CHAPTER 2

CHEMICAL BATH DEPOSITION AND CHARACTERIZATION OF SEMICONDUCTING CdS THIN FILMS

2.1 INTRODUCTION

Extensive research has been done on the deposition and characterization of Cadmium Sulfide (CdS) semiconducting thin films due to their potential application in the area of optoelectronic device fabrication (Morris and Vanderveen 1992a; Chu et al 1992a; Markov et al 1983; Ma and Bube 1977; Pande et al 1984). The polycrystalline CdS thin films have good optical transmittance, wide band-gap and electrical properties suitable for their application to solar cell fabrication (Chu et al 1992b). CdS based solar cell structure exhibits better optical confinement towards higher efficiencies (Shay et al 1976; Birkmire et al 1988; Tyan 1988; Mayers 1988).

Stoichiometric CdS thin films have very high resistivity (Tomas et al 1995) but as for as thin film deposition is considered it is possible to choose the deposition conditions for the deposition of n-type films by reducing the sulfur content in the film or introducing the required doping concentrations of foreign elements such as In, Al, Ga etc., to have suitable resistivity value and carrier concentration for solar cell fabrication. CdS thin films can be grown with α and β phases depending on the deposition conditions (Warekois et al 1962). It is well known that α-CdS invariably grows with columnar structure with c-axis perpendicular to the substrate (Coulls 1982), means that there are
no grain boundaries parallel to the junction which would impede the flow of photogenerated excess carriers to the grid. Reasonable conversion efficiency, stability and availability of low cost deposition techniques attract the usage of CdS as window electrode in solar cells structures (Morris 1997).

In recent years, high priority has been given to develop low cost deposition technique to deposit CdS thin films (Bonnet et al 1995). Though various deposition techniques such as electrodeposition (Baranski et al 1984), screen printing (Clemminck et al 1992), sputtering (Martil et al 1986), spray pyrolysis (Gupta and Agnihotri 1977) have been reported, chemical bath deposition (CBD) method has attracted much attention since it is confirmed as a simple and promising technique to obtain device quality films (Chu et al 1992a; Zelaya-Ange et al 1994; Kuranouchi et al 1994).

The aim of this work is to highlight the modifications introduced in the chemical bath deposition technique for the deposition of CdS thin films bringing out the difficulties involved in the problem. Based on the experience from a series of growth runs, it has been found that the pH of the solution is affected by the evaporation of ammonia from the bath solution due to increase in the bath temperature and hence it is necessary to control the pH for good quality CdS film deposition. As a first step the growth chamber was modified to overcome this problem effectively. CdS thin films were deposited from different cadmium ion concentrations in the bath solution with varying pH and temperatures. Structural, optical, electrical properties and surface morphology of the deposited films were analyzed.
2.2 EXPERIMENTAL

CdS thin films have been deposited on glass substrates using chemical bath deposition (CBD) technique. Glass substrates were cleaned using the procedures reported by Thilakan et al. (1995) to remove the surface contaminations and to make the surface more conducive for uniform film deposition. The cleaned substrates were mounted on a specially designed substrate holder as shown in Figure 2.1. This can be rotated with constant speed for all experiments to obtain homogeneous heat transfer in the entire area of the substrate for uniform film growth. A special reservoir arrangement was made for simultaneous addition of thiourea into the bath during the growth and the rate can be controlled by adjusting the pinchcock position. The whole reaction vessel was heated to a temperature of 90°C using an oil bath medium by resistive heating. CdS films have been deposited on glass substrate of dimension 5 cm x 3 cm by reacting CdCl₂, (NH₂)₂CS and NH₃ in an aqueous solution using NH₃ as complexing agent.

The deposition of CdS films has been carried out for a wide range of cadmium ion concentrations from 0.1 to 1 M in the solution, solution pH range from 9.5 to 11 and bath temperature range from 50°C to 90°C. Bath solution was prepared using the following steps. 50 ml of CdCl₂ solution was taken in a beaker and 14 N aqueous ammonia solution was added to it drop by drop with continuous stirring in order to redissolve the white precipitate of cadmium hydroxide. The addition of 1 M thiourea to CdCl₂ was done at the rate of 1 ml per minute. The pH was optimized at 9.5 during deposition. After reaching the temperature of about 50°C, the colour of the bath solution changes from pale yellow to orange depending on the Cd/S ratio and film deposition starts to appear on the substrate surface. Under these conditions, the chemical reaction and deposition was completed after 30 minutes and a uniform film deposition
Figure 2.1 Modified Chemical Bath deposition apparatus set-up for CdS deposition.
on glass substrate was achieved. Deposited films were detached from the holder after 30 minutes and were washed with deionised water and then with 2\% of hot ammonium nitrate solution to remove the existing surface radicals on the films. These samples were dried in N$_2$ atmosphere and preserved in a desiccator to avoid the surface contaminations.

