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Thermoelectric Properties of Indium Doped Lead Selenide Thin Films Deposited by Vacuum Evaporation Technique

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ABSTRACT

$Pb_{0.8}In_{0.2}Se$ thin films were prepared on glass substrate by vacuum evaporation technique at a pressure of 10^{-5} torr. The thermoelectric properties of the films was determined over the thickness range of 1000 Ǻ, 1500 Ǻ, 2000 Ǻ, 2500 Ǻ and 3000 Ǻ. Thermoelectric properties shows a positive sign exhibiting P- type semiconductig nature of films. Fermi energy and scattering parameter were determined. The estimated values of Fermi energy and scattering parameter are 0.02 eV to 0.16 eV and 0.26 to 0.143 respectively. The XRD analysis confirms that the deposited films are nanocrystalline having grain size 4.428 to 48.00 nm.

Key words: XRD, Fermi energy, scattering parameter.

INTRODUCTION

Currently, electronic and optoelectronic industries provide some of the largest market 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 [1, 2]. 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 [3]. Materials with good thermoelectric properties became a part and parcel of the modern technology because of their potential use in cooling systems [4]. The lead chalcogenides exhibit very interesting photoelectric, photoconducting, thermoelectric, optical and semiconductig properties [5]. 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 (7, 8).From the study of literature review, it can be seen that no attempt has been made to study the variation of thermo electric properties by change in thickness of thin films. In present work effect of film thickness on thermo electric properties over the thickness range 1000 – 3000 Å has been investigated.

MATERIALS AND METHODS

The Indium doped PbSe ingot was prepared from its own constituent elements. Appropriate weight of lead, indium and selenium (purity 99.999%) were mixed together and placed in a quartz ampoule which was heated in furnace at temperature 1120^{0}C for 24 hours, then cooled by melt quench method. Thin films of $Pb_{0.8}In_{0.2}Se$ with varying thickness from 1000 Å - 3000 Å were obtained on clean glass substrates held at room temperature, by vacuum evaporation technique at a pressure of 10^{-5} torr by thin film coating unit model no 12A4D. The lateral dimensions of the glass substrates of size 75mm × 25mm × 1.35mm were used and the source to substrate distance was kept as 20 cm. Quartz crystals monitor Model No. DTM 101 was used to measure the thickness of the films. Appropriate weight of $Pb_{0.8}In_{0.2}Se$ was taken in the molybdenum boat and evaporated at the rate 5 to10 A^0 per second. The deposition condition were maintained nearly the same during evaporation.

X–Ray diffractogram (Rigaku Miniflex, Japan) were obtained for finding out the structural information and qualitative analysis of the grown films. The scanning angle (2θ) with the range of 20^0 - 80^0 (CuK_α line) was used for the XRD.

The thermoelectric power (α) is measured by integral method [5, 6]. In integral method one end of the sample is heated while the other end is held at constant temperature. The temperature difference (ΔT) between two ends of sample causes the emf generation. "Pushpa Scientific" Hyderabad provided the experimental set up used for the measurement of thermal emf. Maximum temperature gradient obtainable is 150^{O}C in this set up

