A Review on CdTe Thin Films Deposited by Different Methods for Solar Cell Applications

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***Abstract:*-Cadmium Telluride(CdTe) plays a significant role in thin film solar cell technology. It is the most favourable thin film material because of its minimum material usage and rising efficiency of nearly 22%. In 2016, CdTe thin film technologies acquired a market share greater than 55%. CdTe solar cell has become the most important among thin film technologies because its high efficiency. Because of the bandgap level and the preparation methods, CdTe becomes one of the leading materials in thin films solar cell applications. This review shows the preparation methods of CdTe and their bandgap levels at different substrates at different annealing temperature and their applications in solar cells.**

***Keywords:* vacuum evaporation, CdTe, solar cell applications.**

I. INTRODUCTION

Several materials has been examined for the applications of solar cells[33], which may contribute to the growth of current and interesting types of semiconductor materials like thin film polycrystalline, amorphous silicon, crystalline silicon materials namely cadmium zinc telluride (CZT), zinc telluride (ZnTe) and cadmium telluride(CdTe)[29]. Binary semiconducting compounds (CdS, CdSe, CdTe) belonging to II-VI group of cadmium chalcogenide family have been studied and found to play a vital role because of their effective use in light-conductive devices and solar cells[1,2]. Among these compounds, CdTe has been accepted as the most favourable material due to its high absorption coefficient in the visible region (>10^5 cm^{-1}) and optimal bandgap 1.45 eV[3]. In the last decade, major research has been done on cadmium telluride thin films mainly owing to their large area of utilization in the branch of optoelectronic devices such as lasers, nonlinear integrated optical devices, optical filters, X-ray detectors, radiation detectors, field effect transistors, light-emitting diodes (LEDs), photo detectors and thin film solar cells[4-8].

Cadmium telluride thin films have been fabricated by chemical and physical techniques such as spray pyrolysis, metal organic chemical vapour deposition, close-space sublimation, thermal vacuum evaporation, pulsed laser deposition, electro deposition and magnetron sputtering[9-15]. The chemical and physical thin film properties mainly rely on the substrate temperature, doping, substrate, annealing, film thickness and fabrication techniques[3]. The annealing can be carried out in gaseous medium such as Ar, N_2, H_2 and air as well as in vacuum[3]. CdTe allows >90% of an incident light to absorb by a minimum thickness (μm) because it has a very sharp absorption edge[16,17]. Siyanaki et al. reported that the bandgap, grain size and refractive index of cadmium telluride thin films could be controlled by the rotation rate of the substrate [18].

Table:1 Summary of CdTe thin films deposited at different substrates and temperatures.

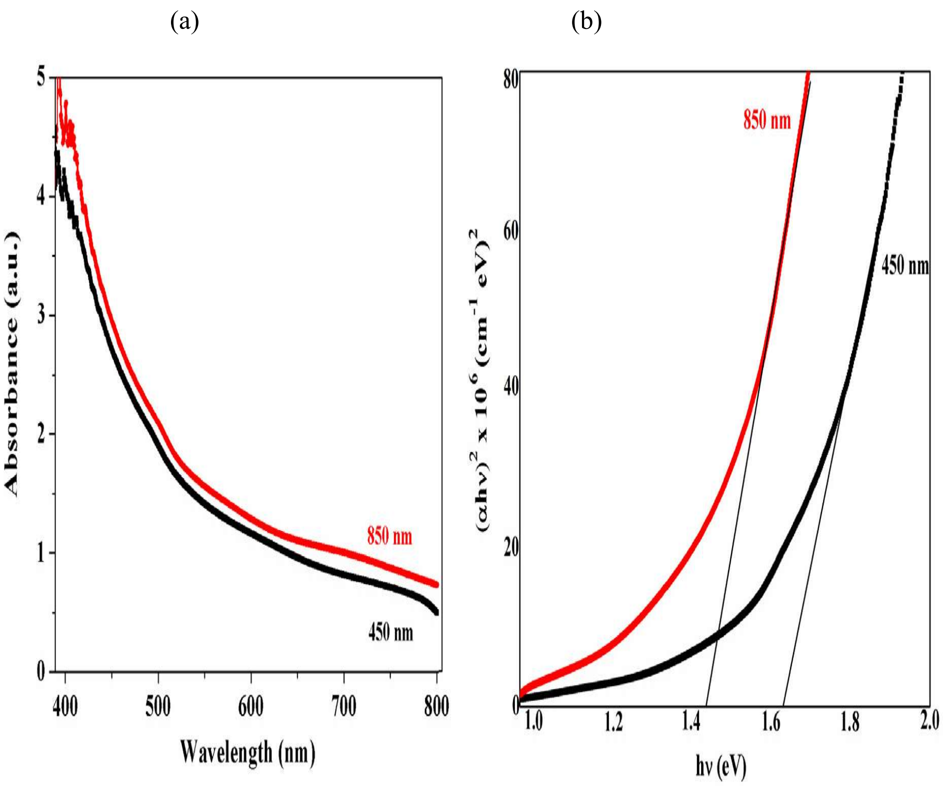
METHOD	SUBSTRATE	ANNEALING TEMPERATURE(ºC)	MATERIAL	BANDGAP (eV)
Low-cost electro deposition	FTO coated	Not studied	CdTe	1.44-1.50
Vacuum evaporation	ITO & glass substrates	150 – 350	CdTe	1.48-1.64
Thermal evaporation	Glass substrate& ITO coated	450 in air	CdTe	1.46-1.64
Thermal evaporation	Glass substrate	Not studied	CdTe	1.48 ±0.01
Vacuum evaporation	Glass substrate	500 in 90s	CdTe	1.4 -1.48
Thermal evaporation	Glass substrate	Not studied	CdTe	1.7 -2.1
Thermal evaporation	Glass substrate	400 for 1hr	CdTe	1.42-1.75
Thermal evaporation	Glass substrate	150-280 (inKelvin)	CdTe	1.5
Thermal evaporation	Glass substrate	30 – 300 (substrate temp)	CdTe	1.475-1.63
Vacuum evaporation	Glass substrate and ITO coated	Not studied	CdTe	1.44-1.63
Vacuum evaporation	Glass substrate	150,250,350	CdTe	1.57-1.87