Films grown from different cadmium ion concentrations were annealed in H$_2$ atmosphere to investigate the annealing effect on the structural, optical and electrical properties.

The deposited thin films were extensively characterized to correlate the quality of the films with the deposition conditions. The deposition conditions were modified according to the results obtained from the characterization studies. Thickness of the films were measured using Dektak 3030 stylus (Sloan Teck Corporation) thickness profiler with ± 10 Å accuracy. Structural and optical properties were analyzed using Rich Seifert X-ray diffractometer with CuK$_{α1}$ radiation and Hitachi double beam UV-Visible spectrophotometer in the range of 200 - 1100 nm in the transmission (T) and absorption (A) modes respectively. Identical glass substrate was used as reference during the spectrophotometer studies. Using the relation A + T + R = 1, the percentage of reflectance (R) was calculated neglecting the scattering losses at the film surface. Surface morphologies of the films were analyzed using Leica (Stereoscan 440 model) Scanning electron microscope (SEM). Electrical resistivity, carrier concentrations and mobilities were measured using the van der Pauw geometry and Hall measurements (MMR Technologies, U.S.A).
2.3 RESULTS AND DISCUSSIONS

2.3.1 Chemical bath deposition of CdS

CdS films have been deposited on glass substrates by the reaction between CdCl₂, (NH₂)₂CS and NH₃ in an aqueous solution. Ammonia is used as a complexing agent, thiourea gives S²⁻ and Cadmium chloride gives Cd²⁺ from the following reactions,

\[
\text{NH}_3 + \text{H}_2\text{O} \leftrightarrow \text{NH}_4^+ + \text{OH}^- \tag{2.1}
\]

\[
\text{Cd}^{2+} + 2\text{OH}^- \leftrightarrow \text{Cd(OH)}_2 \tag{2.2}
\]

\[
\text{Cd}^{2+} + 4\text{NH}_3 \leftrightarrow \text{Cd(NH}_3)_4^{2+} \tag{2.3}
\]

\[
(\text{NH}_2)_2\text{CS} + 2\text{OH}^- \leftrightarrow \text{S}^{2-} + 2\text{H}_2\text{O} + \text{H}_2\text{CN}_2 \tag{2.4}
\]

\[
\text{Cd}^{2+} + \text{S}^{2-} \leftrightarrow \text{CdS(s)} \tag{2.5}
\]

In the presence of sufficient NH₃, cadmium chloride exists predominantly in the form of Cd(NH₃)₄²⁺, and when the ionic product of Cd²⁺ and S²⁻ in solution exceeds the solubility product of CdS, 1.4 x 10⁻²⁹ at 25°C, CdS starts to precipitate. At a given temperature, the rate of formation of CdS is determined by the concentration of Cd²⁺ from Cd(NH₃)₄²⁺ and the concentration of S²⁻ from the hydrolysis of (NH₂)₂CS. The rate of hydrolysis of (NH₂)₂CS depends on the pH and temperature of the solution. At 80°C, the rate constants of hydrolysis are 3.8 x 10⁻³ and 8.2 x 10⁻³ at the pH of 13 and 13.7 respectively. When the solution temperature increases to 100°C the rate constants become 1.1 x 10⁻² and 2.5 x 10⁻² respectively. During the deposition, the following observations were carefully made for different cadmium ion concentrations in the bath. The overall reaction is given below:

\[
\text{Cd(NH}_3)_4^{2+} + (\text{NH}_2)_2\text{CS} + 2\text{H}_2\text{O} \leftrightarrow \text{CdS} + \text{CH}_2\text{N}_2 + 4\text{NH}_3 + 2\text{H}_2\text{O} \tag{2.6}
\]
The deposition of CdS takes place heterogeneously on the glass substrate surface or homogeneously in the solution due to the spontaneous precipitation of CdS. The homogeneous deposition is highly undesirable because it yields powdery and non-adherent films. This process can be controlled by increasing the bath temperature which reduces the concentration of Cd$^{2+}$ and S$^{2-}$ ions in the bath solution. Addition of excess ammonia increases the pH of the solution which in turn promotes the formation of S$^{2-}$ and decreases Cd$^{2+}$ concentration. The rate of hydrolysis of CS(NH$_2$)$_2$ is enhanced as temperature increases. The temperature and pH of the solution can therefore be used to control the rate of CdS formation. For better quality films, heterogeneous process is desirable, in which adsorption of Cd$^{2+}$ and S$^{2-}$ ions takes place followed by the addition of S$^{2-}$ or Cd$^{2+}$ ions (Chu et al 1992a).

