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Surface morphological and thermo electical properties of $In_{0.3}Sb_{0.7}$ thin film

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ABSTRACT

Thin films having different thickness of InSb were deposited by thermal evaporation techniques, onto precleaned amorphous glass substrate. The surface morphological properties of films were evaluated by XRD, Scanning Electron Microscope (SEM), EDAX, Transmission Electron Microscopy (TEM) and optical microscopy. The electrical transport properties of annealed thin films have been evaluated. Thermo Electrical parameters such as Fermi energy (0.11478 to 0.0.9159 eV), absorption coefficient (0.37454 to 10.58) has been estimated. The X-ray diffraction analysis confirms that films are polycrystalline having cubic structure cell. The grain size is found to be 11.32 nm.

Keywords: XRD, Fermi energy, Absorption Coefficient, grain size.

INTRODUCTION

Indium antimonide (InSb) is one of the most widely studied III-V compound semiconductors. It is an important material in the field of infra red detectors in the 3 -5 μm wavelength range due to its high electron and hole mobility and low energy gap at room temperature [1- 2]. It is also used for the fabrication of high speed, Hall and opto electronic devices [3- 5]. These films are especially attractive of low cost, easy handling and availability. In order to obtain InSb films wide variety of preparation methods are available. Carroll et al. [6] achieved room temperature mobilities of about 50,000 cm^2/Vs on InSb films prepared by flash evaporation. Epitaxial growth of InSb on sapphire by RF sputtering was studied by Miyazaki et al. [7]. Very recently, Oszwaldowski et al. [8] investigated textural properties of InSb films deposited in vacuum by flash evaporation on non oriented substrates. Of all methods used to prepare InSb films, vacuum evaporation is the very simple and inexpensive technique and can be used for large area deposition [9]. The problem associated with InSb and other III – V compound films deposited by vacuum evaporation is the film stoichiometry, because of large differences in vapour pressures of In and Sb [10]. The problem of non stoichiometry could be addressed properly by optimizing the condition of evaporation. However, it needs a systematic study by incorporating the changes in deposition parameters. The present investigation is an attempt to study in detail, the structural, electrical and optical studies of these films deposited at room temperature by vacuum evaporation technique.

MATERIALS AND METHODS

Material Preparation -
The InSb compound ingots were obtained by taking appropriate amount of 99.999% pure In and Sb in an evacuated quartz ampoule. The ampoule with the charge was then sealed under a pressure of 10^{-5} torr and was placed in rotating furnace. The temperature of the furnace was raised gradually to 1023 K and left at this temperature for about 40 h. Well mixed charges were then quenched in an ice bath [11, 12]. The InSb ingot was taken out from the ampoule and made into fine powder and used for film preparation.

Synthesis and Characterization of sample -
Polycrystalline InSb films have been deposited by thermal evaporation technique under vacuum of about 10^{-5} torr [13- 15]. The substrate to source distance was kept 20cm. The samples of different thicknesses were deposited under similar conditions. By adjusting the rate of evaporation, the stoichiometry of the compound is controlled in the deposition. The films were annealed at reduced pressure of about 10^{-4} torr and at 523 K for the period of one hour. The thickness of the films was controlled by quartz crystal thickness monitor model No. DTM-101 provided by Hind-Hi Vac. Further confirmation of thickness was estimated by Tolansky's method [16] using multiple beam Fizeau fringes. The deposition rate was maintained 10-20 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). The thermoelectric power (α) is measured by integral method [8]. 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. In the present work the integral method is used to measure thermo emf "Pushpa Scientific" Hyderabad provided the experimental set up used for the measurement of thermal emf. Maximum temperature gradient obtainable is 150^oC in this set up. An electron microscope with an energy dispersive X-ray analysis (EDS) attachment is used to record the scanning electron micrograph (SEM), and EDS spectrum of the sample. Transmission Electron Micrograph (TEM) confirms the nanocrystalline nature of the particles.

