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Structural and Optical Properties of Aluminium Antimonide Thin Films Deposited By Thermal Evaporation Method

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ABSTRACT

Thin films having different thicknesses of AlSb were deposited by thermal evaporation technique onto precleaned amorphous glass substrate. The structural properties of films were evaluated by XRD, TEM and optical microscopy. The optical band gap of the films was measured by using optical absorption spectra. It is found that AlSb is an indirect band gap material having value of 1.58 eV. The Photo Luminescence(PL)study of the films are also studied and it is observed that the peaks are obtained at 488.04, 517.29 and574.8nm shows that zero phonon transition of donor - acceptor pair recombination, where as additional bands corresponds to phonon replicas of the zero phonon DA recombination. The x ray diffraction analysis confirms that deposited films are polycrystalline having cubic structure. The grain size is found to be 10.75 nm.

Keywords: Optical band gap, PL, Donor- Acceptor pair (DA pair), grain size, TEM.

INTRODUCTION

The III – V semiconductors are of great significance due to their applications in various electro-optical devices. Aluminum– antimony (AlSb) seems to be a promising semiconducting material for high-temperature applications especially for transistors and P–N junction diodes because of a large band gap [1]. AlSb, with an energy gap of 1.62 eV, is potentially a high-efficiency solar material [2]. AlSb has a rapidly growing interest in opto-electronics [3]. A greater number of scientists have studied electrical thermal, optical, and structural properties of stoichiometric AlSb in bulk as well as in thin film forms [4–7]. Flash evaporation technique has been employed to grow Al–Sb films [8]. Singh and Vijay [9] prepared semiconductors by using the bilayer structure of Zn–Se and In–Sb thin films, and the AlSb bilayer structure of thin films by thermal evaporation technique and optical, electrical, and thermoelectric power studies were analyzed. From the study of literature review, it can be seen that no attempt has been made to study the variation of optical properties by change in thickness of thin films.

In present work effect of film thickness on optical properties over the thickness range 1000 – 2500 Ǻ has been investigated. An attempt has been made to evaluate optical band gap energy. The PL is also been evaluated.

MATERIALS AND METHODS

Experimental Details

The starting material was prepared by mixing quantities of high-purity (99.999%) aluminum foil and indium powder in the atomic proportion 1/1. The mixture was sealed in an evacuated quartz tube and heated at 1072 K for 72 h. Polycrystalline AlSb 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 films were annealed at reduced pressure of about 10^{-4} torr and at 523 K for the period of three hours. 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 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 X ray shows that all the films prepared were polycrystalline cubic in structure (Table-1). Optical absorption was measured by UV-VIS spectrophotometer model no. Shimadzu -2450.

RESULTS AND DISCUSSION

1.1 Structural characterization

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

Fig. 1(a) Micrograph of AlSb film of thickness 1000 Å

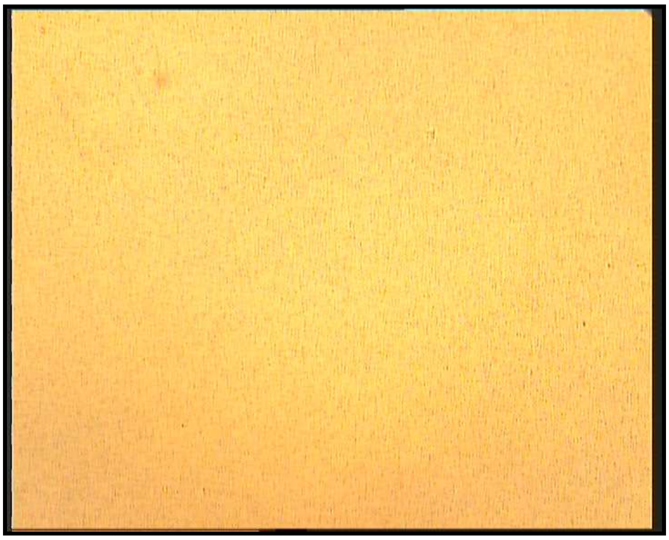

Fig. 1(b) Micrograph of AlSb film of thickness 2500 Ǻ

Fig.1 (a) and Fig 1(b) shows the photomicrograph of the AlSb films of thickness 1000 Ǻ and 2500 Ǻ resp. The films exhibit the growth of small grains distributed across the surface of the substrate.

