IARJSET
ISSN (O) 2393-8021, ISSN (P) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified ⁜ Impact Factor 8.066 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 10, Issue 6, June 2023
DOI: 10.17148/IARJSET.2023.10605

OPTICAL ANALYSIS OF SPRAY PYROLYSIS SYNTHESIZED CDS THIN FILMS FOR SOLAR CELL APPLICATIONS

Mahendra kumar

Department of Physics, Hindu College Moradabad, Uttar Pradesh-244001, India

Abstract: Here we report, room temperature deposition of CdS thin film on antimony doped tin oxide (ATO) substrate through spray pyrolysis technique. The optical properties of the CdS thin film are studied using UV-Vis-spectrophotometer, which operated the UV to the visible wavelength range. Analysis indicates that the absorbance of thin films decreases sharply at a critical wavelength (around 330nm to 349nm). Average absorption was found to be 17%. Optical absorption coefficient was estimated in the energy range. The recorded total reflectance spectra of deposited CdS thin films in the range of 250 nm to 800 nm, on glass substrates. Average reflection was approximately 10% for samples. The calculated values of the band gap of the films were found to be 2.88 eV (by Tauc plot) and 2.82 eV (ASF method). Also, the calculated value of urbach energy for CdS film is 510meV.

Keywords: Spray pyrolysis, CdS, optical characteristics, absorption, reflection, band gap, urbach energy etc.

I. INTRODUCTION

In the last few decades much more effort has been put into the development of thin films. Mostly, thin film research is concentrated around II-VI group semiconductors junction thin films. One of the most promising thin films are Cu_2S/CdS due to the high percentage of conversion of solar energy into electrical energy more than 10%.

To synthesis of different morphologies of CdS based heterostructure such as nano-flakes, triangular, nanospheres, nanorods, flake like shape, up to date various physical and chemical routes are used for the synthesized of CdS or CdS based heterostructures such as magnetron sputtering, thermal evaporation, electron-beam, sol-gel, co-precipitation, chemical bath deposition, spray pyrolysis, etc. On other hand various solution (sol gel, spin coating and all inorganic solution) [1-3] processed thin film heterojunction are used at low temperature for various potential applications, interesting observation the irradiated (200 ◦C) dielectric exhibited the highest number of traps on the same energy level (at 0 eV) [1], the processing temperature dependent tunable electronic band structure for the solution processed dielectric with tuning the electron affinity is applicable to other dielectrics which are useful to obtain improved performance from electro-optical devices[4], on other hand a highly sensitive controllable trap detection method is used to detect shallow and deep level electronic traps in dielectrics. The method is simple, independent of substrate material and captures the trap energy signature in dielectrics; this can assist in material selection during technology development [5], also advantage of solution-processed thin film for fabrication of device is to control the contact resistance due to dimension modification [6]The excellent observation was reported at low temperature below 200 °C solution processed tunable flash memory device without tunneling and blocking layer [7]. Among all mentioned techniques, spray-pyrolysis process is successfully applied to synthesize a thin film. It has several advantages over other processes, like high purity of synthesized films, regular shape of particles, a better control of stoichiometry and chemical regularity in coupled oxide, and continuous working. Also, this technique makes the experimental process relatively simple.

II. EXPERIMENTAL DETAILS

The CdS thin films were prepared onto antimony doped tin-oxide (ATO) substrate by cost affecting spray pyrolysis and dip coating. First the CdS film was deposited at temperature of 320°C. Prior to CdS thin films deposition, the tin oxide and antimony doped tin oxide films on glass substrate were prepared by spray pyrolysis in which an aqueous solution of stannic chloride mixed with alcohol was sprayed over heated clean glass substrate for the undoped tin oxide films. The sprayed droplets undergo an endothermic reaction on the surface of the substrate. The heat of the substrate initiates the chemical reaction, by providing the necessary thermal energy for decomposition of reacting materials into its constituents and recombination of these constituents form desired oxide films. The other volatile products formed during this process escape out. The reaction involved is given as:

