

GROWTH AND CHARACTERIZATION OF NANOSTRUCTURED CdS THIN FILMS BY CHEMICAL BATH DEPOSITION TECHNIQUE

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The effect of deposition parameters of CdS thin films developed by Chemical Bath Deposition (CBD) technique was investigated in this paper. The films of different thicknesses were deposited on to glass substrate. The deposition parameters such as speed of rotation of substrate, temperature of chemical bath, pH of solution and deposition time were optimized. The structural surface morphology of as-deposited CdS thin films were characterized by XRD, SEM. The material was confirmed as single cubic phase. The average grain size obtained of CdS in the film was 10nm to 22nm. The physical conditions were kept identical while growing the samples. The investigation of the effect of the synthesis method on the grain size and the effect of grain size on the properties of semiconductor is under consideration.

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1. Introduction

CdS is an interesting semiconductor material due to its very important role on the photovoltaic technique and optoelectronic devices. It has been used as a partner of several types of thin film solar cells such as CdTe, Cu₂S, CuInSe₂ for the fabrication. CdS has suitable band gap, high absorption co-efficient and considerable energy conversion efficiency. [1, 3]

The thin films has been obtained by number of growth technologies such as electro-deposition, vacuum evaporation, screen printing, photochemical deposition, sputtering, chemical deposition, spray pyrolysis, molecular beam epitaxy, etc have been reported by several workers. Among all, CBD is a well known an easy low cost process and useful for large area industrial applications. CBD is a process to achieve high quality films by controlled chemical reaction with minimum wastage of material. [1,2]

In the present work, efforts are made for the growth of CdS thin films having different thicknesses to optimize the preparative parameters such as speed of rotation of substrate, variation temperature, pH and deposition time and their effects on deposition process. In this work it was employed with intention of improve the CdS film quality. The CdS thin films were characterized by XRD and SEM.

2. Experimental

The CdS thin films were fabricated by CBD technique on glass substrate. The starting materials used were CdSO₄ as a Cd⁺⁺ ion source & thiourea as an S⁻ ion source. An alkaline

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solution of ammonia was used to adjust pH of the reaction mixture as a complexing agent. All the chemicals used were of Analytical Reagent grade. The process involving a controllable chemical reaction at a low rate, by adjusting the pH value and temperature of the working solution allows maintaining the stoichiometry constant for any ratio of anions and cations. The experimental arrangement consists of a special substrate holder which is attached to a motor having a constant speed of 60 r.p.m. The temperature of chemical bath was adjusted with a hot plate and temperature controller ($\pm 2^\circ\text{C}$), while magnetic stirrer is applied to promote ion-by-ion heterogeneous growth on the substrate. The CdS samples were prepared on carefully cleaned corning glass substrates. The glass slides were soaked in chromic acid cleaning solution, for 30 minutes, washed in de-ionized (DI) water and preserved in it and finally used it by drying. The pH value of working solution was adjusted by a pH meter and kept at values 8.2, 9 and 10 for different deposition time (10-60min.) and deposition temperature (45°C and $70\pm 5^\circ\text{C}$). [1-4]

After deposition the substrates were removed from the chemical bath and cleaned in DI water. The crystallographic structure of the films was analyzed with a (XPERT-PRO) X-ray diffractometer using Cu-K α radiation with wavelength, 1.5418Å. The thickness of thin film was measured by the weight difference method at room temperature. The average grain size in the deposited films was obtained from a Debye-Scherrer formula. Surface morphology was examined by JEOL model JSM-6400 scanning electron microscope (SEM).

3. Results and discussion

3.1 Effect of preparative parameters

3.1 a) Rotation of substrate:

Rotation of substrate may help to increase the deposition of CdS molecules on the substrates affecting the quality of the film. It was found that, the films formed on the stationary or low speed of substrates (40-50rpm) were porous, powdery, thick & non-uniform. Whereas at intermediate speed (70-80rpm) films were smooth, specularly reflecting, adhesive & uniform. [2]

3.1 b) Temperature of chemical bath:

Fig.1. shows the variation of film thickness with deposition time at temperatures 45°C and $70\pm 5^\circ\text{C}$. It was found that the optimum temperature of chemical bath for growth of CdS films was determined as $70\pm 5^\circ\text{C}$. It can be seen from fig.1, the average growth rate is high at $70\pm 5^\circ\text{C}$ (9.478nm/min) & it is slow at 45°C (7.622nm/min). [2]

