity.

Photovoltaic effect is a process in which two dissimilar materials in close contact produce an electrical voltage when struck by light. The research work describes the photovoltaic effect and characteristics of CdTe thin film solar cells. The photo electrochemical effect is exhibited by the semiconductor (SC) and electrolytic junction in a cell consisting of photo-responsive electrode, an electrolyte and a suitable counter electrode. When SC-electrolyte junction is illuminated by the high energy photon of hv> Eg, photons are absorbed by SC electrode producing electron-hole pairs. This separation of electron hole pairs results in photo-voltage. The working of solar cell is related to the photo voltaic effect. Cadmium Telluride is well-known p-type semiconductors having potential applications in solar cells. Cadmium telluride is studied with great interest during the past decades because of its potential application in the fabrication of photovoltaic devices.

Present paper describes preparation of nanocrystalline films of CdTe on ITO coated glass substrate their characterization and study of their performance in PEC cell. The effect of deposition time has especially been investigated.

2. Experimental

The nanocrystalline thin film of cadmium telluride were grown on glass and indium tin oxide (ITO) substrates using chemical bath deposition method .The CdTe film are deposited for different deposition time 60 min, 120 min, 180 min at controlled temperature 45^0C. The transparent CdTe thin films were annealed at 200ºC for 2hrs in Oven.

2.1. Photoelectrode Preparation

Chemical reaction_

$CdCl_2 + K_2Te = CdTe + 2KCl$

A reaction vessel containing glass and tin doped-indium oxide (ITO) coated substrates was used in the experiment connected to computerized auto-thermostat to maintain and control the accurate temperature of reaction solution. The reaction vessel was filled with the composition of solution: [0.1 M 20 ml ($CdCl_2$) + 0.1M (K_2Te)] buffer solution is used to maintain 11.2 pH. The reaction was carried out by the refluxing the mixture of starting materials at 90^0 C for 5 hrs. Water bath with reflux assembly was used for this purpose. The aqueous solution of CdTe nanocrystallites was formed at this stage. By the addition of 2- propanol to the solution named as A. The glass slides were cleaned with a suitable cleanser, scrubbed with soft cotton, washed thoroughly with de-ionized water followed by rinsing and drying in the air. These glass and ITO coated glass plates were used as substrates for deposition, fixed to the circular holder (shown in fig.-1) with ITO side facing towards the solution A and allowed to rotate with a speed of 25 rpm. The thermostat was set to a temperature of 45 ^{0}C and the reaction was carried out for 60 Min, 120 Min, and 180 Min with constant stirring of the solution throughout the experiment. Good transparent films were deposited onto both glass and ITO substrates. The temperature, concentration of precursor solution and pH used for deposition are tabulated in Table 1.

Deposition parameter	Optimum value / item
Deposition time	60 min /120min/180min
pH	11.2
Concentration of precursor	Normal B
Deposition temperature	45°C
Solvent	Deionised water

Table 1: Parameter used for deposition of nanocrystalline CdTe thin films.

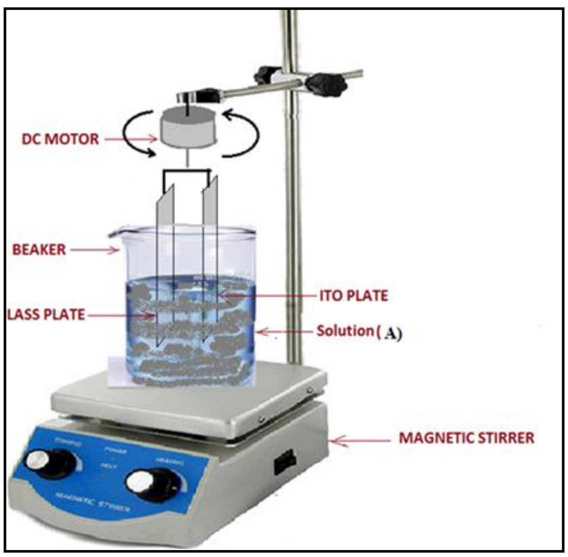

Figure1: Experimental process for preparation of photo electrode

[B]The samples of CdTe thin film deposited onto glass substrates for different deposition time were examined by means of X-ray diffraction (XRD) and (AFM) micrographs for their structural and morphological properties.

