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Thickness Dependent Thermoelectric Properties of $Pb_{0.4}In_{0.6}Se$ Thin Films Deposited by Physical Evaporation Technique

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ABSTRACT

Thin films having different thickness of $Pb_{0.4}In_{0.6}Se$ were deposited by thermal evaporation techniques, onto precleaned amorphous glass substrate. The structural properties of films were evaluated by XRD, optical microscopy, SEM and EDAX. The thermoelectric of annealed thin films have been evaluated. Thermoelectric Properties shows a positive sign exhibiting p- type nature of films. Fermi energy and scattering parameter were determined. The calculated values of Fermi energy and scattering parameter are 4 to 0.4 eV and 0.184 to 0.127 respectively. The X-ray diffraction analysis confirms that films are polycrystalline having orthorhombic structure. The average grain size is found to be 27.08 nm.

Keywords: optical microscopy, XRD, SEM, EDAX, thermoelectric properties.

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, [6- 8] 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 [9, 10]. 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 [11]. Materials with good thermoelectric properties became a part and parcel of the modern technology because of their potential use in cooling systems [12]. The lead chalcogenides exhibit very interesting photoelectric, photoconducting, thermoelectric, optical and semiconducting properties [13]. Lead Selenide is important material of IV- VI group compounds. 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 [14, 15]. From the study of literature review, it can be seen that no attempt has been made to study the variation of surface morphological study by change in thickness of thin films. In present work effect of film thickness on surface morphology over the thickness range 1000 – 3000 Ǻ has been investigated. An attempt has been made to evaluate the electrical parameters such as Fermi energy, scattering parameter and optical band gap.

Majority of these compounds have been reported to be grown in the crystalline form. Thin films preparation with direct materials do not shows any contamination of impurities, therefore the pure form of powder of lead selenide was used for synthesis it.

EXPERIMENTAL

The compound ingot of $Pb_{0.4}In_{0.6}Se$ was obtained by mixing quantities of high-purity (99.999%) lead, indium and selenium powder in the atomic proportion 2:3:5. 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 $Pb_{0.4}In_{0.6}Se$ 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

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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). Optical absorption was measured by UV-VIS spectrophotometer model no. Shimadzu -2450. The thermo electric power of samples was measured by TEP set up using model no. DMV – 001, "Scientific Equipments, Roorkee", as a function of thickness and temperature.

RESULTS AND DISCUSSION

Structural characterization

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

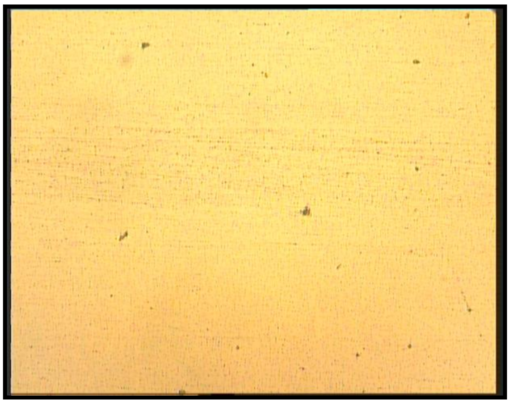

Fig. 1 Micrograph of $Pb_{0.4}In_{0.6}Se$ film of thickness 2000 Å

Fig. 1 shows the micrograph of $Pb_{0.4}In_{0.6}Se$ 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.

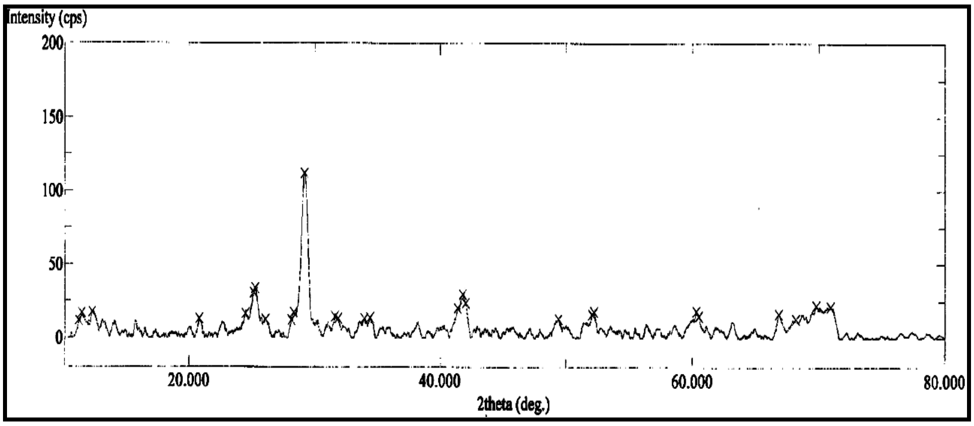

Fig. 2 XRD of $Pb_{0.4}In_{0.6}Se$ of thickness 1000 Å

Fig. 2 shows the XRD pattern of $Pb_{0.4}In_{0.6}Se$ 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 $Pb_{0.4}In_{0.6}Se$. The unit cell volume is 768.23 and lattice parameters are a = 15.2960 Å, b = 12.3080 Å and c =

