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# Preparation and Characterization of CdS Thin Films Grown By Chemical Bath Deposition Method for Photovoltaic Applications

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**Abstract:** A thin film of CdS is a semiconducting material for the use in the fabrication of hetero-junction solar cell. Chemical Bath Deposition is a simple, cheap and inexpensive method of depositing thin films of large area. CdS thin films have been deposited on the glass substrates at 70°C temperature by Chemical Bath Deposition method, using aqueous solutions of cadmium chloride, thiourea and triethanolamine. At higher deposition time period polycrystalline films are obtained with preferential orientation along (111) plane, cubic structure is observed. As the deposition time period increases the intensity of preferential orientation also increases. The grain size increases as the deposition time period increases. The absorbance spectra, the material is found to be highly absorbant in nature. Transmittance decreases with increase in film thickness, which leads to a decrease in light scattering losses. The band gap energy determined shows an inverse dependence on film thickness

**Keywords:** Thin Films, Chemical Bath Deposition, Grain size, Absorbance

## I. INTRODUCTION

CdS thin film belongs to Cadmium chalcogenide family. It is an II-VI wide direct band gap (2.42 eV) semiconductor. This specific property makes it a key element for solar cell applications. Cadmium sulphide (CdS), a wide energy gap semiconductor, has appeared as an vital material due to its applications in photovoltaic cell as window layers, optical filters, multilayer light emitting diodes, fuel cells, optical coatings, photo detectors, thin film field effect transistors, gas sensors and obvious conducting semiconductor for optoelectronic devices[1].

Among the numerous n-type semiconductor materials, it has been perceived that CdS is the most hopeful heterojunction companion for the well-known polycrystalline photovoltaic materials. CdS thin films developed on glass substrate consuming chemical bath deposition scheme have been comprehensively investigated. Many techniques for deposition of CdS thin films are such as sputtering, electro-deposition, metal oxide chemical vapor deposition (MOCVD), spray deposition chemical vapor deposition, vacuum evaporation, spray pyrolysis, pulsed laser deposition and chemical bath deposition (CBD) technique [2,3]. Amongst the various system Chemical bath deposition is now broadly used for the elaboration of low cost polycrystalline thin film solar cells because it offers the advantages of cheap, accessibility and the proficiency of large area deposition[4-6].

The chemical bath deposition method is an economically simple method for the preparation of thin films suitable for scientific studies and for many applications in technology and industry in the research area which is fast, simple, and a low cost technique. In this work the CdS thin films can be prepared by chemical bath deposition method and their categorizations are dignified by the structural and optical properties of the films.

## II. EXPERIMENTAL DETAILS

The deposition of CdS thin films is created on the reaction of Cd<sup>2+</sup> and S<sup>2-</sup> ions in deionised water solution. Chemical baths used for the deposition of CdS thin films comprise of cadmium chloride, thiourea, triethanolamine and ammonia. The pH of the solution can be adjusted by adding ammonia thin film deposition is agreed out at different temperature form 60° to 90°C. Molar proportions of cadmium chloride and thiourea namely 1:1 are used.

The deposition is performed at various pH values of the bath from 9 to 14. The substrates placed vertical in the bath for different deposition time varying from 30 to 120 min. It is perceived that molar concentration of 1:1 have given noble excellence films. While dumping the films at temperature 70°C the surface of the film has become more uniform. While varying the pH of the bath, it is establish that the films prepared pH value 10 was even and compact. Thus deposition parameters such as temperature, concentration of ions in the bath and dipping time have been elevated.

