CdS Thin Film using a Simple Technique

L.F.M. Anand[1]*, A. Srikantha[1], G.N.A. Kumar[2], M. Vishwas[3], R. Darmesh[1] and G. Geetha[1]

[1]Department of Post-Graduation Studies in Physics, Government First Grade College- K R Puram, Bangalore - 560036, India.
[2]Department of Physics, Ramaiah Institute of Technology, Bangalore-560054 India.
[3]Department of Physics, Nrupathunga University, Bangalore-560001, India.
E-mail: francismanand@gmail.com

December 8, 2025

Abstract

Cadmium sulphide (CdS) thin film is synthesized chemically using a simple spray pyrolysis method. CdS solution is prepared from the chemical solution mix of cadmium chloride and thiourea in the ratio of 3:2. The solution is diluted to 0.1M concentration using deionized water and is sprayed using a spray can on a clean glass substrate placed on a hotplate. The thin film deposited on the glass substrate is characterized for structural analysis using X-ray diffraction spectrometer confirming hexagonal structure. XRD data is compared with JCPDS data card. A good agreement is established. The Surface morphology and chemical composition of CdS thin film is characterized using Tescan Vega 3 energy dispersive X-ray spectrometer cum scanning electron microscope. The energy dispersive X-ray spectrum confirms the presence of sulphur K X-ray peak and cadmium X-ray peaks in different concentration of the CdS film deposited. Absorbance and transmittance of UV-VIS radiation in the deposited film is studied and the optical bandgap is calculated to be 2.45eV from the Tauc plot. An uncertainty of less than 2% is reported in the present work over other standard methods.

Keywords: CdS thin film, spray pyrolysis, XRD, SEM, EDAX characterization

1. Introduction

For several centuries, thin film coating on materials is reported as one of the finest art by artisans and goldsmiths across the globe. Thin film is a two-dimensional layer of a material that is formed on a substrate in order to acquire qualities that the same material in its bulk form aren't seem to be easily achieved or cannot be realized at all [1]. Hence, thin films find applications in many fields such as, material science, semi-conductor detector physics, solar cells, optoelectronics, photonics etc. Depending on the application of the films, these films are coated / deposited on different materials with varying thickness [2]. Researchers have used several techniques to synthesize thin films viz. Physical and chemical evapouration, Sol-gel, spray pyrolysis, electroplating, sputtering, Spin coating, Dip coating, Doctor's blade etc as the processes of synthesis of thin film technology [3]. Employing these techniques, many different elements are grown or deposited as thin films for many decades. Several researchers have studied the synthesis of CdS thin films using chemical bath method and spray pyrolysis method [4]. Due to its many distinctive qualities, such as great transmittance in the UV-Visible region, high conductivity, broad band gap value, gas sensing features, etc., CdS semiconductor thin films have a significant potential for use in environmental and energy-related applications [5]. In the present work, using a simple spray can and the well- established spray pyrolysis technique, CdS thin film is deposited on a clean glass substrate. Firstly, aqueous CdS solution is prepared chemically from the admixture of cadmium chloride and thiourea solutions in the ratio 3:2 at room temperature. The glass substrate is placed on a hotplate and is heated gradually and steadily to 300^{o}C. The chemically prepared solution of CdS is taken in the spray can and is sprayed on the heated glass substrate. CdS thin film deposited on the glass substrate is air cooled and characterisation studies like structural, morphological, chemical composition, molecular