RESULTS AND DISCUSSION

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

Fig. 1(a) shows the micrograph of InSb of thickness 1500 Å indicates uniform surface coverage. While fig. 1 (b) shows the photo micrograph of InSb film of thickness 2000 Å indicates that the films exhibit the growth of small spherical grains distributed across the surface of the substrate. Further confirmation of the structure of the grown films was carried out using the x-ray diffraction pattern in Fig. 2.

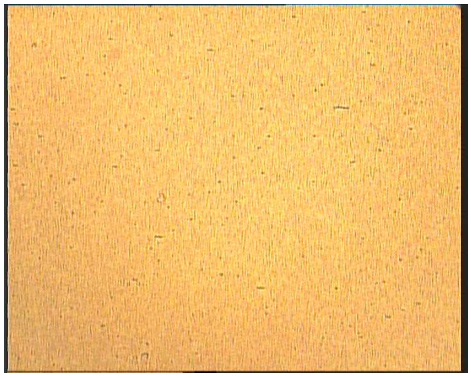

Fig. 1(a) Micrograph of InSb film of thickness 1500 Å

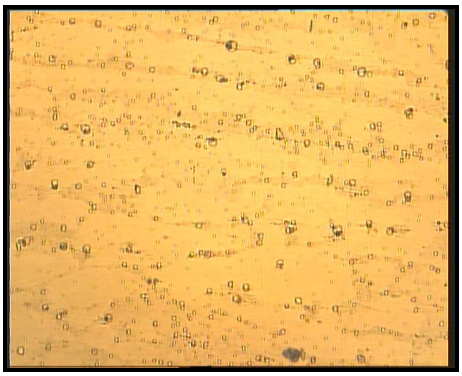

Fig. 1(b) Micrograph of InSb film of thickness 2000 Å

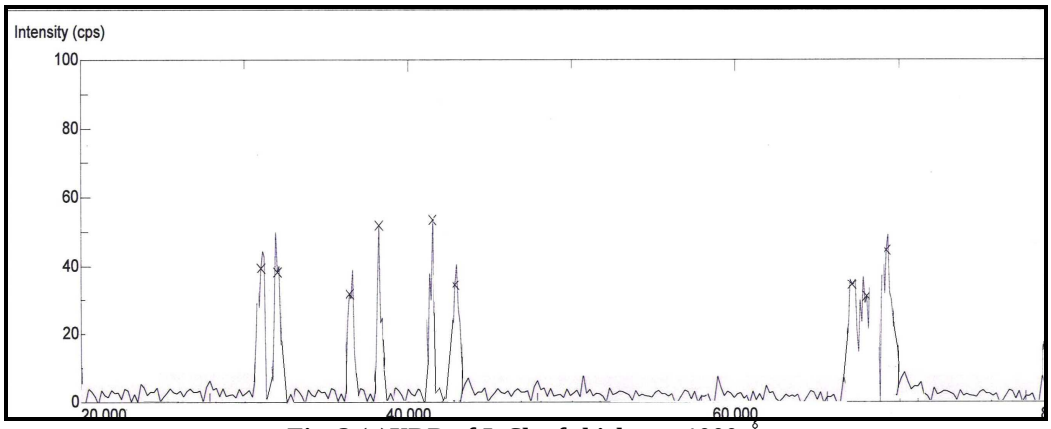

Fig. 2 (a)XRD of InSb of thickness 1000 Å

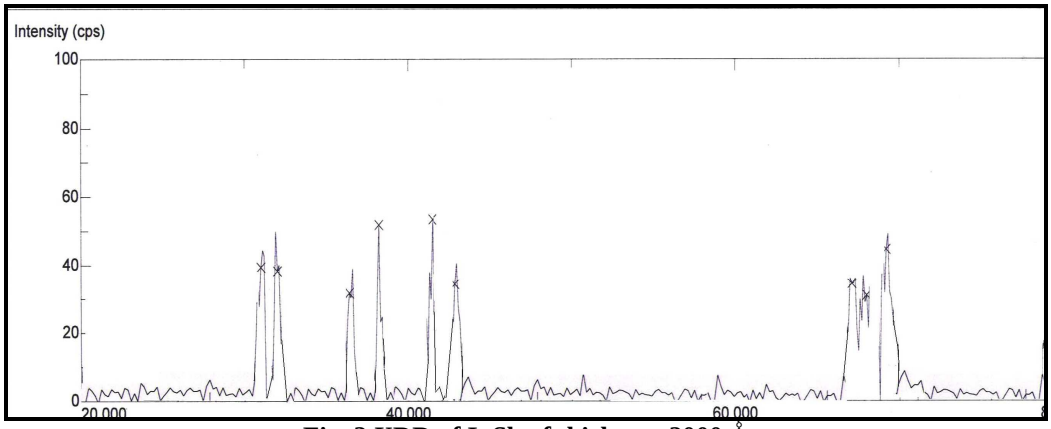

Fig. 2 XRD of InSb of thickness 2000 Å

Fig. 2 (a, b, c) shows the XRD pattern of InSb thin film prepared at substrate temperature of 303k. The value of the lattice parameters obtained from the analysis of x-ray diffraction pattern is shown in Table - 1. The average grain size is found to be 11.32 nm.

TABLE-1 Experimental values of interplaner spacing and the corresponding data of the InSb thin films

