

OPTICAL & AFM STUDIES OF VACUUM EVAPORATED CDS THIN FILMS

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ABSTRACT

Thin films of CdS of different thickness have been prepared on glass substrates at room temperature by vacuum deposition. The thickness of the deposited films was measured by employing quartz crystal monitor method. The optical properties have been studied in the range of wavelength 300-900nm. The optical band gap, absorption coefficient and extinction coefficient values of different thickness have been estimated. The surface morphology of the films is investigated by means of atomic force microscope (AFM).

1. INTRODUCTION

The ever widening search for new thin films materials to meet the challenging demand, which has lead to the selection of inorganic material [1-2]. Because of these, semiconductors are becoming very popular due to their wide band gap engineering [3-5]. Cadmium Sulphide is an important semiconductor with the bandgap energy $E_g = 2.40\text{eV}$. The semiconducting CdS possess unique electronic properties, which are essential in device fabrication like photo diodes, solar cells, photo detectors, light emitting device and thin film resistors [6-7]. Among various methods the reliable, simple and cost effective route to synthesis CdS thin film is vacuum evaporation techniques and also the development of low cost solar cells depends on the exploitation of the thin films and thus CdS films obtained various experimental conditions require comprehensive optical characterization [8-9]. Cadmium Sulphide belongs to II – VI group of a semiconducting material and they have higher bandgap energy than the corresponding III – V compounds due to the larger ionicity in II – VI compounds [10-12]. Also, the effective mass of mass carriers in II – VI compounds is relatively high, the radiative carries life time is small and the carrier diffusion length is short as compared with the III – V compounds. The optical absorption spectrum showed an exponential edge. The AFM is the best tool to investigate the surface morphology and also expose the smoothness and to find the grain size of the particle.

2. EXPERIMENTAL DETAILS

The CdS powder of purity 99% was evaporated using Tungsten conical basket (200 amps) under the pressure of 2×10^{-5} Torr on to a pre cleaned glass substrate (3.25 x 2.75 x 0.1 cm dimension). The pressure was obtained by diffusion pump backed by rotary pump in the coating unit and was measured using Pirani and Penning gauge. A constant rate of evaporation of the order of $1 \text{ \AA} / \text{sec}$ was maintained through out the film fabrication. A rotary

device was employed to maintain uniformity in film thickness. The thickness of the film was controlled and measured by Quartz crystal monitor and the thickness monitor in a flat circular plate approximately 0.05 inch (1.4cm) in diameter and 0.011 inch (0.28 cm) thick. A substrate heater arrangement was employed to grow the thin film at different substrate temperature. The Copper – constant and thermocouple was employed to measure the temperature inside the chamber. The optical transmission measurements were made in the spectrum range (190 – 2500nm) through UV-visible spectrometer [JASCO CORP V570] using unpolarized light at near normal incidence. Double beam spectrometers were used in all ranges. The optical constants have been evaluated from the measured values of the transmittance and the wavelength of light.

3. RESULT AND DISCUSSION

3.1. OPTICAL PROPERTIES

Optical properties of CdS thin films are determined from absorbance measurements in the range of 300-900nm. The absorption coefficient can be written in terms of the incident radiation energy.

$$\alpha = A (h\nu - E_g) \text{-----} \quad (1)$$

Where ‘h’ is the Planck’s constant and ‘ ν ’ is the frequency of the incident radiation.

The value of Extinction Coefficient (K_f) decreases with the increases in the film thickness. Absorption coefficient (α) associated with the strong absorption region of the films was calculated from absorbance (A) and the film thickness (t) using the relation.

$$A = 2.3026 \alpha t \text{-----} \quad (2)$$

The Extinction coefficients are calculated using the equation.

$$K_f = 2.303 \lambda \log (1/T_0) / 4\pi d \text{-----} \quad (3)$$

The extinction coefficient (K_f) is directly related to the absorption of light. In the case of polycrystalline films, extra absorption of light occurs at the grain boundaries [13]. This leads to non-zero value of (K) for photon energies smaller than the fundamental absorption edge [14].

The optical band gap can be obtained by extra plotting the linear portion of the plot $(\alpha h\nu)^2$ Versus $h\nu$. From the plot, the variation of $(\alpha h\nu)^2$ Versus photon energy for different thickness (880 Å, 930 Å, 2550 Å) CdS thin films are shown in Fig. 1, 2 and

Fig. 3. respectively. The presence of a single slope in the curves suggests that from thermal evaporation are of single phase in nature and the type of transition is direct and allowed.