2.2. Photoeletrochemical Cell Studies

The configuration of PEC cell is a single glass vessel surrounded by dark black paint, using CdTe nanocrystalline film on ITO substrate as photo electrode, graphite as counter electrode and polysulphide solution as electrolyte. Photo-electrochemical (PEC) performance of cadmium telluride formed onto ITO was investigated. The distance between working electrode and counter electrode was fixed at10 centimetre. Photocurrent–voltage (I–V) characteristics of cadmium telluride photoelectrodes were measured with change in resistance using potentiometer in circuit, with 315 Lux light illumination intensity.

3. Results and Discussion

The thickness of the CdTe film was measured with the help of weight difference method or gravimetric method, employing sensitive electronic microbalance using bulk density of CdTe ($6.02 gm/cm^3$).

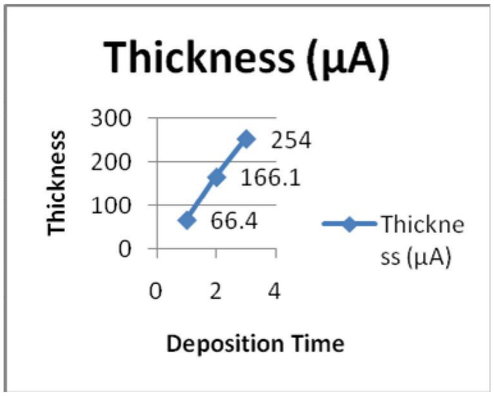

Figure 2: Thickness of the films as a function of deposition time

The thickness of the deposited Cadmium Telluride thin film increases with deposition time. The linear increase in thickness with deposition time could be due to the change in crystallite size and grain size accompanied with deposition time.

3.1. XRD Studies

In order to determine the size and to study the structural properties of the synthesized CdTe thin films, the XRD analysis was performed. The phenomenon of X-ray diffraction can be pictured as a reflection of the incident beam from the lattice plane. The X-ray diffraction patterns of nanocrystalline CdTe thin film was performed by using X-ray diffractometer ((XRD-SMART lab) - Rikagu, NIKON, Japan) using CuKα radiation with a wavelength, $\lambda = 1{\cdot}542$ Å.Copper target was used as source of X-rays (30 kV, 100 mA). The scanning range was 10.0000-80.0000 deg. Scan speed/Duration Time of 4.0000deg/min and a scan mode continuous and scan axis 2 Theta were maintained.

The average crystal size of CdTe samples were calculated by using the Scherer's formula

$D = 0{\cdot}9\lambda / \beta\cos\theta$ -------------------- (1)

Where:

- D = Average crystallite size
- λ = X-ray wavelength (1·542 Å)
- β = FWHM of the peak
- θ = Bragg angle.

