Electrical Properties of Cadmium Sulphide Thin Films Prepared by Chemical Bath Deposition Technique: A Review

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In this work I tried to summarize some electrical properties of CdS thin films prepared by Chemical Bath Deposition (CBD) technique. CBD is very easy and cost effective. I focused on semiconductor type, resistivity and carrier mobility of CdS thin films. There is a good agreement in previous workers for these properties. They agreed that CdS is n type semiconductor and resistivity decreases while carrier mobility increases due to annealing of CdS thin films.

Keywords: Chemical Bath Deposition (CBD) technique, Semiconductor type, Resistivity and Carrier mobility.

1. INTRODUCTION

The investigation of fundamental electrical properties of Cadmium Sulphide (CdS) thin films is of great importance due to its use in solar cells, sensors, high speed transistors etc. [1].

There are many techniques to prepare thin films of CdS including sputtering [2,3], chemical bath deposition [4], thermal evaporation [5], close space sublimation [6], molecular beam epitaxy [7], spray pyrolysis [8] etc.. Enriquez and Mathew [9] and Ramirez and Espinoza [1] reported that chemical Bath Deposition (CBD) technique can be used to obtain good quality of CdS thin films.

This method does not require sophisticated instruments but it has minimum material wastage, economical way of large area deposition, and no need of handling poisonous gases. The chemical bath deposition (CBD) method appears to be a relatively simple method to prepare homogenous films with controlled composition and good quality CdS thin films [10].

2. CHEMICAL BATH DEPOSITION (CBD) PROCESS

The growth process involved in the deposition of the CdS layer is important in optimizing the quality of the thin film. The deposition of CdS by CBD is usually based on the decomposition of thiourea in an ammonical alkaline solution containing a cadmium salt. The reaction can be represented by equation (1).

$$Cd^{2+} + CS(NH_2)_2 + OH^- \rightarrow CdS + H_2CN_2 + 2H_2O \quad (1)$$

The properties of the chemically deposited films depend on the pH and the temperature of the reaction solution and on the relative concentration of the chemical precursors presented in equation (2) [1,9].

$$Cd^{2+} + S^{2-} \rightarrow CdS \tag{2}$$

The deposition of CdS on glass using the CBD method depends on six important parameters which includes: molar concentration of the reagents, pH level of the solution prepared, the deposition temperature, the deposition time, the stirring rate and the complexant agent used for slowing down the reaction. It is simple and economic method [11] than others.

3. ELECTRICAL PROPERTIES

3.1. Conductivity Type

M. Abulmakarim *et al*. [12] studied the CdS thin films of thickness ranging from 0.8-3.26 micrometer on microscope glass slides by hot–probe measurement technique.

It consists of a hot-point probe, usually a soldering iron heated to red level, a cold point probe and a centre zero milliammeter. The average value of voltages measured across the semiconductor was -0.285 V. The voltmeter reading was observed to be opposite in direction and of values -0.285 V when compared to that of p-type silicon which was observed to have a reading of +0.354 V. Hence conductivity of CdS thin film is n type. Films of CdS are n-type whether deposited by Vacuum Evaporation, Spray Pyrolisis or Chemical bath method [13].

C.C. Bijumon *et al*. [14] studied CdS thin film as-depoited has thickness 745nm and annealed at 150^0C for 1.5 hrs has thickness 670 nm and annealed at 200^0C for 1.5 hrs has thickness 492nm. Their Hall coefficients were -159.4cm^3/C, -280.8cm^3/C and -245.3 cm^3/C respectively. The Hall effect measurement are carried out at room temperature using Ecopia Hall Effect Measurement System (HMS- 3000). The negative value of Hall coefficient confirms the n-type conductivity of the as-deposited and annealed samples.

S. Thirumavalavana *et al*. [15] studied CdS thin films for various thicknesses prepared by CBD and their average Hall coefficient by Van Der Pauw method (ECOPIA HMS - 3000) at room temperature as -2.65X 10^6 cm^3/C. The negative value of Hall coefficient confirms the n-type conductivity of the as-deposited and annealed samples.

