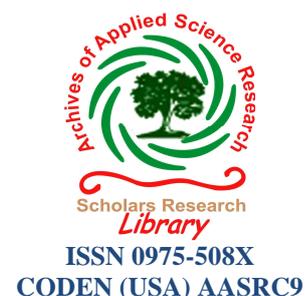




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Crystallographic, morphological, optical and electrical properties of CBD deposited cadmium sulphide thin films

A. S. Khomane

Department of Chemistry, Government Rajaram College, Kolhapur, Maharashtra, India

ABSTRACT

Chemical deposition technique has been implemented for the deposition of cadmium sulphide thin films on glass substrates. The deposited CdS film samples were characterized by X-ray diffraction, scanning electron microscopy and optical absorption techniques. The electrical and thermo-electrical properties are also studied. XRD analysis of annealed showed that the film sample is deposited in cubic and hexagonal phases. The optical band gap energy of CdS film sample was found to be 2.4 eV. The electrical conductivity of the film sample was found to be in the order of $10^{-7} (\Omega \text{ cm})^{-1}$ with n-type of conduction mechanism.

Keywords: Chemical bath, Thin film, XRD, SEM and Optical properties.

INTRODUCTION

Technologically important semi conducting materials from II-VI group studied very intensively in the last two decades. CdS is one of the cheapest semi conducting material from same group. It is used in the optoelectronic and semi conducting devices [1-10].

CdS thin films can be fabricated by successive ionic layer adsorption reaction (SILAR), spray pyrolysis, electro deposition, rf sputtering, pulse laser evaporation, physical vapour deposition, screen printing, metal organic vapour phase epitaxy(MOVPE)/metal organic chemical vapour deposition (MOCVD) and chemical bath deposition(CBD) method [11-19].

In this paper cadmium sulphide material is fabricated by CBD method. The deposited films samples were characterized by XRD, SEM, UV-vis-NIR and electrical techniques.

MATERIALS AND METHODS

2. Experimental work

The analytical grade chemicals such as cadmium sulphate octahydrate, potassium sulphide, sulphur powder and ammonia were used for the fabrication of CdS thin films.

2.1 Fabrication of CdS thin film sample

In the Fabrication of CdS thin films cadmium sulphate and potassium poly sulphide solution were used as source of Cd^{2+} and S^{2-} ions respectively. Potassium poly sulphide solution was obtained by making paste of equimolar amount of sulphur powder and potassium sulphide then required quantity of distilled water added in it. The glass substrates of dimensions 26 mm x 76 mm x 2 mm were used for deposition of CdS material. The glass substrates were washed in chromic acid followed by ethanol then finally with distilled water before deposition of the CdS film sample.

In the synthesis of CdS thin film 10ml 0.5N cadmium sulphide was taken in 100ml capacity of beaker. NH_3 was added in the above solution to precipitate out $\text{Cd}(\text{OH})_2$ then it is dissolved in excess of NH_3 to form $\text{Cd}[\text{NH}_3]_4\text{SO}_4$. Then whole solution was diluted to 40 ml with distilled water. Then 10 ml 0.25 M potassium polysulphide solution was added in above reaction mixture. Then glass substrates were kept in reaction mixture for a day night at room temperature. As the ionic product of Cd^{2+} and S^{2-} ions exceeds the solubility product of CdS, then deposition of CdS thin films on the glass substrates takes place.

Day after, the glass substrates were removed from the beaker and washed with distilled for several times. The deposited films of CdS dried naturally and kept in a desiccator over anhydrous CaCl_2 . Cadmium sulphide films were found to be homogenous, well adherent to the glass substrate. The colour of deposited CdS film was found to be dark yellow.

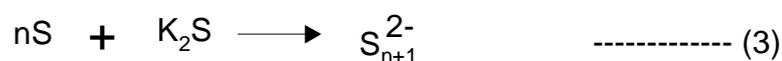
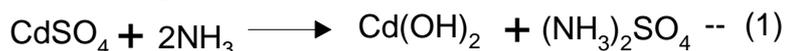
2.2 Characterization of CdS material

X-ray diffraction technique has been employed for the crystallographic analysis of CdS film sample. The annealed CdS film sample scanned on Phillips make PW-1710 instrument in the range of 30° to 90° as 2θ using Cr K α 1 line (wavelength = 2.28970 Å). Cambridge Stereo Scan (USA) Scanning Electron Microscope (SEM) was used for surface morphological analysis of CdS film sample. The optical absorptions/reflections were recorded in the wavelength range from 400-800 nm using UV-vis-NIR double beam spectrophotometer (Hitachi-330 Japan). The characterization of spectrum was done by computing the values of absorption at every step of 5 nm. The thickness of the film was calculated by weight difference density consideration method. The electrical conductivity of the films sample were carried out in the temperature range of 300-550 K on Zintek - 502 BC Milliohm meter using two-probe method. Thermo electric power measurements (TEP) were carried out for the detection of type of conduction mechanism.