### III. RESULTS AND DISCUSSION

#### A. Structural Analysis

Investigational study of crystalline materials became promising only after the discovery of X-rays by Roentgen in 1895. An X-ray diffraction is defined as bending of X-rays around the obstacle. Bending of X-rays produces maximum and minimum intensities on the screen based on Bragg's law. The X-rays produce diffraction when the size of the opaque obstacle is comparable to the wavelength. X-ray diffraction is very humble and non-destructive technique demanding only very small area of the film. With the development in technology and computer control over the high power X-ray sources, diffractometers and counters, this method of investigation has become very popular and is widely used [7]. Diffraction angles and intensity of lines are measured with greater exactness. It gives information on the interplanar distance, lattice parameter, and crystal structure, degree of crystallinity, grain size, defects and strain state, which are present in the films. From the XRD profiles, the interplanar spacing  $d_{hkl}$  was calculated using the Bragg's relation  $2d\sin\theta = n\lambda$  Where  $n$  is the order of reflection,  $\lambda$  the wavelength of the incident X-rays,  $d$  the distance between planes parallel to the axis of incident beam and  $\theta$  the Bragg's angle. XRD analysis is carried out on CdS films and typical diffraction patterns of as grown CdS thin films prepared by CBD technique on glass substrates with different thickness. Figure.1- 3 show the XRD patterns of the CdS thin films grown by the chemical bath deposition technique at  $70^{\circ}\text{C}$  for different deposition time periods with pH value 10. The diffraction peaks shows that the films prepared were a polycrystalline in nature with cubic phase, and (111) preferred orientation.

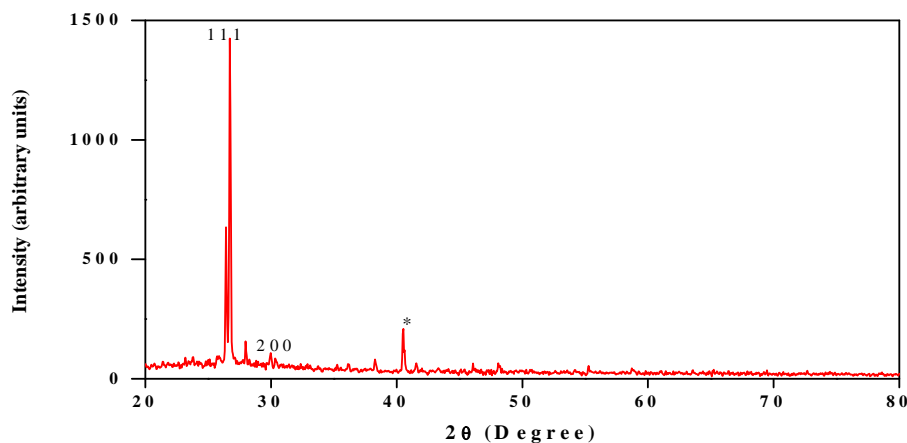


Fig.1 X-ray diffraction pattern of CdS thin film of thickness 3000 Å (60 minutes)

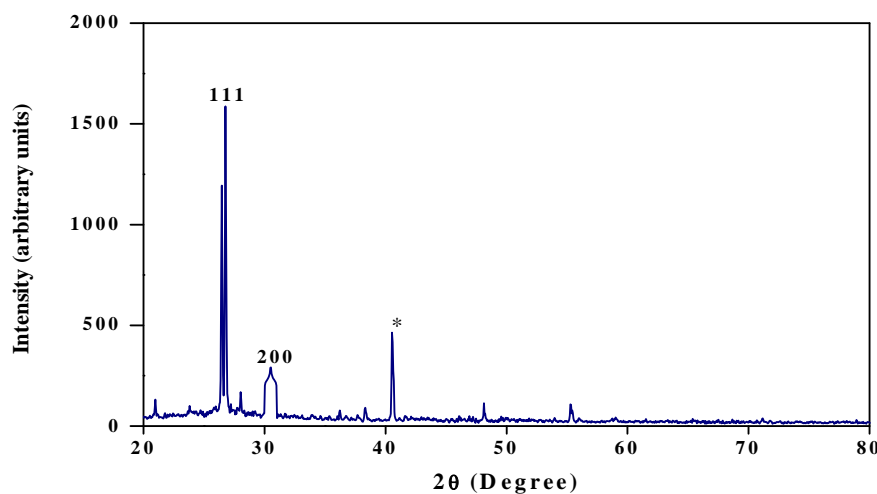


Fig.2 X-ray diffraction pattern of CdS thin film of thickness 6000 Å (90 minutes)