II. LITERATURE REVIEW OF THE PREPARATION METHODS OF CdTe THIN FILMS

S.Alam et al. investigated CdTe layers grown on FTO coated glass substrates by electro deposition method showing p-type conductivity and bandgap in the range of 1.44 -1.50 eV, and it was in polycrystalline structure[19].

Subhash Chander et al. reported the vacuum evaporation method coated on indium tin oxide and glass substrate to promote the growth of physical properties of cadmium telluride TFMs. It is then followed by thermal annealing temperature at 150 – 350 ºC which shows the optical bandgap between 1.48eV and 1.64 eV. It reveals that the annealed thin films are used as the absorber layer for cadmium telluride TFMs solar cells[3].

Subhash Chander and M.S.Dhaka observed the properties of thermally evaporated cadmium telluride thin film coated on glass and ITO substrates. Coated films annealed at 450ºC in air, showing the direct bandgap (1.46eVand 1.64eV) for 850nm & 450nm thickness. Cadmium telluride thin films have greater thickness acting as the absorber layer for solar cells[20].



Ref[20] : Subhash Chander, M.S.Dhaka, Enhancement in microstructural and optoelectrical properties of thermally evaporated CdTe films for solar cells, Results in Physics 8(2018)1131.

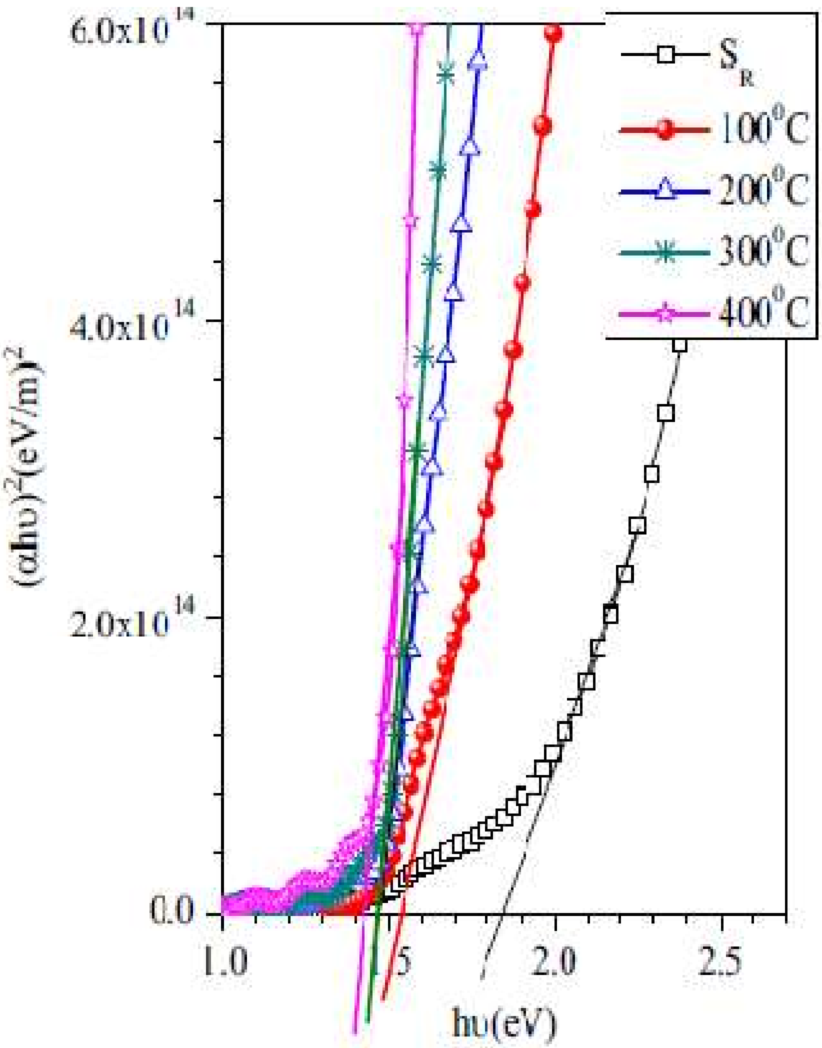
Fig:1 (a) UV spectral analysis and (b) Photon energy vs tauc plot of cadmium telluride thin films [20]

