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Electrical Properties Of Polycrystalline $Pb_{0.2}In_{0.8}Se$ Thin Films Deposited By Physical Evaporation Technique

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ABSTRACT

Thin films having different thickness of $Pb_{0.2}In_{0.8}Se$ were deposited by physical evaporation techniques, onto precleaned amorphous glass substrate. The structural properties of films were evaluated by XRD, optical microscopy and Transmission Electron Microscopy (TEM). The electrical properties of annealed thin films have been evaluated. The resistivity of the films is determined over the thickness range of 1000 Ǻ, 1500 Ǻ, 2000 Ǻ, 2500 Ǻ and 3000 Ǻ. The temperature dependence of resistivity shows semiconducting behavior. The thickness dependence of resistivity is found to follow Fuch-Sondheimer size effect theory. Activation energy is found to be 0.059 to 0.082eV. Estimated values of Carrier concentration was 3.789 $x10^{21}$ cm^{-3}. Hall coefficients and Hall mobility were also determined. The estimated values of Hall mobility and Hall coefficients are 6.77 X 10^{-4} to 1.128X 10^{-4} cm^2/V-sec. and 6.4 X 10^{-8} to 1.6205 X 10^{-8} cm^3/C respectively. Positive sign of the Hall coefficient shows P- type nature of films. The X-ray diffraction analysis confirms that films are polycrystalline having orthorhombic structure. The average grain size is found to be 6.136 nm.

Key words: optical microscopy, XRD, TEM, Electrical properties.

1. INTRODUCTION

In the recent years a fair amount of research has been carried out on PbSe and InSe because of their narrow band gap [1] and application in devices such as infrared devices [2,3], diodes [2,-5], lasers, thermo photovoltaic conversions, solar cells [2-5], opto electronic devices, etc. Currently, electronic and optoelectronic industries provide some of the largest markets and challenges for thin film semiconductors. Current techniques for growth of these materials include physical methods. Physical methods are expensive but give relatively more reliable and reproducible results [6-9]. InSe and PbSe based materials are of considerable technological interest for application to high speed and optoelectronic devices because of their high electron mobility and low effective electron mass [10]. Lead Selenide is important material of IV- VI group compounds[11]. Due to its potential applications, thin films of lead chalcogenides have been extensively studied by doping n or p – type, so that they may be used in various solid state devices [11-

15].In present work, the effect of film thickness of thin $Pb_{0.2}In_{0.8}Se$ films over the thickness range of thickness 1000 – 3000 Å has been investigated. An attempt has been made to evaluate the electrical parameters such as Mean free path λ_0, Bulk Resistivity ρ_0, Carrier concentration η, Mobility μ, activation energy, Hall parameters such as Hall coefficient and Hall mobility.

2. EXPERIMENTAL

The compound ingot of $Pb_{0.2}In_{0.8}Se$ was obtained by mixing quantities of high-purity (99.999%) lead, indium and selenium powder in the atomic proportion 1:4:5. The mixture was sealed in an evacuated quartz tube at a pressure of 10^{-5} torr and heated at 1120 K for 36h and then quenched in ice cooled water. Polycrystalline $Pb_{0.2}In_{0.8}Se$ films have been deposited by physical evaporation technique under vacuum of about 10^{-5}torr. The substrate to source distance was kept 20cm. The samples of different thicknesses were deposited under similar conditions. The thickness of the films was controlled by quartz crystal thickness monitor model No. DTM-101 provided by Hind-HiVac. The deposition rate was maintained 5-10 Å/sec throughout sample preparation. Before evaporation, the glass substrates were cleaned thoroughly using concentrated chromic acid, detergent, isopropyl alcohol and distilled water.

X – Ray diffractogram (Rigaku Miniflex, Japan) were obtained of these samples to find out structural information and to identify the film structure qualitatively. The scanning angle (2θ) range was from 20^0 - 80^0 (CuK_α line). Resistivity of the samples was measured by four probe technique using model No. DEP-02 "Scientific Equipment Roorkee", as function of thickness and temperature.