4.0806 Å. The structural parameters of $Pb_{0.4}In_{0.6}Se$ thin film shows that the film has average grain size of 3.432 nm for the film of thickness 1000 Å.

Fig. 3 shows typical SEM micrograph of $Pb_{0.4}In_{0.6}Se$ thin film of thickness 2500 Å. The surfaces of $Pb_{0.4}In_{0.6}Se$ deposits are showing spheres of 50nm-0.4μm diameter. The micrograph also consists of nano wires oriented in two directions. The surface roughness is seems to be improved greatly by the addition of third element. The EDAX spectral analysis for the $Pb_{0.4}In_{0.6}Se$ thin film prepared by thermal evaporation technique is shown in Fig. 4. The obtained percentages of the constituent elements in all investigated films indicate that samples are nearly stoichiometric. The obtained results give support for the quality of the prepared $Pb_{0.4}In_{0.6}Se$ thin films by thermal evaporation technique. The actual atomic % for $Pb_{0.4}In_{0.6}Se$ compositions of lead, indium and selenium are in the ratio of 19.90:29.31: 50.79.

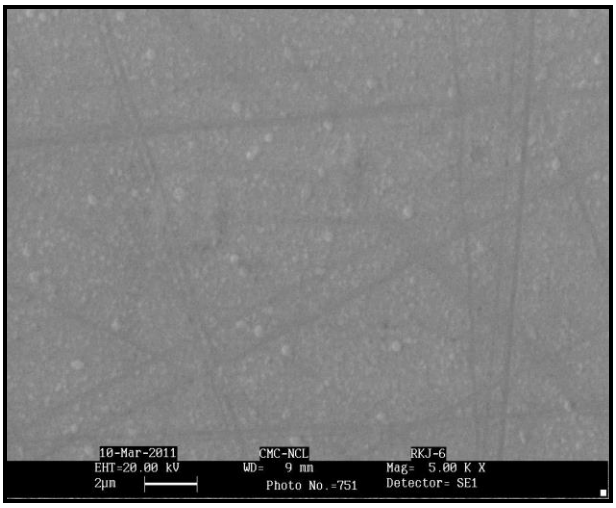

Fig. 3 SEM image of $Pb_{0.4}In_{0.6}Se$ thin film of 2500 Å

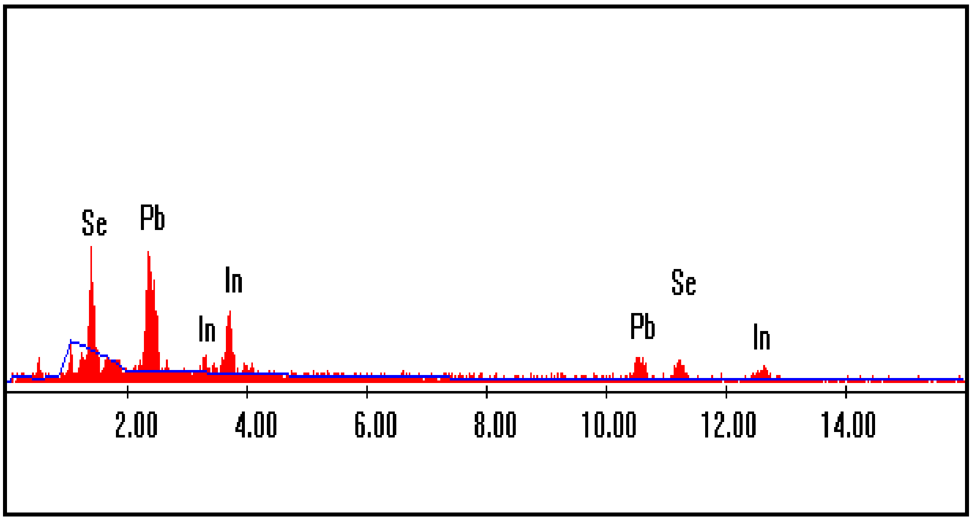

Fig. 4 EDS Spectra of $Pb_{0.4}In_{0.6}Se$ thin film

Thermo Electrical Properties of $Pb_{0.4}In_{0.6}Se$ thin films

The TEP is measured by integral method [13, 16]. The graphical representation of thermo emf verses change in temperature for different thickness of $Pb_{0.4}In_{0.6}Se$ thin films are shown in fig. 5 and fig. 6 represents the Seebeck coefficient versus 