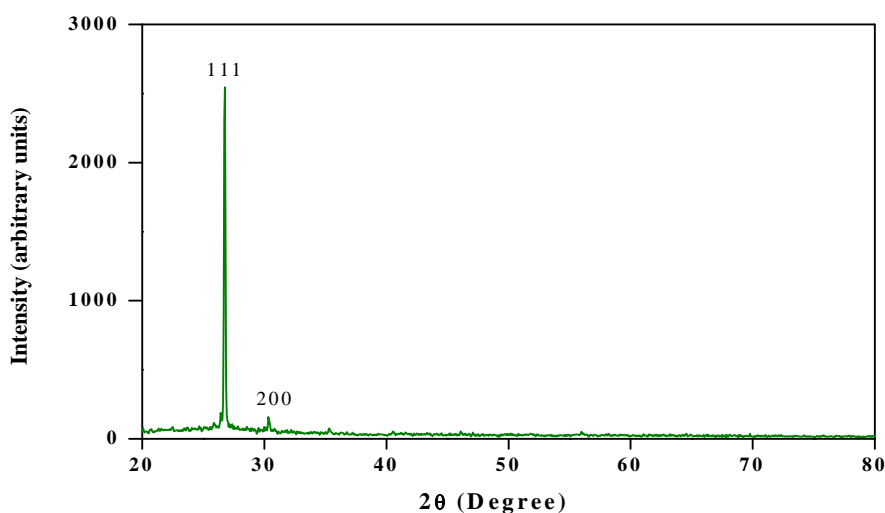


Fig.3 X-ray diffraction pattern of CdS thin film of thickness 10000 Å (120 minutes)

The preferred orientation factor  $f(hkl)$  of the prominent peaks of the equipped CdS films has been attained by assessing the fraction of the intensity of that certain plane over the sum of the intensities of all the peaks inside a given  $2\theta$  range ( $20^\circ$ - $80^\circ$ ). The preferential orientation factor of the (111) plane of the samples deposited at higher deposition time period (120 minutes) are very large (0.9669) when related with samples grown at lower deposition time periods (60 and 90 minutes). The high intensity peaks designates a substantial increase in crystallite size with the cubic amendment [8,-10]. The differences in thermal expansion coefficients and lattice constants between the film and the substrate causes mechanical stress, resulting in film unpredictability or even cracking. Therefore, it is an essential step in film deposition to reduce the film stress, which usually can be done by raising the deposition time period or through film annealing. It can be seen from Table.2 that the grain size decreases progressively with increasing deposition time period. It is generally believed that the surface migration of adsorbed particles on substrates increases with the increasing deposition time period and is of benefit to grain growth and crystalline quality. From the table1 and 2 it is found that, the grain size of the film decreases with film thickness. The dislocation density and micro strain is found to upturn. It can be accredited to the decrease in imperfections and dislocations of the films with increasing film thickness.

pH value	Time period (minutes)	Thickness (Å)	hkl planes	2θ Value (Degree)		d-spacing Value (Å)		Lattice Constant a (Å)	FWHM (β)
				JCPDS	EXPT	JCPDS	EXPT		
10	60	3000	111	26.45	26.42	3.36	3.37	5.8370	0.0984
			200	30.64	30.37	2.92	2.94	5.8800	0.1968
	90	6000	111	26.45	26.78	3.36	3.36	5.8196	0.0984
			200	30.64	30.08	2.92	2.94	5.8800	0.1476
	120	10000	111	26.45	26.75	3.36	3.33	5.7677	0.1476
			200	30.64	30.37	2.92	2.94	5.8800	0.0984

Table 1. Comparison of calculated and standard 'd' and '2θ' values of the CdS thin films for different deposition time periods at 70°C (pH-10)

pH value	Time period (minutes)	Thickness (Å)	hkl planes	Grain size D (nm)	Micro Strain( $\epsilon$ ) ( $\text{Lines}^{-2} \text{m}^{-4}$ ) $10^{-4}$	Dislocation Density ( $\text{Lines}/\text{m}^2$ ) $10^{15}$
10	60	3000	111	86.79	4.670	1.400
			200	57.67	4.600	1.400
	90	6000	111	86.65	6.920	3.100
			200	58.19	4.040	1.200
	120	10000	111	86.35	8.080	4.700
			200	43.67	6.120	2.700