3. Results and Discussion

3.1 Structural characterization

The structural composition of the grown films was studied through the optical microscopy, XRD analysis and TEM.

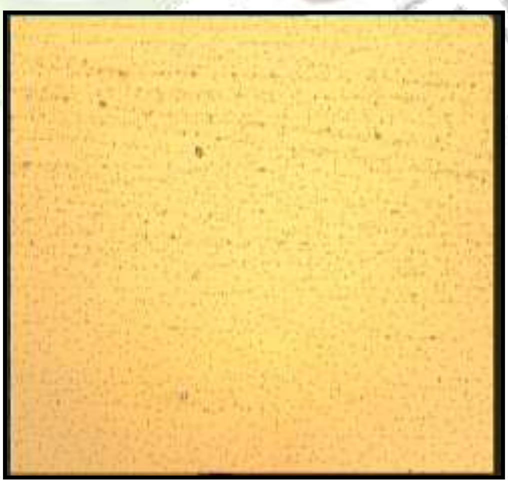

Fig. 1 Micrograph of $Pb_{0.2}In_{0.8}Se$ film of thickness 2000 Å

Fig. 1 shows the micrograph of $Pb_{0.2}In_{0.8}Se$ of thickness 2000 Å indicates particles are uniformly distributed over the surface. Further confirmation of the structure of the grown films was carried out using the x-ray diffraction pattern in Fig. 2.

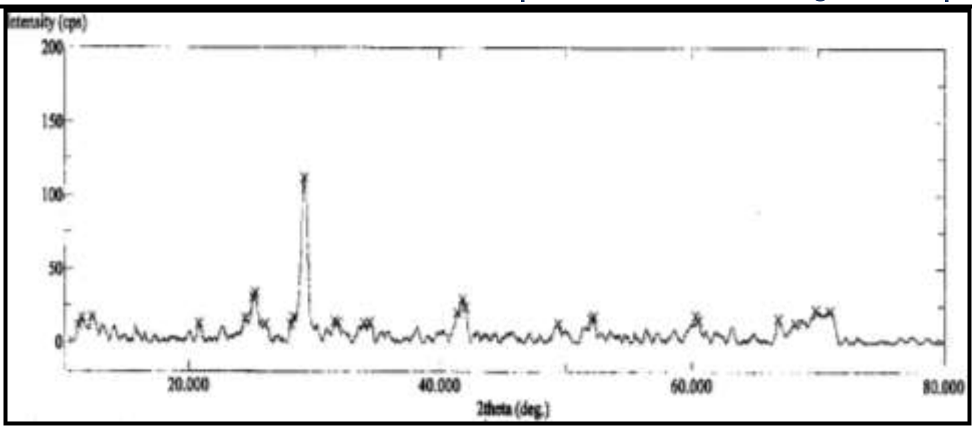

Fig. 2 XRD of $Pb_{0.4}In_{0.6}Se$ of thickness 2000 Ǻ

Fig. 2 shows the XRD pattern of $Pb_{0.2}In_{0.8}Se$ thin film prepared at substrate temperature of 303k. The plane indices are obtained by comparing the intensities and position of the peaks with JCPDS data. There is no JCPDS slandered data available for different composition of $Pb_{1-x}In_xSe$. The presence of large number of peaks indicates that the films are polycrystalline in nature, exhibit the formation of the orthorhombic phase of $Pb_{0.2}In_{0.8}Se$. The unit cell volume is 768.23 and lattice parameters are a = 15.2960 Ǻ, b = 12.3080 Ǻ and c = 4.0806 Ǻ. The structural parameters of $Pb_{0.2}In_{0.8}Se$ thin film shows that the film has average grain size of 6.136 nm for the film of thickness 2000 Ǻ.

TEM micrograph gives the morphology of the nanocrystallites. Figure 3(a) shows the TEM micrograph of as-prepared $Pb_{0.2}In_{0.8}Se$ nanoparticles. The image obtained is a translucent; it may be due to higher thickness. The selected area electron diffraction (SAED) pattern in figure 3(b) furthermore indicated that the nanocrystalline $Pb_{0.2}In_{0.8}Se$ had a polycrystalline in nature.