Shadia J et al. prepared CdTe thin films coated on glass substrate by vacuum method at atmospheric temperature and the optical bandgap energy was observed to be 1.48±0.01eV[21].

Raid A.Ismail described the consequence of RTA on the properties of crystalline nanostructured cadmium telluride films prepared by vacuum evaporation method followed by annealing at 500ºC for 90s, which increased the bandgap from 1.4eV to 1.48eV. Increased annealing time showed a decreased resistivity revealing that after post-annealing the conductivity type of CdTe thin films did not change [22].

B.Lakshmi Shree et al. discussed the CdTe bilayer deposition on cleaned glass substrate by vacuum evaporation; the bandgap was found to be 2.1 to 1.7eV, which decreased with the increase in film thickness. This bilayer thin film could be used to fabricate multijunction solar cell [23].

When polycrystalline cadmium telluride thin films were fabricated by vacuum evaporation technique coated on the glass substrate at atmospheric temperature followed by annealing at 400ºC for an hour, the optical bandgap was found to be 1.42 – 1.75eV. G.H.Tariq et al. reported that thin films prepared by the above method were potential candidates for PV applications[24].



Ref[24] : G.H.Tariq, M.Anis-ur-Rehman, Annealing effects on physical properties of doped CdTe thin films for photovoltaic applications, Materials Science in Semiconductor Processing, 30(2015)665.

Fig:2Plotsof $(\alpha h\nu)^2$ vs hv, CdTe thin films annealed at 100-400ºC[24].

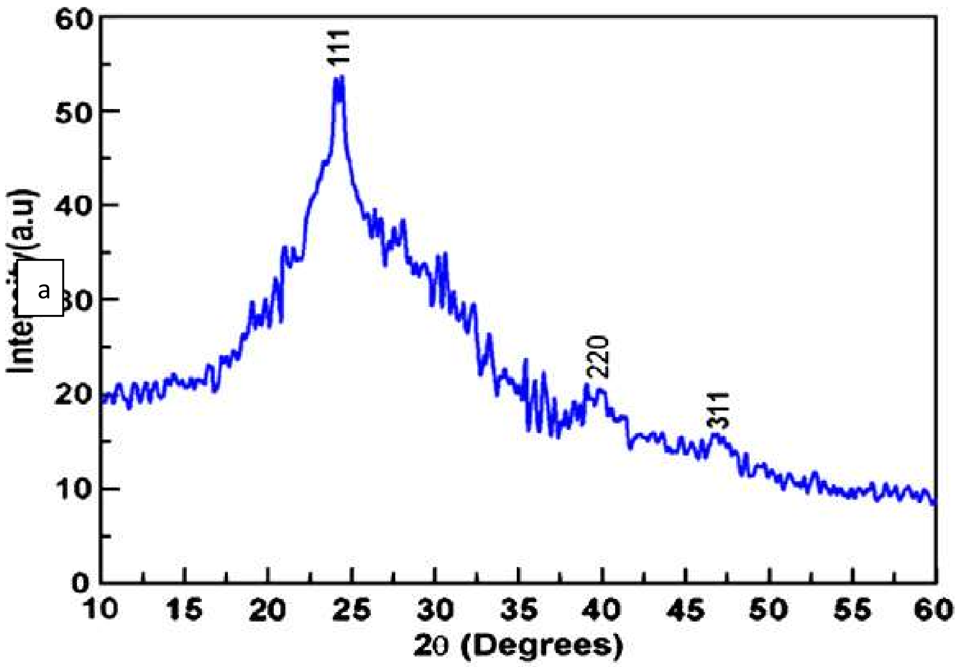
CdTe semiconductor TFMs were deposited by vacuum evaporation method on an optical glass substrate, and the bandgap values were found to be in the range 1.5eV reported by O.Toma et al.[25].