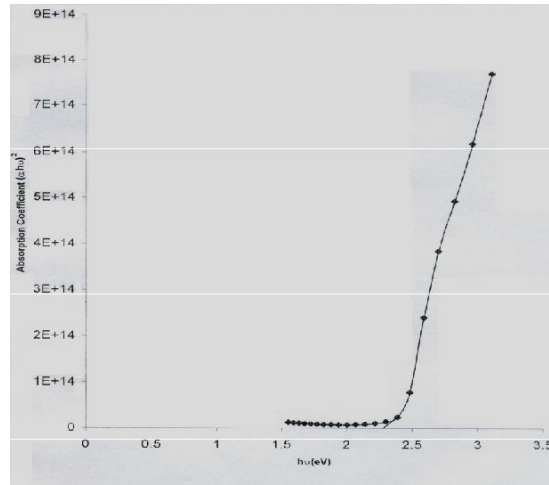


Fig. 1. A plot of $(\alpha h\nu)^2$ Vs. $(h\nu)$ for CdS thin film of thickness 880 Å.

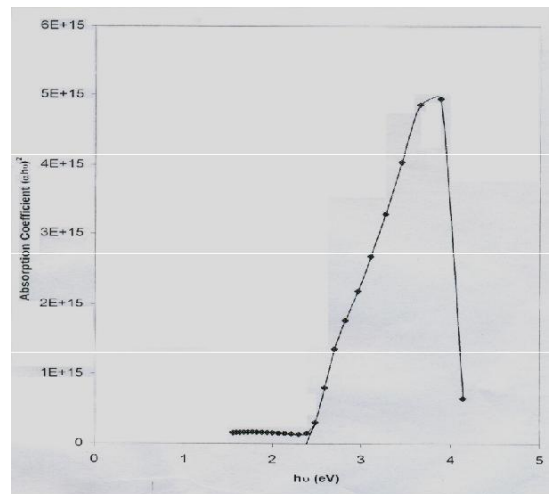


Fig. 2. A plot of $(\alpha h\nu)^2$ Vs. $(h\nu)$ for CdS thin film of thickness 930 Å.

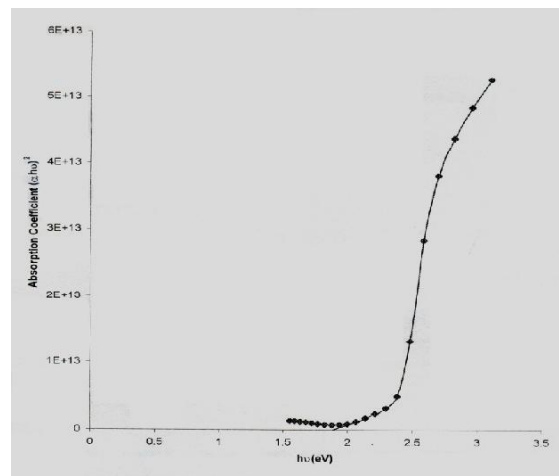


Fig. 3. A plot of $(\alpha h\nu)^2$ Vs. $(h\nu)$ for CdS thin film of thickness 2550 Å.

From these absorption peaks, the direct and allowed band gap energy is evaluated from the plot $(\alpha h\nu)^2$ Versus $h\nu$ are shown in table 1.

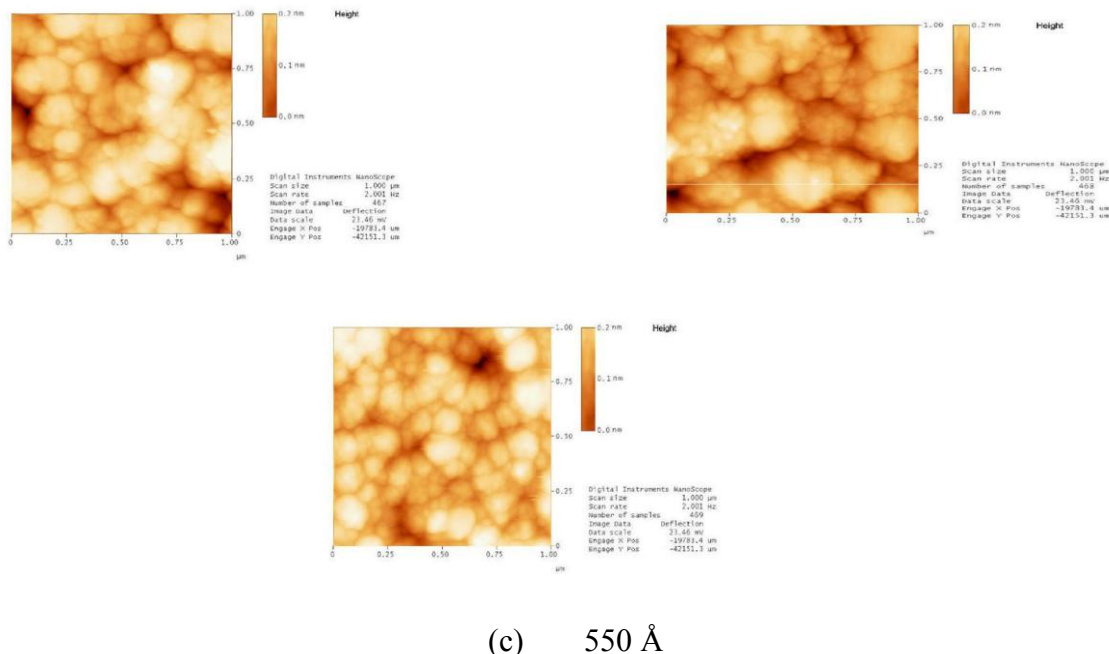
Table 1. Variation of energy gap, Absorption coefficient and Extrinsic coefficient with thickness.