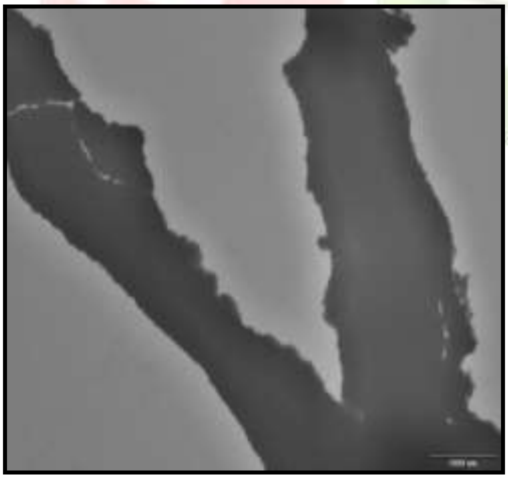

Fig. 3(a) TEM Micrograph of $Pb_{0.2}In_{0.8}Se$ film of thickness 2000 Ǻ

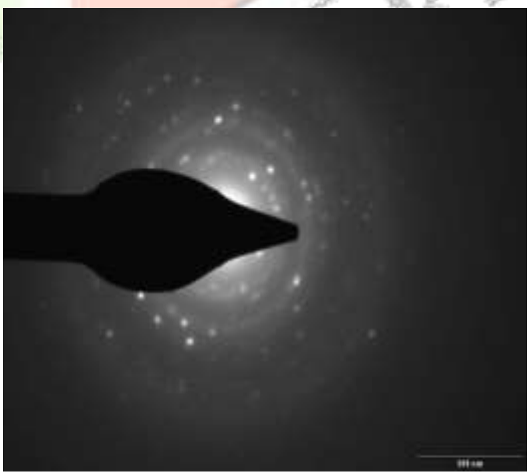

Fig. 3(b) SAED patternn of $Pb_{0.2}In_{0.8}Se$ film of thickness 2000 Ǻ

3.2 Electrical properties of $Pb_{0.2}In_{0.8}Se$ thin films

3.2.1 Resistivity measurement

3.2.1 a) Room temperature resistivity measurement by Four-probe method

The resistivity of $Pb_{0.2}In_{0.8}Se$ films of different thickness (1000- 3000 Ǻ) was measured by Four-probe set up, resistivity for all samples were measured at room temperature. The graphical representation of probe voltage versus probe current for different thickness is as shown in fig. 4. The plot of resistivity as a function of thickness fig.5 indicates that resistivity of film increases as thickness increases, obeying size effect theory and shows the semiconducting nature of the material. This fact is further confirmed from the plot ρ against 1/d (fig 6), and plot of ρd against d (fig 7). From these graphs one can calculate bulk resistivity (ρ_0), mean free path and charge carrier concentration [16]. The calculated values are as shown in table 1.