Table 2. Structural parameters of CdS thin films for different deposition time period at 70°C (pH-10)

**B. Optical Analysis**

Optical exploration of CdS illustrations deposited over glass was performed using UV-Visible spectroscopy. The revision of optical possessions of thin films has superior implication in the world of science, technology and trade for the development of new photosensitive devices. Optical absorption study of materials offers useful evidence to analyse some topographies concerning the band structure of materials. The optical band gap energy of the semiconductor is an important restriction that plays a key role in the assembly of photovoltaic cells. The optical belongings of semiconducting material predominantly depend upon band gap [11, 12]. Optical absorption and transmittance spectra of CdS thin films measured as a function of the wavelength of incident photons for different deposition time periods and thicknesses are shown the figure 4-9. As seen, the transmittance decreases with increase in film thickness, which leads to a decrease in light scattering losses. The transmittance is high between wavelengths of 600-1100 nm with a regular fall near the necessary absorption region. The films show an optical transmittance of 70-80 % in the 600-800 nm range which is high adequate for photovoltaic application.

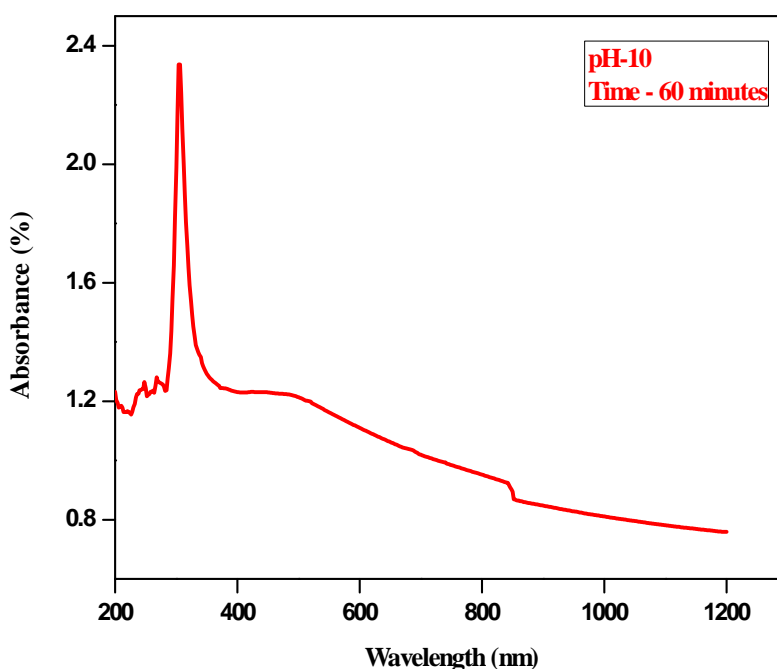


Fig. 4 UV-visible absorption spectrum of CdS thin films prepared at pH-10 (60 minutes) of thickness 3000 Å

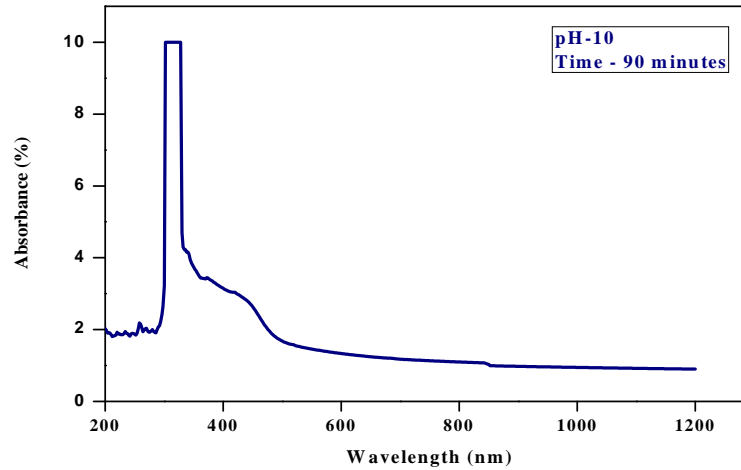


Fig.5 UV-visible absorption spectrum of CdS thin films prepared at pH-10 (90 minutes) of thickness 6000 Å

