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Research Article

Effect of Pb additive on the Grain size and D.C Electrical Properties of $Cd_{1-x}Pb_xSe$ Thin Films

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Abstract

The alloys of $Cd_{1-x}Pb_xSe$ at different Pb concentration (i.e. X=0, 0.025, 0.050, 0.075, and 0.1) were prepared successfully, Thin films of these alloys are deposited using thermal evaporation technique at thickness (126) nm. From the studied D.C measurements The D.C conductivity decreases with the increase of Pb concentration of thin films and we noticed different activation energies. Hall Effect measurements show that the type of thin $Pb_{1-x}Cd_xSe$ films for all Pb concentration are n-type. From the Hall measurement The Hall mobility increases with the increase of temperature, while it decreases with the increase of Pb concentration. Atomic force microscopy (AFM) measurements shows that average crystallite size are increase with the increase of Pb concentration equal to (0, 0.025, 0.050 and 0.075), except for X=0.1 it is decreased, The average surface roughness decreases for films at X equal to (0.025,0.075,and 0.1) while the behavior for(X=0, 0.050) is opposite.

Keywords: *$Cd_{1-x}Pb_xSe$, additive, Grain size, Electrical Properties, Thin Films.*

1. Introduction

The discovery of semiconductors is one of the greatest scientific and technological breakthroughs of the 20th century. It has caused major economic change, and has perhaps changed civilization itself [B. Sapoval *et al*, 1995] Due to variety of applications. Number of binary and or ternary II-VI and IV-VI compounds have been used as efficient absorbers and window layers in thin film for photovoltaic and detector configurations [M. Guitierrez *et al*, 1989, D. R. Kendrea et al, 2012] Among various semiconducting materials, CdSe is one of II-VI compounds which has band gap energy equal to 1.74 eV and CdSe thin film has several unique properties like direct band gap matching with visible region of solar spectrum, high absorption coefficients, good electrical and optical properties. The increased capability in obtaining n- or p-type conductivity by doping that make very promising in semiconducting devices, photodetectors, lasers, thermoelectrically devices, solar energy converters, sensors etc [S. Delekar *et al*, 2010]. The systematic studies on these properties are still necessary for a more comprehensive understanding and control over the properties. Although studies pertaining to binary CdSe thin films have been made to a large extent, investigation on their composite /alloyed structures are rare [V.B. Pujari *et al*, 2002, V.B. Pujari *et al*, 2004, V.B. Pujari *et al*, 2001]. In the present work, the effect of Pb additive of CdSe compound on grain size is studied by Atomic Force Microscopy and on D.C electrical properties and Hall measurements.

2. Experimental Work

$Cd_{1-x}Pb_xSe$ compound were prepared by taking pure element of , Cd and Pb and Se elements (purity 99.999 %) for x values (i.e. 0,0.025.0.05,0.075,and 0.1) were finely ground, mixed in the correct stoichiometric ratio, and sealed in quartz tube under vacuum. After that, we put it inside on electric furnace of type (634 HBTMN) and raised the temperature up to 900 C° by steps of 200 C° by remaining it at each step for two hours and continuing up to 900 C° and remain it at this temperature for two hours after that thin films of $Cd_{1-x}Pb_xSe$ alloys for all x values deposited on to glass substrates by thermal evaporation technique which are cleaned by distilled water, pure alcohol, and then by ultrasonic vessel using An (Edward E306), at room temperature, Molybdenum boat was used as the source holder and the pressure inside the chamber was better than $2*10^{-5}$ mbar$Cd_{1-x}Pb_xSe$ were evaporated thermally with a deposit rate of 8.4 nm/min to get thin films with thickness (126) nm.For $Cd_{1-x}Pb_xSe$ thin films, aluminum electrodes of thickness 200 nm were evaporated from a tungsten spiral using an (Edward E 306)a coating unit in order to provide ohmic contact for $Pb_{1-x}Cd_xSe$ thin films.

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2.1. D.C conductivity

D.C conductivity measurements were made by using sensitive digital electrometer type Keithley 616 and electrical oven in order to measure the electrical resistance for thin films as a function of the temperature at the range (283-473) K

The sample resistivity (ρ) was calculated from the relation below [B. Sapoval *et* al, 1995, L. A. Rauf *et al*, 1996]

$$\rho = R\frac{wt}{\ell} \quad (1)$$

Where t, R, w, ℓ are the film thickness, the electrical resistance, the width of the electrode, and the distance between two electrodes respectively.