$$SnCl_4 + 2H_2O \rightarrow SnO_2 + 4HCl$$

DOI: 10.17148/IARJSET.2023.10605

However, the reaction does not proceed towards completion, thus forming oxygen deficient SnO_2 films. The alcohol acts as a reducing agent and deeds as carrier solution and dispersive medium. A transparent layer of antimony doped tin oxide (ATO) which acts as the bottom electrode to the CdS layer, was achieved by adding antimony chloride ($SbCl_2$) dissolved in concentrated hydrochloric acid. This procedure was repeated for different concentrations of antimony chloride. The deposition was carried out at 320°C. Thus, we obtained conducting glass. To deposit a film of CdS onto ATO substrate, the solution of cadmium chloride ($CdCl_2$) and thiourea (NH_2CSNH_2) was spread over ATO at 320°C. The reaction involved was given as:

$$CdCl_2 + NH_2CSNH_2 + 2H_2O \rightarrow CdS + 2NH_4Cl + CO_2$$
$$NH_4Cl \rightarrow NH_3 + HCl$$

The volatile products formed during this process escape out to the ambient atmosphere. Now the films were annealed for 10 minutes in vacuum to decrease the resistivity of the alloy films by removal of acceptor like oxygen levels.

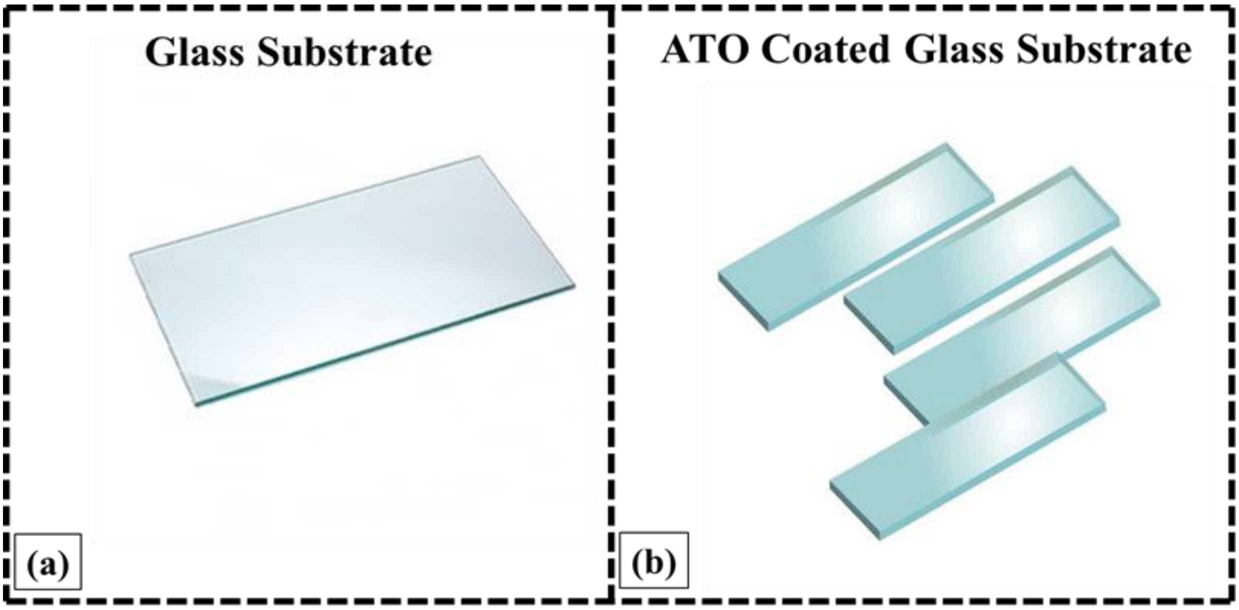

Fig.1 Different substrate used to deposition of thin films

3. Optical analysis of CdS thin film

The optical absorption, transmission and reflection of CdS thin film are measured using a UV-Vis spectrophotometer, which operated the UV to the visible wavelength range.

3.1 Total reflectance, transmission, absorption spectra of CdS thin films

Transmission spectra of CdS thin films in wavelength range of 250 nm to 800 nm on glass substrate is shown in Fig.2(a). Average transmission was observed 80%. A very weak transmittance in the ultraviolet (UV) region, which is close to 0% was also observed for sample. The region of strong absorbance for all films was observed between λ = 280 to 330 nm due to the excitation and the migration of the electrons from the valence band to the conduction band [7]. Fig.2. (b) shows the spectra of absorbance vs wavelength of thin films (onto glass substrate). Analysis indicates that the absorbance of thin films decreases sharply at a critical wavelength (around 330nm to 349nm), and then become relatively constant (wavelength regions > energy bandgap)**.** Average absorption was found to be 17%. Optical absorption coefficient was estimated in the energy range. The behavior of optical absorption coefficient is like the absorption spectra of thin films. The absorption coefficient increases with increase in photon energy. This is because the chances of electron transfer between the valence band (VB) and the conduction band (CB) are minimal in the lower photon energy region and very significant in the higher photon energy region.

