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Structural, optical and electrical properties of thermal evaporated nano sized In_2Te_3 thin films

R. Revathi [a,*], R. Karunathan [a]

[a] Department of Physics, DR .N .G .P Arts and Science College, Coimbatore-641048, Tamil Nadu, India

*Corresponding Author
revathiinuk@gmail.com
(R. Revathi)
Tel.: +91 9842482106

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ABSTRACT: Indium Telluride thin films were prepared by thermal evaporation technique. Films were annealed at 573K under vacuum for an hour. Both as-deposited and annealed films were used for characterization. The structural parameters were discussed on the basis of annealing effect for a film of thickness 1500 Å. Optical analysis was carried out on films of different thicknesses for both as - deposited and annealed samples. Both the as- deposited and annealed films exhibit direct and allowed transition. Electrical resistivity measurements were made in the temperature range of 303-473 K using Four-probe method. The calculated resistivity value is of the order of 10^{-6} ohm meter. The activation energy value decreases with increasing film thickness. The negative temperature coefficient indicates the semiconducting nature of the film.
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Keywords: Metal oxide nanoparticles; polyaniline; structural properties

1 Introduction

Binary chalcogenide alloys $A_2^{III} B_3^{VI}$ (A = Al, Ga, In and B = S, Se, Te) with semiconducting properties have been widely studied. Among these compounds Indium Telluride is mostly used for its photo conducting properties [1,2] and also for its switching and memory effects [3,4]. It is found to have two modifications labelled as α and β corresponding to low and high temperature formation.

In the present work, the structural, electrical and optical properties of In_2Te_3, in thin film form were studied. The effect of annealing on the structural and optical properties of In_2Te_3 was also investigated.

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2 Experimental Procedure

The pure Indium Telluride (In_2Te_3), (99.999%, Aldrich Chemicals) was evaporated from a molybdenum boat under a vacuum of 10^{-6} Torr and deposited onto pre-cleaned glass substrates. The film thickness was measured by Quartz crystal monitor .The structure of the film was analysed using Shimadzu XRD 6000 X-ray diffractometer. Optical analysis was carried out using JASCO- UV/VIS/NIR (JASCO V-570) double beam spectrometer and electrical resistivity measurements were made in the temperature range of 303K-473K using Four-Probe method.

3 Results and Discussion

3.1. Structural Analysis

X–ray diffraction patterns for as-deposited and annealed In_2Te_3 films of thickness 1500Å were obtained. The analysis shows that the as-deposited film is amorphous and annealed film is polycrystalline in nature [5]. The prominent diffraction peak is found to be at (2θ = 40.1233°) which corresponds to (8 2 0) plane and is shown in Fig 1. The crystallite size D [6,7] of In_2Te_3 thin films was calculated using the formula,

$$D = \left(\frac{k\lambda}{\beta \cos\theta} \right)$$

Where k is the Scherer's constant [8,9], λ is the wavelength of the X-rays used, β is full width and half maximum and θ is Bragg angle. The strain was calculated using the formula,

$$\varepsilon = \left(\frac{\beta \cos \theta}{4} \right)$$

And the dislocation density was calculated using the formula,

$$\delta = \frac{1}{D^2}$$

The crystallite size, strain and dislocation density are calculated using the above formula for annealed film. The calculated values are present in the Table.1. In the case of In_2Te_3; it is known that this material exists in a high temperature β-phase, which transforms reversibly at (900+/- 10) K to the low temperature α-phase [10, 11]. Therefore, since the annealing temperature used in the present work is smaller than that of the α to β transition only the α-phase is present in our film.