3.1 c) variation of pH of solution:

The variation of pH during the growth is important in the structural film quality and was observed experimentally. Fig.2. shows variation of CdS film thickness with deposition time for different pH values. It was found that, for low pH the Cd⁺⁺ ion concentration in solution is more due to less complexation of Cd⁺⁺ ions and the homogeneous process takes place at slow rate resulting in a lower thickness. At high pH the Cd⁺⁺ ion concentration is less due to higher complexation but S⁻ ion concentration is more that gives higher deposition rate.

3.2 Structural analysis

a) XRD:

X-ray diffraction studies were carried out at room temperature as shown in fig.3. The sharp peak of XRD pattern suggested the formation of single phase new compound which is CdS with cubic structure (ASTM data file). [1,8]

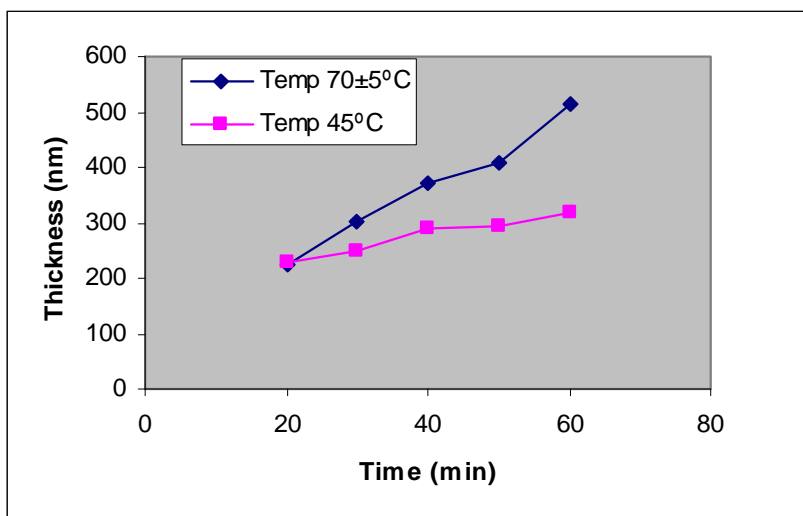


Fig 1. Variation of film thickness with deposition time at temperatures 45°C and 70±5°C.

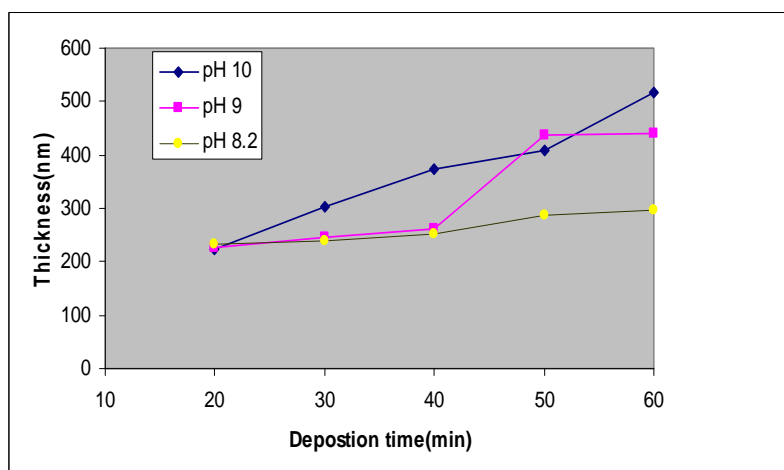


Fig 2. Variation of CdS film thickness with deposition time for pH 8.2, 9 and 10.

The grain size (g) of the nanocrystalline films was estimated using Debye-Scherrer's formula, [1, 5]

$$g = K\lambda / \beta \cos\theta$$

Where,

K = constant taken to be 0.94,

λ = wavelength of X-ray used (1.5418Å),

β = FWHM of the peak and

θ = Bragg's angle.