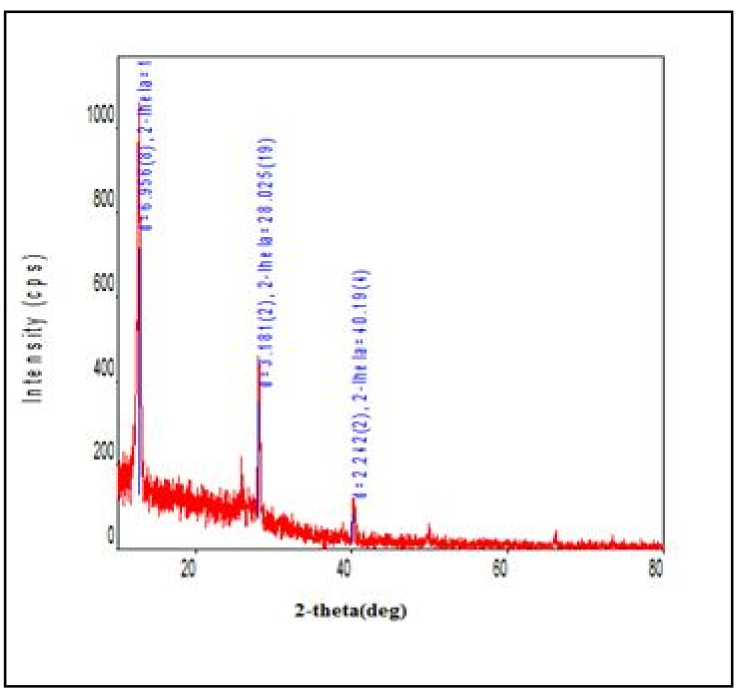

Figure 3 [A]: X-ray diffraction pattern of deposited CdTe thin film (Deposition time- 60 min.)

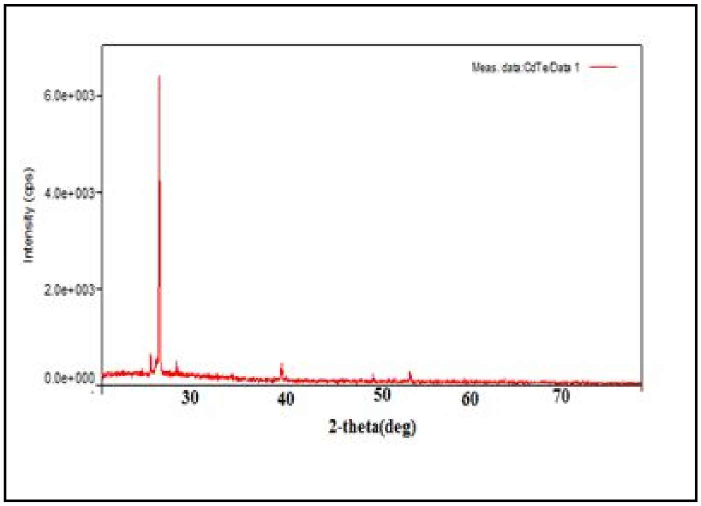

Figure 3[B]: X-ray diffraction pattern of deposited CdTe thin film (Deposition time- 120 min.)

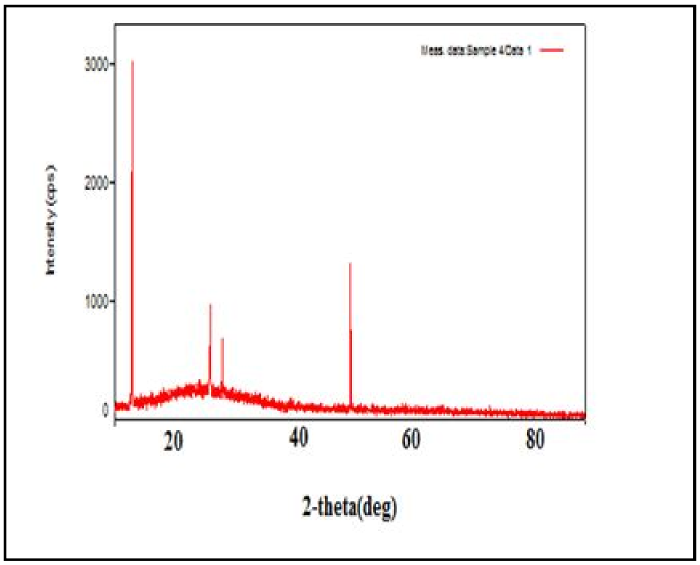

Figure 3 [C]: X-ray diffraction pattern of deposited CdTe thin film (Deposition time- 180 min)