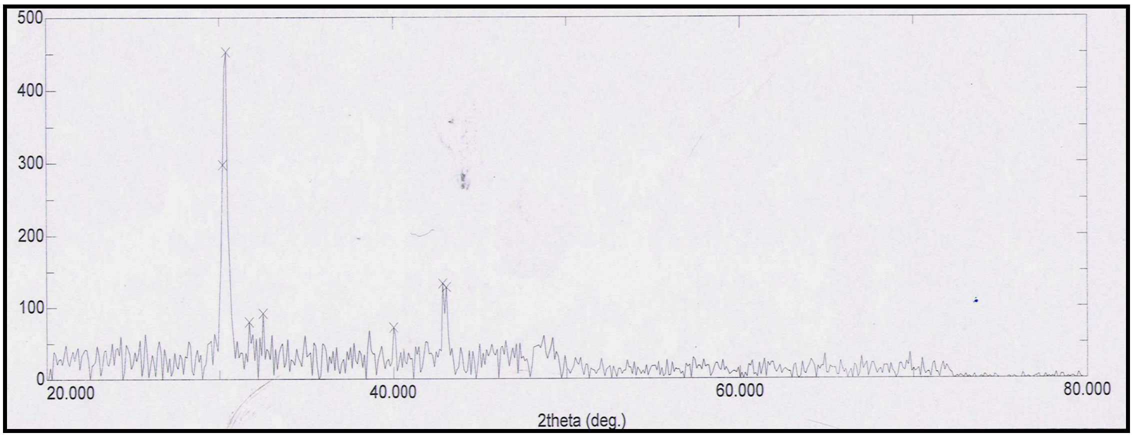

Fig.1 XRD of $Pb_{0.8}In_{0.2}Se$ thin film of thickness 2500 Å

RESULTS AND DISSCUSSION

The structural composition of the grown films was studied through the XRD analysis and optical microscopy. Figure 1 shows the XRD pattern of $Pb_{0.8}In_{0.2}Se$ thin film prepared at substrate temperature of 303k. The presence of large number of peaks indicates that the films are polycrystalline in nature [7]. These results are well in agreement with the reported values. The XRD analysis is as shown in table 1. 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 calculated grain size was 4.428 - 48.00 nm.

Table 1

Thickness Å	hkl	2θ Degree	D Å		FWHM rad	Grain Size nm	Average grain size nm
			Measured	Standard			
1000	---	26.00	3.4241	3.4241	0.0287493	4.699	4.428
	200	30.20	2.9568	2.9568	0.0287493	4.656	
	220	42.80	2.1110	2.1110	0.032851356	3.929	
2500	021	26.40	3.3731	3.3731	0.00410205	32.906	48.00
	121	26.60	3.3482	3.348/2	0.00205975	65.507	
	510	30.30	2.9473	2.9472	0.00205975	16.275	
	031	30.60	2.9190	2.9190	0.00822156	64.928	
	---	34.60	2.5902	2.5902	0.00616181	21.483	
	600	35.00	2.5615	2.5615	0.00205975	64.195	
	521	39.90	2.2575	2.2575	0.00410205	31.764	
	051	42.80	2.1110	2.1110	0.00205975	62.674	
	151	43.20	2.0924	2.0924	0.00205975	61.913	
	402	50.60	1.8024	1.8023	0.00205975	60.856	
	422	53.00	1.7263	1.7262	0.00616181	20.136	
	152	59.10	1.5618	1.5618	0.002059756	58.541	
	290	69.80	1.3463	1.3462	0.002059756	55.209	
	513	77.10	1.2360	1.2360	0.002059756	55.617	

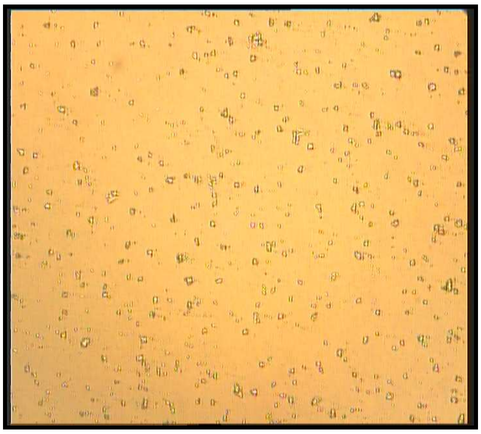

Fig. 2 Micrograph of $Pb_{0.8}In_{0.2}Se$ thin film of thickness 3000 Å

Figure 2 shows the photomicrograph of the $Pb_{0.8}In_{0.2}Se$ films of thickness 3000 Å. The films exhibit the growth of small grains distributed uniformly across the surface of the substrate.

The graphical representation of thermo emf verses change in temperature for different thickness of $Pb_{0.8}In_{0.2}Se$ thin films are shown in fig. 3, fig 4 shows the plot of thermo emf verses 1000/ΔT. fig. 5 shows the plot of Seebeck coefficient verses ΔT and the graphical representation of Seebeck coefficient versus 1/ΔT for different thickness of thin films are as shown in fig 6.