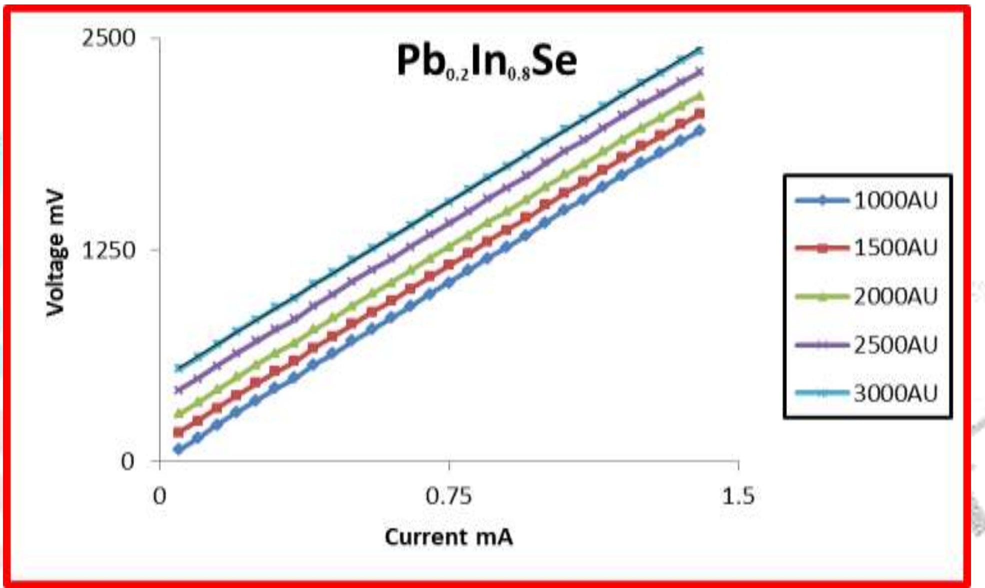

Fig 4 Voltage versus current

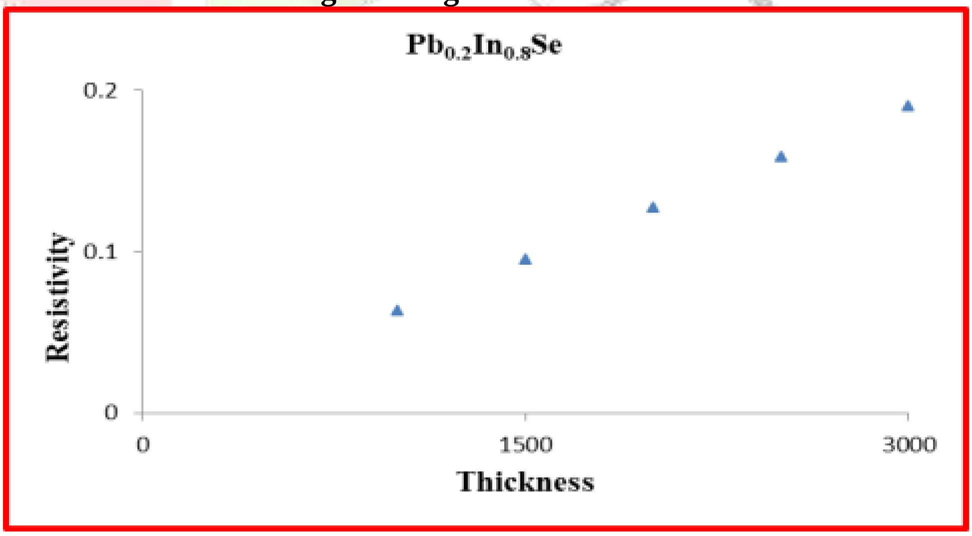

Fig 5 Resistivity versus thickness

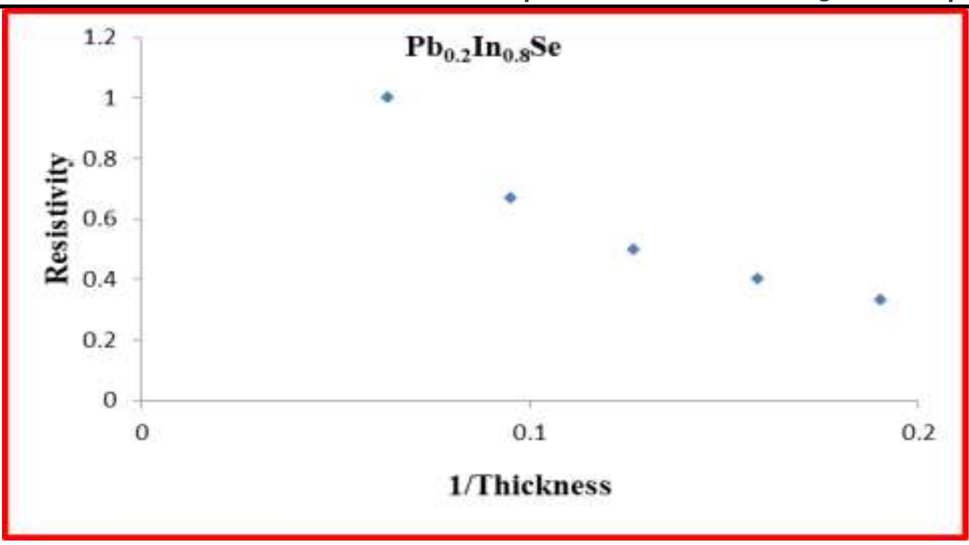

Fig 6 Resistivity versus 1/thickness

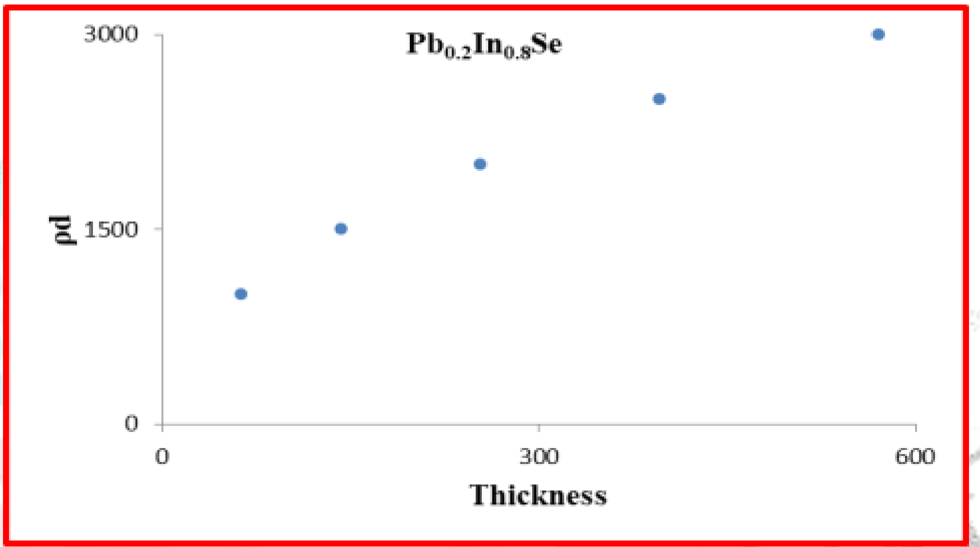

Fig 7 ρd versus thickness

Table 1

Mean free path λ_0	349 Å
Bulk Resistivity ρ_0	6.756 x 10^{-4} Ω cm
Carrier concentration η	3.789 x10^{21} cm^{-3}
Mobility µ	0.699x 10^4 cm^2/Volt-Sec

3.2.1 b) High Temperature (303 to 453 K) in plane resistivity measurement by four probe method

Using the high temperature Four- probe resistivity set up the resistivity of $Pb_{0.2}n_{0.8}Se$ (Thickness 1000 - 3000 Ǻ) thin films was measured in the temperature range 303-453 K. A graphical representation of log p versus 1000/T is shown in fig. 8. The study of the data presented in figure, suggest that resistivity of material is temperature dependent. Graphical representation gives the relation between them as temperature of thin film is increases the resistivity decreases it suggest the semiconducting nature of material. The calculated activation energy of $Pb_{0.2}In_{0.8}Se$ thin films are as shown in table 2, whose values are varied between 0.059 to 0.082 eV [16] which shows that activation energy increases with the thickness.