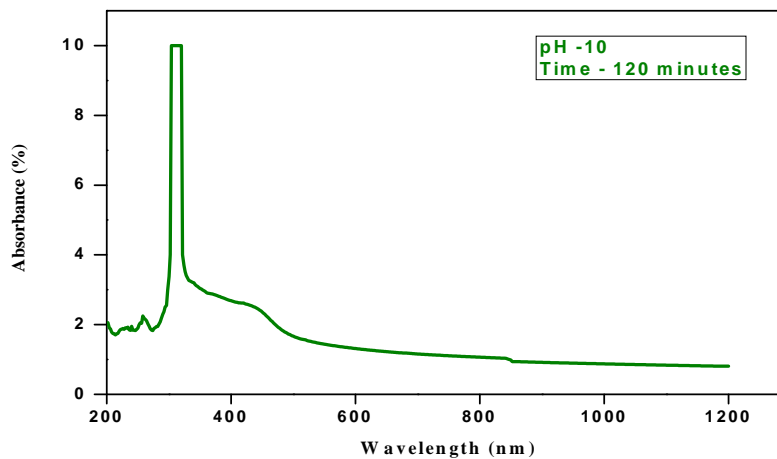


Fig.6 UV-visible absorption spectrum of CdS thin films prepared at pH-10 (120 minutes) of thickness 10000 Å

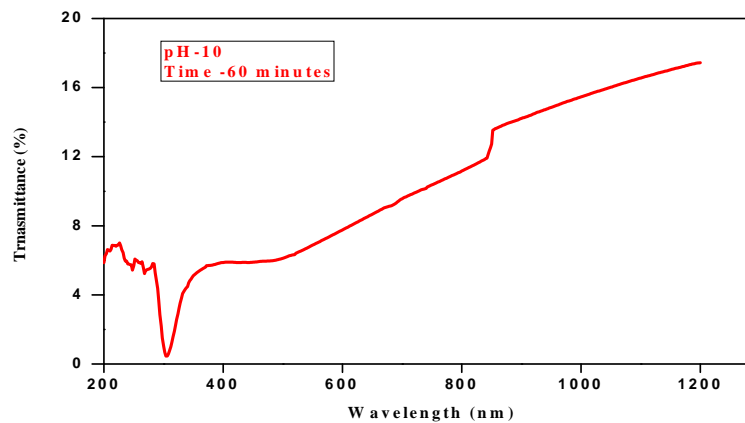


Fig.7 Transmittance Spectrum of CdS thin films prepared at pH-10 (60 minutes) of thickness 3000 Å

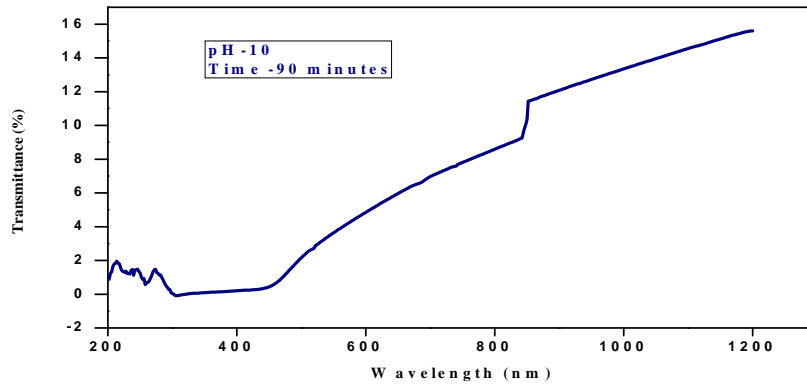


Fig.8 Transmittance Spectrum of CdS thin films prepared at pH-10 (90minutes) of thickness 6000 Å