RESULTS AND DISCUSSION

3.1 Growth Kinetics

The solubility product of CdS is $(K_{sp} \text{ CdS}) = 10^{-27}$. As the ionic product of Cd^{2+} and S^{2-} ions exceeds to solubility product of CdS then deposition of CdS film takes place. The growth kinetics of deposited CdS thin films is given as [20- 22].



3.2 Crystallographic and morphological Analysis

Crystallographic parameters of CdS film were determined from the X - ray diffraction technique. X-ray spectrum of annealed CdS films at 425 °C is shown in Fig.1.

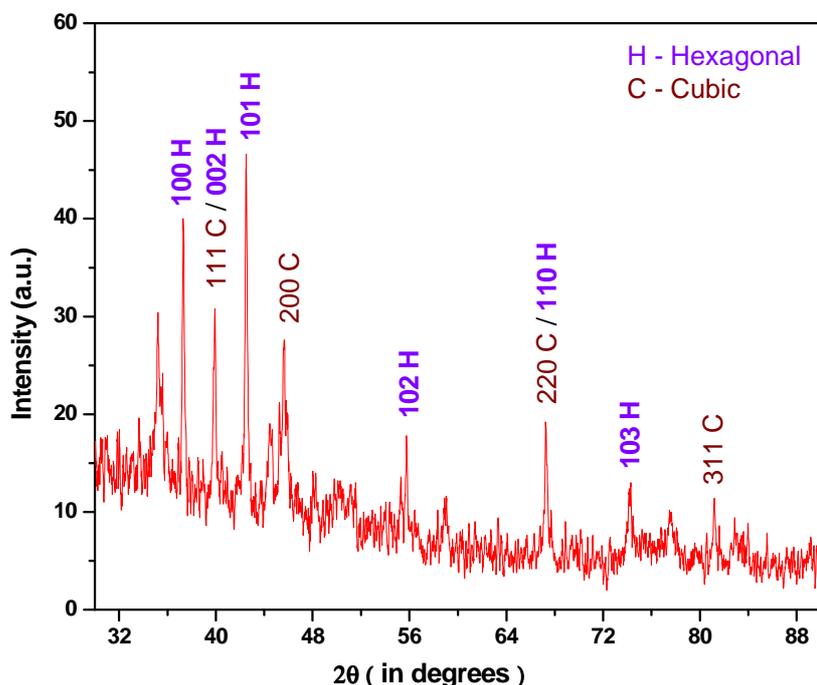


Fig.1 XRD spectrum of CdS thin films annealed at 425 °C

The large number of peaks indicates the polycrystalline nature of the CdS film sample. From the XRD spectrum it is clear that CdS film sample deposited in the cubic and hexagonal phases. The observed d-values which coincide well with the JCPDS data [23-24]. 'hkl' planes of cubic phase is shown in the Fig. without bold faces while the 'hkl' planes of hexagonal phase is shown in the bold faces. The results of X-ray analysis well agrees with earlier investigators report [3, 25-28]. X-ray analysis showed that CdS films are poly crystalline in nature with cubic and hexagonal modification. The increase in the intensity of peak is observed at 40° due to merging of peaks of cubic and hexagonal phases takes place. Similarly the increase in the intensity of peak is observed at 67° due to merging of peaks of cubic and hexagonal phases takes place. Alternatively interplanar distance (d) and 2θ values of merged peaks are also found intermediate between d and 2θ values of standard cubic and hexagonal phases. The lattice parameters of cubic and hexagonal phases have been calculated by using equation (5) and (6) respectively.

$$a = d (h^2 + l^2 + k^2)^{1/2} \quad \text{-----} \quad (5)$$

$$1/d^2 hkl = 4/3 [(h^2 + hk + k^2) / a^2] + (l^2/c^2) \quad \text{-----} \quad (6)$$

Where 'd' is the interplanar distance and 'h, k, l' are Miller indices of the lattice planes. The lattice parameter 'a' of cubic phase was found to be in the order of 5.8476 Å. The lattice parameter 'a' and 'b' of hexagonal phase were found to be in the order of 4.1338 Å and 7.7127 Å respectively. The structural parameters of Cubic phase are shown in Table.1 while structural parameters of hexagonal phase are shown in Table.2.