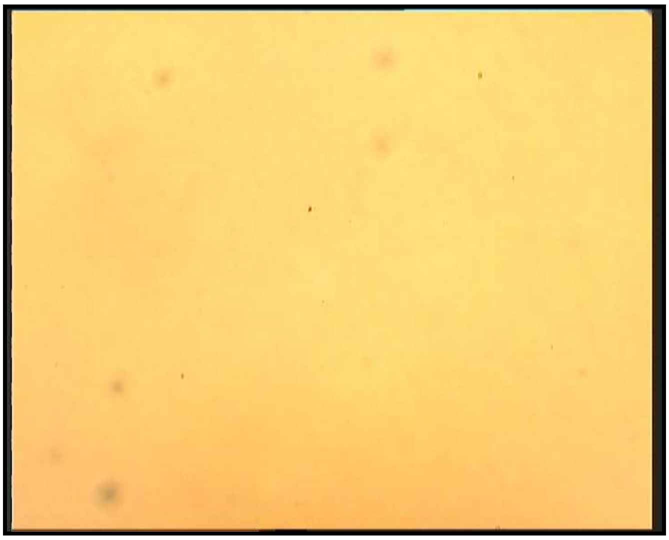

Fig. 1(c) Micrograph of AlSb film of thickness 1500 Ǻ

Fig. 1(c) shows the micrograph of AlSb of thickness 1500 Ǻ indicates uniform surface coverage. Further confirmation of the structure of the grown films was carried out using the x-ray diffraction pattern in Fig. 2.