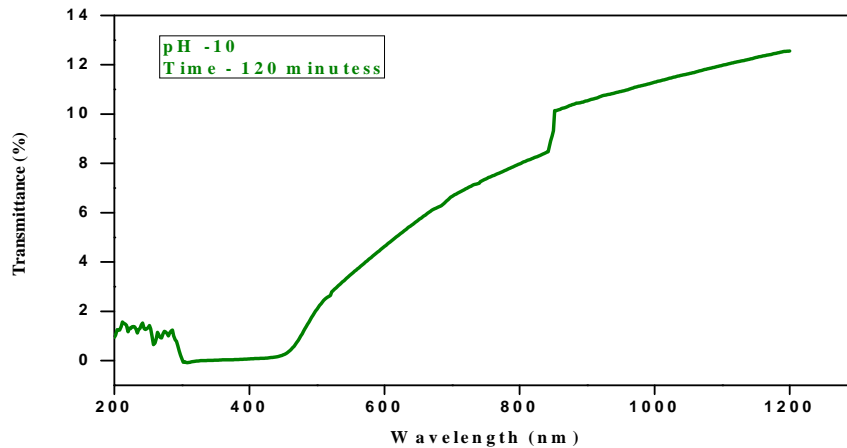


Fig.9 Transmittance Spectrum of CdS thin films prepared at pH-10 (120 minutes) of thickness 10000 Å

The spectrum figure 4-6 exposes that the deposited film has low absorbance in the VIS/NIR region whereas the absorbance is high in the UV region. Hence absorbance of the film decreases with increasing wavelength and decreasing photon energy. The absorbance is detected to be increasing with increase in film thickness. It can be positively established that the material is of highly absorbing in nature. The figure shows a high absorbance in the visible region between 300 to 400 nm and a corresponding decrease in absorbance as the wavelength increases along the near infra-red region. The decrease in absorbance in the near infra-red region shows high transmittance near the infra-red region of the spectrum for all samples of CdS thin films [13].

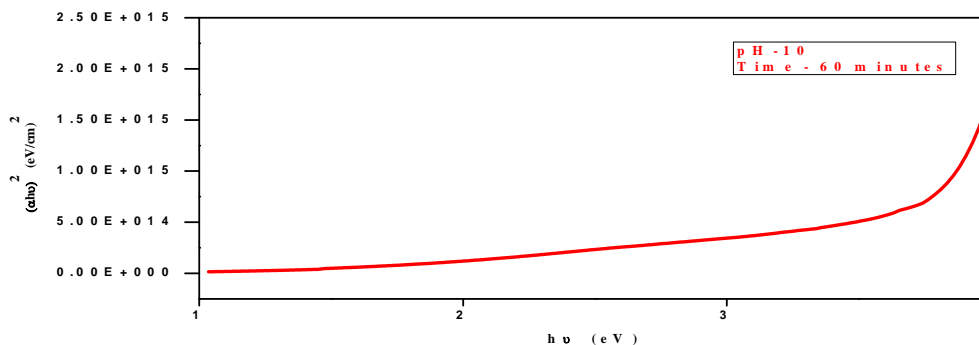


Fig.10 A plot of  $(ahv)^2$  Vs  $(hv)$  for CdS thin films prepared at pH 10 (60 minutes) of thickness 3000 Å

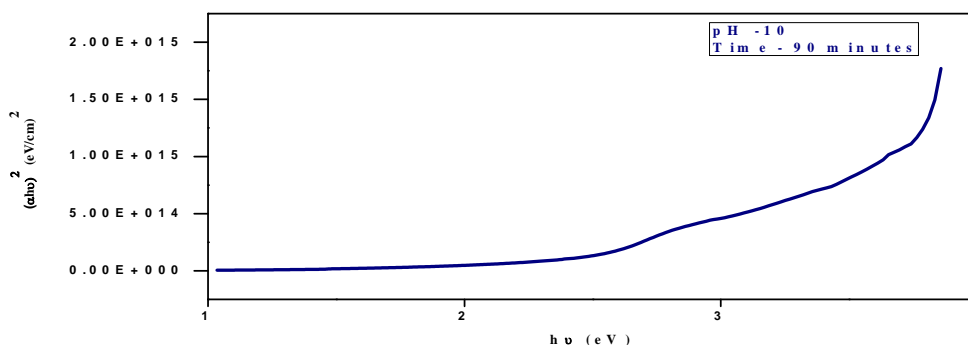


Fig.11 A plot of  $(ahv)^2$  Vs  $(hv)$  for CdS thin films prepared at pH 10 (90 minutes) of thickness 6000 Å