Whenever the cadmium ion concentration increases in the solution, it was observed that the rate of deposition increases up to 0.8 M and again decreases as shown in Figure 2.2. After heating, the bath solution becomes colloidal with yellowish colour for less cadmium ion concentration and precipitate becomes orange in colour with a granular nature for increased concentration. During the increase in cadmium ion concentration, the rate of deposition increases due to the increased availability of cadmium and sulfur ion concentrations resulting in the reduction of porosity with better structural, optical, electrical and adhesive properties.

It was also observed that the uniformity of the film mainly depends on the constant rate of stirring of the solution during the entire period of deposition. Variation in the stirring rate affects the uniformity of the films resulting in island growth on the film surface. Apart from the Cadmium ion concentration, the film growth rate at a particular cadmium ion concentration also depends on the rate of thiourea addition during deposition.
Figure 2.2 Rate of deposition versus cadmium ion concentration of CdS thin film.
CdS depositions were carried out at 90° C with control over the evaporation rate of NH$_3$ (i.e. pH of the solution). At this temperature it was observed that the ammonia content in the solution decreases due to the evaporation of ammonia during the growth of CdS film. This inturn influences the deposition of cadmium hydroxide slowly along with the CdS. At this condition, the deposited films exhibit decreased percentage of transmissions and increased insulating nature. To overcome the ammonia evaporation from the bath solution, reaction vessel was sealed with mercury liquid seal along with the stirrer as shown in Figure 2.1.

The upper portion of the reaction vessel was purposely designed longer than the top portion of the vessel in contact with air at room temperature. This arrangement causes the ammonia vapour to condense and fall back to the deposition solution. In order to avoid accident the vessel has been designed with side valve, in such a way that it can release the excess ammonia vapour whenever necessary.

2.3.2 Structural characterization

CdS thin films crystallize with Wurtzite (α-CdS) and Zinc blende (β-CdS) phases (Warekois et al 1962). Both the structures were characterized by tetragonal co-ordination and diamond structure along <111> direction (Zinc blende) or along the <001> direction (Wurtzite) as shown in Figure 2.3. The basic difference between the above two structures is the stacking pattern. Zinc blende structure can be represented as A-B-C-A-B-C whereas in the Wurtzite the repetition of stacking occurs according to AB-AB, etc (Warekois et al 1962). In particular, the semiconducting CdS crystallizes with a highly stable hexagonal α-CdS structure or with metastable cubic β-CdS structure depending on the deposition conditions (Zelaya-Angel et al 1994).
Figure 2.3 Model of the (a) zinc-blende and (b) the Wurtzite structures.
Moreover the microstructure of CdS is columnar in nature and each column is a single grain. The grain size of these films is generally observed in the range of 1 to 5 μm. Larger grain size up to 30-50 μm has also been obtained for films grown on InP substrate by chemical vapour deposition method (Coutts 1982). At low film thickness, the grains are smaller and randomly oriented. The crystallographic structure and microstructure of the films strongly depend on the deposition conditions.

Present studies on CBD deposited CdS have shown that it is possible to produce CdS films with both cubic and hexagonal phases. However, the growth procedures used to obtain such films in either of the phases have not been understood until presently. Recently, the XRD analysis on thermally annealed cubic CdS films shows phase transition from cubic to hexagonal phase (Zelaya-Angel et al 1994).

