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ELECTRICAL CHARACTERIZATION OF ELECTRON BEAM EVAPORATED $Cd_{1-x}Se_x$ THIN FILMS

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CdSe is an important compound semiconducting material for the development of various applications in solid state devices such as solar cells, high efficiency thin film transistors. In recent years major attention has been given to the investigation of structural properties for the improvement of performance of such devices and applications. The prepared starting materials have composition $Cd_{1-x}Se_x$ ($0.22 \leq x \leq 0.40$) was used to fabrication of thin films. The n-type cadmium selenide thin films have been deposited by electron beam evaporation technique on well cleaned glass substrate in vacuum $\sim 10^{-5}$ torr keeping substrate temperature at 300 K. The resistivity, conductivity, Hall mobility and carrier concentration of the deposited films were calculated of different compositions ratio of Cd/Se.

Keywords: N-TYPE CdSe, RESISTIVITY, HALL MOBILITY, HALL COEFFICIENT, CARRIER CONCENTRATION.

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1. INTRODUCTION

In recent year, there has been rapid development in the field of II-VI group (CdSe, CdS, ZnSe, CdTe) semiconductor thin films owing to their wide range of applications. As an important member of this group is a binary compound cadmium selenide (CdSe) with a band gap of 1.7 eV [1, 2]. It is interest because of its optical and electrical properties which is applicable in production of high efficiency thin film transistors [3]. Electrical and optical properties of semiconducting films are very sensitive to ambient condition and deposition technique used. Therefore study of such properties of the films with respect to their different growing as well as ambient conditions is a matter of profound importance [4]. In present paper electrical properties of CdSe thin films studied under deposited by electron beam evaporation technique in vacuum.

In the present works, cadmium and selenium in the pure metallic powder form procured from Alfa Aesar Ltd. U.S.A. (Cadmium-99.999% pure and Selenium 99.999% pure).

2. EXPERIMENTAL DETAILS

The starting materials were prepared using different composition of high purity cadmium (99.999%) and selenium (99.999%) using formula $Cd_{1-x}Se_x$ ($0.22 \leq x \leq 0.40$). The starting materials of each composition were mixed by pestle rod and then heated in vacuum (Hind Hivac Vacuum Coating Unit,

model 12A4) using molybdenum boat in temperature range 423 K to 523 K for dry powder reaction in vacuum better than 10^{-4} torr for six hours and cooled in same vacuum condition. The cooled materials were taken out from the coating unit and again grinded by pestle rod and kept at same vacuum condition in vacuum coating unit for heating for the completion of reaction. This process was repeated five times for each composition for better formation of CdSe compound.

The glass slide has been used as substrate for the fabrication of CdSe thin films. Substrate cleaning play very important role in the deposition of thin film, here we use commercially available glass slide with size of (75mm \times 25mm \times 1mm) washed in initially chromic acid. Finally it was washed with distilled water in ultra sonic cleaner and dried at 423 K in oven. We fabricated n-type CdSe thin films on glass substrate using prepared starting materials of various composition of Cadmium and Selenium by electron beam evaporation technique under vacuum 10^{-5} torr keeping substrate at room temperature of the thickness of 500 nm in vacuum coating unit (Hind Hivac, model 12A4).

The CdSe thin films were electrically characterized with help of various electrical parameters such as resistivity, carrier concentration, mobility, Hall coefficient etc. by four probe resistivity measurement setup and Hall setup designed by Scientific Equipment and Services-Roorkee (UK).

3. RESULTS AND DISCUSSION

The measurements of electrical resistivity and conductivity of the samples have been done by using a standard four probe method. This technique is widely used for the measurement electrical property of materials and has been proved a convenient tool for the resistivity measurement.

A four probe measurement is performed by making four electrical contacts to a sample surface, two of the probes are used as source current and remaining other two probes are used to measure voltage. The advantage of the using probe is to eliminate the occurrence of errors due to the probe resistance, spreading resistance under contact resistance between each metal probe and material. The electrical resistivity ρ evaluated by applying a direct current I through the outer pair of probes and measuring the voltage drop V between the inner pair of probes, which are positioned at a distance of $S = 0.2$ cm using the following equation,

$$\rho = \frac{2\pi S \times V}{G_7(w/s) \times I} \quad (i)$$

Where $G_7(w/s) = \frac{2S}{w \log_e 2}$, w - thickness of the film.