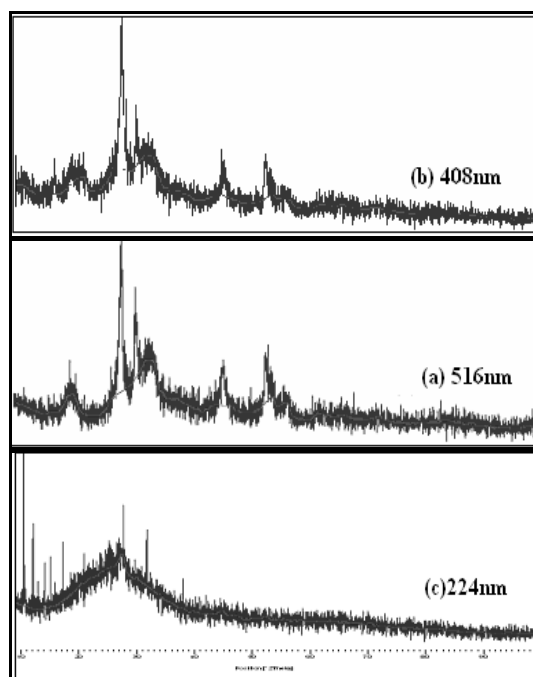


Fig 3. XRD pattern of thicknesses
(a) 516nm (b) 408nm (c) 224nm.

The variation of grain size with film thickness is shown in fig.4. It shows, as the film thickness changed from 224 nm – 516 nm, the grain size was changed from 10.77 nm – 20.17 nm and the growth rate varies from 11.2 nm/min to 8.6 nm/min.

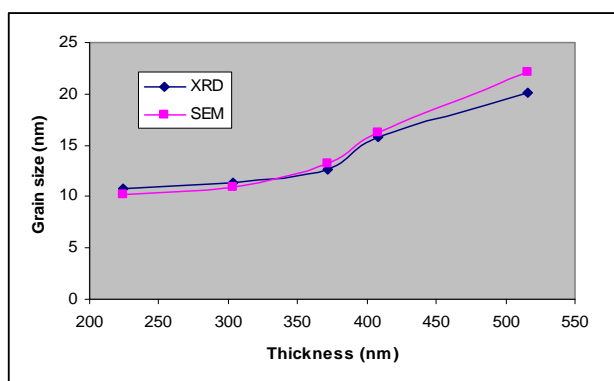


Fig 4. Variation of grain size with film thickness.

b) SEM:

Fig.5 shows the SEM micrographs of the CdS films at different magnitudes. The grain size was measured from SEM photograph by keeping the photograph under traveling microscope having high accuracy. We observed that the grain size have nano-metric dimensions ranging from 10.26 nm to 22.12 nm. It is found that, the grain size of CdS thin films from XRD and SEM were nearly same (fig.4).

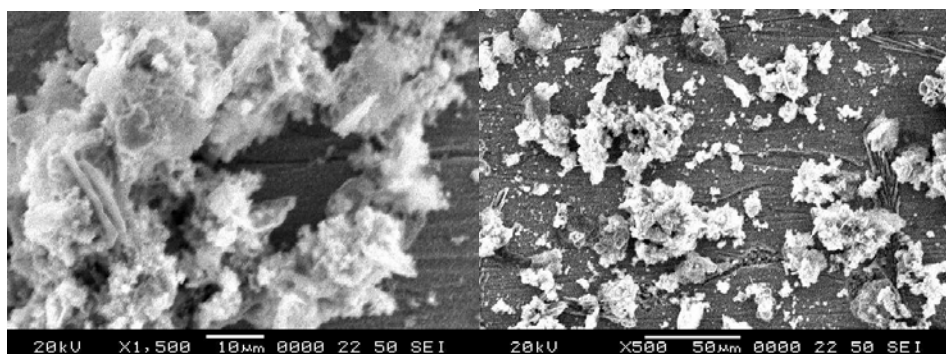


Fig 5. SEM images of CdS nano-crystalline thin films.

4. Conclusion

We have successfully deposited the good quality thin films of CdS by CBD technique on commercial glass substrate. The prepared films were found to be nano-crystalline. The grain size obtained by XRD and SEM were nearly equal. XRD shows the material is of single cubic phase, which is an important characteristic for the device performance. The preparation parameters play important role in the process of deposition of thin films and it affects the deposition rate.

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