The structural identification of CdTe films was carried out with X-ray diffraction in the range of angle 2θ between 10ºto 80º. Fig. 3 shows the XRD patterns for CdTe thin films, which are nanocrystalline in nature. The well defined (110), (101), (111), (200), (210) (220), (311) and (222) peaks were observed in the XRD patterns due to CdTe crystals. The strong and sharp diffraction peaks indicate the formation of well crystallized sample. It can be seen that the major peak (111) at 2θ is strongly dominating the other peaks. From the full-width at half-maximum of the diffraction peaks, the average sizes of the nanocrystallites have been calculated by Debye-Scherrer formula for various deposition times and given in table 2. The structure of CdTe deposited is predominantly tetragonal and reasonably crystalline. PDF card number 9007154 is used for comparing the standard values with the experimental data. The deposition time dependence of size may be explained according to that the larger crystallites being more stable than the smaller ones which are formed at the initial deposition time.

S. No.	Deposition Time	Particle Size
1	60 Min	4.6996 nm
2	120 Min	25.3207427 nm
3	180 Min	26.097329 nm

Table 2: Effect of deposition time on, Particle Size

3.2. AFM Studies

Surface morphologies of films were measured using AFM. The microstructure and element composition of the films were analyzed using Atomic Force microscope (NTEGRA PRIMA NTMDT Ireland). By Centre for nanoscience and Nanotechnology Sathyabama university Chennai)

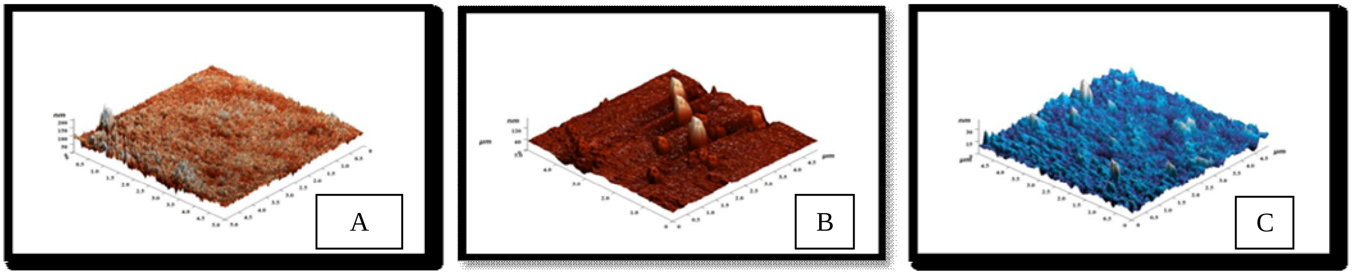

Figure 4: [A], [B], [C] shows AFM 3D image confirming surface morphology of CdTe thin film at deposition time 60 Min, 120 Min and 180 Min

There was agglomeration of particles in most of the cases as evident from the 3D image (Fig.4). The surface roughness is 2.67867 nm 8.14745 nm 9.34155 nm. The surface roughness of the film is unavoidable because particles are spherical in shape. This observation reveals that the films are crystalline in nature. It is found that roughness of surface of electrode increases with deposition time and is maximum with CdTe thin film photo electrode prepared with deposition time 180Min.It may be due to the formation of new bigger domed spherical grains.

3.3. Photovoltaic Studies

Photovoltaic response of the CdTe thin films was studies. The characteristics are plotted for three different electrodes. The deposition time of CdTe for each electrode is kept different, viz. 60 min.120 min and 180 min. The light illumination used is 315 Lux and polysulphide solution serves as a redox to maintain the stability of the Cadmium telluride photo electrodes. Fig. 5 shows the I–V characteristics of solar cell that uses ITO coated glass plates photo electrode with cadmium telluride deposited on it. The different behaviour of I-V curve is obtained because the thickness as well as roughness of electrode surfaces increases with deposition time. It is observed that the performance is poor for 60 min deposited film and improves for thicker CdTe film. It is nearly same for 120min and 180 min deposition time.