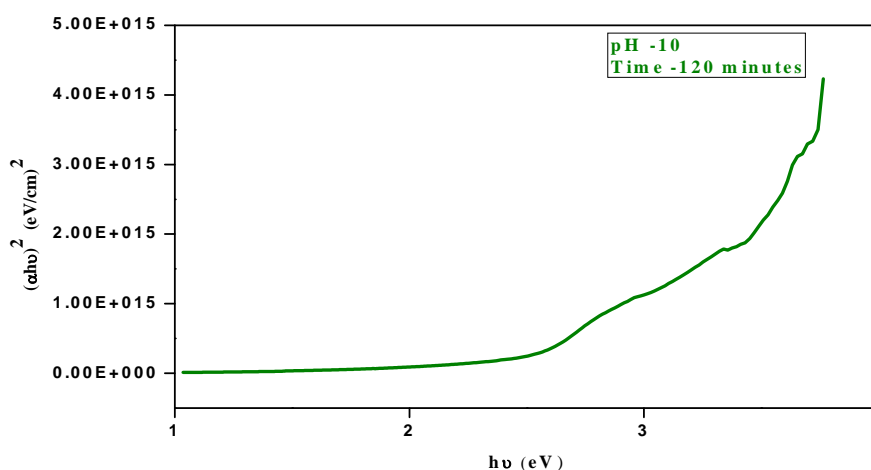


Fig.12 A plot of  $(ahv)^2$  Vs  $(hv)$  for CdS thin films prepared at pH 10 (120 minutes) of thickness 10000 Å

The  $E_g$  value is dogged by extrapolating the linear part of the plot  $(ahv)^2$  versus  $(hv)$  in the abscissa (x axis), which specifies a direct optical transition. The  $(ahv)^2$  versus  $(hv)$  plots for films prepared at pH value 10 are shown in Figure 9-12. As can be seen from this figures, band gap energy of the film decreases from 2.6 to 2.45 eV due to the variation of time period of deposition and film stoichiometry accompanying with the affinity of Cd towards oxygen, shrinkage of strain, reduction in grain size, enhancement the width of grain boundaries, the oxidized compounds at the surface of films. These values obtained are in agreement to the previous studies by Metin et al, Ezema et al and Ximello-Queibras et al [14]. Due to the suitable direct energy gap value for an absorber layer for efficient light absorption, CdS thin films can be used as absorber layer in solar cells. Such films could be used as photovoltaic cells, photoconductive devices, thin film transistors, diodes, piezoelectric ultrasonic transducers, amplifiers, piezoelectric acoustic resonators and electron beam-pumped lasers [14]. Table 3 directs the effect of deposition time period and pH bath on optical band gap of the CdS thin films deposited on glass substrates.

S.No	pH of the Bath	Deposition Time Period (minutes)	Thickness (Å)	Band gap (eV)
1	10	60	3000	2.61
2	10	90	6000	2.52
3	10	120	10000	2.42

Table 3. Effect of deposition time period and pH bath on optical band gap of the CdS thin films deposited on glass substrates



#### IV. CONCLUSION

The CdS thin films were effectively deposited on commercially unfilled glass substrate using chemical bath deposition technique. X-ray diffraction patterns for CBD CdS thin films ratify that the peaks are well defined, matched with JCPDS data and revealing cubic structure. The intensity of preferentially concerned with direction of (111) plane upturns with increase in deposition time period. The several structural aspects such as grain size, strain and dislocation density of CdS thin films designed are depending upon deposition time period and temperature. The transmittance and absorbance spectra in the range of 200 to 1200 nm have been taken for chemical bath deposited thin films using FTIR spectrophotometer. The material is found to be highly absorbant in nature, which is confirmed by absorbance spectra. Transmittance decreases with increase in film thickness, which leads to a decrease in light scattering losses. The band gap energy determined shows an inverse dependence on film thickness. The possible transition of these films may be identified as direct absorbance. It is observed that the transmittance decreases with increase in deposition time. The band gap value decreases with increase in deposition time period. The optical gap of the material can be controlled by the deposition conditions. The film has good optical properties and is well-suited for photovoltaic cells application.

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