# Variation of Hall Coefficient of CdS Thin Films at Different Temperatures

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**Abstract**:- Cadmium-Sulphide thin films are prepared by spray pyrolysis technique. The substrate temp. is kept 200ºC (low), 232ºC, 250ºC (high). The electrical properties are studied using Hall measurement system and the results are presented in this paper. The minimum sheet resistance of
$2.93 \times 10^3$ Ω/sq. is obtained for the films prepared at temperature 232ºC. The carrier concentration for the bulk as well as for the sheet decreases for high and low substrate temperatures. The mobility of charge carriers of low substrate temperature films and also at 232ºC temp. has been observed. The various electrical properties have been calculated and reported in this article.

## Introduction:

CdS is an important II-VI group compound semiconductor Material. CdS films are regarded as one of the most promising materials for hetro-junction thin film solar cells. Wide band gap CdS has been used as the window material together with several semiconductors such as $Cu_2S$/CdS & CdS/ $CuInSe_2$ [1].

However, due to the high cost of such a material, studies were developed towards polycrystalline semiconductor and particularly thin polycrystalline films. There are many different techniques for depositing the films, Chemical bath deposition, vacuum evaporation, spray pyrolysis & screen printing with sintering are well known and widely used techniques for the preparation of the films. Generally, in each of these methods, polycrystalline, stable, uniform, adherent and hard film are obtained. The chemical spray pyrolysis or pray pyrolysis is regarded as one of the simplest & economical method for the preparation of different types of thin films.

Extensive research has been done on decomposition & characterization of CdS semiconducting thin films due to their potential in the area of electronic device fabrication. CdS films attracted much interest because of their preferred properties of intermediate band gap [2,3].

The Hall measurement of CdS thin films deposited on conducting glass by spray pyrolysis technique have been investigated in the present paper.

## 2. Experimental Detail

In the present work CdS thin films is prepared by spray pyrolysis technique at various substrate temperatures onto conducting glass substrates [4].

An aqueous solution of stannic chloride (1M) mixed with alcohol and adding antimony chloride ($SbCl_2$) dissolved in conc. Hydrochloric acid is sprayed on glass substrate. The deposition of antimony doped tin oxide films is carried out at 200°C for 5 minutes. The reaction involved is give as

$$SnCl_2 + 2H_2O – SnO_2 + 4\ HCl$$

Thus we obtain a conducting glass.

Now thin/films of CdS on thin conducting glass is deposited by spraying a solution of cadmium chloride & thiourea temperature 200°C (low), 232°C, 250°C (high) for 5 minutes. The reaction involved is given as

$$CdCl_2+NH_2CSNH_2+2H_2O – CdS + 2NH_4Cl+CO_2$$

$$NH_4Cl \xrightarrow{heat} NH_3 + HCl$$

The volatile products formed during the process escapes out to the ambient atmosphere. Now the film are annealed for 10 minutes in vacuum to decrease the resistivity of the alloy films by removal of acceptor like any Oxygen level. The electrical studies of as deposited films carried out using Hall measurement system (Ecopia, HMS- 300) at room temperature with varying the current.

## 3. Result and Discussion

### Sheet Resistance (Rsh) and Resistivity (*ρ*)

The thickness of the films was maintained approx. 1 um the input current of 0.8μA is given to 232°C and 250°C high substrate temperature samples whereas for low substrate temperature 1.0 μA of current source is applied. The magnetic field of 0.580 gauss was applied in all cases. The

value of sheet resistance Rsh and resistivity (*ρ*) are shown as a function of substrate temperature in Fig.1(a) & (b) respectively.