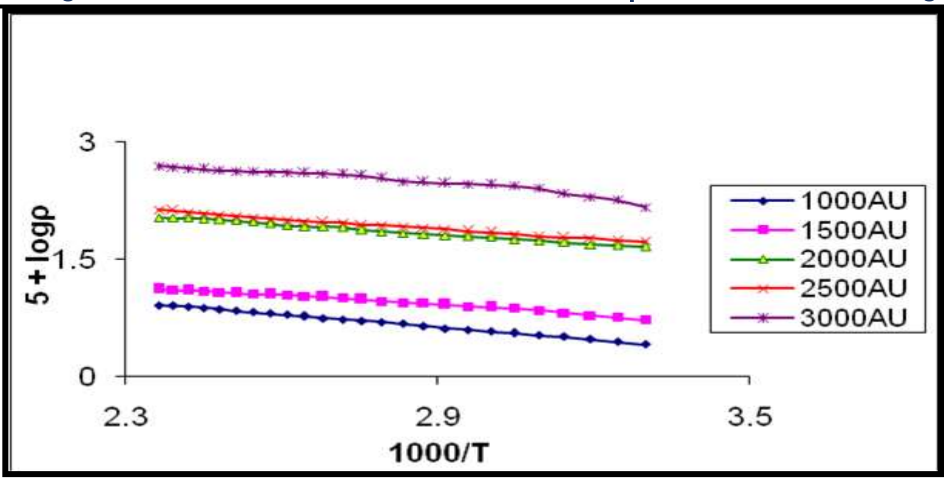

Fig 8 5 + log ρ versus 1000/T

Table2

Thickness Å	ΔE eV
1000	0.059
1500	0.064
2000	0.071
2500	0.079
3000	0.082

3.3 Hall measurement

Hall measurement for different thickness of $Pb_{0.2}In_{0.8}Se$ (1000 - 3000 Å) was carried out using Hall set up. The graphical representation of it's at different thickness at constant magnetic field 3.16 K Gauss is shown in fig 9. From the graph of Hall voltage against Probe current, the evaluated values of Hall Mobility, Hall coefficient and carrier concentrations are as shown in table 3. Positive sign of the Hall coefficient shows P- type semiconducting nature of films [16].

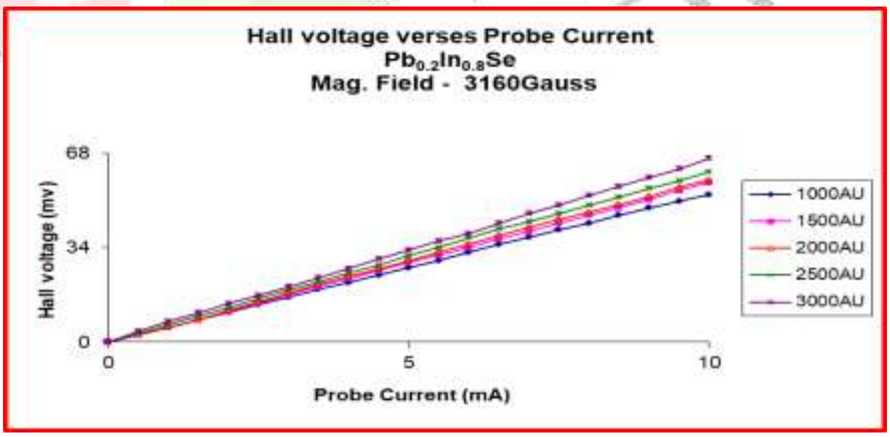

Fig 9 Hall voltage versus probe current

Table 3

Thickness Å	R_H x 10^{-8} Volt-cm/A-Gauss	Mobility x 10^{-4} cm^2/Volt-Sec	η x 10^{21} cm^{-3}
1000	6.42	6.77	3.819
1500	5.48	6.17	3.781
2000	4.74	5.562	3.665
2500	3.12	3.215	3.421
3000	1.62	1.128	3.6715

4. Conclusion

From optical micrograph of $Pb_{0.2}In_{0.8}Se$ the particles are uniformly distributed over the surface. From XRD, the deposited films are polycrystalline exhibit the formation of the orthorhombic phase and the average particle size was 6.136 nm which was again confirmed by TEM. Resistivity measurement shows the deposited films shows the semiconducting nature of the material. , The calculated values of activation energy are 0.059 to 0.082 eV [16] which shows that activation energy increases with the thickness. Positive sign of the Hall coefficient shows P- type semiconducting nature of films.

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