Volume 4 / Issue 7/ July 2026
ISSN:2584-2706
International Journal of Modern Science and Research Technology
DOI: https://doi.org/10.5281/zenodo.21410464

Optimization of CDS Thin Films Characterization for High Efficiency Photovoltaics & Sustainable Energy Solutions

Hiya Jain; Dr. Neeraj Verma; Dr. Nisha Devi
Department of Physics, Saraswati Mahila Mahavidyalaya, Palwal.
Email: jainhiya7@gmail.com

Abstract
With the increasing consumption of conventional energy and the gradually serious environmental crisis, the research and application of solar cells attracted a worldwide attention. In the past ten years, the progress of the thin film preparation technology promoted the technology of the second generation Solar cells based on semiconductor thin film materials. Due to the demand for less material, the thin film solar cell technology can effectively reduce the cost of materials. Moreover, the thin film materials can flexibly deposit on substrates such as glass, stainless steel, and plastic, especially suitable for solar building integration. Thin film solar cells (TFSC) are a promising approach for terrestrial and space. For large-area devices required for realistic applications, thin-film device fabrication becomes complex and requires proper control over the entire process sequence. Proper understanding of thin-film deposition processes can help in achieving high-efficiency devices over large areas. The study is motivated by the broader need for scalable and cost-effective semiconductor coatings for energy conversion, for which chemical-bath-derived CdS remains a technologically relevant benchmark till now. Thin films deposited on glass substrates are generally characterized using X-ray diffraction, scanning electron microscopy, compositional analysis, and UV & Visible light spectroscopy to evaluate phase constitution, crystallinity, surface coverage, stoichiometry, transmittance, and optical band-gap behaviour.

Article History
Submission date-: 17/07/2026
Acceptance date-: 17/07/2026
Publicationdate-: 17/07/2026

Introduction

Cadmium sulfide (CDS), which is a Chalcogenide material, is of great scientific importance due to its low resistivity, high transmittivity, good chemical stability and large band gap of 2.42 eV at room temperature. CdS thin film have played very interesting role for their photovoltaic applications like photo conducting cells, light emitting diodes and non-linear integrated optical devices. Thin films of CdS, as a window layer, have been largely in use in the application of high efficiency solar cells.

The deposition techniques also have great influence on the properties of the CdS thin films. Various deposition techniques are used like Chemical Bath Deposition (CBD), Electrodeposition, Spray pyrolysis, Chemical Vapor Deposition (CVD), spin coating etc. were also investigated. Among these techniques, the Chemical bath deposition is a popular method for its simplicity and low cost and that's why CBD method was chosen for the deposition of CdS thin film in this research.

Thin films deposited on glass substrates are generally characterized using X-ray diffraction and Scanning Electron Microscopy to evaluate phase constitution, crystallinity, surface coverage, stoichiometry, transmittance, and optical band-gap behaviour. These diagnostic procedures are important in order to understand the condition required for higher absorption of energy from photons in deeper layer thereby increasing the efficiency. Particular emphasis is placed on the role of controllable synthesis parameters which includes precursor chemistry, pH, deposition temperature,

ISSN:2584-2706
DOI: https://doi.org/10.5281/zenodo.21410464

deposition time, and post-deposition treatment, since these govern nucleation, grain growth, compactness, defect density, and ultimately the optoelectronic quality required for efficient solar-cell integration which has profound usage in Tropical and Semi-tropical region and can help massively is clean energy.

Materials and Methods

CdS (Cadmium Sulphide) thin films have been synthesized by Chemical Bath Deposition Technique. The chemicals used for the synthesis of CdS thin films were : Cadmium Chloride [$CdCl_2$], Thiourea (NH_2CSNH_2), Triethanolamine ($C_6H_{15}NO_3$) and Ammonia solution. The cadmium chloride & thiourea are the sources of Cd^{2+} and S^{2-} ions, respectively. Triethanolamine works as a complexing agent to impede agglomeration during film formation. It helps in the slow release of ions leading to slow reaction and uniform deposition of a thin film.

The solution was made alkaline by adjusting the pH so that it does not self corrode the deposited thin film. The alkaline medium of solution was adjusted by adding ammonia solution. In deposition of CdS thin films by CBD technique: Initially 20mL of 13M Ammonia was added dropwise into 40mL of 2M Cadmium Chloride ($CdCl_2$) solution. The solution is stirred for 5 minutes. Now, in the prepared solution, 110mL of 0.65mL triethanolamine is added and stirred well for another 5 minutes. In constant stirring condition, 40mL of 2M Thiourea (NH_2CSNH_2) is added. The solution was stirred for another 5 minutes. The pH of final bath solution was measured and found to be 11. The solution was observed to turn yellow from colourless.

