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Effect of deposition parameter on structural and electrical properties of n-type cadmium selenide thin films

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ABSTRACT

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 and electrical properties for the improvement of performance of such devices and its applications[1]. We prepared n-type CdSe thin films on glass substrate using cadmium selenide material with various composition of Cd (99.999%) and Se (99.999%) by electron beam evaporation technique under vacuum 10^{-5} torr in vacuum coating unit, keep substrates at room temperature and studied the effect of composition ratio of cadmium & selenium on thin films and evaluate the grain size, resistivity, hall mobility and carrier concentration in n-type CdSe thin films.

KEYWORDS

n-type CdSe;
Grain size;
Resistivity;
Hall mobility;
Carrier concentration.

INTRODUCTION

Among chalcogenide semiconductors II-VI group compound semiconductors have drawn interest of many researchers because they found many applications in solid state physics[2]. II-VI compound semiconductors having band gap between the range of 1 to 3 eV in visible region and these semiconducting materials are use world wide in opto-electronics devices. Cadmium selenide (CdSe) thin films has long popular in the field of opto-electronics because of its direct band gap[1]. CdSe, along with some additives in it, from an application point of view important class of compound semiconducting materials, which find applicable in production of in low cost devices such as light emitting diode, solar cells, photo detectors, laser gas sensors, thin film transistors and gamma ray detectors etc[3]. Cadmium selenide thin films have been prepared by using different methods such as electron deposition, molecular beam epitaxy, spray pyrolysis, successive ion layer adsorption and reaction methods etc. Among these methods the electron beam evaporation method is found to be interested for the preparation of high purity and good semi-conduction thin films[1]. The properties of thin films prepared by electron beam evaporation method critically depend on various preparative parameters such as a substrate temperature, vacuum and composition ratio etc.

In this investigation CdSe thin films were prepared by electron beam evaporation technique with various com-

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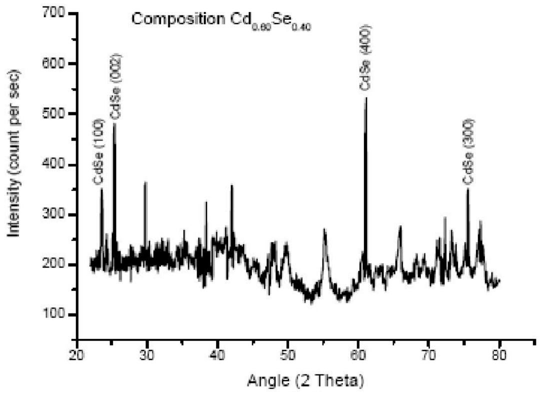

Figure 1

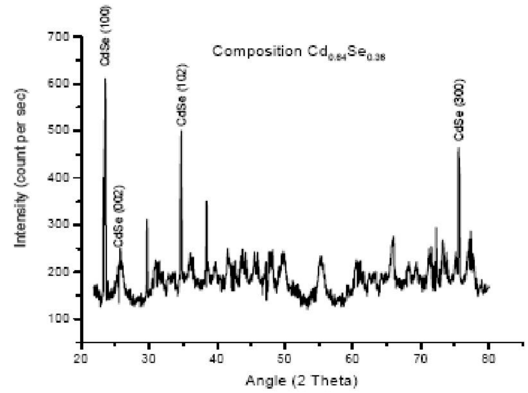

Figure 2

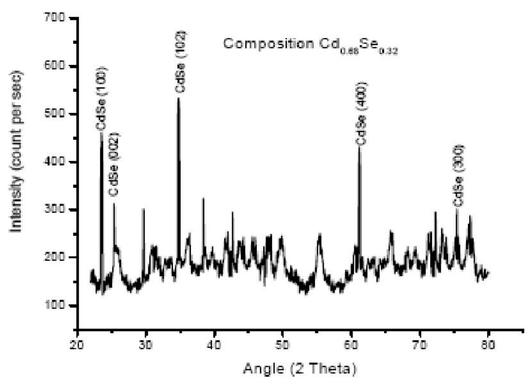

Figure 3

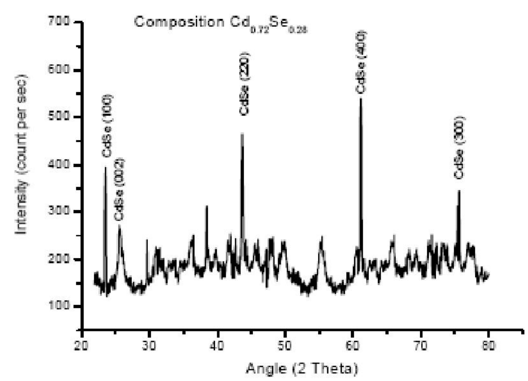

Figure 4

position ratio of Cd/ Se and studies the effects of composition ratio on structural and electrical properties.