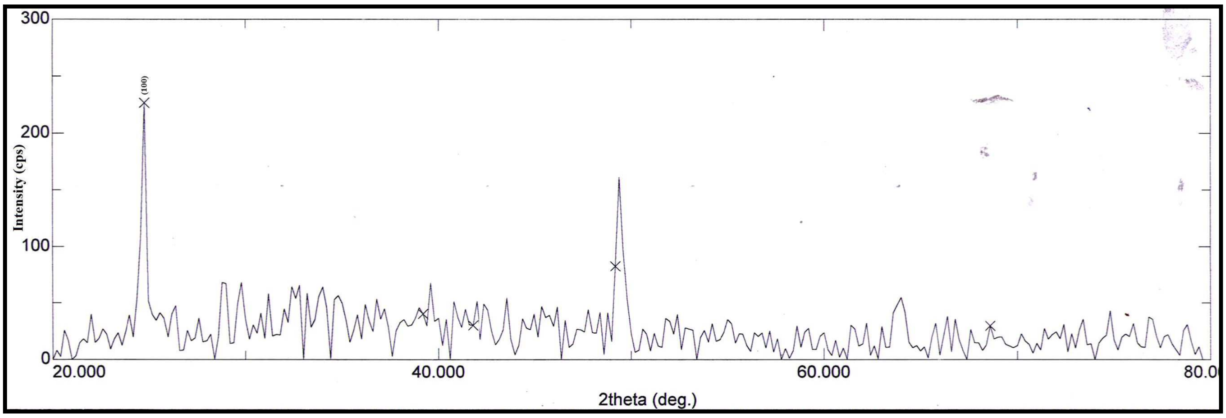

Fig. 2 (a) XRD of AlSb of thickness 1000 Ǻ

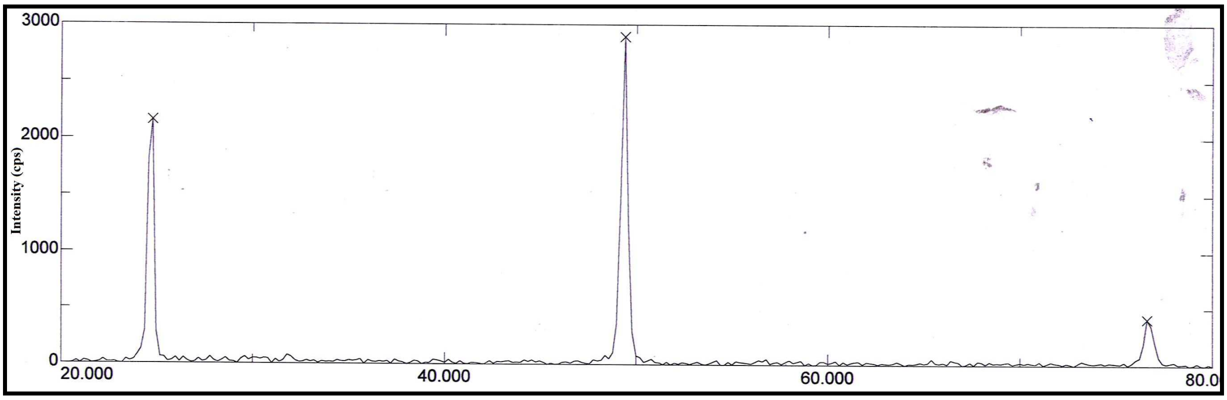

Fig.2 (b) XRD of AlSb of thickness 1500 Ǻ

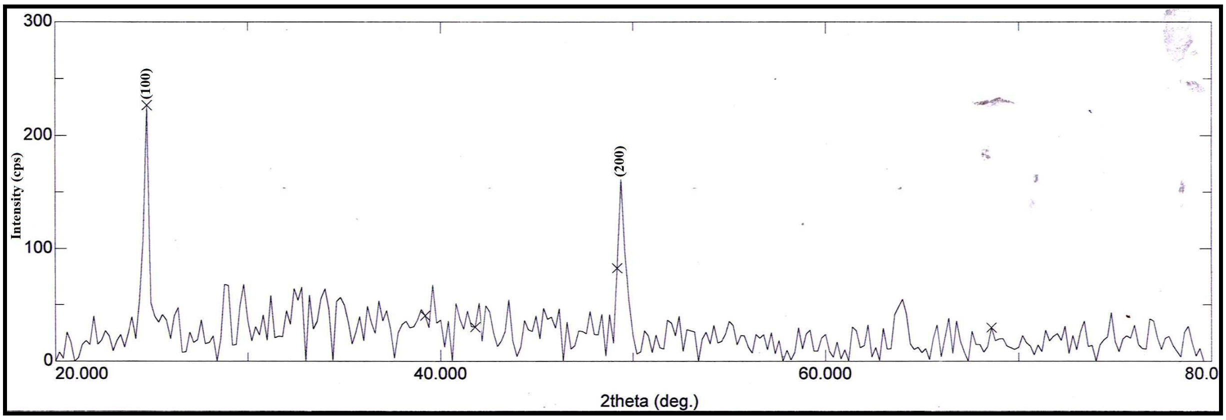

Fig.2 (c) XRD of AlSb of thickness 2500 Ǻ

Fig. 2 shows the XRD pattern of AlSb thin film prepared at substrate temperature of 303k. The 2θ peaks observed at 24.8^0, 39.2^0, 41.8^0, 49.2^0 and 76.6^0 exhibit the formation of the cubic phase of AlSb which correspond to the (111), (220), (311) and (100) planes of reflections. The inter-planar distances as were indicated in the XRD result were found to be 3.5870 Å, 2.4149 Å, 2.1591Å, 1.8503 Å and 1.2428Å. The presence of large number of peaks indicates that the films are polycrystalline in nature.