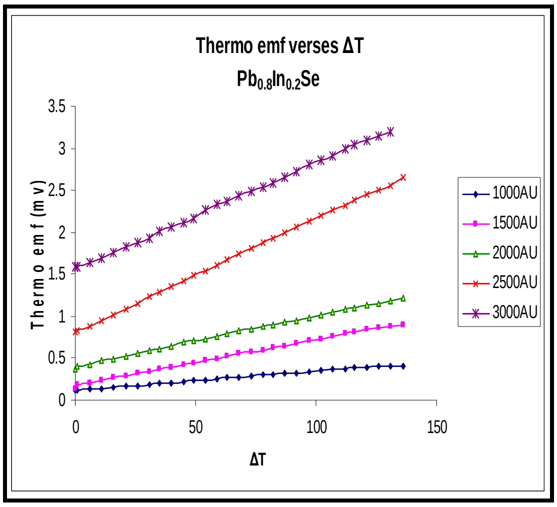

Fig 3: Thermo emf Verses ΔT

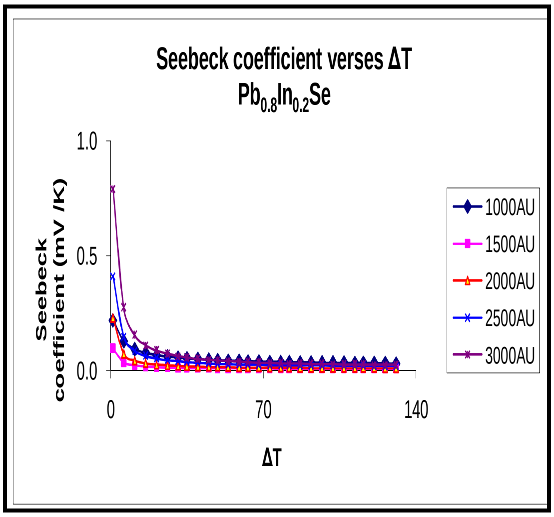

Fig5: Seebeck coefficient verses ΔT.

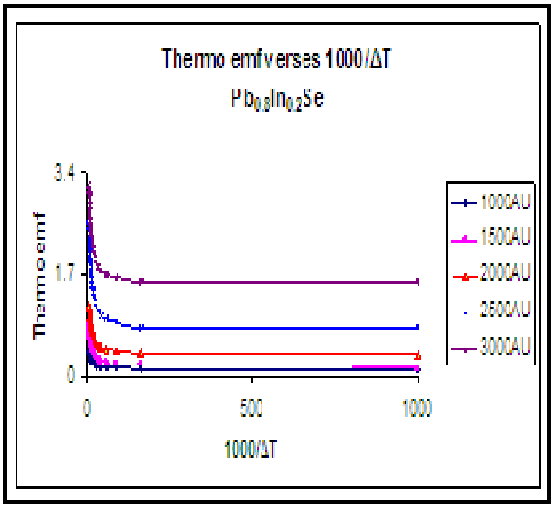

Fig 4: Thermo emf Verses 1000/ΔT

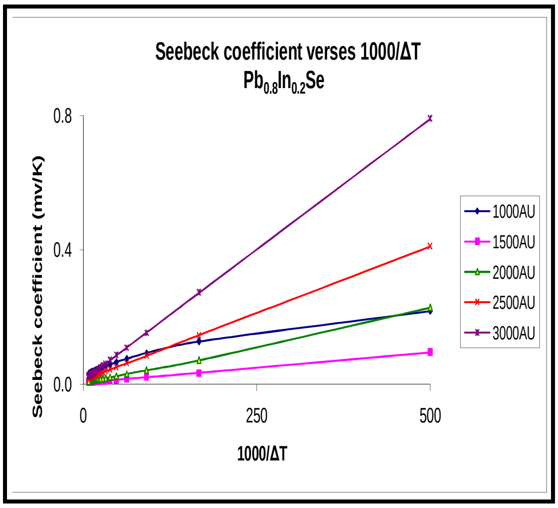

Fig 6: Seebeck coefficient verses 1/ΔT.

Table1

Thickness Å	Fermi Energy (eV)	Scattering parameter
1000	0.02	0.26
1500	0.02	0.061
2000	0.04	0.07
2500	0.08	0.15
3000	0.16	0.143

The positive slope of fig. 3 shows that deposited films are P- type semiconducting nature [7]. This fact again confirms by fig. 4 and fig. 5. From figure 6 the estimated values of the Fermi energy and Scattering parameter were calculated and represented in table - 2[10].The evaluated value of scattering parameter was 0.26 – 0.143 which suggest that the predominant scattering mechanism in lattice scattering, in thin films the surface and grain boundaries scattering should be taken into account [10].

CONCLUSION

1. XRD analysis confirms that the deposited films are nanocrystalline nature.
2. From the temperature dependence of Thermo Electric Power the Fermi energy (E_f) and scattering parameter (A) are thickness dependent
3. The Seebeck coefficient is positive throughout temperature range used suggesting that the deposited films were P type semiconductig in nature.
4. The grater value of A suggest that the predominant scattering mechanism in lattice scattering. In thin films, the surface and grain boundaries scattering should be taken into account.

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