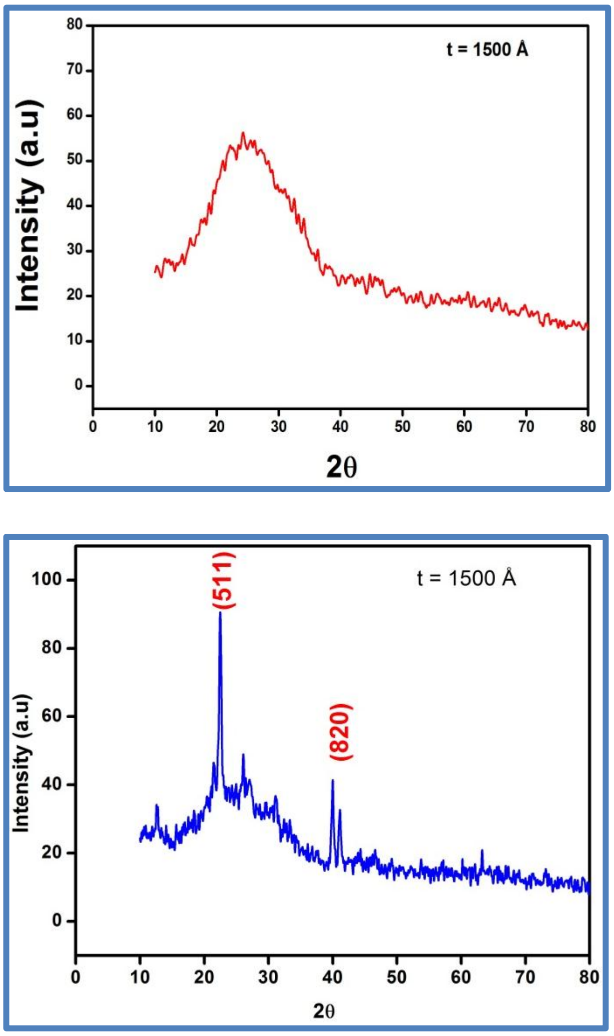

Figure 1 XRD spectrum of as-deposited and annealed In_2Te_3 Thin films of thickness 1500 Å.

Table 1 Determination of Structural parameters of annealed 1500 Å film

Film Thicknesses (Å)	Annealed		
	Crystallite Size (10^{-10}) nm	Dislocation Density (10^{15}) lines/m^2	Strain (10^{-3})
1500	276.257	1.310	1.311

3.2 Optical Analysis

For different thicknesses of vacuum evaporated In_2Te_3 thin films the optical analysis was carried out. The transmittance and absorption spectra for as-deposited In_2Te_3 films of different thickness are shown in figure 2 and 3. From these figures it is noted that the transmittance decreases with increasing film thickness and absorbance increases with increasing film thickness. Similar results were obtained for annealed films of same thicknesses and it is shown in figure 4 and 5.

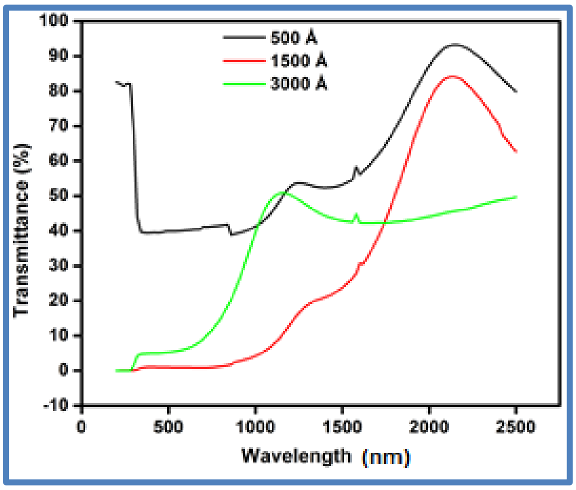

Figure 2 Transmittance Spectra of as - deposited In_2Te_3 thin films of different thicknesses

The band gap energy was calculated using the standard formula

$\alpha(\nu) = A (h\nu - Eg^{opt})^p / h\nu$

The parameter 'p' determines whether the transition is direct or indirect and allowed or forbidden. The usual method for the determinations of the value of Eg opt involves plotting a graph of (αhν) 1/p against hν. Here in our result the value of p is taken as 2 and it obeys the formula, here exists the direct-allowed transition [12] and by extra plotting the line corresponding bandgap was found.