These results are well in agreement with the reported values From the results shown above, the strongest peak for the grown films in Figure 2 occurred at 2θ=49.2° with d = 1.8503Å and 2θ=24.8° with d=3.5870 Å which corresponds to (200) plane. The value of the lattice parameters obtained from the analysis of x-ray diffraction pattern are shown in Table 1

Table 1 Result obtained from X-ray diffractogram:

Thickness	hkl	2θ	d Å	d Å	FWHM	Grain Size	Average grain size
Å		Degree	Measured	Standard	rad	nm	nm
1000	111	24.8	3.5870	3.587	0.02874	9.42	8.65
	220	39.2	2.4149	2.1994	0.02874	9.08	
	--	41.8	1.1591	--	0.2874	9.01	
	311	49.2	1.8503	1.8433	0.02874	8.76	
	100	76.6	1.2428	1.1994	0.03285	6.97	
1500	111	24.8	3.5870	3.587	0.00822	16.47	20.13
	311	49.4	1.8433	1.8433	0.0041	30.70	
	100	76.6	1.2428	1.1994	0.00822	13.23	
2500	111	24.6	3.6157	3.587	0.02874	4.71	4.77
	--	34.8	2.7281	--	0.03285	4.02	
	220	43.2	2.1396	2.1994	0.02464	5.23	
	311	49.2	1.8503	1.8433	0.02464	5.11	

The structural parameters of AlSb thin film show that the film has average grain size of 8.65 nm for the film of thickness 1000 Å, 20.13 nm for film of thickness 1500 Å and 4.77 nm for film of thickness 2500 Å.

TEM micrograph gives the morphology of the nanocrystallites. Figure 3(a) shows the TEM micrograph of as-prepared AlSb nanoparticles. The particles were homogeneous and spherical. The sample was agglomerated slightly, but a few separated particles still could clearly be observed in the image. The particle size ranged from 8.95 - 17 nm. This result was in good agreement with XRD result. The selected area electron diffraction (SAED) pattern in figure 3(b) furthermore indicated that the nanocrystalline AlSb had a good crystallinity.