Thickness Å	hkl	2θ	d Å	d Å	FWHM (radian)	Grain size (nm)	Average grain size (nm)
			Obs.	Std.			
1000	100	31	2.8823	2.8823	0.01026	13.016	11.32
	211	32	2.7945	2.7944	0.01232	10.81	
	320	36.4	2.4661	2.5334	0.01026	12.83	
	321	38.2	2.3540	2.3539	0.01026	12.76	
	322	41.5	2.1741	2.1252	0.01026	12.64	
	--	42.9	2.1063	2.1063	0.01438	8.97	
	--	67.1	1.3937	1.3937	0.01026	11.27	
	220	68	1.3774	1.3774	0.01026	11.19	
	533	69.2	1.3565	1.3564	0.01232	9.26	
	721	79.1	1.2019	1.2097	0.01026	10.43	
2000	100	23.7	3.7509	3.7509	0.01026387	13.22719	11.023
	211	24.8	3.5870	3.5870	0.01642568	8.244132	
	211	32	2.7945	2.7941	0.01026387	12.98539	
	321	40.4	2.2307	2.2307	0.01232362	10.55852	
	322	47.5	1.9125	1.9125	0.01026387	12.36131	
	--	48.6	1.8718	1.8717	0.01232362	10.25363	
	220	52.2	1.7508	1.7508	0.01438338	8.656104	
	311	56.4	1.6300	1.6300	0.01026387	11.90474	

Fig.3 shows SEM images of InSb thin film of thickness 1500 Å. The surface of InSb deposits are covered with spherical and rough crystals and all the particles are align in one direction also some hollow spaces are also there which can be used for doping of other foreign material to improve its characteristics and crystal sizes that are in the range of 10 - 15 nm.