The crystallinity of the as-deposited films at various cadmium ion concentrations, pH and bath temperatures are characterized using the X-ray powder diffraction. Figure 2.4 shows the X-ray diffraction pattern of as-deposited CdS films at various cadmium ion concentrations from 0.2 to 1 M. The film deposited with 0.2 M shows poor degree of crystallinity due to the more S²⁻ ion concentration which gives colloidal precipitation during heating. As cadmium ion concentration increases, the degree of crystallinity gradually increases up to 0.8 M and it shows a single diffraction peak at 2θ= 26.6° indicating a strong preferred orientation along (111) plane of reflection corresponding to the cubic phase. Hence the preferred orientation of CdS film is due to the controlled nucleation process associated with the low deposition rate. Crystallization starts with cubic and continues up to 0.8 M and above it grows as a hexagonal phase due to the crystallographic coincidence of (111).
Figure 2.4 X-ray diffractogram of as-deposited CdS films for different cadmium ion concentrations in the bath solution.
cubic and (002) hexagonal planes (Zelaya-Angel et al 1994). The peaks corresponding to (100) and (110) planes have also been observed along with (002) plane as predominant plane of crystallization for the film grown from 1 M cadmium ion concentration. This may be due to the faster nucleation rate because of higher cadmium ion concentration so that the film becomes poly crystalline. Below 0.2 M the deposit becomes amorphous in nature.

Figure 2.5 shows the X-ray diffractograms of CdS films after annealing at 350° C in hydrogen atmosphere for 30 minutes and it shows the improved crystallization. Annealing of film deposited from 1 M cadmium ion solution concentration resulted in appearance of (101) peak with a slight shift towards lower scattering angles. The shift towards a lower scattering angle is the consequence of an increase in the lattice parameter resulting from the enlargement of CdS lattice due to filling of the vacancies and the appearance of sulfur at the interstitial positions (deMelo et al 1994)

Structural changes of the films deposited at different bath temperatures ranging from 50° C to 90° C for constant pH of 9.5 with the fixed Cadmium ion concentration of 0.8 M are presented in Figure 2.6. Cubic phase of CdS with (111) predominant plane of crystallization was observed for the films deposited above 80° C and an increased bath temperature improves the degree of crystallinity of the films.

In CBD technique, pH of the solution plays a major role in the deposition of stoichiometric CdS films which can be fixed using the complexing agent of NH₃. Depositions were carried out for the pH range from 9.5 to 11 for a fixed cadmium ion concentration of 0.8 M in the solution. Smooth and dense surface morphology was observed on the films deposited for the pH range from 9.5 to 10.5. On the other hand, no diffraction peaks were found in the XRD patterns for the films deposited from the solution having pH
Figure 2.5 X-ray diffractograms of CdS films annealed at 300°C under hydrogen atmosphere for 30 minutes.
Figure 2.6 X-ray diffractograms of CdS films grown from different bath temperatures.
above 11. The films grown from the solution having pH of 9.5 result in cubic CdS with (111) predominant plane of crystallization as shown in Figure 2.7.

The surface features of the films were observed using scanning electron microscope (SEM). This revealed that annealing does not affect the surface morphology of the as grown films. Figures 2.8a, 2.8b and 2.8c correspond to 0.6, 0.8 and 1.0 M of Cadmium ion concentration. After annealing it reveals seed like indistinguishably small grains, clearly distinguishable improved grains underneath the small grains with cauliflower structure and uniform grain growth with smooth surface respectively.

2.3.3 Optical properties

The most direct and perhaps the simplest method for probing the band structure of semiconductor is to measure the absorption spectrum. In the absorption process, a photon of known energy excites an electron from a lower to a higher energy state and from this one can discover all possible transitions an electron can make and learn much about the distribution of states. Absorption is expressed in terms of a coefficient $\alpha$ which is defined as the relative rate of decrease in light intensity $L(hv)$ along its path($x$) followed by the equation (Pankov 1971)

$$\alpha = \frac{1}{L(hv)} \frac{d[L(hv)]}{dx} \quad (2.7)$$

UV-Visible spectrophotometer in the transmittance and absorbance mode was adopted to calculate the absorption coefficient ($\alpha$) of the films. Figures 2.9a & 2.9b show the effect of cadmium ion concentration on the optical transmissions spectra of the as deposited CdS films. It was observed that the transmittance of the film decreases with the increase in Cadmium ion
Figure 2.7 X-ray diffractograms of CdS films grown from different pH at 90°C of 0.8 M Cd\(^{2+}\) ion concentration.
Figure 2.8 SEM micrograph of annealed CdS samples grown from (a) 0.6 M, (b) 0.8 M and (c) 1 M cadmium concentration in the solution.
Figure 2.9a Optical transmittance spectrum of as deposited CdS films

Figure 2.9b Optical transmittance spectrum of as deposited CdS films
concentration up to 0.8 M after which it starts increasing with further increase in Cadmium ion concentration. The increase and decrease in transmittance percentage during the continuous increase in Cadmium ion concentration is due to the transition of CdS phase from Wurtzite to Zinc blende structure associated with the stoichiometric ratio between Cadmium and sulfur. This phase change was already confirmed by XRD analysis as shown in Figures 2.4 and 2.5. Apart from this, it was observed that the strong absorption region of the transmittance spectra is also shifted towards the higher energy region slowly with the change in Cadmium ion concentration. Further annealing of the as deposited films increases the optical transmittance and the absorption edge shifts towards low energy region and becomes much sharper as shown in the Figure 2.10.