Sample Deposition Time (H)		**Temp (^{0}C)**	**Short Ckt Current Isc**	**Open Ckt Voltage Voc (Mv)**	**Fill Factor ff (%)**
1	60 Min	45	.035	95	.1894737
2	120 Min	45	.034	110	.3379679
3	180 Min	45	.031	115	.3657143

Table 3: solar cell parameter

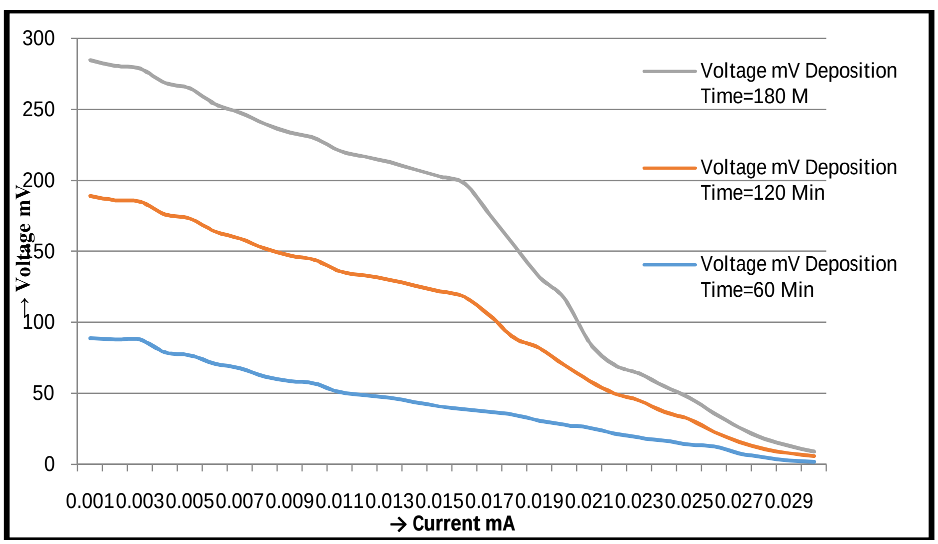

Figure 5: (I-V characteristics of PEC solar cells for photo electrodes prepared at different deposition time)

Observation shows cadmium telluride electrode in solar cell is P -type. It was observed that the solar cell parameters short circuit current (Isc), open circuit voltage (Voc). Fill factor (FF) and efficiency (η%) are influenced by deposition time (i.e. thickness) used for preparation of photoelectrodes.