The recorded total reflectance spectra of deposited CdS thin films in the range of 250 nm to 800 nm, on glass substrates. Average reflection was approximately 10% for samples deposited on glass substrate. In addition, it is found that the sum of transmittance, absorption and reflectance is found in the order of the unit [8].

$$A+R+T=1$$

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁒ Impact Factor 8.066 ⁒ Peer-reviewed / Refereed journal ⁒ Vol. 10, Issue 6, June 2023

DOI: 10.17148/IARJSET.2023.10605

It is evident from Fig.2(b) that the first Region-I (UV-Region), the absorption edges were found for CdS film.

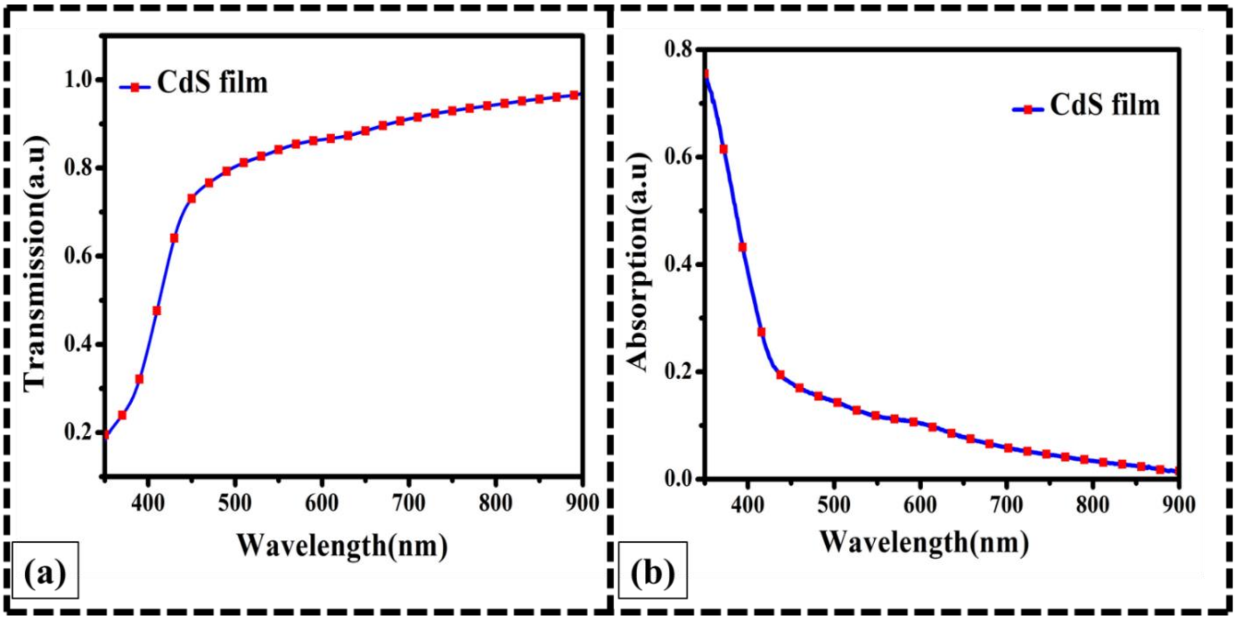

Fig.2. (a) Transmission, (b) absorption of CdS thin film

3.2 Optical energy gap and Urbach energy of CdS thin films

The band gap of CdS films was estimated using Tauc's plot method. This method is based on a mathematical equation that relates the absorption coefficient (α), the energy of photons (hν), the transition probability constant (R), and the power factor (n) to the band gap (Eg), which is expressed as [9]:

$$\alpha h\nu = R\,(h\nu - E_g)^n$$

The band gap was calculated by extrapolating the straight linear region of the plot to the energy of photons equal to 0, as shown in Fig. 3(a). The calculated values of the band gap of the films were found to be 2.88 eV.