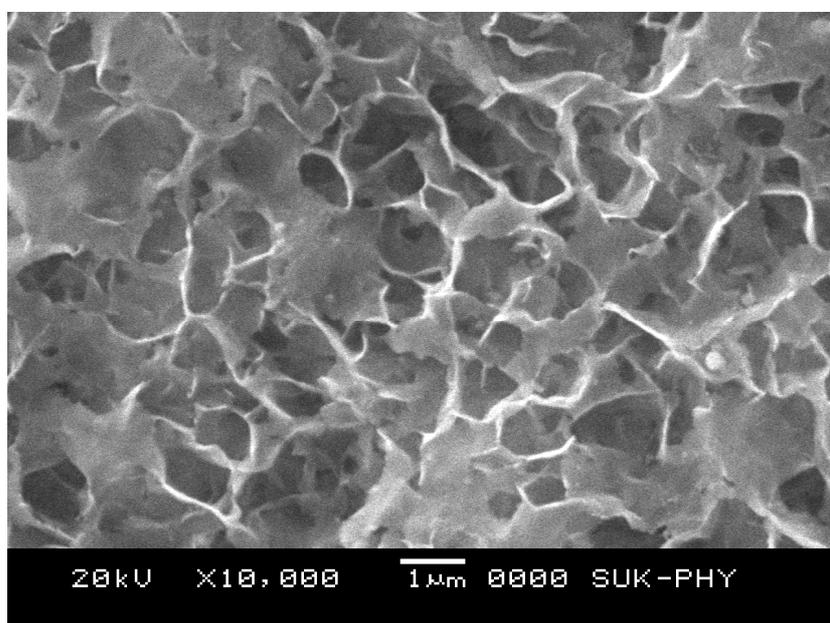
Table.1 The structural parameters of cubic phase CdS thin films.

Film sample	d-values Å		hkl planes	Cell parameter (Å)	
	Cubic phase			a	
	Standard	Observed		6.776	
CdS	3.360000	3.3533	111	5.8476	
	2.900000	2.9516	200		
	2.060000	2.0665	220		
	1.760000	1.7591	311		

The grain size (D) annealed films have been calculated by using Scherrer's formula.

$$D = K\lambda / \beta \cos \theta \quad \text{-----} \quad (7)$$

Where K is constant (0.94), λ is the wavelength of the X-ray used, β is broadening of diffraction line measured at half of its maximum intensity (in rad) and θ is Bragg's diffraction angle.

**Fig.2 SEM micrograph of CdS thin films****Table.2 The structural parameters of hexagonal phase CdS thin films**

Film sample	d-values Å		hkl planes	Cell parameters (Å)	
	Hexagonal phase			a	c
	Standard	Observed			
CdS	3.560000	3.5800	100	4.1338	7.7127
	3.350000	3.3533	002		
	3.140000	3.1587	101		
	2.450000	2.4478	102		
	2.070000	2.0665	110		
	1.900000	1.8978	103		
		1.8978			

The scanning electron microscopy (SEM) was used for surface morphological analysis of CdS film samples. Fig.2 shows SEM micrograph of as deposited CdS thin films.

The SEM micrograph reveals the film surface looks highly porous and interconnected network of honeycomb. The honeycomb network of CdS nanostructured films may provide novel platforms for photovoltaic, sensor and other device applications [29-30].

3.3 Optical and electrical properties

The optical absorbance of CdS film sample was measured on UV-vis-NIR spectrophotometer to determine the band gap of materials. The band gap (E_g) was determined by plotting a graph of $(\alpha h\nu)^2$ versus $h\nu$. The band gap energy ' E_g ' was determined by extra plotting the straight line to the energy axis whose intercept to the x-axis gives the optical band gap. The band gap energy curve is shown in Fig. 3. The linear nature of curve indicates the presence of the band to band direct transitions. The band gap energy of CdS film was found to be 2.4 eV [1-2, 31-32].