 DOI 10.69710/ljp.v2i2.15037

bonding and optical properties have been studied using X-ray diffractometer (XRD), Scanning electron microscope (SEM), energy dispersive X-ray analysis spectrometer (EDAX), Fourier transform Infrared (FT- IR) and UV-visible spectrometers using methods in [6, 7]. XRD analysis of the CdS thin film in the present work confirms the presence of hexagonal structure in the crystalline plane (002). SEM analysis shows that CdS thin film in the present work to have a thickness of 200nm. The values for these parameters is compared with the standard values for the same parameters of CdS thin films reported by others' experimental and the standard data tables available in the literature. The presence of K X-ray peaks of Sulphur and cadmium in different composition enunciates the chemical composition of CdS in the film deposited. The C-S bond at 793 cm^{-1} and a strong sharp peak at 661 cm^{-1} indicates the presence of Cd-S stretching that agrees well with the reported values of [8]. The intensity peak position at 2θ values in XRD spectrum, the (h k l) value for CdS thin film deposited on glass substrate in the present work agrees well with the standard values within experimental uncertainty of less than 2%. The optical energy bandgap is determined using Tauc's method and found to be 2.45eV which is in good agreement with the theoretical and others' experiment value. In the present work, we propose a simple less expensive method to deposit CdS thin film on glass substrates by using non-vacuum technique.

2. Methodology

In the present work, we have employed the technique of spray pyrolysis to synthesize CdS thin film on a glass substrate using a spray can in a non-vacuum medium. The CdS solution is prepared from the mixture of 0.1 M solution of cadmium chloride and 0.1 M solution of thiourea in the ratio 3:2. Using standard methods discussed in [5, 9] 0.1 M aqueous solution of cadmium chloride ($CdCl_2$) and 0.1 M aqueous solution of thiourea [$(NH_2)_2CS$] is been prepared. Formula and method discussed elsewhere in [10 – 12], the weight of salt to prepare the 100 ml of 0.1 M solution were used.

$$W = M_t \times M \times V \tag{1}$$

where, W = Weight of salt (g); M_t = Molecular weight ($gmol^{-1}$); V = Volume of solvent (ltrs.). The CdS solution is prepared by mixing 0.1 M solution of cadmium chloride ($CdCl_2$) and 0.1 M solution of thiourea [$(NH_2)_2CS$] in the 3:2 ratio in a separate beaker and stirred it with magnetic stirrer for 30 min. A clear solution of cadmium sulphide (CdS) solution is obtained [5, 13]. CdS thin film is deposited on the plane glass slide that is washed with soap solution to remove grease and dust and rinsed in de-ionised water and air dried in a closed environment. The cleansed glass substrate is carefully placed on a hot plate and the temperature of the hotplate is gradually increased from room temperature. The prepared 0.1 M solution of CdS is taken in a spray can fitted with a fine nozzle having 1.4mm in diameter. The CdS solution is sprayed on the heated glass substrate as in Figure 1. CdS solution when sprayed on the glass substrate, the chemical reaction on the surface of the heated glass substrate according to [11] is as given in eqn.2.The solution sprayed settles down on the glass substrate and results in the growth of CdS thin film on the glass substrate. In order to have a film thickness of around 200nm, 30 sprays were sprayed in the time interval of 3 minutes. Once the spraying of CdS solution on the glass substrate is completed the substrate is allowed to cool to room temperature. Resulting in clean thin layer of CdS thin film deposition observed as a yellow coating on the erstwhile glass substrate as shown in Figure 2.

$$\mathbf{CdCl_2 + (NH_2)_2CS + 2H_2O \rightarrow CdS\downarrow + 2NH_4Cl\uparrow + CO_2\uparrow} \tag{2}$$

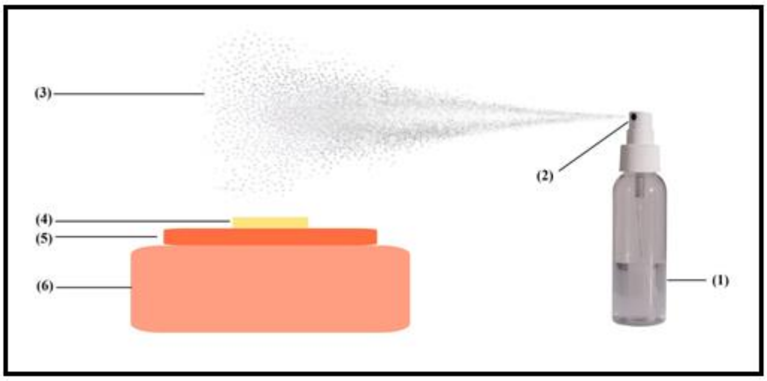

Figure. 1– Schematic diagram of spray pyrolysis method; (1)-Spray bottle containing solution, (2)-Spray nozzle, (3)-Fine droplets of solution, (4)-Glass substrate, (5)-Hot plate, (6)-Heater.