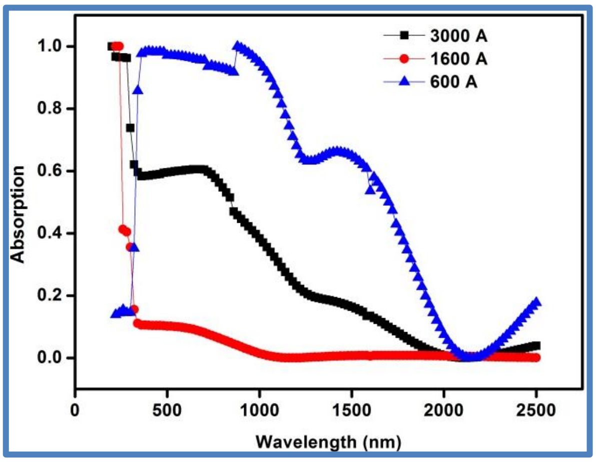

Figure 3 Absorbance Spectra of as - deposited In2Te3 thin films of different thickness.

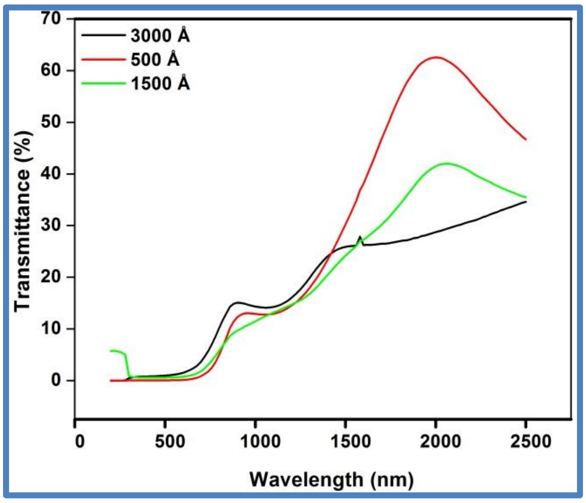

Figure 4 Transmittance Spectra of annealed In2Te3 thin films of different thickness.

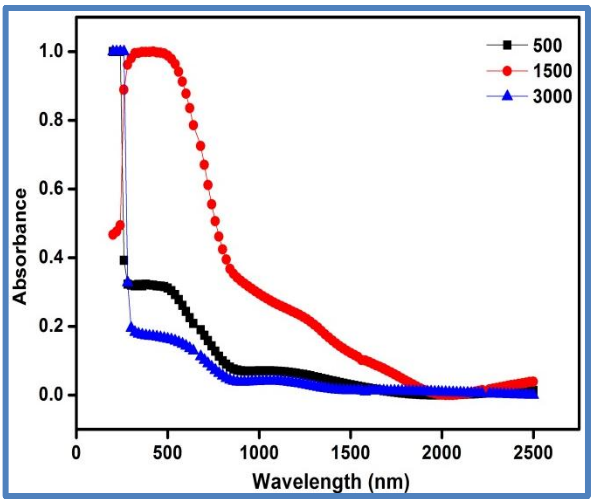

Figure 5 Absorbance Spectra of annealed In2Te3 thin films of different thickness.

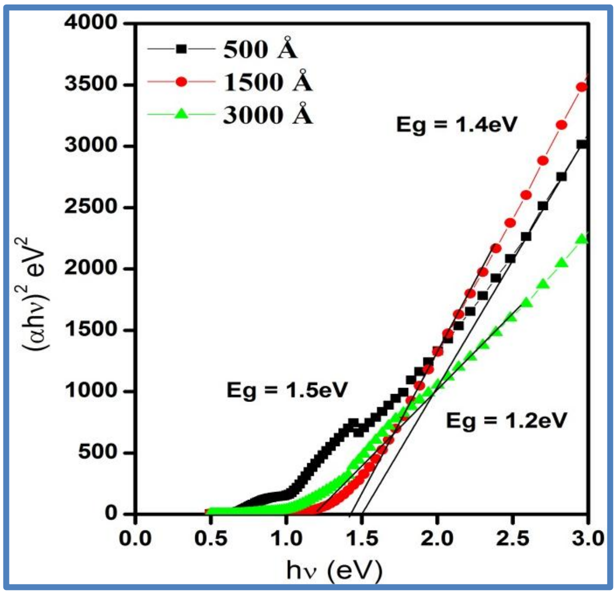

Figure 6 Plot of (αhν) ^{2} vs hν of In_2Te_3 as-deposited thin films.