Thickness Å	Band gap energy (eV)	Absorption coefficient	Extrinsic coefficient
880	2.33	1.72	0.37
930	2.31	2.04	0.35
2550	1.96	2.21	0.21

The observed decrease in the band gap energy with increases in thickness is due to the changes in the barrier height to the size of the grain in crystalline film and large density of dislocation.

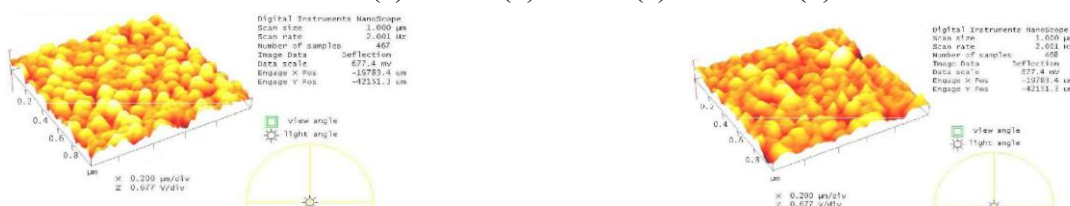
3.2. AFM STUDIES

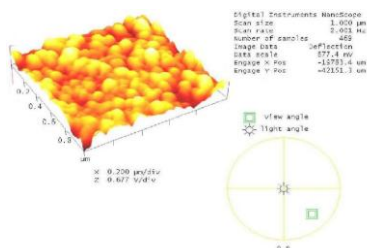
Fig. 4 & 5 shows the two dimensional and three dimensional AFM micrograph of the CdS thin films having thickness of 290 Å, 880 Å, 930 Å and 2550 Å. The scanning is done over an area of 1µm x 1µm. The AFM images exposed the high uniformity of the films with round-shaped nano particles, and also shows the beta phase films which consists of grain size 40-180 nm.



(c) 550 Å

Fig. 4. Two dimensional AFM micrographs of CdS thin film of thickness (a) 290 Å (b) 880 Å (c) 930 Å & (d) 2550 Å





(c) 2550 Å

Fig. 5. Three dimensional AFM micrographs of CdS thin film of thickness (a) 290 Å (b) 880 Å (c) 930 Å & (d) 2550 Å

The maximum size of the particle is calculated by Scheorer equation. The maximum size and the root mean square of the roughness (rms) of the surface of CdS films of thickness 880 Å, 930 Å and 2550 Å are tabulated in Table 2.

Table 2. Variation of particle size with thickness.

Sl. No.	Film thickness (Å)	Particle size (nm)	Roughness of the surface (nm)
1	880	57.20	12.50
2	930	60.45	13.12
3	2550	165.75	23.78

From the Table 2 reveals that, the particle size and roughness of the surface of the CdS thin films increases with increase in thickness.

4. CONCLUSION

CdS thin films grown on glass substrates using High Vacuum Evaporation method. The transmittance and absorbance spectra in the range of 400-900nm has been taken by using FTIR spectrometer. In absorbance spectra, the material has a high absorbing nature. The observed band gap energy and extinction coefficient has inversely dependent on film thickness. The absorption coefficient increases as the thickness of the material increases. The prepared CdS may have future applications in nanoscale optics, electronics and magnetic. The surface morphological studies show that the size of the particles increases with increase in thickness of the films by means of AFM.

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Conflict of Interest Reported: Nil; Source of Funding: None Reported.