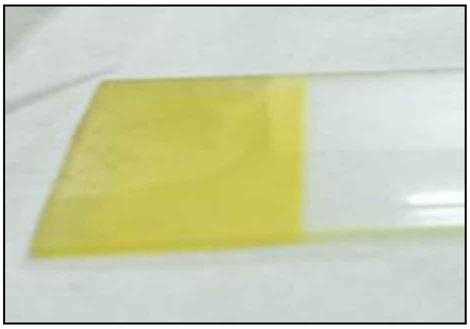

Figure 2. CdS thin film on glass substrate at 300K

In the present work, the glass substrate coated with CdS thin film is characterized for their structural, chemical and optical properties. The structural properties of CdS thin film prepared is confirmed by X-Ray Diffraction pattern performed using (Bruker D8 Advance X-ray diffractometer) with Cu Kα ray of wavelength λ=1.54 Å.The lattice constants have been calculated using Bragg's equation. The crystallite's grain size is determined by substituting Full Wave at Half Maximum (FWHM) values in the well-known Debye-Scherrer equation as follows.

$$D = \frac{k\ \lambda}{\beta \cos \theta} \quad (3)$$

Where, D is the crystallite size, K is the constant ~1 and λ=1.54 Å, β is full width at half maxima of the peak (FWHM) in radians, and θ is diffraction angle [4]. The chemical composition and surface morphology of CdS thin film prepared in this present work is studied using Energy Dispersive X – Ray Analysis (EDAX) and Scanning Electron Microscope (SEM) using (Tescan Vega 3). Using Fourier-Transform Infrared Spectroscopy (FTIR) (Bruker Alpha) make, the functional groups, molecular structure and molecular arrangements of the CdS thin film have been studied. The transmission coefficient and absorption coefficient of the CdS thin film in the present work is studied using UV-Visible spectrometer (Perkin – Elmer Lambda 365) in the wavelength range 190 -100 nm. The direct optical band gap is calculated from the Tauc plot of $(\alpha h\nu)^2$ versus photon energy hν in eV. Energy gap of the CdS thin film is calculated using [14] as in equation 4.

$$E_g = \frac{(-\,Y\ intercept)}{(\mathrm{Slope})}\ \mathrm{eV} \quad (4)$$

3. Result and Discussion

CdS thin film is synthesized from cadmium chloride and thiourea solutions in the ratio of 3:2. The solution so prepared is diluted to 0.1M by adding de ionized water and stirred for 30 min in a magnetic stirrer. The solution of CdS in the spray can is deposited in the form of a thin film in a non-vacuum medium by spray pyrolysis method. A homogeneous and uniform surface morphology is observed in prepared CdS thin film and the grains seems to be spherical in shape as shown in the SEM image in Figure 3. The thickness of the film in the present study is found to be 200nm. The structural properties of CdS thin film prepared in the present work is studied by subjecting the film to X-Ray Diffraction using Bruker D8 Advance X-ray diffractometer with Cu K_α X-ray of wavelength λ=1.54Å. The diffraction spectrum is shown in Figure 4. The peaks observed at 2θ angles are, 24.753, 26.510 and 28.165 degrees, corresponds to the planes with (h k l) parameters of (100), (002) and (101) planes confirming the hexagonal nature of CdS thin film. It is in good agreement with standard X-ray diffraction data reported elsewhere in JCPDS card also now known as ICDD (JCPDS powder diffraction file no. 96-901-1664) [11]. The grain size is calculated using the Debye -Scherrer's formula is 18.08 nm at (002) plane. In the present work, the surface morphology of CdS thin film is studied using scanning electron microscope (SEM). Elemental composition and its concentration in the prepared CdS thin film is studied using Energy Dispersive X-Ray Spectroscopy Analysis (EDAX). The spectrum of CdS thin film is shown in Fig. 5. The presence of peaks at 3.2 keV, and 3.4 keV for Cd L_α X-rays and L_β X-rays confirms the presence of Cd element and peaks at 2.3 keV confirms the presence of Sulphur element. Cd M X-ray peaks and S L X-ray peaks are also seen. Cadmium and Sulphur concentration in the thin film prepared in the present work is tabulated in table 1. The functional groups, molecular structure and molecular arrangements of the CdS thin film prepared in the present work is studied using Fourier-Transform Infrared Spectroscopy (FTIR).

