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RESEARCH ARTICLE

Preparation and Characterization of CdS Thin Films Prepared by Chemical Bath Deposition Route

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ABSTRACT

Cadmium sulphide is an extensive energy gap semiconductor, which has gained significance, since it is widely used in window layers in photovoltaic cells, gas sensors, antireflection coating, photo detectors, resistors, capacitors, transistors, and semiconductors for optoelectronic devices. CdS is an n-type compound with 2.4eV energy gap. Chemical Bath Deposition (CBD) method along with micro glass substrates is used in the preparation of CdS thin films at 80°C with constant pH (10). X-ray diffraction patterns for CBD CdS thin films confirm that the peaks are finely coordinated with JCPDS data and exhibit cubic structure. The intensity of preferentially oriented direction of (200) plane increases with increase in deposition time period. Several structural aspects like grain size, strain and dislocation density of CdS films are determined depending on deposition time periods. Studies based on the optical properties of CdS thin films are conducted using absorbance spectra. The film directly transits at 2.48 eV. The deposition conditions can control the optical gap of the material. Due to such factors in the CdS films, they are opted for several optoelectronic and device applications.
Keywords: Cadmium sulphide, Thin films, Chemical bath deposition, X-ray diffraction, Structural studies, Optical properties.

1. INTRODUCTION

Application of chalcogenide films has developed throughout science and technology sector. CdS, which is chemically stable, is employed in solar cells along with absorbers like Cu (In Ga) Se w1x and CdTe w2x. The maximum efficiencies of 1yxx 2 cell obtained till date are 16.5% w3x (CdTeyCdS) and 21.5% w4x and 18.8% w5x (CIGSyCdS), with and without concentration respectively. Almost all such elements are semiconductors, which find application in photoelectric and other types of appliances. [1-7] Progressive development in colloidal science dramatically influence the growth of cost effective and high efciency solar cells. High optoelectronic phase synthesis has emerged well due to its factors of mono-dispersity, passiveness and non-aggregated behavior. Pyrolysis, sputtering, and evaporation are certain methods used to deposit thin films of metal chalcogenides over substrates. It can also be deposited chemically. [8-14] The morphological, structural, optical and electrical properties of film deposited structures vary with respect to the usage of deposition method. Studies show that chemical bath deposition is the simpler and more economic method applied for the design of metal chalcogenide films. The present article reports about the CBD strategy, which is used to fabricate CdS thin films at 80°C on glass substrates. Finally, the article concludes with the effect of time period over the properties of CdS films, which is one of the significant steps in structuring CdS and other semiconductors employed in photovoltaic systems. [15-17] CBD process is gaining importance because it is simple and cost effective, which can also result in homogeneous, translucent, and stoichiometric CdS thin films. CBD method, also termed as solution growth or restricted precipitation, yields thin inorganic semiconductor films from cations, anions and sulphide and selenide ions. To deposit any material using CBD method, the material has to be prepared by easy precipitation, and it should be extremely insoluble and possesses chemical stability in the solution. Furthermore the process must continue with a gradually generated free anion. Generally CBD processes use alkaline solution. Metal hydroxides precipitation can be avoided by adding a complexing agent that helps in reducing the need of free metal ions. Also it checks bulk precipitation of the preferred item and releases Cd^{2+} ions. The formation of CdS films is thus based on cadmium salt and thiourea

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processing in an alkaline solution. [18, 19] Due to decomposition, the S^{2-} ions are more. The present article elaborates the preparation of cadmium sulphide thin films by CBD method over glass substrates. Based on X-ray diffraction, the structural and natural patterns of the obtained films are described and the band gaps are assessed in accordance with the optical representation [20].

2. MATERIALS AND METHODS

2.1. Preparations of CdS thin films from chemical bath deposition technique

CdS thin films are deposited on the basis of Cd^{2+} and S^{2-} ionic reaction in deionised water solution. Chemicals such as cadmium chloride $CdCl_2$, triethanolamine, ammonia and thiourea ($SC(NH_2)_2$) are also included in the process of CdS thin film deposition. Ammonia is added to adjust the pH of the solution. The temperature of this procedure varies from 60°C to 90°C, pH values of the bath vary from 9 to 14 and the vertical substrates in bath have deposition time that varies from 30 to 120 min. Molar proportion of $CdCl_2$ and ($SC(NH_2)_2$) observed at 1:1 has revealed in attaining good quality films. When the films are deposited at 80°C, the film surface becomes more uniform, and preparing the solution with pH value 12 makes the films more uniform and compact. Hence optimization of the deposition factors like temperature, ion concentration in the bath and dipping time is performed and noted.