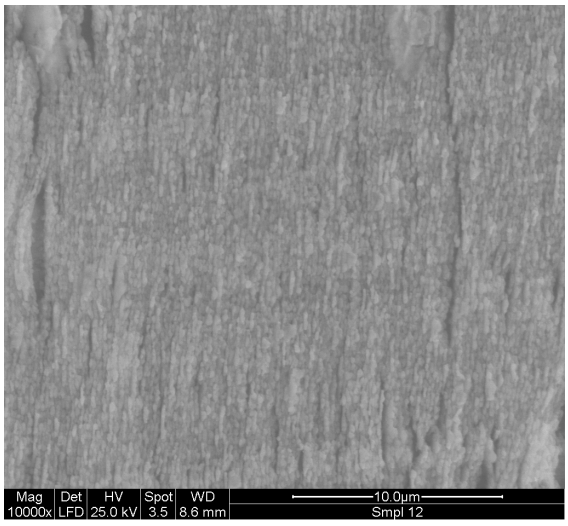

Fig. 3 SEM image of annealed InSb thin film of 1500 Å

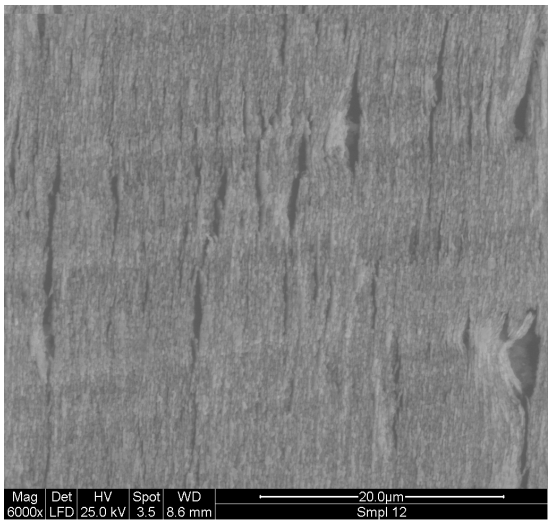

Fig. 3 SEM image of annealed InSb thin film of 1500 Å

EDS analysis -

The stoichiometry and atomic wt% of InSb thin films was found by EDS. Figure 4 shows EDS spectrum of the annealed InSb thin films. The actual atomic % for various compositions of Indium 30.6% and antimony 69.4%.

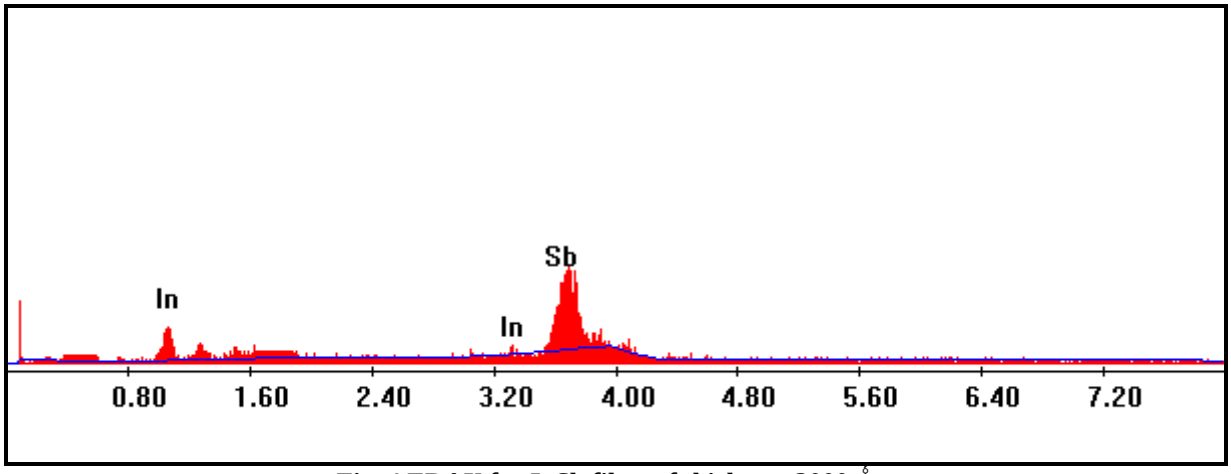

Fig. 4 EDAX for InSb films of thickness 2000 Å

TEM micrograph gives the morphology of the nanocrystallites. Figure 5(a) shows the TEM micrograph of annealed InSb nanoparticles. The particles were homogeneous. The sample was agglomerated, but a few separated particles still could clearly be observed in the image. The particle size ranged from 10 - 20 nm. This result was in good agreement with XRD result. The selected area electron diffraction (SAED) pattern in figure 5(b) furthermore indicated that the nanocrystalline InSb had a crystalline in nature.