The cleaning of the glass slide was already done with help of Acetone and then wiped dried by tissue paper. Finally, the glass slides were dried for 1 hour at 70 degrees in an oven. This pre cleaned glass slide was then placed in bath solution for CdS thin film deposition. The beaker containing the final solution and glass substrate was maintained at constant temperature of 70 degrees Celsius. After finite time, the glass slide was removed from the solution. Homogenous CdS thin films deposition was observed on the glasss substrate. The substrate with the deposited film was washed serval times with distilled water to remove extra chemicals and solvents.

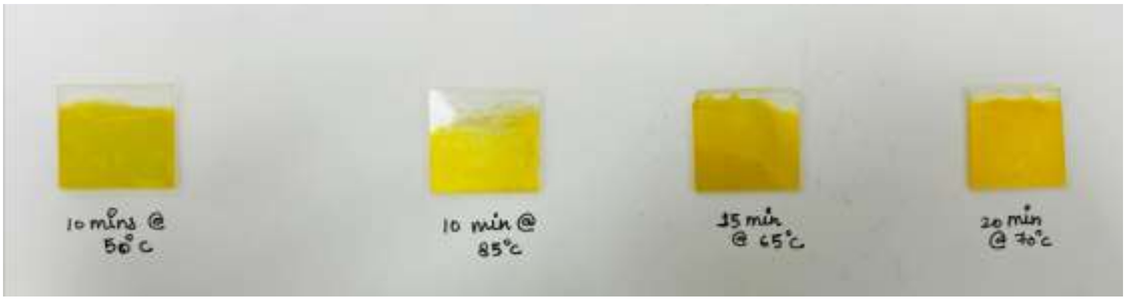
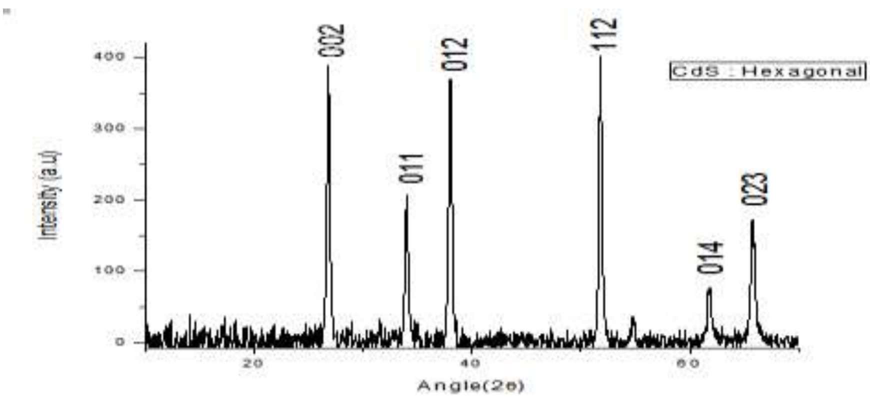


Fig: Thin Films fabricated with different Parameters

Results and Discussion

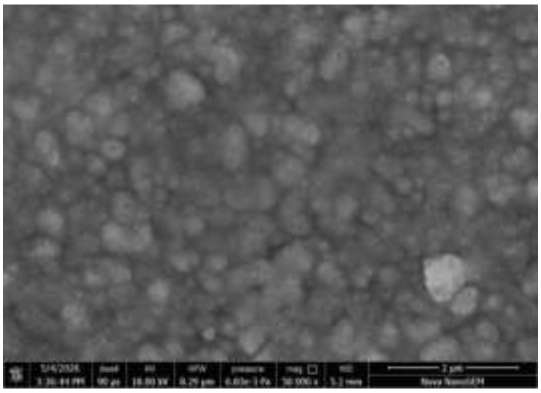
XRD - CdS Thin film:

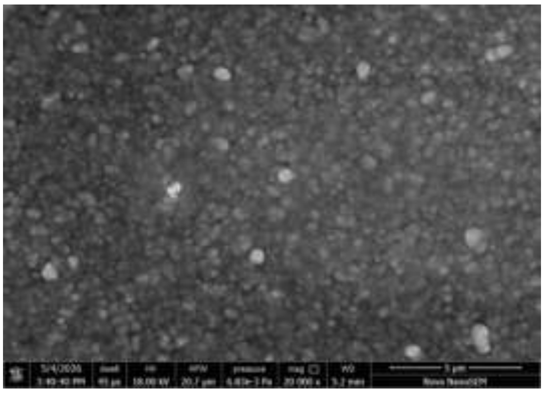


ISSN:2584-2706 DOI: https://doi.org/10.5281/zenodo.21410464

The XRD spectra of CdS thin films are recorded using Rigaku X-Ray diffractometer and displayed in Fig. XRD pattern exhibits four preferential peaks assigned to (002), (011), (012) and (112), orientations of hexagonal phase of CdS material. The hexagonal phase of CdS is crystalline. The observed diffraction patterns are in good agreement with the standard crystallographic data of JCPDS card No. 80-0006 of CdS material. The values of lattice constant a and c for hexagonal planes of the CdS thin films were calculated using checkcell software. The calculated values of lattice constant a and c are 4.183 nm (4.121 nm) and 6.562 nm (6.682 nm) respectively. The unit cell volume is 99.47(99.45). The calculated values of a and c are very close to observed values of CdS thin films.

SEM of CdS Thin film :





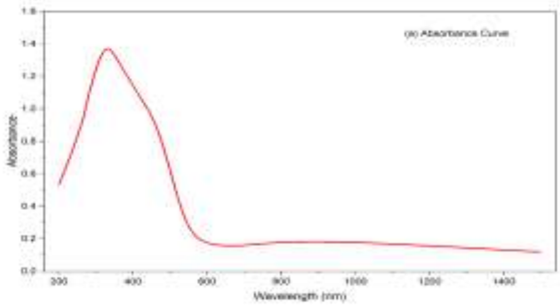
SEM (Scanning Electron Microscopy) images are displayed in Fig. for pure CdS.

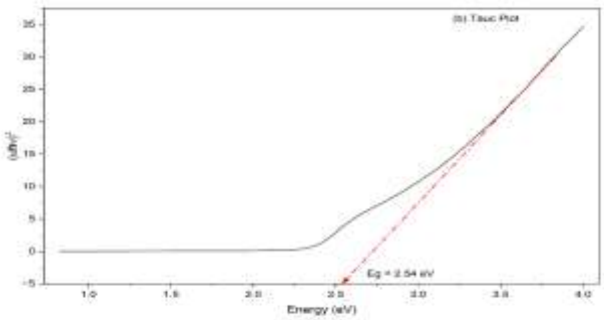
SEM image for CdS Thin film are very compact, the surface's uniformity is also good, the particle size was ~200nm, and the particle size distribution was also narrow. These surface characteristics are in good agreement with the film's high transparency. Some of the larger sized grains assigned to colloidal particles of S ions.

UV Vis Spectroscopy

The optical properties were investigated with UV-Visible spectroscopy. The Absorption Spectrum for the Cadmium Sulphide is shown in Fig. (a), indicating strong absorption in the range around 300-500 nm with an absorption edge at 333.33nm. The Tauc's relation is important in the calculation of optical band gap energy of CdS thin films. It shows the dependence of the absorption coefficient (α) on the photon energy ($h\nu$) by relation, $(\alpha h\nu)^n = K(h\nu - E_g)$ where K is Tauc's constant, which is a parameter independent of photon energy, ν is photon frequency and E_g is band gap of the material, n refers to the type of transition and equal to 2 in case CdS which is direct bandgap material. The band gap energy is the intercept obtained from the extrapolated line on the energy in the Tauc plot, i. e. $(\alpha h\nu)^2$ vs. photon energy ($h\nu$) plot. The optical band gap obtained from the Tauc's plot shown in Fig.(b) is 2.54 eV. The structural, composition, and optical characterizations were performed and deemed appropriate for photovoltaic applications.

ISSN:2584-2706
DOI: https://doi.org/10.5281/zenodo.21410464





Conclusions

In this work, CdS thin films found a greater role in development of sustainable, cheaper, and scalable materials for energy applications through a fabrication and characterization framework. Superior quality thin films of cadmium sulfide (CdS) having particle size of ~200 nm were successfully synthesized through the use of triethanolamine as a solvent on glass substrates by easy and cost-effective Chemical Bath Deposition technique. The XRD analysis of the sample confirms that the CdS thin films possess a highly crystalline hexagonal structure with preferential orientations. This structural consistency, along with the accurate unit cell volume, validates the phase purity and high crystallographic quality of the synthesized material.

Future Scope

By linking fabrication conditions to functional thin-film quality, this work supports the optimization of CdS coatings for next generation thin film energy devices and establishes a concise materials pathway from laboratory synthesis to photovoltaic applicability for clean energy generation.

References

[1] M. A. Scarpulla et al., "CdTe-Based Thin Film Photovoltaics: Recent Advances, Current Challenges and Future Prospects," Solar Energy Materials and Solar Cells, vol. 255, 112289, 2023. doi: 10.1016/j.solmat.2023.112289.