The conductivity of the sample (σ) is given by the relation

$$\sigma = \frac{1}{P} \ in \ (\Omega.cm)^{-1} \quad (2)$$

The equation which represents the variation of the electrical conductivity as a function of temperature is

$$\sigma = \sigma_0 \exp(-E_a / K_B T) \quad (3)$$

Where σ_o is the minimum electrical conductivity at (0) K, E_a is the activation energy. From plotting the relationship of Ln σ vs. 1000/T, one can deduce the activation energy of the film conductivity from the slop of the straight line of the plot.

2.2. Hall Effect

When a magnetic field is applied at right angles to current flow ,an electric field E_H is generated which is mutually perpendicular to the current and the magnetic field , and is directly proportional to the product of the current density (J) and the magnetic induction (B) [S. M. Sze, 1990, N. Amin *et al*, 2000] as

$$E_H = R_H JB \quad (4)$$

Where R_H is Hall coefficient and $J = \frac{I}{A'}$ where A/ is the cross section area.

The generated electric field (E_H) is called Hall field which is related to the Hall voltage (V_H) by the relation

$$V_H = E_H W \quad (5)$$

Where W is the distance between the two electrodes. From the relation 4 and 5 Hall coefficient can be determined by the relation

$$R_H = \frac{V_H}{I} \cdot \frac{t}{B} \quad (6)$$

Where t is the film thickness.

Carrier concentration can be determined by using the relation

$$n_c = \frac{-1}{q \ R_H} \quad (7)$$

or

$$p = \frac{+1}{q \, . \, R_H} \quad For \ holes \quad (8)$$

From Hall measurements the Hall mobility can be obtained according to the relation

$$\mu_H = R_H \, \sigma_{R.T} \quad (9)$$

Where $\sigma_{R.T}$ is the conductivity at room temperature.

2.3 Atomic Force Microscopy (AFM)

Surface topography was studied by using atomic force microscopy (AFM) using (Scanning probe Microscope type AA3000), supplied by Angstrom Advanced Inc. to determine the Nano spikes dimensions range of the prepared thin $Cd_{1-x}Pb_xSe$ films deposited onto glass substrate and their statistical distribution .

3. Result and dissection

3.1 Atomic Force Microscopy

Table 1 indicates values of grain size and average roughness for $Cd_{1-x}Pb_xSe$ for all Pb concentration as analysis by atomic absorption spectroscopy for thin films,

It is obvious from table 1 that the average grain size and roughness of the surface vary with the concentration in non-systematic and these returns to the preparation condition.

Table 1 Values of grain size and average roughness

t (nm)	x	Average grain size (nm)	Average roughness (nm)
126	0	89.84	1.99
	0.025	91.56	0.14
	0.050	94.96	2.21
	0.075	165.37	0.272
	0.1	82.94	0.21

3.2 D.C conductivity

Fig 2 shows the plot of Ln σ as a function of. 1000/T it is obvious that there is two activation energy for the behavior of conductivity with the temperature the first activation energy of temperature (283-363) K, and the conduction mechanism of this stage is due to carrier transport to localized states near the valance and conduction band, while the second activation energy (Ea2) occurs at higher temperature within range (363-473) K, and this is due to conduction of carrier excited into the extended states beyond the mobility edge.