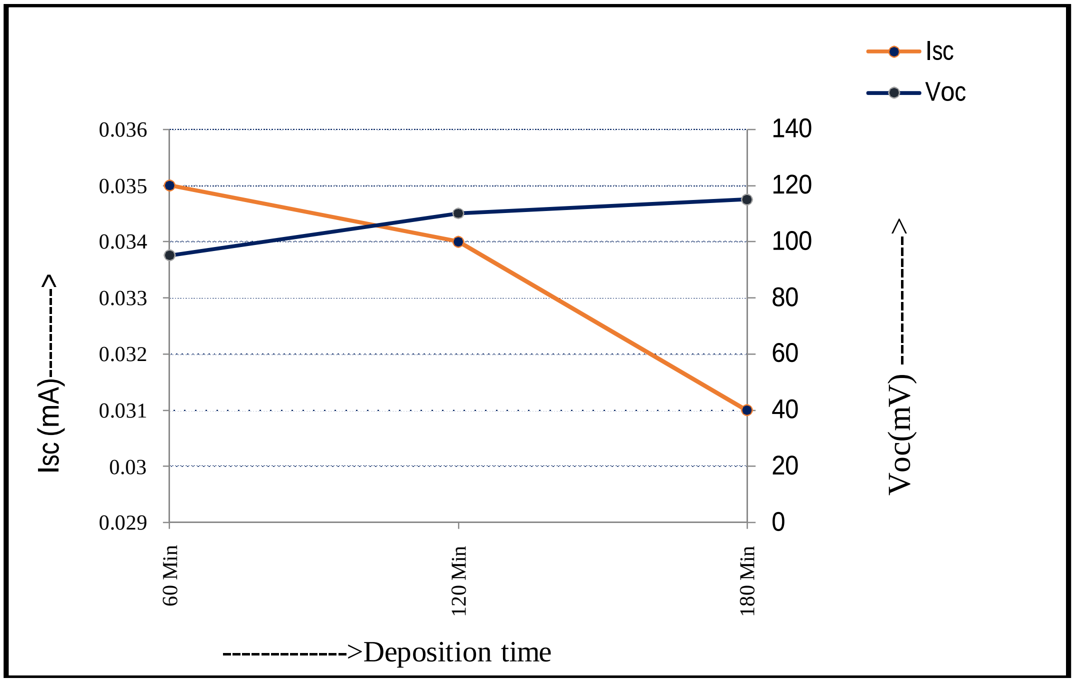

Figure 6: (Graph showing Voc and Iso with different deposition time of photo electrodes)

Fig.6 shows variation of solar cells parameters Voc and Isc for different deposition time of photo electrodes. From the results it may be observed that Isc increases where as Voc decreases by increasing deposition time.

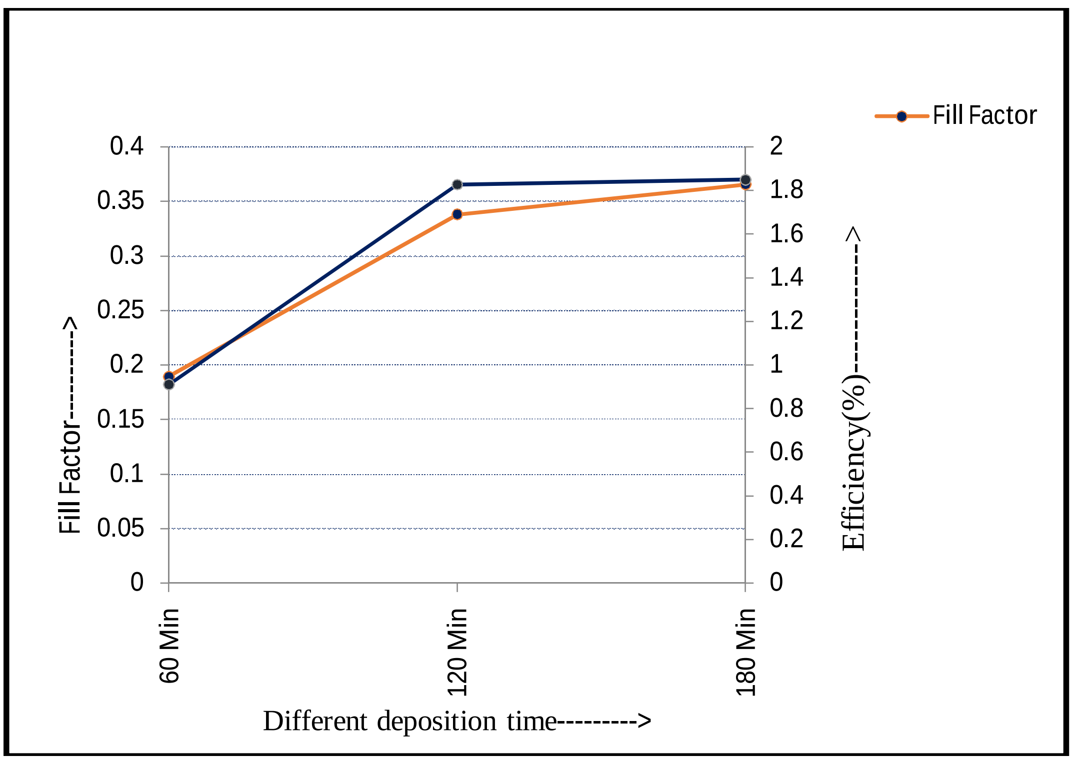

Figure 7: (Graph showing Fill factor and efficiency with different deposition time of photo electrodes)