Absorption coefficient values associated with the strong absorption region of the films were calculated using the formula suggested by Meng and Santos (1994) from the optical transmittance and reflectance values,

$$\alpha = \frac{\ln \left( \frac{T}{(1-R)^2} \right)}{d} \text{ cm}^{-1}$$  \hspace{1cm} (2.8)

Calculated values are of the order of $10^4$ cm$^{-1}$ in the strong absorption region as shown in figures 2.11a & 2.11b for the as deposited and annealed films.
Figure 2.10 Optical transmittance spectra of annealed CdS films
Figure 2.11 Absorption coefficient of (a) as-deposited and (b) annealed films as a function of wavelength.
Using the calculated absorption coefficient values, the type of transition associated with the band structure of CdS can be identified using the following equation,

$$\alpha = \frac{A (h \nu - E_g)^{m'}}{h \nu} c m^{-1} \quad (2.9)$$

where \( m' \) is a constant associated with the type of transition. \( m' \) takes the value of 1/2, 2, 3/2 and 3 for the direct allowed, indirect allowed, direct forbidden and indirect forbidden transitions respectively. Where \( E_g \) is the band gap extracted after extrapolation of the plot at \( \alpha = 0 \). \( A \) is a constant which is related to the effective mass associated with the bands, and \( h \nu \) is the energy of the incident photon. Figure 2.12 shows the \((\alpha h \nu)^2 \) versus \( h \nu \) plot for the as deposited and annealed films deposited from 0.2 M Cd\(^{2+}\) ion concentration. The studies on the band structure of CdS using Equation 2.8 results in the direct allowed transition associated band structure for as-deposited and annealed films. In both the cases band gap increases along with Cadmium ion concentration upto 0.8 M as shown in Figure 2.13 and again decreases for the further increase. This may be associated with a phase transition from cubic to hexagonal phase. Comparison of the band gap values obtained for both as-deposited and annealed films reveals that the annealed films have reduced band gap values than the as-deposited films. This is due to the interference effects in the compressed multilayered structure formation of CdS after annealing (Mendoza-Galvan et al 1996).

Refractive index values are calculated using the following equation beyond the strong absorption region, where the extinction coefficient values become very low and their effect is negligible (Manificier et al 1976; Bhattacharyya et al 1993).
Figure 2.12  The $(\alpha \nu v)^2$ versus $\nu v$ of as-deposited and annealed films grown from 0.2 M cadmium ion concentration.

Figure 2.13  Band gap of the as-deposited and annealed films as a function of cadmium ion concentration in the solution.
Refractive index value of the films in the strong absorption region were calculated including the extinction coefficient values using the formula

\[ n = \frac{(1 + R)^{\frac{1}{2}}}{(1 + R^{-1})^{\frac{1}{2}}} \]  

(2.10)

\[ k = \frac{4 \pi \alpha}{\lambda} \]  

(2.11)

Calculated values of \( n \) at 550 nm wave length are plotted against the Cadmium ion concentration as shown in Figure 2.14 for the as-deposited and annealed films. Figure 2.14 implies that the refractive index follows the same relation like band gap and electrical resistivity with the Cadmium ion concentration. The equations used with and without extinction coefficient did not result in any appreciable change in the calculated refractive index values.

2.3.4 Electrical properties

Electrical resistivity, carrier concentration and carrier mobility of the films were measured using the van der Pauw geometry and Hall measurements.

In van der Pauw technique, four contacts were placed on the periphery of the samples and measurements were carried out using the following equation

\[ R_{12,34} = \frac{\text{Potential difference between 3 and 4}}{\text{Current through 1 and 2}} \]  

(2.13)
Figure 2.14 Variation of refractive index with respect to cadmium ion concentration at 550 nm.