[2] P. K. Nair et al., "Semiconductor Thin Films by Chemical Bath Deposition for Solar Energy Related Applications," Solar Energy Materials and Solar Cells, vol. 52, no. 3 4, pp. 313–344, 1998. doi: 10.1016/S0927-0248(97)00237-7.

[3] A. S. Najm et al., "Mechanism of Chemical Bath Deposition of CdS Thin Films: Influence of Sulphur Precursor Concentration on Microstructural and Optoelec tronic Characterizations," Coatings, vol. 12, no. 10, 1400, 2022. doi: 10.3390/coat ings12101400. [4] S. Hariech et al., "Cadmium Sulfide Thin Films Growth by Chemical Bath Deposi tion," Journal of Semiconductors, vol. 39, no. 3, 034004, 2018. doi: 10.1088/1674 4926/39/3/034004.

[5] U. I. Danasuriya et al., "Recent Advancements in Chemical Bath Deposited Pristine CdS Thin Films for Photovoltaic Applications," Journal of Desk Research Review and Analysis, vol. 2, no. 2, 2024. doi: 10.4038/jdrra.v2i2.44.

[6] R. C. Ruiz-Ortega et al., "Comprehensive Analysis of CdS Ultrathin Films Modified by the Substrate Position inside the Reactor Container Using the CBD Technique," ACS Omega, vol. 8, no. 35, pp. 31725–31737, 2023. doi: 10.1021/acsomega.3c02158.

[7] Kemell M, Ritala M, Leskela M (2005) Thin film deposition meth ods for CuInSe2 solar cells. Crit Rev Solid State Mater Sci 30:1
[8]Mohammed, W.F., Al-Tikriti, M. (2015) Novel electronic approach for efficient energy harvesting from Cu2S/CdS solar cell, 2015 IEEE 12th International Multi Conference on Systems, Signals & Devices (SSD15), 1–8.
[9] . Li J (2015) Preparation and properties of CdS thin films depos ited by chemical bath deposition. Ceram Int 41:S376
[10] Kamila Z, Magdalena S (2011) Electrodeposition of CdS from acidic aqueous thiosulfate solution-investigation of the mecha nism by electrochemical quartz microbalance technique. Elec trochim Acta 56:5731
[11] Aboul-Enein S, Badawi MH, Ghali M, Hassan G (1998) Preparation and properties of CdS thin films prepared on cold substrate as a window layer for solar cells. Renew Energy 14:113
[12]Senthil K, Mangalaraj D, Narayandass SK (2001) Structural and optical properties of CdS thin films. Appl Surf Sc 169–170:476
[13] Rondiya SR et al (2016) Film thickness effects on morphology, optical and structural properties of chemical bath deposition grown CdS thin films for solar cell applications. Adv Sc Lett 22:854
[14] Enriquez JP, Mathew X (2003) Influence of the thickness on structural, optical and electrical properties of chemical bath deposited CdS thin films. Sol Ener Mat Sol Cells 76:313 [15] Bagnall DM, Ullrich B, Qiu XG, Segawa Y (1999) Microcavity lasing of optically excited cadmium sulfide thin films at room temperature. Opt Lett 24:1278
[16] Maneeshya LV, Anitha VS, Thomas PV, Joy K (2015) Thickness dependence of structural, optical and luminescence proper ties of BaTiO3 thin films prepared by RF magnetron sputter ing. J Mater Sci: Mater Electron. https ://doi.org/10.1007/s1085 4 015-2781-1
[17] Mahmood W et al (2018) Optical and electrical studies of CdS thin films with thickness variation. Optik 158:1558
[18]Kumar S et al (2012) CdS nanofilms: effect of film thickness on morphology and optical band gap. J App Phy 112:123512
[19] Ikhmayies, S. J. (2014). The influence of thickness on the optical parameters of thermally evaporated CdS thin films, TMS 2014 Supplemental Proceedings, 383. 4
[20] Mohamed HA (2015) Optimized conditions for the improvement of thin film CdS/CdTe solar cells. Thin Sol Films 589:72
[21] Ikhmayies SJ, Ahmad-Bitar RN (2008) Effect of film thickness on the electrical and structural properties of CdS: In thin films. Am J Appl Sci 5:1141–1143
[22]Kariper IA et al (2011) The structural, electrical and optical prop erties of CdS thin films as a function of pH. Mater Chem Phys 129:183–188
[23] Kariper IA et al (2012) Effect of PH on the physical properties of CdS thin films deposited by CBD. Chalcogenide Lett 9:27–40