The FTIR spectrum of prepared CdS thin film in the range of 500-4000 $cm^{-1}$is fitted for baseline correction using Origin software and is shown in Fig. 6. From the FTIR spectra, we observe the presence of broad band at 3300 cm^{-1} which is assigned to hydrated water and the hydroxyl group. The transmission band at 3339-3737 cm^{-1} shows the presence of strong hydrogen bond O-H stretch. The peak at 2339-2653 cm^{-1} attributes the C-H stretch. The vibration of C=O stretch is at 1768 cm^{-1}. The band 1541 cm^{-1} corresponds to C=N stretching, the bands at 1086 cm^{-1} to C-C stretching. C-S bond at 793 cm^{-1}, strong and sharp peak at 661 cm^{-1} shows the presence of Cd-S stretching, which agrees well with the reported values of [8]. UV-VIS spectroscopy is used to determine the optical parameters like absorption, transmission and band gap energy of the CdS thin film material prepared in the present work. The band gap of the CdS thin film is determined by plotting the graph of $(\alpha h\nu)^2$ versus photon energy hν in eV as in Fig. 8. From the formula as in equation (4) the determined band gap of prepared CdS film is 2.84 eV. The value for optical direct band gap of the CdS film in the present work is in good agreement with the others' experimental values.

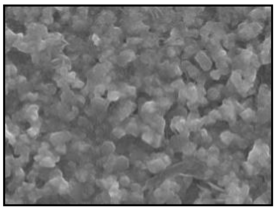

Figure 3. SEM of CdS film view field of 10.4μm

Table 1. Proportion of elements in CdS thin film

Z	X-ray	Weight %	Atomic %
S	18.04	18.04	43.55
Cd	81.96	81.96	56.45

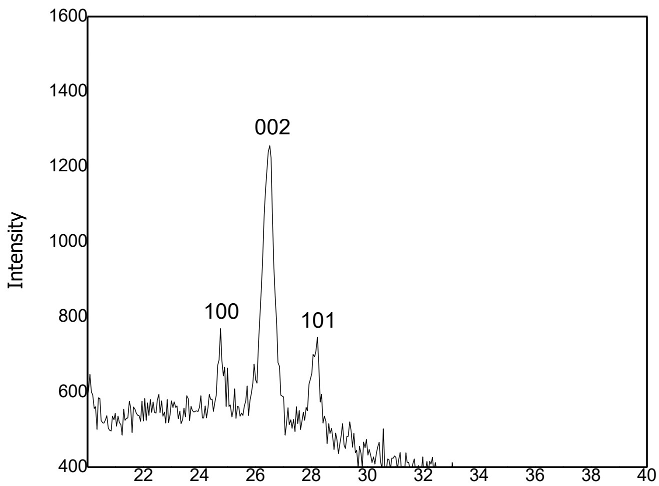

Figure 4. XRD spectra of CdS thin film on glass substrate of the present work

 DOI 10.69710/ljp.v2i2.15037

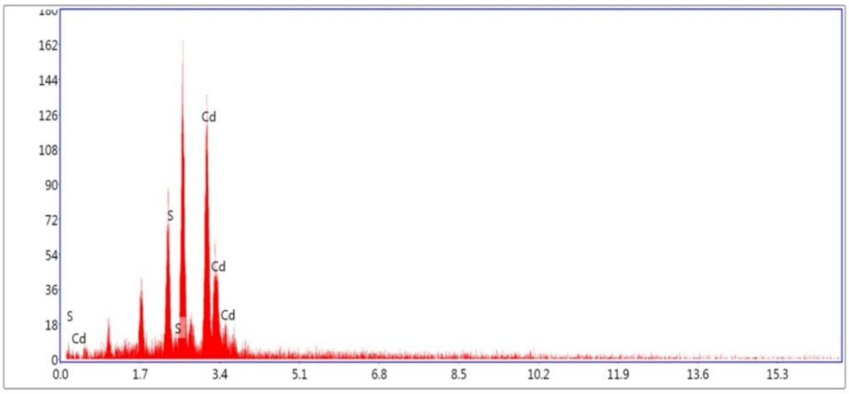

Figure 5. EDAX spectrum of CdS thin film showing Cd and S X-ray peaks

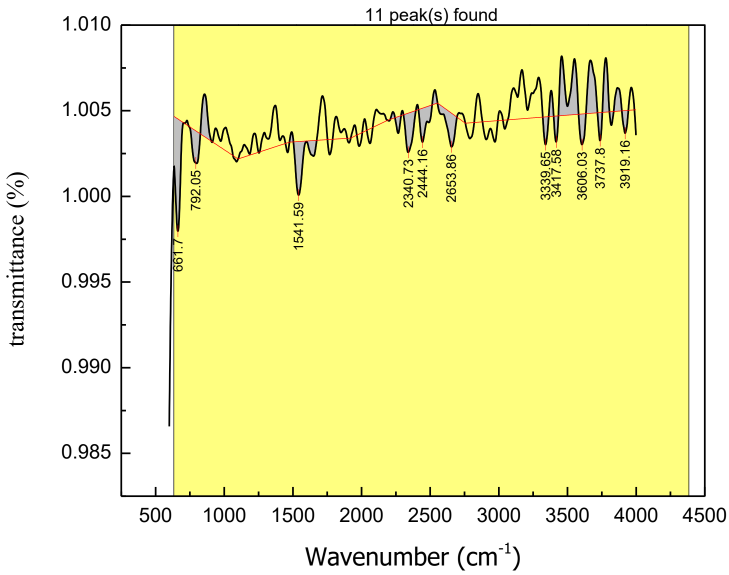