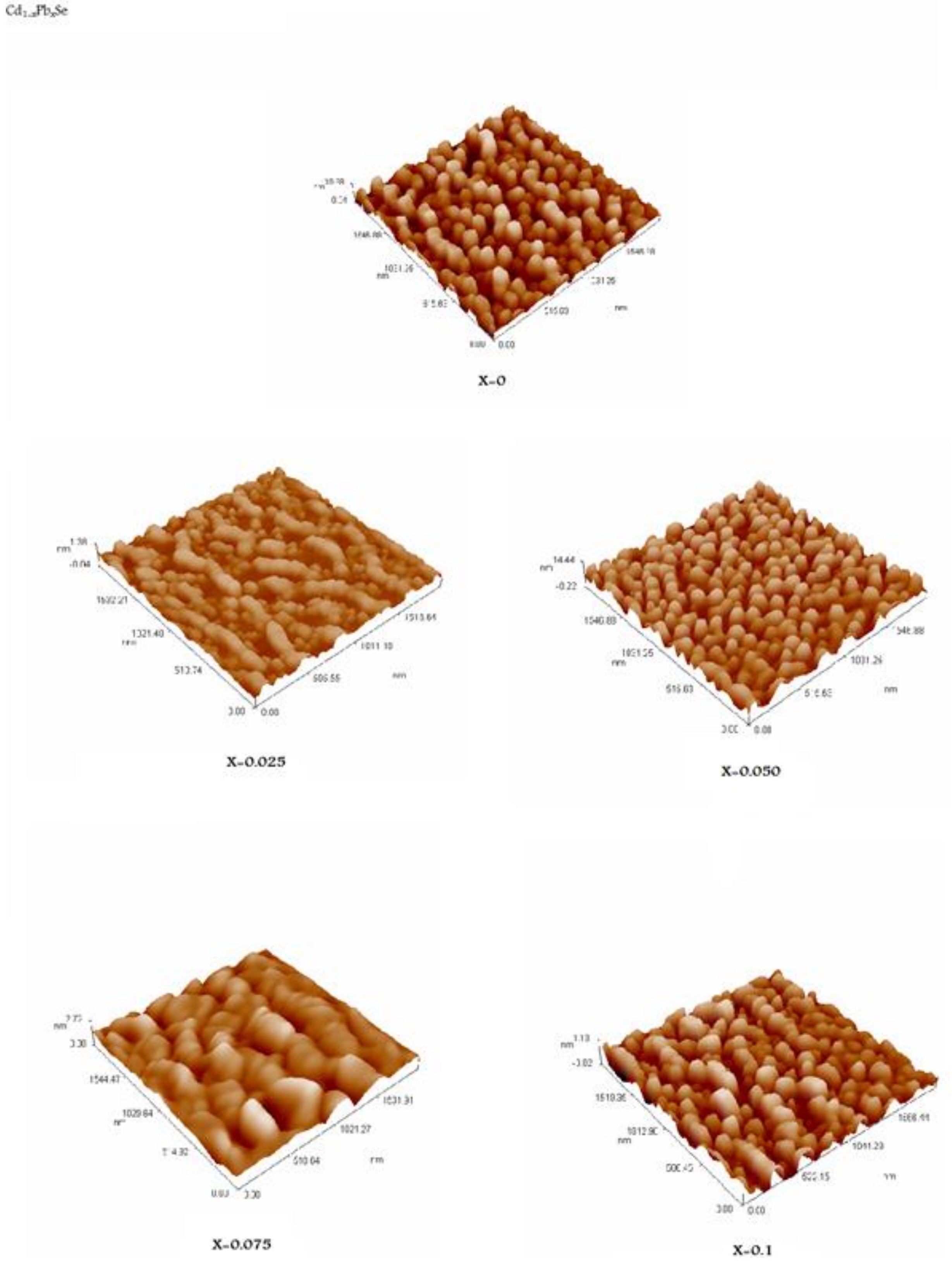

Fig.1 Atomic Force Microscopy in three dimensions

Fig 3 shows the variation of conductivity as a function of Pb concentration. On can notice that the conductivity has minimum value at x=0.025 and this can be attributed to the variation of grain size with Pb concentration as indicated in Fig 1.

Fig 4 shows the variation of activation energy with Pb concentration. From the figure, the activation energy has maximum value at x=0.025 of Pb concentration and this, as mentioned before, can be attributed to variation of grain size.

Table 2 All parameter for D.C conductivity

Pb Concentrations	thickness (nm)	Ea1 (eV)	Range (K)	Ea2 (eV)	Range (K)	σRT (Ω-1.cm-1)
x=0	126	0.076	283-363	0.345	363-473	4.03E-02
x=0.025	126	0.148513789	283-363	0.424706669	363-473	0.010416667
X=0.050	126	0.127261097	283-363	0.405152666	363-473	0.013888889
X=0.075	126	0.106491463	283-363	0.366804909	363-473	0.017857143
X=0.1	126	0.094252559	283-363	0.357371613	363-473	0.025