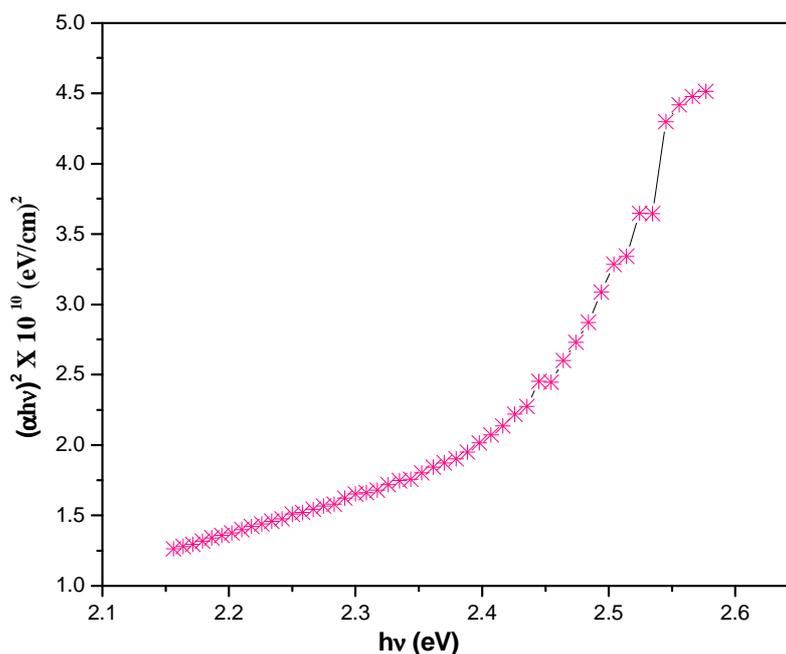


Fig.3 Plot of $(\alpha h\nu)^2$ versus $h\nu$ of CdS thin films.

Along with optical properties, the electrical properties of as deposited film samples are also studied. The dark electrical conductivity of CdS films sample was measured in the temperature range of 300-550 K in the air atmosphere. The electrical conductivity of film sample increases with increase in temperature indicates semi-conducting nature of the CdS film sample. The plot of $\log \sigma$ versus $(1000/T)$ of the film is shown in Fig.4. The non-linear nature of the plot indicates two types conduction mechanism. The electrical conductivity of the film sample was found to be in the order of $10^{-7} (\Omega \text{ cm})^{-1}$ [1-2, 33]. The activation energy (E_a) of CdS thin film was determined by using Arrhenius relation [34].

$$\sigma = \sigma_0 \exp(-E_a/kT) \quad \text{----- (8)}$$

Where σ is measured electrical conductivity, σ_0 is the conductivity pre exponential factor, k is Boltzmann's constant and T is absolute temperature.

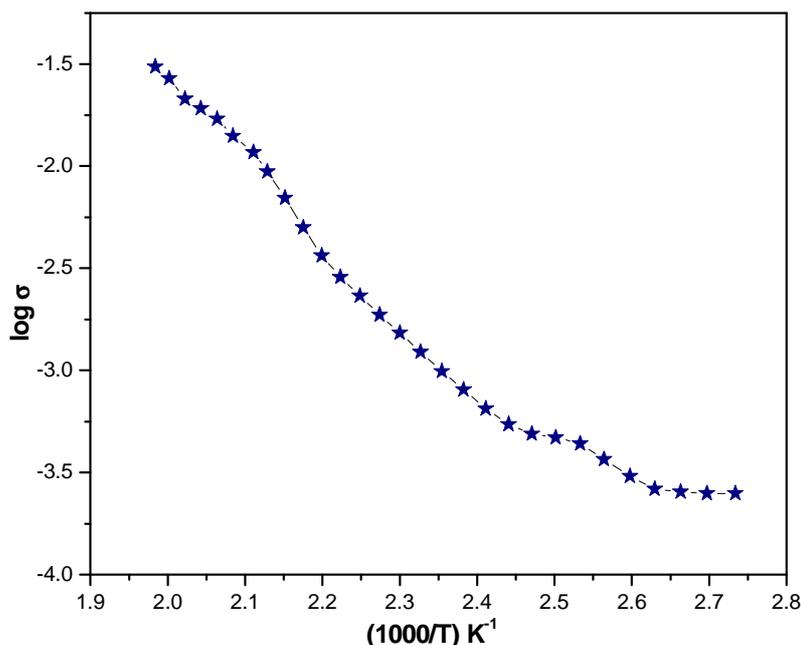


Fig.4 Plot of $\log \sigma$ versus $(1000/T) K^{-1}$ of CdS thin film.

The activation energy of CdS thin film was found to be in the range of 0.685 to 0.209 eV at high and low temperature region respectively [1-2, 35]. Thermoelectric power measurement shows n-type conductivity.

CONCLUSION

- (i) Chemically CdS thin film can be deposited by using potassium poly sulphide solution.
- (ii) X-ray analysis reveals annealed CdS film deposited in the mixed cubic and hexagonal phases.
- (iii) The optical band gap energy of CdS film sample was found to be in the order of 2.4 eV.
- (iv) The dark electrical conductivity of CdS thin film sample was found to be in the order of $10^{-7} (\Omega \text{ cm})^{-1}$ with n-type of transport property.

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