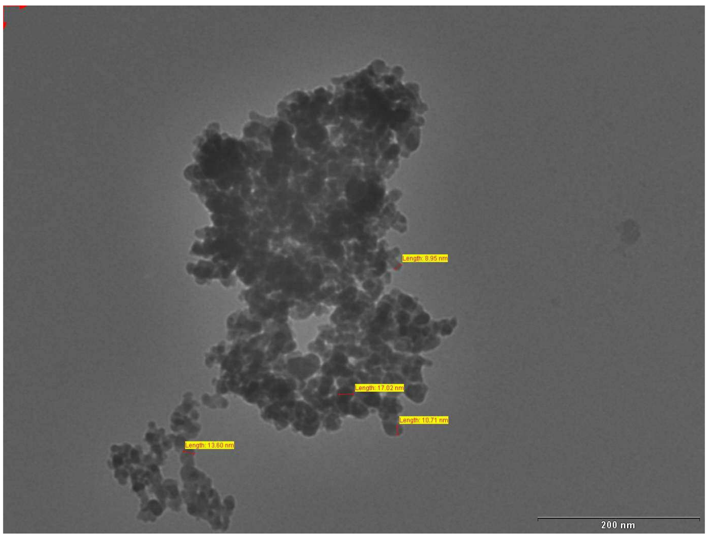

Fig. 3(a) TEM Micrograph of AlSb film of thickness 1000 Å

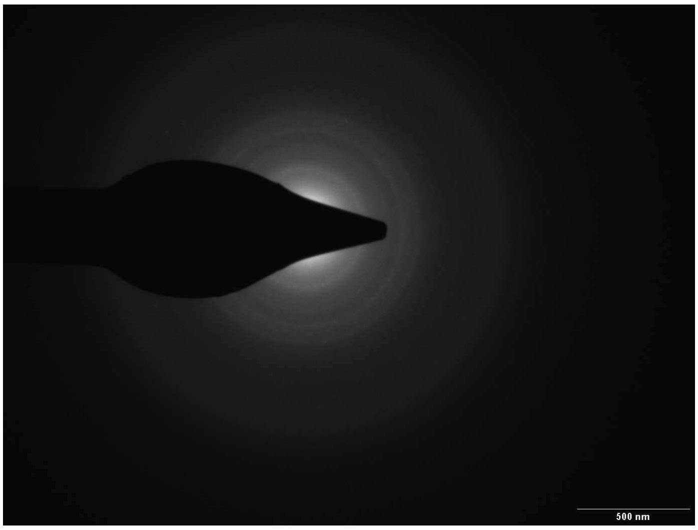

Fig. 3(b) SAED patternn of AlSb film of thickness 1000 Ǻ

1.2 Optical properties of AlSb thin films

The optical absorption spectra were obtained in the 200nm-900nm wavelength range by employing a Shimadzu 2450 UV-Visible model of the spectrophotometer.

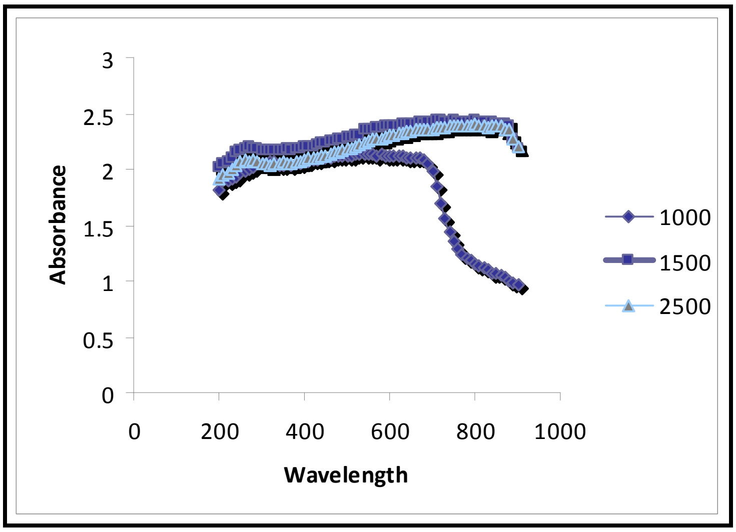

Fig. 4 Spectral absorbance for AlSb

Fig. 4 show the optical absorbance spectra of the films deposited in this work. The high absorbance in the UV region makes the material useful in forming p-n junction solar cells with other suitable thin film materials for photovoltaic applications.

The optical band gap of these films has been calculated using the relation (Tauc 1974).

$$\alpha h\nu = A\,(h\nu - Eg)^{n}$$

where, $h\nu$ is the photon energy, α the absorption coefficient, Eg the band gap, A is constant and, $n = 0{\cdot}5$ for direct band gap material, $n = 2$ for indirect band gap material. The AlSb is an indirect band gap material, so, in the present work, we have taken $n = 2$ for calculation. Figure 4 shows the photon energy vs. $(\alpha h\nu)^{1/2}$ for AlSb thin films. This graph shows the value of optical band gap for films. The optical band gaps nearly agree with the reported band gap (1·62 eV) (Rittner *et al* 1954; Herczog *et al* 1958; Yu *et al* 1995). The variation observed in samples having different thicknesses is due to non-uniform mixing of Al and Sb.