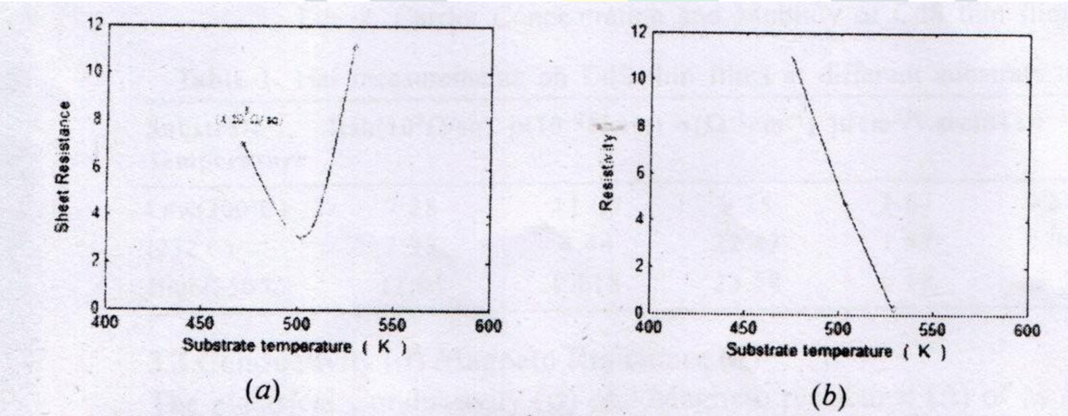


**Fig. 1.** Sheet Resistance and electrical Resistivity of CdS thin flims.

The minimum sheet resistance of 2.93 x $10^3$ Ω/sq was observed at the film prepared at 232° temperature substrate. The low substrate temperature films have the sheet resistance of 7.28x$10^3$ Ω /sq was achieved for the CdS thin films & reported in this paper. The very high sheet resistance of 11.01 x $10^3$ Ω/sq was observed on high temperature substrate CdS films. The electrical resistivity of the thin films was found to decrease with increase in the substrate temperature [5]. The very high resistivity of $11.00 \times 10^{-2}$ Ω-cm was observed on low substrate temperature films. The $232^{o}C$ and high temperature substrates have the resistivity of $4.44 \times 10^{-2}$ U cm and $0.018 \times 10^{-2}$ Ω-cm respectively.

**Carrier Concentration (n) and Mobility (μ)**

The carrier concentration of the bulk and sheet of deposited CdS thin films are shown in Fig. 2a The minimum bulk concentration of $0.34 \times 10^{12}$ $cm^{-2}$ was observed at high substrate temperature and the sheet concentration has $0.51 \times 10^{17}$ $cm^{-2}$ (Fig.2a)

The carrier concentration for the sheet and bulk has high value of $14.68 \times 10^{12}$ $cm^{-2}$ and $9.78 \times 10^{17}$ $cm^{-2}$ respectively. The mobility of the deposited CdS films as a function of substrate temperature is shown in Fig. 2b. It is found that the Hall mobility of the films decreases with increasing the substrate temperature. The high mobility of 2.67 $cm^2$/V-sec is observed on low substrate temperature CdS thin films may be due to un attached carriers freely moving due to Brownian motion [6]

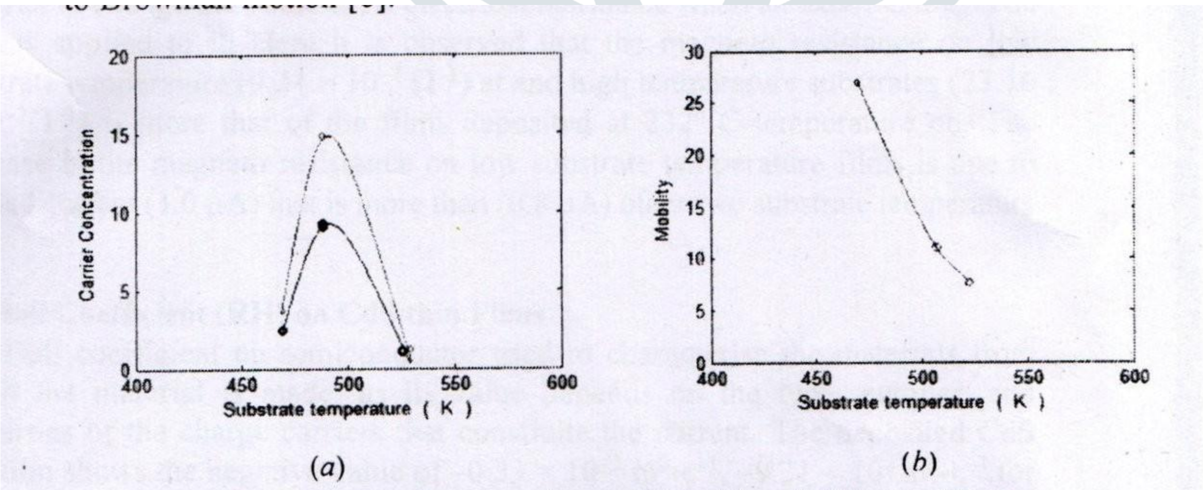


**Fig.2 Carrier Concentration and Mobility of Cd tin films.**

Table 1. Hal measurements on Cd thin films at different substrate temperature.

| Substrate Temperature | Rsh($10^3$ Ω/sq) | p(10-2 Ω.cm) | σ($Ω^{-1}$ cm-1) | μ($cm^2$/V. sec) | Δ($10^{-2}$ $Ω^{-1}$) | Nb($cm^{-2}$) |
|---|---|---|---|---|---|---|
| Low )200$^O$C) | 7.28 | 11.00 | 9.25 | 2.67 | 9.24 | 2.14 |
| (232$^o$C) | 2.93 | 4.44 | 22.43 | 1.45 | 0.04 | 9.78 |
| High(250$^o$C) | 11.01 | 0.018 | 23.58 | 0.68 | 23.36 | 0.34 |