1/ΔT for different thicknesses of thin film. From this graph the Fermi energy and scattering parameter are calculated and represented in Table 1, the Fermi energy of $Pb_{0.4}In_{0.6}Se$ thin films is thickness dependant, as thickness increases Fermi energy decreases, and as thickness increases scattering parameter increases. A Thermoelectric power measurement shows that $Pb_{0.4}In_{0.6}Se$ is a P type material due to positive slop of the graph.[15-17].

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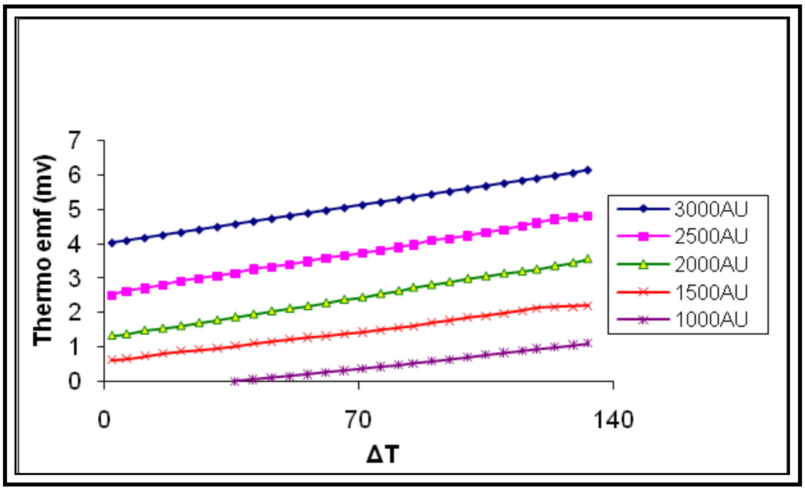

Fig 5 Plot of Thermo emf verses ΔT

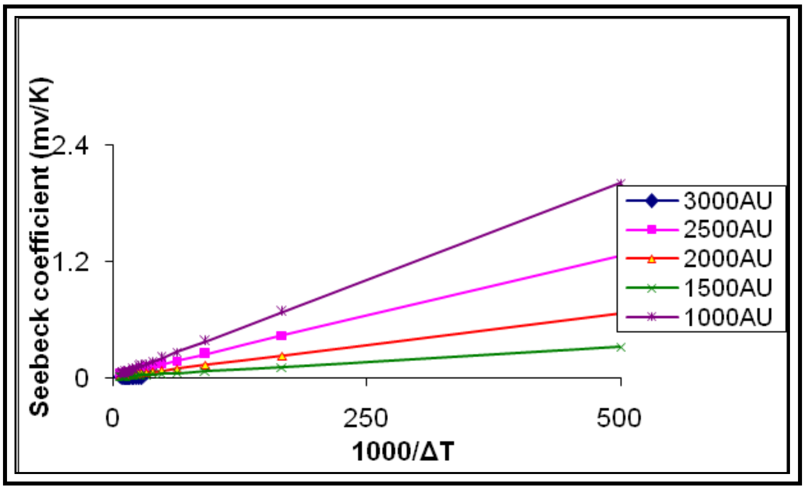

Fig 6 Plot of Seebeck coefficient versus 1/ΔT

Table1 Estimated parameter from TEP measurement

Thickness Å	Fermi Energy (e V)	Scattering parameter
1000	4	0.124
1500	0.6	0.1414
2000	1.3	0.188
2500	2.5	0.213
3000	0.4	0.227

CONCLUSION

From the temperature dependence of Thermoelectric Power, the Fermi energy E_f and scattering parameter are determined is thickness dependent The XRD shows that all the films prepared were polycrystalline orthorhombic structure. Indium Selenide and Lead Selenide and its intermediate combination, thin films exhibit promising thermoelectric properties due to their layered structure and tunable electrical characteristics.

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These films were shown potential for applications in thermoelectric power generation, photovoltaic's and other optoelectronic devices.

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