Cadmium Telluride thin films prepared by vacuum evaporation and the substrate temperature ranges from 30ºC to 300ºC and the bandgap was found to be 1.475eV to 1.63 eV. The decrease in resistivity with an increase in substrate temperature was explained by Rehana Zia et al.[26].

Subhash Chander et al. described the influence of thickness (450, 650, 850nm) of CdTe films prepared by TVE method, deposited on indium tin oxide coated glass substrate. The bandgap values were found to be 1.44-1.63eV. CdTe thin films having higher thickness might be used in the solar cell's application as an absorber layer[27].

Subhash Chander et al. investigated thermally evaporated cadmium telluride TFMs with temperature-induced optical and structural properties annealed at (150,250,350) ºC, and the optical bandgap values were 1.57 -1.87eV. For the preparation of CdTe solar cells, annealed films at 350ºC can be used as absorber layer[28].

Sukhvir Singh et al. have succeeded in preparing CdTe thin films of good quality consisting of a single phase and found them to be in stoichiometric proportion, by depositing on potassium chloride and also on glass substrates by using vacuum evaporation method [29].



Ref[29] : Sukhvir Singh, Rajeev Kumar, K.N.Sood, Structural and electrical studies of thermally evaporated nanostructured CdTe thin films, Thin Solid Films, 519(2010)1078.