EXPERIMENTAL

Substrate cleaning

The substrate cleaning play an important role in the deposition of thin film, commercially available glass slide with size of (75mm×25mm×1mm) washed using detergent, chromic acid and finally washed with double distilled water in ultra sonic cleaner and dry at 150^{o}C in oven.

Deposition of thin films

The starting material with composition of high purity cadmium (99.999%) and selenium (99.999%) prepared by using formula $Cd_{1-x}Se_x$ (where, x varies form 0.24 to 0.40) of finite composition under dry powder reaction in vacuum 10^{-5} torr below melting temperature. Films are deposited on glass substrate by electron beam evaporation using graphite crucible in vacuum coating unit (Hind Hivac model -12A4) in vacuum (~10^{-5} torr).

Characterization of the CdSe thin films

The CdSe thin films were electrically characterized by four probe resistivity measurement setup designed by Scientific Equipment and Services-Roorkee (UK), Hall mobility measured using Hall setup and structural property measured with the help of X-ray diffractometer designed by Philips Analytical (Germany, model PW 3710).

RESULT AND DISCUSSION

Structural properties

The typical X-ray diffraction pattern of n-type CdSe thin films are recorded by diffractometer and given in figure 1 to 5.

The grain size 'D' of the film was calculated from the Debye Scherrer's formula from the full width at half maxima(FWHM) of the X-ray diffraction pattern shown in figure1-5[4].