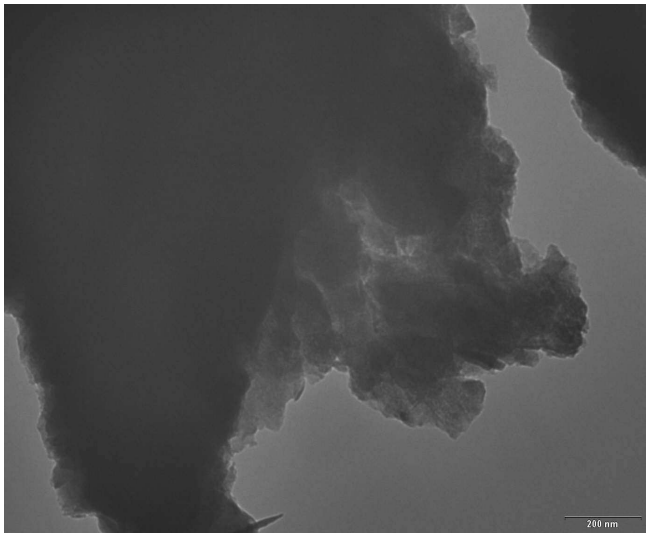

Fig. 5 (a) TEM Micrograph of InSb film of thickness 1000 Å

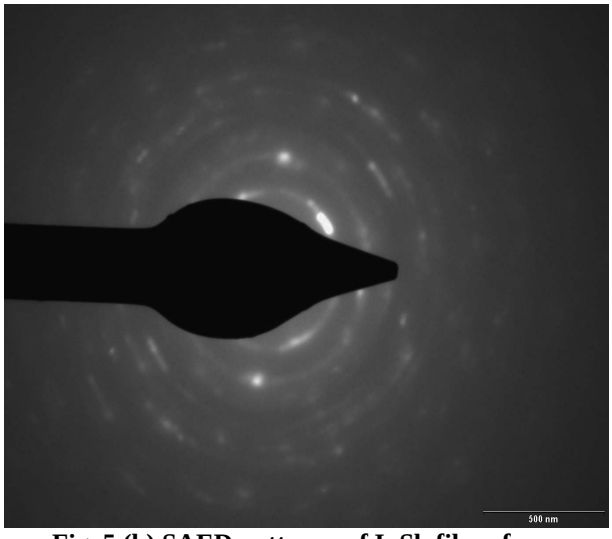

Fig. 5 (b) SAED patternn of InSb film of thickness 1000 Å

Electrical Analysis –

The graphical representation of thermo emf verses change in temperature for different thickness of InSb thin films are shown in Figure 6 and the graphical representation of Seebeck coefficient versus 1/ΔT for different thicknesses of the same thin film are as shown in Fig 7. From this graph the Fermi energy and absorption coefficient are calculated and represented in Table 2 the Fermi energy of InSb thin films is thickness dependant. It shows that InSb is a P type material.