Figure 6. FTIR spectrum of CdS thin film in the present work

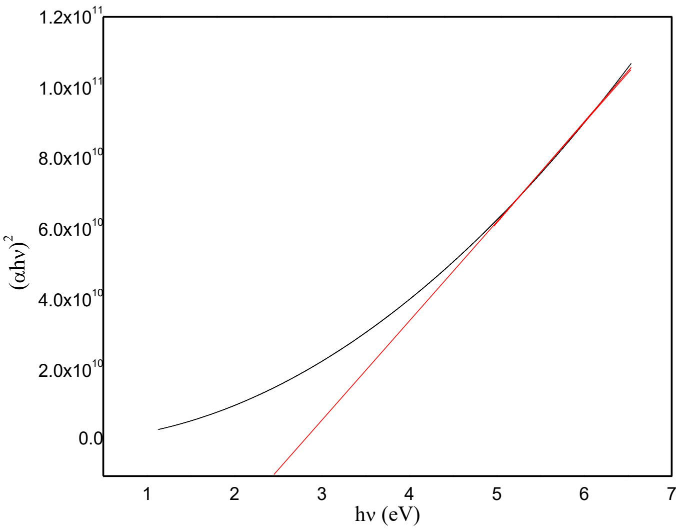

Figure 7. Plot of $(\alpha h\nu)^2$ versus hν of CdS thin film in the present work

 DOI 10.69710/ljp.v2i2.15037

4. Conclusions

CdS thin film is been deposited on a clean glass substrate using chemical spray pyrolysis method using a simple spray can with a nozzle size of 1.4mm in diameter. In the present work, CdS solution prepared by chemical method is sprayed on a glass substrate using 0.1M precursor solutions of cadmium chloride and thiourea at substrate temperature of 300oC. The film deposited has a hexagonal structure with crystal grain size of 18.08nm. The physical, chemical and structural properties viz. structural, surface morphology, element composition, is studied using the techniques discussed in methodology. XRD confirms the crystalline nature with a hexagonal structure in the (002) plane. Uniform and spherical shape grains are observed from SEM images. Element composition and proportions of the film have been studied by EDAX and the obtained result agrees with the values set as standard for CdS thin films on glass substrate. Hence, the CdS film deposited in the present work, shows good structural and chemical properties. From this study, the method discussed earlier in methodology seems to be a simple method to prepare CdS thin film on glass substrate. However, for the properties like, mechanical strength, transmittance, electrical conductivity and applications of CdS film grown by this method needs further study. Hence, we suggest the study may be extended further for the complete picture of films grown by the method of chemical spray pyrolysis and their applications in the field of semiconducting devices and optoelectronic industries.