The traditional Tauc equation was rewritten as a function of wavelength (λ) and then modified to form the absorption spectrum fitting (ASF) method, which is written as [10]

$$\alpha(\lambda) = R_1 (hc)^{n-1} \lambda \left(\frac{1}{\lambda} - \frac{1}{\lambda_g} \right)^n$$

Where λ_g are wavelengths corresponding to the band gaps of CdS films. The above equation can be modified as follows [11]:

$$A(\lambda) = R_2 \lambda \left(\frac{1}{\lambda} - \frac{1}{\lambda_g} \right) + R_3$$

Where, $R_2 = \left[\frac{(hc)^{n-1} x}{2.303} \right]$

, x is thickness, R_1, R_2 and R_3 are constant. The band gaps of CdS films can be calculated by an ASF method.

DOI: 10.17148/IARJSET.2023.10605

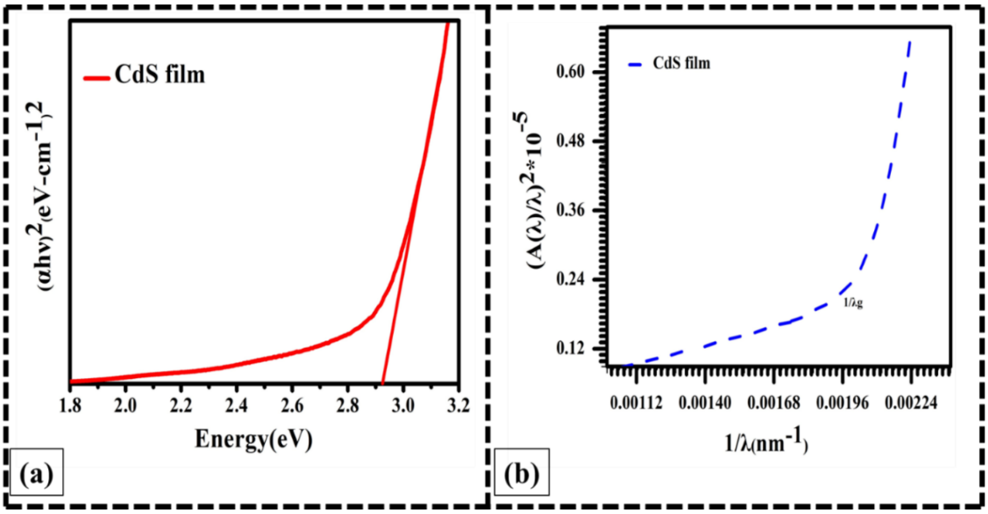

Fig.3. (a) band gap (Tauc plot), (b) band gap (ASF plot) of CdS thin film

This method allows the calculation of the band gap of CdS films without knowing their thickness. The modified equation was used to estimate the band gap using the ASF method. The value of the band gap could be calculated from the parameter [12]:

$$E_g = \frac{hc}{\lambda} = \frac{12400}{\lambda(\text{Å})} eV$$

The value of λ_g was extrapolated from the linear region of a graph $\left(\frac{A(\lambda)}{\lambda}\right)^{\frac{1}{n}} vs\ \frac{1}{\lambda}$ curve at $\left(\frac{A(\lambda)}{\lambda}\right)^{\frac{1}{n}} = 0$. The best fit was observed when the slope was equal to 2, as shown in Fig. 3b. The estimated value of the band gap for the CdS films was 2.82 eV. Another important optical parameter is urbach energy, it is an exponential region of absorption spectra in energy range, which reveals a transition between occupied states in the VB edge to unoccupied states of the edge of CB. The urbach energy present in the non-crystalline, defect, randomness, disordered, and amorphous thin film owing to the localization states such materials, which may be either extend or narrow the band gaps. Which is expressed as[13]:

$$\alpha = \alpha_0 \exp\left(\frac{h\nu}{E_U}\right)$$

$$ln\alpha = ln\alpha_0 + \left(\frac{h\nu}{E_U}\right)$$

Here E_U is the Urbach energy, which characterizes the slope of the exponential edge. Urbach energy has been estimated by the reciprocal of gradient of the linear part of ln α vs energy plot, as shown in Fig. 4. The calculated value of urbach energy for CdS film is 510meV.