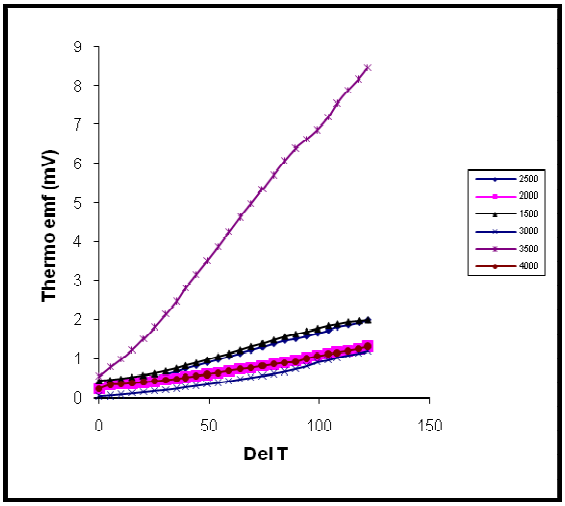

Fig. 6 (a)Plot of Thermo emf Vs. ΔT

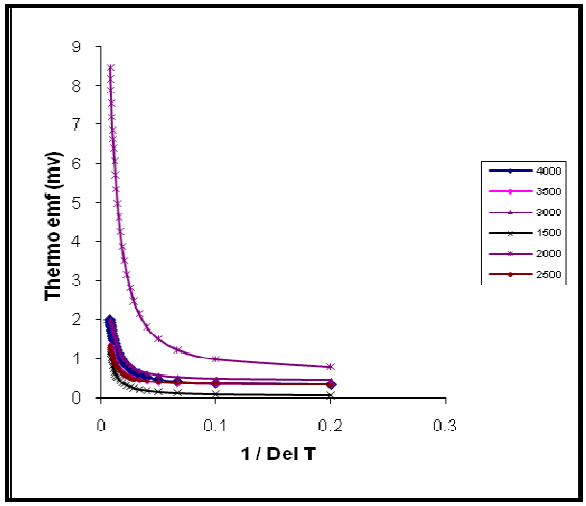

Fig. 6 (b) Plot of Thermo emf Vs. 1 / ΔT

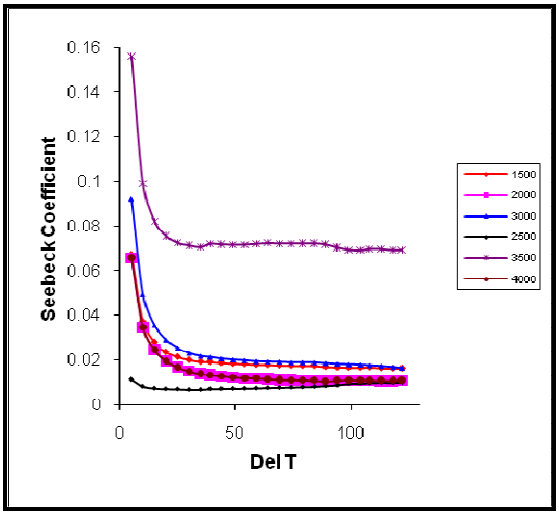

Fig. 7 (a)Plot of ΔT Vs. Seebeck Coefficient

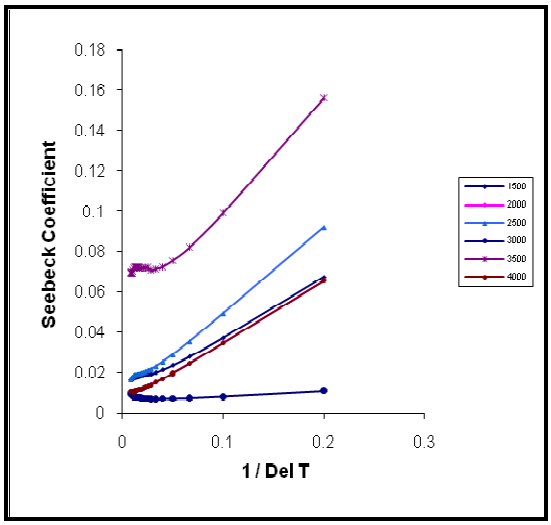

Fig. 7 (b)Plot of Seebeck Coefficient Vs. 1 / ΔT

Obs No.	Thickness of Sample Å	Fermi Energy(eV)	Absorption Coefficient
2	1500	0.1971	10.58
3	2000	0.91594	0.95
4	2500	0.2086	0.7133
5	3000	0.11014	0.74
6	3500	0.11594	0.3886
7	40000	0.11478	0.37454

CONCLUSION

1. The deposited InSb thin films are P type of semi conducting in nature.
2. The films are polycrystalline in nature and having cubic structure.
3. SEM study shows the Spherical shaped grains uniformly grown over the surface of the substrate and align in one direction. The films are mechanically stable since no cracks are observed in the low magnification SEM image
4. The Fermi energy is found to be 0.11478 to 0.0.9159 eV.
5. The value of absorption coefficient was evaluated as 0.37454 to 10.58.

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