2.2. Thin film reaction mechanism

In the development of CdS thin films, the reversible adsorption of dihydroxo-cadmium species is made from the tetra amino cadmium complex [n=4], as in (1).

$$Cd\,(NH_3)_n^{2+} + 2OH \longrightarrow [Cd(OH)_2]_{ads} + nNH_3 \tag{1}$$

When thiourea is adsorped, dihydroxo-cadmium adsorbed species develops a net stable structure as in (2),

$$[Cd\,(OH)_2]_{ads} + SC\,(NH_2)_2 \longrightarrow [Cd\,(OH)_2\,SC\,(NH_2)_2]_{ads}^{2+} \tag{2}$$

Equation (3) shows the net stable complex decomposition and the formation of CdS.

$$[Cd\,(OH)_2\,SC\,(NH_2)_2]_{ads}^{2+} \longrightarrow CdS + CN_2H_2 + 2H_2O \tag{3}$$

Film formation is confirmed based on the white precipitate (dihydroxo-cadmium species) thus formed. The deposited films on glass substrates are pre-cleaned using chemical substance and dried using oven. During the formation of CdS, the cloudy solution becomes green, which is continuously stirred till it turns yellow. The resulted dark yellow colored CdS films are washed well using pure water and then dried such that the solution becomes bright orange. This article focuses on the films formed by a single deposition. Likewise, repeated depositions helps in preparing films of varying thickness, which can be assessed by gravimetric. The films possess the characteristics such as adhesiveness, uniformity and reflectiveness.

3. RESULTS AND DISCUSSION

3.1. X-ray diffraction studies

As per the studies, it is physically observed that the CdS thin films, which are in yellow, do not have pinholes or cracks and adhere firmly to the substrate. XRD methods are carried out to study the lms structure. In this strategy, the incident beam is reflected from the lattice planes. XRD patterns of CdS thin films having thickness 2200 and 4600 Å are shown in figures 1 and 2.

Two films having thickness 2200 and 4600 Å, reveals that prominent peak is obtained at 29.54° and 30.50° respectively, which corresponds to (200) plane. The occurrence of peaks in structure indicates that the material is polycrystalline in nature. When the attained diffraction peak patterns are compared with that of standard diffraction pattern, it is deduced that the deposited material is the cubic modication of CdS. Identifying the peaks and assigning with the respective Miller indices based on the database are the major tasks. The main crystallites growth along 200 plane gives rise to the cubic configuration of CdS as mentioned in ASTM $(10-0454)$. The intensity and the number of peaks observed are higher in films with thickness 4600 Å, than the films with thickness 2200 Å. It means that the films of higher thickness are more crystalline. These results authenticate that the deposition has proved more flattering as the intensities of peaks. Earlier researches agree well with the premeditated peaks.

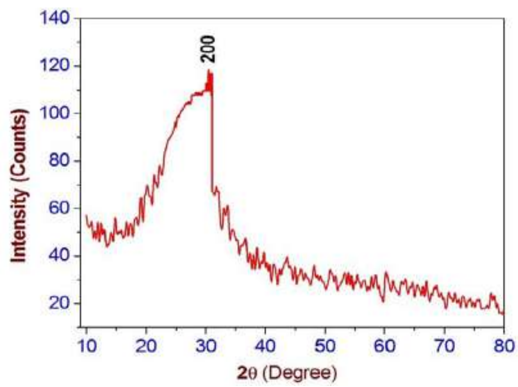

Figure 1.X-ray diffraction pattern of CdS thin film of thickness 2200 Å (1 hour)

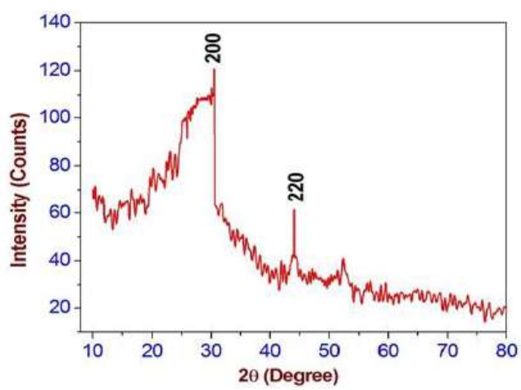

Figure 2.X-ray diffraction pattern of CdS thin film of thickness 4600 Å (2 hours)

Tables 1 and 2 show that, the grain size of the films decreases with thickness of films. But there is increase in the dislocation density and micro strain, which reduces faults and dislocations of the films when film thickness is increased. Further, Full Width Half Maximum (FWHM) is also increased with thickness, which specifies the residual growth in crystalline size or the rise of residual micro strain.