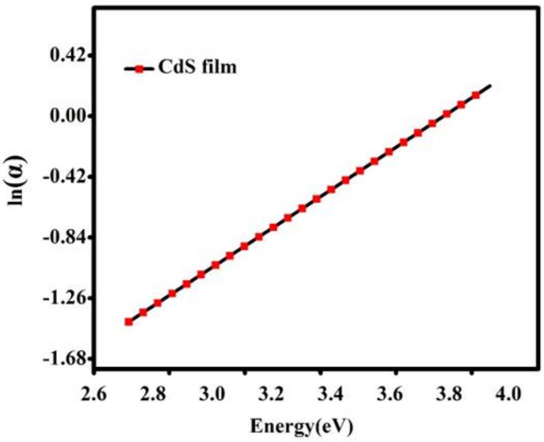

Fig.4. Urbach energy of CdS thin film

DOI: 10.17148/IARJSET.2023.10605

CONCLUSIONS

In summary, CdS thin films were prepared on ATO/glass substrate using spray pyrolysis methods. The films were characterized for their optical properties. The optical properties were. The optical characteristics reveal that the various optical parameters estimated using different equations and show quite good response. Thus, the obtained results show that CdS films are beneficial to develop large-area, low cost and high-quality photovoltaic devices for advanced future technology.

ACKNOWLEDGEMENTS

Author is grateful to **Dr. Kapil Saxena**, K.N.I.T. Sultanpur for fruitful discussion and encouragement.

REFERENCES

[1] 1.Mondal, S., & Kumar, A. Tunable electronic trap energy in sol-gel processed dielectrics. IEEE Transactions on Electron Devices, 68(3), 1190-1195. (2021).
[2] Venkataraman, V. All inorganic solution processed three terminal charge trapping memory device. Applied Physics Letters, 114(17), 173502. (2019).
[3] Mondal, S., & Venkataraman, V. Tunable electron affinity with electronic band alignment of solution processed dielectric. Applied Physics Letters, 111(4), 041602. (2017).
[4] Mondal, S., Paul, T., Ghosh, A., & Venkataraman, V. Gate-controllable electronic trap detection in dielectrics. IEEE Electron Device Letters, 41(5), 717-720. (2020).
[5] Mondal, S. Controllable surface contact resistance in solution-processed thin-film transistors due to dimension modification. Semiconductor Science and Technology, 35(10), 10LT02. (2020).
[6] Mondal, S., & Venkataraman, V. Low temperature below 200° C solution processed tunable flash memory device without tunneling and blocking layer. Nature communications, 10(1), 1-7. (2019).
[7] Kumar, C., Donoso, B., Silva, H., Padilla-Campos, L., & Zarate, A. (2021). The enhanced light trapping nature of NiOx thin films deposited by magnetron sputtering onto silicon solar cells at room temperature. Materials Letters, 297, 129961.
[8] Gunasekaran, M., & Seenuvasakumaran, P. (2022). Structural and optical properties of CdS & Pb doped CdS thin films coated by spin coating technique. Materials Today: Proceedings, 49, 2707-2711.
[9] Jubu, P. R., Yam, F. K., Igba, V. M., & Beh, K. P. (2020). Tauc-plot scale and extrapolation effect on bandgap estimation from UV–vis–NIR data–a case study of β-Ga2O3. Journal of Solid-State Chemistry, 290, 121576.
[10] Souri, D., & Shomalian, K. (2009). Band gap determination by absorption spectrum fitting method (ASF) and structural properties of different compositions of (60− x) V2O5–40TeO2–xSb2O3 glasses. Journal of Non-Crystalline Solids, 355(31-33), 1597-1601
[11] Ghobadi, N. (2013). Band gap determination using absorption spectrum fitting procedure. International Nano Letters, 3(1), 1-4.
[12] Souri, D. (2011). Effect of molybdenum tri-oxide molar ratio on the optical and some physical properties of tellurite–vanadate–molybdate glasses. Measurement, 44(4), 717-721.
[13] Jamal, M. S., Shahahmadi, S. A., Chelvanathan, P., Alharbi, H. F., Karim, M. R., Dar, M. A., ... & Akhtaruzzaman, M. (2019). Effects of growth temperature on the photovoltaic properties of RF sputtered undoped NiO thin films. Results in Physics, 14, 102360.