$$D = 0.94\lambda / \beta \cos\theta$$

where, D = Grain size, λ= wave length (=1.5404Å) of

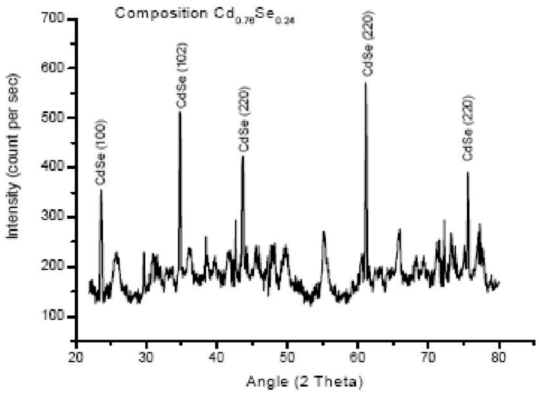

Figure 5

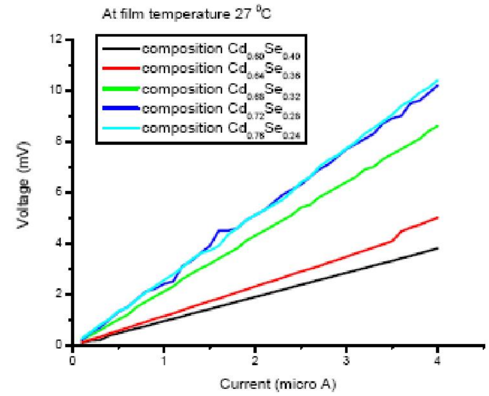

Figure 6

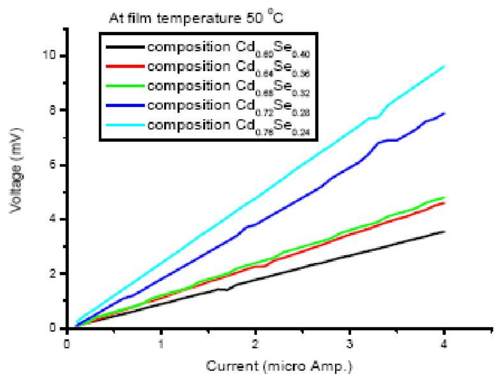

Figure 7

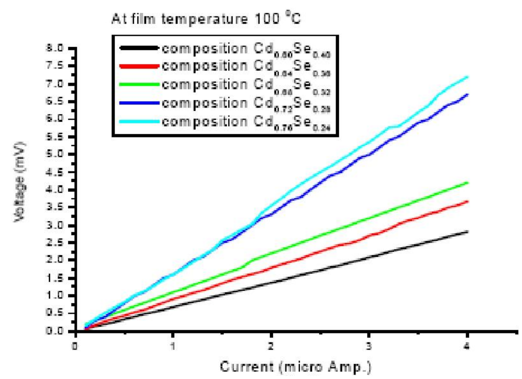

Figure 8

TABLE 1

S.No.	Composition ratio	Grain Size 'D' (Å) for Planes			
		(1 0 0) plane	(0 0 2) plane	(4 0 0)	(3 0 0)
1	$Cd_{0.60}Se_{0.40}$	2.0717	4.0336	3.9932	6.3385
2	$Cd_{0.64}Se_{0.36}$	2.0602	4.0118	-----	6.2311
3	$Cd_{0.68}Se_{0.32}$	2.0319	3.9269	3.8121	5.9295
4	$Cd_{0.72}Se_{0.28}$	1.9723	3.7579	3.6948	5.8354
5	$Cd_{0.76}Se_{0.24}$	1.9361	3.7109	3.5024	5.5702

TABLE 2

S. No.	Composition	Thickness	Hall coefficient (m^3/colam)	Carrier concentration (per m^3)	Hall mobility (cm^2/volt sec)	Resistivity ρ (Ω-cm) at RT
1	$Cd_{0.60}Se_{0.40}$	5kÅ	2.58×10^{-4}	2.422×10^{22}	1232	20.93×10^{-2}
2	$Cd_{0.64}Se_{0.36}$	5kÅ	3.18×10^{-4}	1.965×10^{22}	1215	26.16×10^{-2}
3	$Cd_{0.68}Se_{0.32}$	5kÅ	3.51×10^{-4}	1.780×10^{22}	724	48.46×10^{-2}
4	$Cd_{0.72}Se_{0.28}$	5kÅ	3.81×10^{-4}	1.640×10^{22}	663	57.46×10^{-2}
5	$Cd_{0.76}Se_{0.24}$	5kÅ	3.97×10^{-4}	1.574×10^{22}	679	58.45×10^{-2}

used X-ray, β = Full width half maxima, θ = Diffracted angle.

From TABLE 1 we found that the maximum orientation of particle in each sample along (1 0 0), (0 0 2), (3 0 0) planes and grain size according to each planes decreases with increase of the amount of cadmium. This causes occurs due to presence of highly agloramation effect because the diameter of particle less than Rb (bore excitation (≅11.1 nm) radious and hence the particles are more alogomorated by increase the quantity of cadmium in composition and correspondingly decreases. Thus grain size decreases and hence correspondingly its conductivity decreases because conductivity directly proportionally to grain size[5].

Electrical properties

The measurements of electrical resistivity and conductivity of the sample using a standard four probe method. The method is the most widely used technique for electrical profile measurement of materials and has been proven to be 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 use probe is to eliminate the occurrence of errors in due to the probe resistance, spreading resistance under each probe and the contact resistance between each metal probe and material. The electrical resistivity 'ρ' is evaluated by loading 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,

$$\rho = V \times 2 \Pi S/(I \times G_7 (w/s))$$

where G_7 (w/s) = 2S/w $\log_e 2$, w = thickness of the film, ρ= resistivity.

Figure 6, 7 and 8 shows that resistivity increase with increasing of Cd/Se ratio. Films are in semi-conducting nature because the resistivity decreases according to temperature. All films are of n-type as confirmed by Hall effect data. In TABLE 2 shows the carrier concentration decrease with increase the Cd/Se ratio and same nature show in case of hall mobility. The agglomeration effects gives rise to larger absorption edge blue shift and this explains the discrepancy in the crystallite size as measured from XRD measurements[6].

$$\text{Hall coefficient } (R_H) = (V_H \times w) / (I_x \times B_z)$$

$$\text{Carrier concentration } (n) = 1/(R_H \times q)$$

$$\text{Hall mobility } (\mu_H) = R_H/\rho$$

where V_H is Hall Voltage, I_x = Constant current in x direction, B_z = Constant magnetic field in z direction, ρ = Resistivity of the film.

CONCLUSION

In summary the effect of composition ratio of cadmium & selenium (Cd/Se) on the structural and electrical properties of the electron beam evaporated CdSe thin films was investigated. The grain size decreases from 2.0717 to 1.9361 for (1 0 0) plane, 4.0336 to 3.7109 for (0 0 2) plane, 6.3385 to 5.5702 for (3 0 0) plane, 3.9932 to 3.5024 for (4 0 0) plane and the resistivity increase from 20.93×10^{-2} to 58.45×10^{-2} ohms cm with slightly increase 0.60 to 0.76 cadmium amount of the composition at room temperature and charge concentration decrease from 2.422×10^{22} to 1.574×10^{22} per m^3.

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