## Conductivity (σ) Magneto Resistance (Δ)

The electrical Conductivity (**σ**) and Magneto resistance (Δ) of as deposited are shown in Fig. 3(a) and 3(b) respectively. The conductivity of a material depends directly both on the number 'n' of free electrons per unit volume and on the

average time '**τ**' between collisions. As we increase temperature, average speed of the electrons (which act as the carriers of current) increases, resulting in frequent

collisions. The average time of collision **τ** thus decreases with temperature which decreases the conductivity of metals.

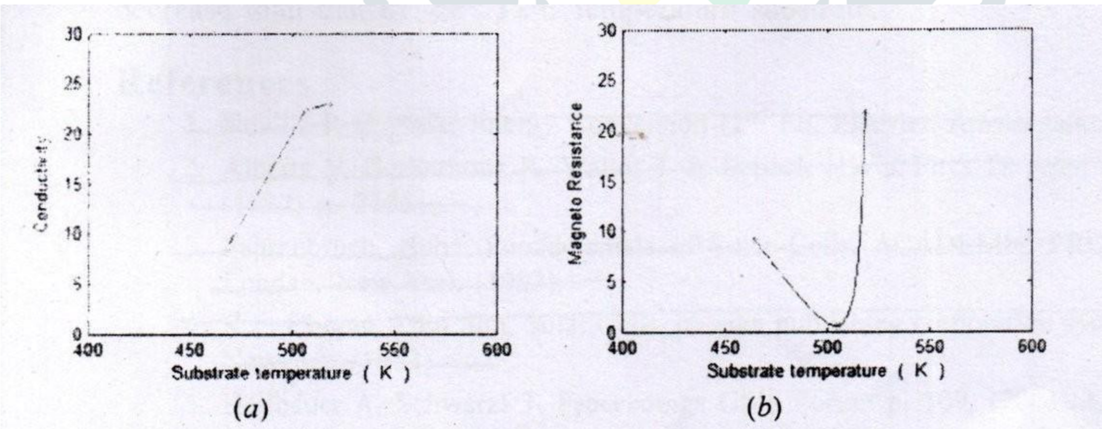


**Fig. 3.** Carrier Concentration and Mobility of CdS thin flims.

In Semiconductors the number of free electrons increases with increasing temperature, thus increasing conductivity. In this case the electrical conductivity of low substrate temperature films found to be less (9.25 $Ω^{-1}$ $cm^{-1}$) than that of the conductivity of 232$^o$C film (22.43 $Ω^{-1}cm^{-1}$) and high temperature substrates (123.58 $Ω^{-1}cm^{-1}$) shown in Fig. 2a. The magneto resistance is the property of a material to change the value of its electrical resistance when an external magnetic field is applied to it. Here it is observed that the magneto resistance on low substrate temperature (9.24 x $10^{-2}$ $\Omega^{-1}$) at and high temperature substrates (23.36x $10^{-2}$ $\Omega^{-1}$) is more that of the films deposited at 232$^{o}$ C temperature on. The increase in the magneto resistance on low substrate temperature films is due to applied current (1.0 µA) that is more than (0.8 µA) other two substrate temperatures [7].

**Hall coefficient (RH) on CdS thin Films**

The Hall coefficient on semiconductor used to characterise the materials from which the material is made, as its value depends on the type, number and properties of the charge carriers that constitute the current. The deposited CdS thin films shows the negative value of -0.33 x $10^{-2}$ $m^2$-$c^{-1}$, -9.21 x $10^{2}$ $m^2$-$c^{-1}$ for films at 232$^{o}$C and high substrate temperature respectively. These values of Hall coefficient yields to the deposited films are of n-type in nature. Some of the previous workers also identified that the CdS thin films have n-type in nature using various deposition method [8]

**Conclusions**

CdS thin films were deposited by spray pyrolysis technique. The Hall coefficient of all as deposited films showed the n- type semiconducting nature observed from its negative values. The electrical conductivity on low substrate temperature observed as 9.25 $\Omega^{-1}cm^{-1}$ and this yield to even at low temperature CdS thin films with suitable electrical properties for application towards single electron transistor devices. The mobility of the films observed shows linear decrease with increasing substrate temperature. The minimum sheet resistance 2.93x$10^{3}$ $\Omega$/sq was observed for films deposited at 232$^{o}$C temperature of substrate. The carrier concentration of low and high temperature substrate is found to be decreased than that of the 232$^{o}$C temperature substrate.

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