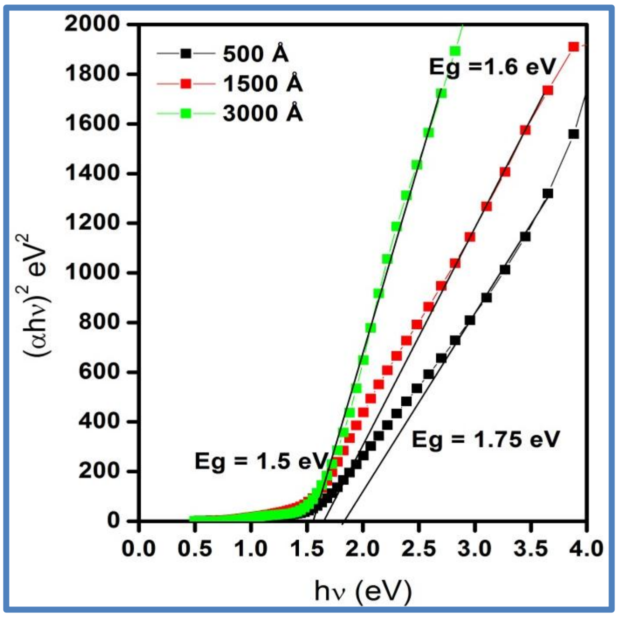

Figure 7 Plot of (αhν) ^{2} vs hν of In_2Te_3 annealed thin films.

Plot of (αhν) ^{2} versus (hν) for as-deposited and annealed In_2Te_3 thin films of different thicknesses are shown in fig 6 and 7 the band gap energy decreases as the film thickness increases. The calculated band gaps were presented in Table.2.The bandgap was found to be enhanced in the case of annealed ones which may be attributed to the reduction in the number of unsaturated defects decreases the density of localized states in the band structure and consequently increase the optical bandgap [13] of the annealed films.

Table 2 Calculated Band gap for different film conditions and Thickness

Film Thicknesses (Å)	Band gap (eV)	
	As-deposited	Annealed
500	1.5	1.75
1500	1.4	1.6
3000	1.25	1.5

3.3 Resistivity Analysis

The logarithm of resistivity is plotted against the reciprocal of absolute temperature for different thickness and is shown in figure 8 for a film of thickness 500 Å and current 25μA. The activation energy was calculated by taking the slope and using the corresponding equation,

$$\frac{Eg}{2k} = \frac{\log_e \rho}{1/T}$$

Table 3 Calculated activation energy for different current values and thicknesses

Current in (μA)	Thickness 500Å	Thickness 1500 Å	Thickness 3000 Å
5	0.46eV	0.34 eV	0.32 eV
15	0.39 eV	0.27 eV	0.21 eV
25	0.28 eV	0.21 eV	0.10 eV

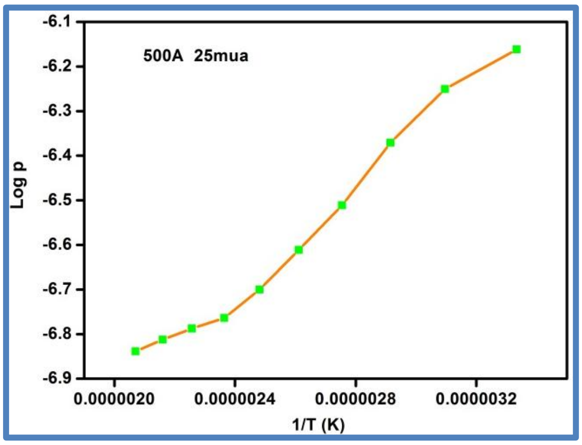

Figure 3.8 Variation of log ρ vs inverse temperature in (Kelvin).

The activation energy was found to be decreases when the current value increases for film of thicknesses 500 Å, 1500 Å, and 3000Å respectively. The corresponding values are shown in the Table 3. The Temperature Coefficient of Resistance of the film was calculated and it was found to be negative, which indicates the semi conducting nature of the film [14, 15].

4. Conclusion

Indium Telluride films of different thickness were obtained by thermal evaporation technique. XRD analysis shows that the as-deposited films are amorphous and annealed films are polycrystalline in nature. Optical analysis indicates that the transition was direct allowed. From the analysis of electrical resistivity, the existence of negative temperature coefficient of resistance indicates the semi conducting nature of the prepared films.

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Competing Interests:

The authors declare that they have no competing interests.

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