Figure 2.15 Variation of electrical resistivity with respect to the cadmium ion concentration for annealed samples.
Similarly, the values for $R_{23,41}$ can also be obtained. Then, the resistivity ($\rho$) can be calculated by including the thickness of the sample ($d$) in the following equation,

$$\rho = \frac{\pi d}{\ln 2} \left[ \frac{R_{12,34} + R_{23,41}}{2} \right] f$$  \hspace{1cm} (2.14)

Where $f$ is the geometrical correction factor deduced from the transcendental equation as discussed by Look (1989) and the Hall mobility values are obtained by applying the magnetic ($B$) field perpendicular to the direction of current and voltage using the equation, below

$$\mu_H = \frac{d}{B} \left[ \frac{R_{24,13}}{\rho} \right]$$  \hspace{1cm} (2.15)

and the carrier concentration values are obtained from the measured electrical resistivity and carrier mobility values using the relation,

$$n_c = \frac{1}{\rho e \mu_H}$$  \hspace{1cm} (2.16)

Measured electrical resistivity of the as-deposited films are in the order of $10^6 \ \Omega\cdot\text{cm}$ and the results are in good agreement with the reported values (Tomas et al (1995). Figure 2.15 gives the variation of electrical resistivity with respect to the Cadmium ion concentration for the annealed films. Resistivity decreases from $1.72\times10^2 \ \Omega\cdot\text{cm}$ to $5.10\times10^3 \ \Omega\cdot\text{cm}$ with the increase in Cadmium ion concentration from 0.2 M to 0.8 M and further increases to $5.20\times10^3 \ \Omega\cdot\text{cm}$ for 1.0 M Cadmium ion concentration. The
observed trend in electrical resistivity in correlation with structural and optical properties implies that a phase change in CdS from metastable cubic $\beta$-CdS to stable hexagonal $\alpha$-CdS phase influences the continuous change in the structural, optical and electrical properties. This variation may be due to the increase in the availability of Cadmium ions during the increase in concentration and its associated changes in the stoichiometric precipitation and deposition of CdS from high resistive to low resistive $\beta$-CdS and again to high resistive $\alpha$-CdS. The observation is in good agreement with the earlier reports by Tomas et al (1995).

Table 2.1 gives the Cadmium ion concentration dependent resistivity, mobility and carrier concentration values of the films annealed at 350°C under hydrogen atmosphere. Increase in carrier concentration with reduced carrier mobility was observed for the increase of cadmium ion concentration. These observed results confirm that the grown films with increasing Cadmium ion concentration in the bath solution incorporate more Cadmium in the deposited films.

<table>
<thead>
<tr>
<th>Cadmium ion conc. In the solution (M)</th>
<th>Resistivity (Ω·cm)</th>
<th>Mobility (cm²/V·s)</th>
<th>Carrier density (cm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0.172</td>
<td>89.31</td>
<td>1.378 x 10¹⁶</td>
</tr>
<tr>
<td>0.4</td>
<td>0.163</td>
<td>85.31</td>
<td>2.18 x 10¹⁶</td>
</tr>
<tr>
<td>0.6</td>
<td>0.092</td>
<td>11.45</td>
<td>5.9 x 10¹⁸</td>
</tr>
<tr>
<td>0.8</td>
<td>0.051</td>
<td>2.37</td>
<td>4.82 x 10¹⁹</td>
</tr>
<tr>
<td>1.0</td>
<td>0.052</td>
<td>2.57</td>
<td>5.87 x 10¹⁹</td>
</tr>
</tbody>
</table>
2.4 CONCLUSION

The II-VI binary compound Cadmium Sulfide has been successfully deposited using the modified chemical bath apparatus. The deposition conditions for different solution pH, cadmium ion concentrations and bath temperature were optimized. It was confirmed that the pH of the solution affects the CdS deposition by the incorporation of Cadmium Hydroxide along the deposit. To maintain the constant pH of the solution during the deposition, the bath chamber was successfully modified. A higher bath temperature enhances the degree of crystallization. Different Cadmium ion concentrations varying from 0.2 to 1 M drives the CdS deposition from cubic β-CdS to hexagonal α-CdS deposition. The observed structural properties reveal the change in crystallization from cubic to hexagonal phase. The structural changes due to varying Cadmium ion concentration affect the optical and electrical properties. Minimum electrical resistivity with optimum band gap and refractive index values are observed for the annealed films deposited with 0.8 M Cadmium ion concentration, which is suitable for solar cell fabrication.