3.2. Optical properties

Figure 3 indicates UV visible absorbance spectra of CdS thin films of thickness 4600 Å prepared at pH 10 in two hours. The absorbance characteristics of the deposited CdS thin films are studied under the wavelength ranges from 200 to 800nm. The band gap energy is determined by the relation,

$$Eg = \frac{hc}{\lambda},$$

where h refers to Planck's constant and c denotes the velocity of light. The calculated value for sample prepared at pH 10 in two hours are 2.48eV agrees with literature reports. Such films widely find applications in transistors, diodes, amplifiers and photoconductive, piezoelectric and laser devices.

Table 1.Comparison of calculated and standard 'd' and '2θ' values of the CdS thin films for different deposition time periods at 80°C

pH value	Time Period (hrs)	Thickness (Å)	hkl planes	2θ values (degree)	(degree)	d-spacing values (Å)	(Å)	Lattice constant a(Å)	FWHM (β)
				JCPDS	EXPT	JCPDS	EXPT		
10	1	2200	200	30.63	29.54	2.91	2.91	6.154	0.1476
	2	4600	200	30.63	30.50	2.91	2.93	5.857	0.7874
			220	43.87	44.06	2.05	2.05	5.806	1.1808

Table 2.Structural parameters of CdS thin films for different deposition time periods at 80°C

pH value	Time Period (hrs)	Thickness (Å)	hkl planes	Grain size D (Å)	Strain (ε) (Lines^{-2} m^{-4}) 10^{-4}	Dislocation Density (Lines/m^2)10^{15}
10	1	2200	200	581.3	6.232	0.2959
	2	4600	200	109.3	33.12	8.3709
			220	75.87	47.73	17.77

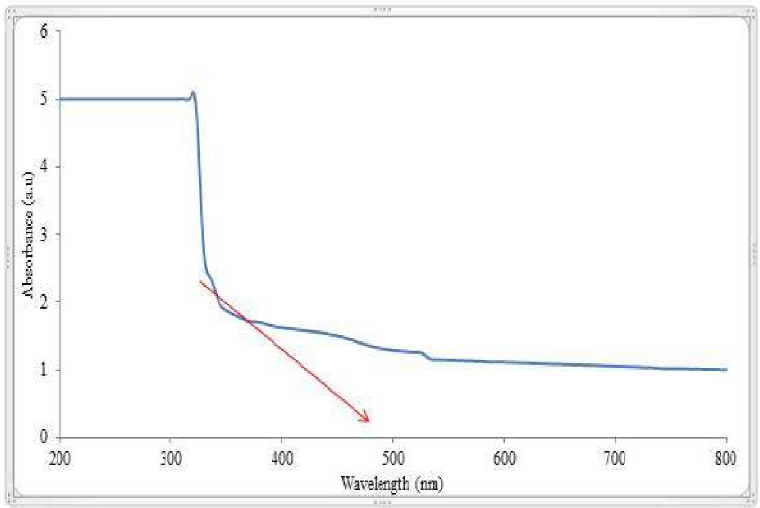

Figure 3.UV Visible absorbance spectra of CdS thin film of thickness 4600 Å (2 hours)

4. CONCLUSION

We have analyzed the effect of time period during CdS thin film deposition. CdS thin film is deposited over a glass substrate at 80°C using CBD method and categorized optically and structurally. XRD patterns for CBD CdS thin films confirm that the peaks are well defined, matched with JCPDS data and exhibiting cubic structure. The intensity of preferentially oriented direction of (200) plane increases with increase in deposition time period. Several structural aspects such as grain size, strain and dislocation density of CdS films are assessed depending on deposition time period and temperature. The optical properties of CdS thin films are studied using absorbance spectra. The film has good optical properties and is applied in solar cells. The film exhibits a direct transition of 2.48 eV. The resultant energy band gap value by the film is the actual value applied as window layer in solar cell construction. These results suggest that the CBD method based CdS thin films possess good characteristics to be employed in photovoltaic applications.

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