The increase in electrical resistivity with increase of composition of Cd/Se ratio in CdSe thin films (thickness-500 nm) deposited at room temperature shown in Fig. 1 to 10 and also represents ohmic behavior. The Hall Effect can be achieved by inducing a magnetic field perpendicular to the current flow direction in a CdSe thin film. Under such conditions, a Hall voltage is developed perpendicular to both the current and magnetic field. The generated Hall voltage can be observed by considering the forces on a charged carrier in the presence of a magnetic field.

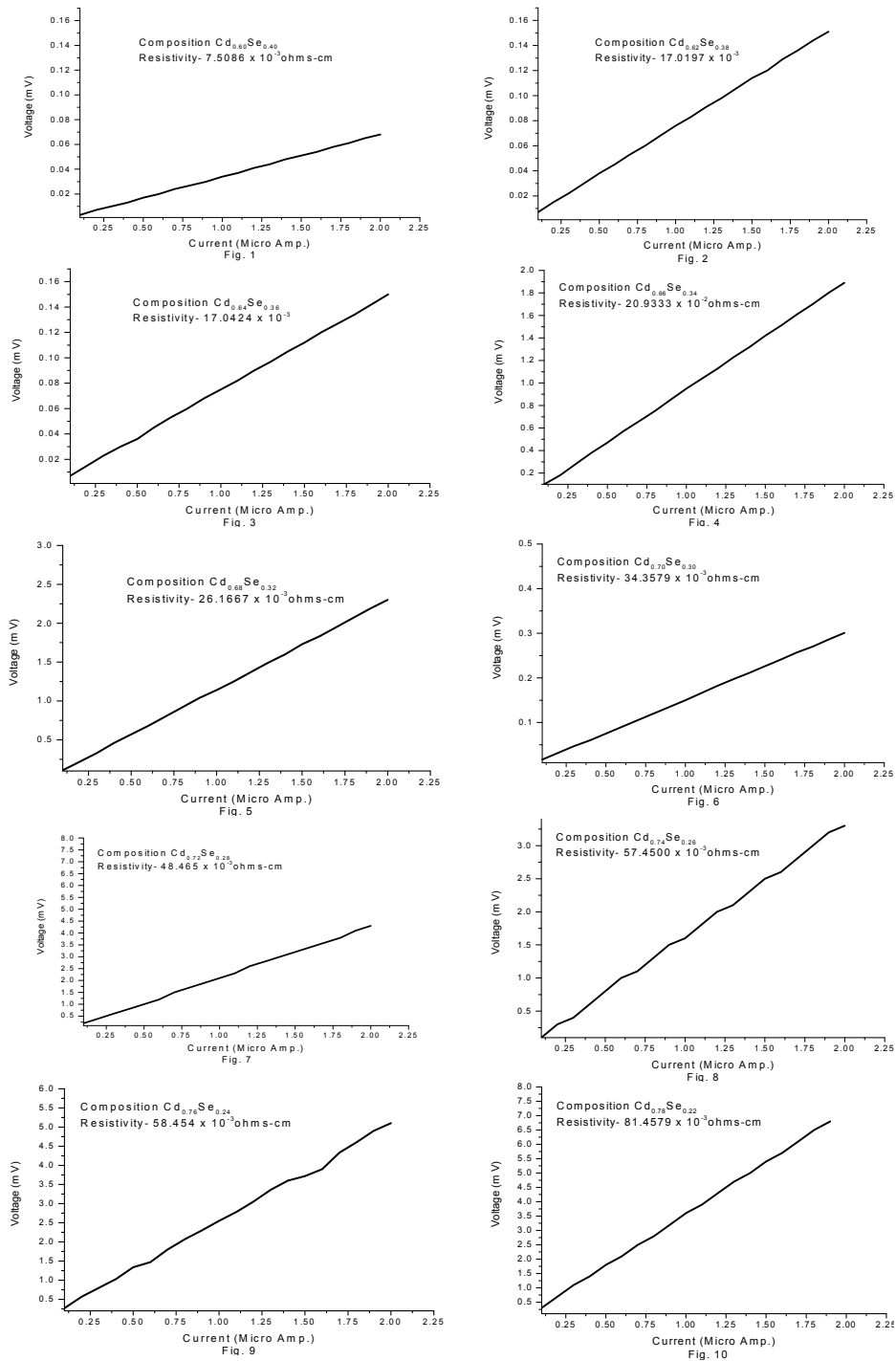


Fig. 1-10 – Electrical resistivity with increase of composition of Cd/Se ratio in CdSe thin films (thickness-500 nm)