3.2. Resistivity

M. Abulmakarim *et al*. [12] studied the CdS Thin films of thickness ranging from 0.8-3.26 micrometer on microscope glass slides by four point probe method to measure the resistivity of the CdS layer. A JADEL of model RM3000 current source was used to pass in the current and measure the voltage drop across the semiconductor. A known current was passed in through the outer two probes while the voltage drop was measured using the two inner probes. A graph of voltage against current was plotted to obtain the slope

(V/I). Semi conductor resistivity ρ was then computed from the formula presented in equation (3) [16].

$$\rho = 2\pi S \frac{V}{I} \tag{3}$$

The average value of resistivity for the annealed and unannealed samples in the current research was $9.653\times10^3$and 1.01217×10^4 respectively. A decrease in average resistivity values of the samples were observed when the samples were annealed. This is in agreement with previous works in this field such as that of Chaure et al. [17] and that of Sundus *et al*. [18].

Resistivity ranging from 10^{-2} to 10^8 Ω-cm can be achieved for CdS thin films deposited on amorphous substrates [13,17,18].

C.C. Bijumon *et al*. [14] found that resistivity of as-deposited and annealed CdS thin films at 150^0C and 200^0C for 1.5 hrs were found $1.878\text{x}10^2$ ohm-cm, 1.5 $\text{x}10^2$ ohm-cm, and 1.307 $\text{x}10^2$ ohm-cm respectively. It shows resistivity decreases by annealing.

S. Thirumavalavana *et al*. [15] found that average resistivity of CdS thin films under investigation was $4.36\text{x}10^4$ ohm-cm and it decreases by the thermal treatment of the films.

3.3. Measurement of Charge Carrier Mobility (μ)

M. Abulmakarim et al. [12] used Hall Effect principle for the measurement of carrier mobility. The principle is based on the fact that an electro-motive force (e.m.f) is set up across a current carrying conductor (or semiconductor) when a magnetic field is applied normal to the direction of flow of current. The charge carrier mobility was calculated using equation (4) [16].

$$\mu = \frac{Slope}{B(\frac{W}{L})} \tag{4}$$

Where: W - width of the slide, equals to 2.54×10^{-2} m; L - Length of the slide, equals to 7.62×10^{-2} m; B - magnetic force (Tesla), equals to 0.03 T.

The sample of CdS thin film was held with a wooden stand and placed between the opposite poles of the magnet. Using the variable control of the direct current (dc) power supply, the applied voltage V_I was increased in steps of 0.5 volts from 0.5 to 4.0 Volts and the corresponding Hall Voltages V_H were recorded.

The average charge carrier mobility for the annealed and unannealed samples for this work was 2481.2 $cm^2V^{-1}s^{-1}$ and 2209.4 $cm^2V^{-1}s^{-1}$respectively. This is in agreement with results obtained by Chaure *et al*. [17] and Sundus *et al*. [18].

It was also observed that with increase in thickness, there was a corresponding increase in the charge carrier mobility of the material. The charge carrier mobility was, also, found to be inversely proportional to the roughness.

C.C. Bijumon *et al*. [14] found that mobality of as-deposited and annealed CdS thin films at 150^0C and 200^0C for 1.5 hrs were 0.8491$cm^2V^{-1}s^{-1}$ and 18.77 $cm^2V^{-1}s^{-1}$ respectively. It shows mobality increases due to annealing.

S. Thirumavalavana *et al*. [15] also show that average mobality of CdS thin films under investigation was very high i.e. 61 $cm^2V^{-1}s^{-1}$.

4. CONCLUSION

Analysis of the results from the previous researchers indicated that the CdS thin film developed is an n-type semiconducting material. It is in agreement with result of other researchers [19]. The Hall Effect principle was used for the measurement of electrical resistivity and carrier mobility. Present work shows that a fair decrement in resistivity due to annealing of CdS samples was reported by various researchers. This work also indicates that the carrier mobility of samples exhibited better results after annealing. The resistivity and charge carrier mobility are within the acceptable range.

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