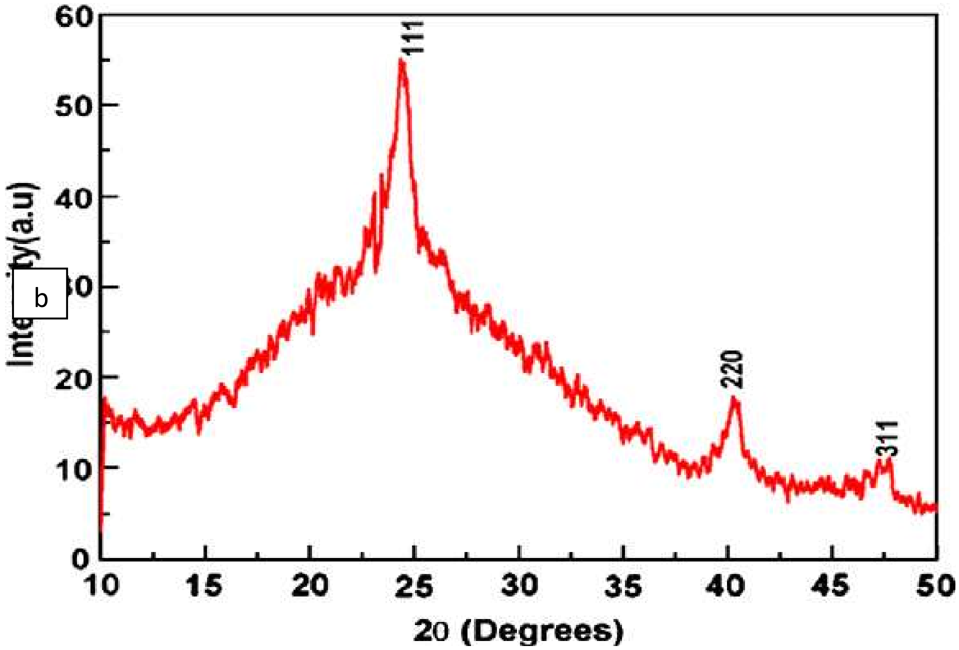
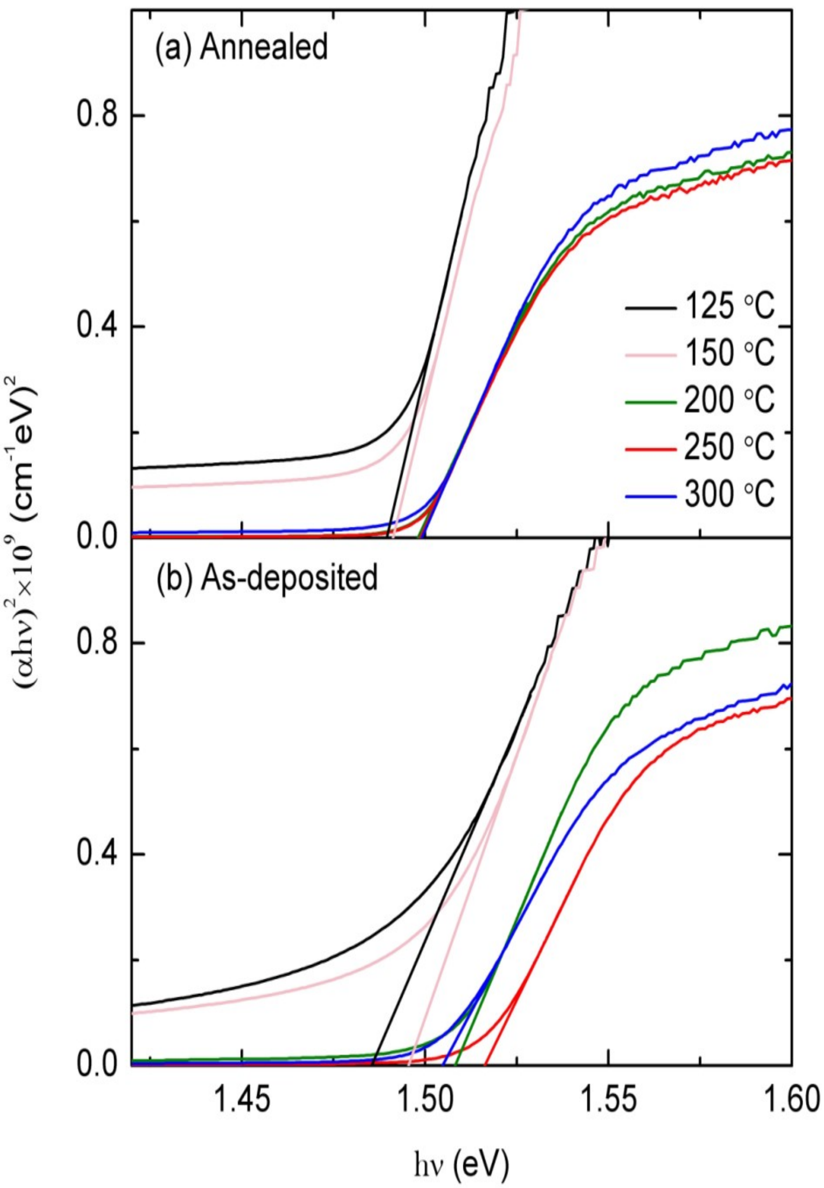


Fig:3. (a) and (b) XRD pattern of CdTe thin films deposited on potassium chloride substrate at 300K , 473K [29].

B. L.Williams et al. achieved 8.01% of peak efficiency for substrate configuration of CdTe solar cells by a combination of radio frequency sputtering and close-space sublimation [30].

C. M.T.Dejpasand et al. deposited the thin layers of CdTe on glass substrates at various substrate temperatures (100, 200, 300 & 400)ºC by using thermal evaporation method. By increasing the substrate temperature, the bandgap energy was found to decrease. The optical properties of cadmium telluride thin films can be tuned by this substrate temperature[31].

P.K.K.Kumarasinghe et al. concluded that by using vacuum evaporation technique CdTe films fabricated at 250ºC substrate temperature were found to be the most suitable films for PV applications[32].



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Fig,4: Plots of $(\alpha h\nu)^2$vshvfor (a) the annealed films, (b)as - prepared cadmium telluride TFMs at (125-300)ºC [32].

Among these different methods, thermal evaporation technique has advantages such as very high deposition rate, profitable method of operation and low material consumption. So, this technique is generally used for the deposition of thin films [3]. Nanostructured semiconducting compound of CdTe thin films are also fabricated through a chemical method, which has glucose biosensors application[34].

III. CONCLUSION

This article summarizes the different methods of cadmium telluride thin film preparations and their bandgap levels based on thickness, substrate temperature and post deposition annealing temperature. From this review, zinc blende structure of cadmium telluride TFMs fabricated by vacuum evaporation technique is the most convenient method for the production of solar cells for a wide area.

ABBREVIATIONS

TFMs-Thin films, RTA-Rapid Thermal Annealing, PV-Photovoltaic, TVE-Thermal Vacuum Evaporation.

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