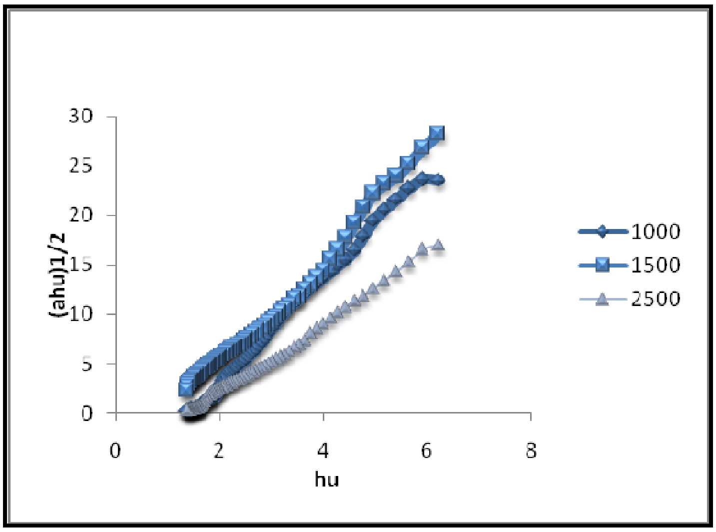

Fig. 5 Plot of photon energy versus $(\alpha h\upsilon)^{1/2}$

1.3 Photo Luminescence study of AlSb Films

The PL spectrum consists of several PL bands. The PL band with its maximum at 2.14 eV is the phonon transition of a donor acceptor pair recombination additional band corresponds to replicas of zero phonon DA recombination. The sharp lines are typical for radiative recombination of donor bound electrons with acceptor bound holes at closely spaced DA pairs [10]. Figure 6 shows the graph of wavelength Vs. Intensity and Figure 7 shows the Energy vs. Intensity for AlSb films.

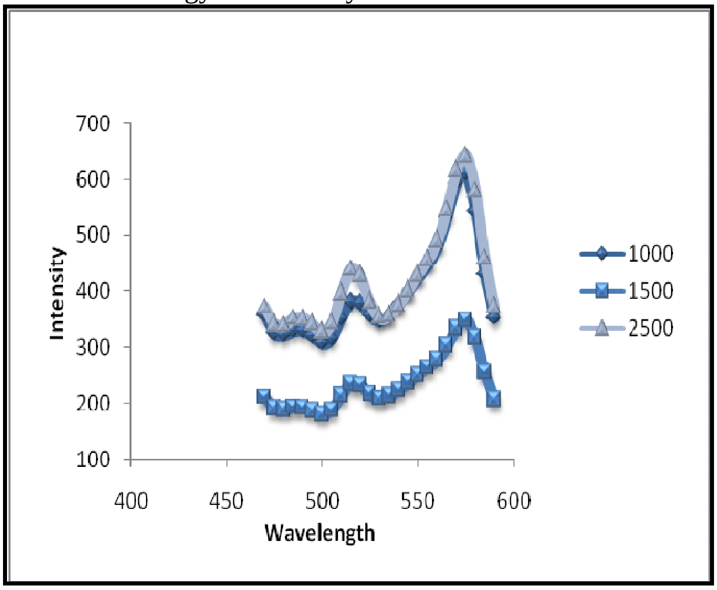

Fig. 6 Plot of wavelength vs. Intensity

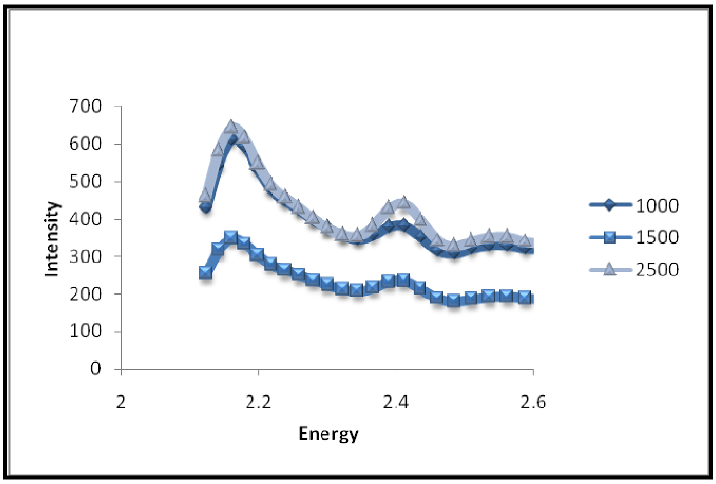

Fig. 7 Plot of Energy vs. Intensity

CONCLUSION

1. The deposited Al-Sb thin films are P type of semi conducting in nature.
2. The films are polycrystalline in nature and having cubic structure.
3. The optical band gap is found to be 1.58 eV.
4. The PL spectra shows phonon transition of a donor acceptor pair recombination additional band corresponds to replicas of zero phonon DA recombination

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