Table 3 Indicated Hall measurement

X	t (nm)	σ RT	RH	n (cm-3)*1015	type	μH (cm2/v.sec)
x=0	126	3.53E+00	7.52E+01	8.30E+16	p	2.66E+02
x=0.025	126	2.43E+01	1.13E+00	5.50E+18	p	2.76E+01
x=0.050	126	1.30E+00	-1.21E+03	-5.16E+15	n	1.57E+03
x=0.075	126	1.49E-04	-1.92E+06	-3.26E+12	n	2.86E+02
x=0.1	126	5.43E-05	-3.79E+07	-1.65E+11	n	2.06E+03

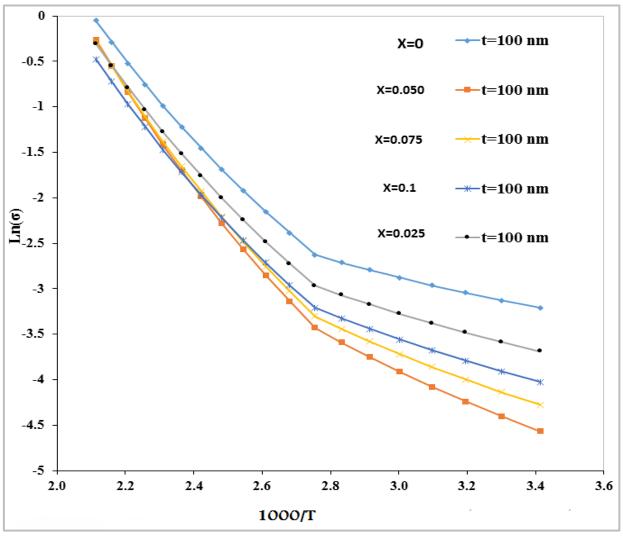

Fig. 2 Lnσ Vs 1000/T

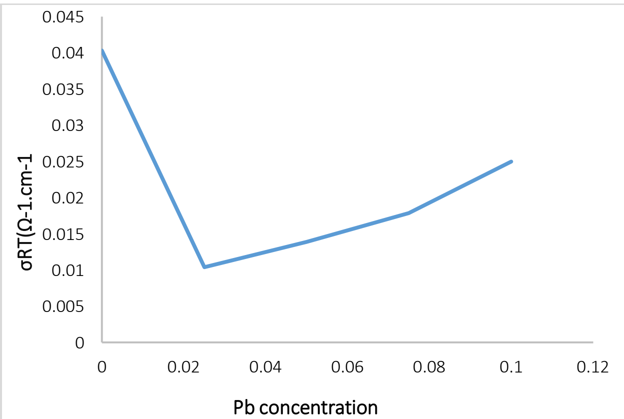

Fig.3 Variation of conductivity with x values of Pb concentration

3.3. Hall Measurements

From the measurement of Hall Effect as indicated in Table 3, the type of conductivity is n- type for all values of Pb concentration .at increase of Pb concentration the Hall coefficient RH decreased, and that because of of increased charge carrier and this leads to increased Hall mobility.

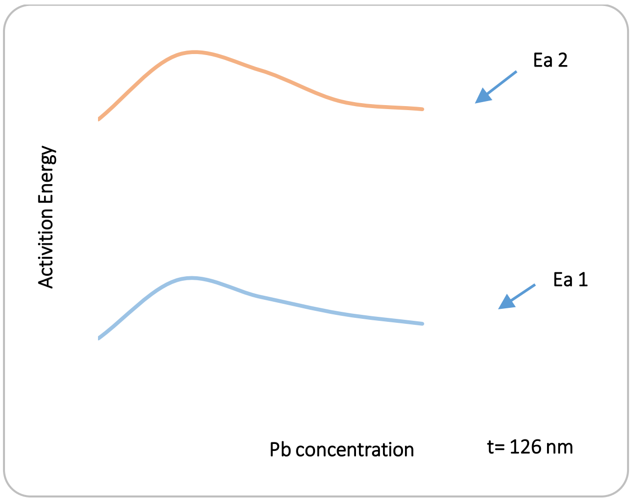

Fig. 4 Variation of activation energy with Pb concentration

Conclusion

Alloy of Cd1-xPbxSe are prepared successfully. Thin films of such concentration are prepared by thermal evaporation. The behavior of the grain size is non-systematic with the increase of Pb concentration. The D.C conductivity has minimum value at x= 0.025 and then increases with the increase of Pb concentrations from the results, the thin film is n-type.

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