5. Acknowledgement

The authors would like to thank Dr. Shymala, Head, Department of Physics, Mount Carmel College –Autonomous, Bangalore for the technical expertise.

6. Conflict of Interest

All the authors hereby declare that this project is not funded by any organization. All the authors have equal contribution in the research work and have no conflict in the journal publishing our work.

7. Copyright Notice

References

[1] S. Kumar and D. K. Aswal (2020) *Recent Advances in Thin Films* 1.
[2] C. Schaefer, G. Brauer and J. Szczyrbowski (1997) *Surface Coating Technology* **93** 37.
[3] M. A. Abdullah, H. Al. and A. J. J. Salah (2012) *J. Assoc. Arab Univ. Basic Appl. Sci.* **11** 27.
[4] T. Geremew (2022) *J3DPA* **1**1.
[5] M. Vishwas, K. S. Shamala and B. G. Satheesh (2022) *J. Opt.* **51** 736.
[6] W. Zhou, R. Apkarian, Z. L. Wang and D. Joy (2007) *Scanning microscopy for nanotechnology, Techniques and Applications* 1.
[7] H. D. Sachin and M. S. Bhagwat (2006) *Int. J. Phys. Res.* 58.
[8] K. Manikandan, D. C. Surendra, P. Mani and P. J. Joseph (2015) *AJEAS* **8** 318.
[9] R. M. Perez, G. S. Rodriguez, J. S. Hernandez, A. M. Aevedo, A. A. Carbajal, O. V. Galan, J. C. Alanso and G. C. Puente (2005) *Thin Solid Films* **480** 173.
[10] R. J. Vikram, G. N. Sneha, M. M. Rayate and A. Bhagyashri (2019) *IJRR* **6** 1172.
[11] M. A. Sundus and Al-Dujayli (2012) *IREPHY* **6** 409.
[12] M. A. Manthrammel, S. Mohd. Shkir S and A. S. Mohd. Anis (2020) JMR **35** 4112.
[13] N. J. Ghdeeb (2020) IJTFST **11** 1 115.
[14] M. R. Ranganath and B. Lobo (2012) Int. Conf. on Materials Science Research and Nanotechnology, Mother Teresa Women's University, Kodaikanal, TN, India, ISBN 81-86520-14-7 194.
[15] A.B. Hirpara, S.H. Chaki, A.J. Khimani, R.M. Kannaujiya, M.P. Deshpande (2022) *J. Mater. Sci. Mater. Electron.* **33** 25 20303.

[16] K. Balakrishnan, B. Vengateshan, N. Kanniah, P. Ramasamy (1999) *J. Mat. Sci. Let.* **9** 785.
[17] H.T. Shaban, M. Mobarak, M.M. Nassary (2007) *Physica B* 389 351.
[18] D.K. Dwivedi, D. Shankar, M. Dubey (2010) J. Ovonic Res. 6 57.
[19] S.A. Mahmoud, A.A. Ibrahim, A.S. Riad (2000) *Thin Solid Films* **372** 144.
[20] A.N. Kadam, R.S. Dhabbe, M.R. Kokate, K.M. Garadkar (2014) *J. Mat. Sci. Mat. Elec.* 25 1887.
[21] A.I. Oliva, O. Solis-Canto, R. Castro-Rodriguez, P. Quintana (2001) *Thin Solid Films* 391 28.
[22] R.S. Meshram, B.M. Suryavanshi, R.M. Thombre (2012) *Adv. Appl. Sci. Res.* 3 1563.

 DOI 10.69710/ljp.v2i2.15037