Fig.7 shows variation of solar cell parameters fill factor and efficiency for different deposition time of CdTe photo electrodes. The value of fill factor and efficiency increases with increase in deposition time (i.e. 60 min, 120 min upto180 min.) because the amount of deposited CdTe (i.e. thickness increases). From these results we also see that solar cell efficiency as well as fill factor is optimum when electrodes are prepared with 180 minute deposition time.

4. Conclusions

The chemically synthesized cadmium telluride thin film photo electrodes have been investigated for photovoltaic response in PEC cell The thickness of the Cadmium Telluride thin film increases with deposition time .The XRD shows the structure of CdTe is predominantly tetragonal and reasonably crystalline. PDF card number 9007154 is used for comparing the standard values with the experimental data. It is concluded from AFM that roughness of surface of CdTe thin film photo electrode increases with deposition time. A photoelectrochemical study confirms p-type conductivity. By increasing deposition time or the thickness of film, Isc increases where as Voc decreases. The fill factor and efficiency initially increases but for more than 120 min these are nearly constant. In preparation of photo electrodes, deposition time and temperature plays an important role. The investigation may be useful in obtaining efficient, stable and low cost solar cell to compete with the existing technology.

5. References

1. K.L. Choy, B.Su, Thin solid Films 388, 9 (2001).
2. J.M. Nel, H.L. Gaigher, F.D. Auret, Thin Solid Films 436, 186 (2003)
3. Pinheiro W, Falcao V, Cruc L, Ferreira C. "Comparative Study of CdTe Sources Used for Deposition of CdTe Thin Films by Close Spaced Sublimation Technique", Materials Research9,47(2006).
4. S.J. Castillo, A.Mendoza-Galvan, R. Ramirez-Bon, F.J. Espinoza-Beltran,M. Sotelo-LermaJ.Gonzalez-Hernandez, G.Martinez, Thin Solid Films373, 10 (2000) [5]Kakishita, K., Aihara, K., & Suda, T. (1994). Zn3P2photovoltaic film growth for Zn3P2/ZnSe solar cell. Solar Energy Mater Solar Cells, 35, 333-40
5. Melendez-Lira M, Becerril-Silva M, Zapata-Torres M, Mendoza-Galvan A, Jimenez-Sandoval S. ,"Semiconductor Thin Films Grown by RF-co-sputtering of CdTe and Al Targets",Superficies YVacio18,22 (2005).
6. Deivanayaki S, Jayamurugan P, Mariappan R, Ponnuswamy V.,"Optica and Structural Characterization of CdTe Thin Films by Chemical Bath Deposition Technique"Chalcogenide Letters 7,159(2010)
7. V. M. Nikale, S. S. Shinde, C. H. Bhosale, and K.Y. Rajpure é Physical properties of spray deposited CdTe thin films: PEC performance Vol. 32, No. 3 Journal of Semiconductors March 2011
8. R. H. Bari, S. B .Patil, A.R. BariI, G. E. Patil, J. Aambekar, Sensors & Transducers Journal 140 (2012) 124-132.
9. Thangaraju B., Kaliannan P., Semicond. Sci. Technol. 2000, 15,71.
10. Zhao Yu., Hong Liao X., Hong J., zhuJ., Mater. Chem. Phys., 2004 87, 149.
11. Seghaier S., Kamoun N., Brini R., Amara A.B., Materials Chemistry and Physics, 2006, 97, 71
12. M. Nikale, S. S. Shinde, C. H. Bhosale, and K.Y. Rajpure Vol. 32, No. 3 Journal of Semiconductors March 2011