$$\vec{F} = q\vec{E} + q\vec{V} \times \vec{B} \quad (\text{ii})$$

The first term in above expression is occur due to the total electric field driving the current through the sample and the second term is occur due to the presence of Lorentz force on the charged carriers, and tends to deflect the carrier toward the side of the sample. The direction of the deflection depends on the sign of the charge carrier's which identify the type of semiconductor (i.e. p-type or n-type). The Hall coefficient, carrier concentration, and mobility can be measured by following formula

$$R_H = \frac{V_H \times w}{I_x B_z} \quad (\text{iii})$$

$$n = \frac{1}{R_H \times q} \quad (\text{iv})$$

$$\mu = \frac{R_H}{\rho} \quad (\text{v})$$

Where, R_H is Hall coefficient, n is Carrier concentration, μ is Mobility, V_H is Hall voltage, w is film thickness, I_x is applied current in x -direction, B_z is applied magnetic field in z -direction.

Table 1 – Carrier concentration, mobility, and resistivity variation of $\text{Cd}_{0.60}\text{Se}_{0.40}$ at different composition

S.N o.	Composition	Thickness	Hall coefficient (m ³ /coulomb)	Carrier concentration (per cm ³)	Hall mobility (cm ² /Volt sec) at RT.	Resistivity (Ohms-cm)
1	$\text{Cd}_{0.60}\text{Se}_{0.40}$	5 kÅ	5.428×10^{-6}	1.151×10^{18}	722	7.5086×10^{-3}
2	$\text{Cd}_{0.62}\text{Se}_{0.38}$	5 kÅ	5.536×10^{-6}	1.128×10^{18}	325	17.0197×10^{-3}
3	$\text{Cd}_{0.64}\text{Se}_{0.36}$	5 kÅ	5.547×10^{-6}	1.126×10^{18}	325	17.0424×10^{-3}
4	$\text{Cd}_{0.66}\text{Se}_{0.34}$	5 kÅ	5.682×10^{-6}	1.099×10^{18}	271	20.9333×10^{-3}
5	$\text{Cd}_{0.68}\text{Se}_{0.32}$	5 kÅ	5.721×10^{-6}	1.092×10^{18}	218	26.1667×10^{-3}
6	$\text{Cd}_{0.70}\text{Se}_{0.30}$	5 kÅ	5.935×10^{-6}	1.053×10^{18}	172	34.3579×10^{-3}
7	$\text{Cd}_{0.72}\text{Se}_{0.28}$	5 kÅ	6.279×10^{-6}	9.953×10^{17}	129	48.4652×10^{-3}
8	$\text{Cd}_{0.74}\text{Se}_{0.26}$	5 kÅ	6.361×10^{-6}	9.825×10^{17}	110	57.4500×10^{-3}
9	$\text{Cd}_{0.76}\text{Se}_{0.24}$	5 kÅ	6.389×10^{-6}	9.782×10^{17}	109	58.4540×10^{-3}
10	$\text{Cd}_{0.78}\text{Se}_{0.22}$	5 kÅ	6.865×10^{-6}	9.104×10^{17}	84	81.4579×10^{-3}

Hall effect measurement show that films are n-type, Table 1 optimized that composition $\text{Cd}_{0.60}\text{Se}_{0.40}$ is better in all composition having carrier concentration 1.151×10^{18} per cm³, mobility 722 cm²/Volt sec and resistivity 7.5086×10^{-3} Ohms-cm.

4. CONCLUSION

In summary we concluded that the effect of composition Cd/Se ratio on electrical properties deposited by electron beam evaporation n-type CdSe thin

films. The resistivity of n-type CdSe thin films increases (7.5086-81.4579) $\times 10^{-3}$ Ohm-cm while charge concentration decreases (1.151-0.9104) $\times 10^{18}$ per cm^3 and mobility (722-84) $\text{cm}^2/\text{Volt sec}$. It is also observed that the films are n-type and optimized composition $\text{Cd}_{0.60}\text{Se}_{0.40}$ is best.

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