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Effect of annealing on the structural and electrical properties of thermally evaporated In_2Te_3 thin films

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Indium telluride thin films of higher thickness were prepared by thermal evaporation technique and the as-deposited films were annealed in a vacuum at different temperature. The influence on structure and electrical properties were characterized by X-ray diffraction (XRD) and resistivity measurements. From the structural analysis, the as-deposited In_2Te_3 films which were annealed at 423K and 573K respectively, reveals that the films are polycrystalline in nature. The structural parameters such as crystalline size, strain and dislocation density were determined using X-ray diffractogram of the film. Resistivity measurement by four probe method shows semi conducting nature.

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1. Introduction

Indium telluride (In_2Te_3) belong to III-VI group of semi conducting material, which has very interesting electrical and optical properties [1-5] for an eventual use in solar cells , and also it find application in IR detectors. In_2Te_3 thin films have been prepared by vacuum evaporation [11] and electron beam evaporation methods [13]. Due to extensive application and future prospectus, semi conducting indium telluride films have received much attention in recent years.

In the present work, the electrical properties deduced from the resistivity measurement of thermally deposited films of In_2Te_3 for higher thickness annealed at 150°C and 300°C. These data are analyzed to determine the activation energy, sheet resistance, temperature coefficient of resistance (TCR). Hence analyses of the activation energy have been determined in order to obtain the resistivity nature of the material.

In addition X-ray diffraction studies have been carried out to get an idea of the structural changes produced in In_2Te_3 thin films due to annealing at different temperature. X-ray studies have shown that it crystallizes in two polymorphic modifications, α- and β- In_2Te_3 [6-9]. The high temperature β-phase has a zinc blende structure which transforms from this state (which is characterized by a completely random distribution of the metal ions in their sub lattice) to the ordered state (α-phase) [10] and the XRD results were discussed.

2. Experimental procedure

The films of indium telluride were obtained from 99.999% pure In_2Te_3 powder [Aldrich chem. Co, USA) by thermal evaporation method using HIND HI Vacuum coating unit at a pressure of about 10^{-5} Torr. Indium telluride thin films having thickness of 5000Å were prepared and then annealed at different temperature, 150°C and 300°C for about 1 hour.

X-ray diffraction analyses were done for annealed In_2Te_3 films of different temperature were characterized by Shimadzu XRD-6000 X-ray diffractometer. Electrical characteristics of the film were measured by using four probe methods for studying the resistivity of In_2Te_3 films.

3. Results and discussion

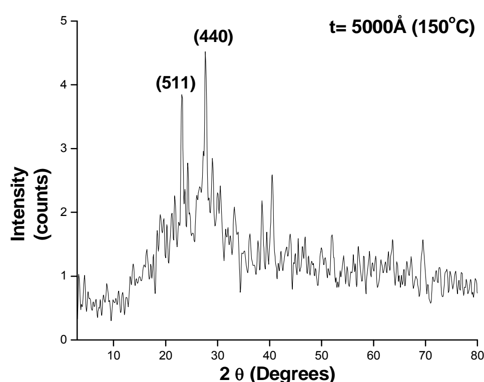
3.1 Structural analysis

X-ray diffraction patterns for annealed indium telluride films of different temperature were obtained and are shown in Fig.1 (a), 1(b) respectively. The prominent diffraction peaks are found to be (2θ = 27.661 ^{o}) which corresponds to (440) plane, according to JCPDS number 33-1488 [14] for thickness 5000Å annealed at 300°C. Also diffraction peaks for 150°C are found to be (2θ =23.097 ^{o}) which corresponds to (511) plane and (2θ = 27.698 ^{o}) which corresponds to plane (440). Along with the preferred orientation peaks some additional peaks are observed and it may be due to secondary growth in the films. The analysis shows that annealed films possess polycrystalline structure.

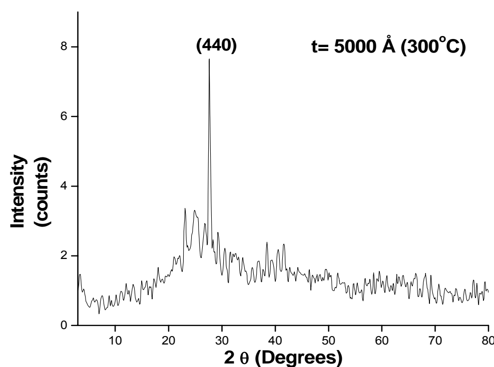
Table 1. Temperature dependence on structural parameters for In_2Te_3 films.

Thickness (Å) Annealed at temperature	Plane (hkl)	2θ (Degree)	d(Å)	FWHM (Degree)	Strain (ε) Lines/m^2 10^{-3}	Dislocation Density (δ) Lines/min 10^{18}	Crystalline size (D) (Å)
5000Å at 150 °C	(511)	23.097	3.8476	0.288	1.2305	11.476	2.9518
	(440)	27.698	3.2180	0.370	1.5663	18.680	2.3132
5000Å at 300 °C	(440)	27.661	3.222	0.250	1.0557	8.493	3.4312

The structural parameters such as crystalline size is deduced from Debye-Scherrer formula $D=k\lambda/\beta\cos\theta$, where β→the broadening of diffraction line measured at half of its maximum intensity, λ→X-ray wavelength (1.5406 Å), θ→Bragg angle, k→constant (0.9), strain is calculated using the formula $\varepsilon=\beta\cos\theta/4$ and dislocation density are calculated from $\delta=1/D^2$ and are shown in the Table 1. From the table it is noted that the crystalline size increases with increase in annealed film at different temperature. The strain, dislocation density decreases with increase in annealed film.



(a)



(b)

Fig. 1. XRD of In_2Te_3 thin films: (a) 150°C annealed sample,(b) 300°C annealed sample.

In the case of indium telluride, it is known that this material exist in a high temperature β phase which transforms reversibly at (900+/- 10) K to the lower temperature α phase. Therefore in the present work, it confirms that indium telluride thin films have polycrystalline β-phase structure at annealed temperature 150°C and 300 °C.

3.2 Electrical analysis

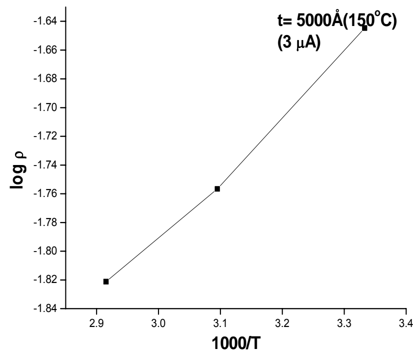
The logarithm of resistivity is plotted against the reciprocal of absolute temperature for thickness 5000Å annealed at 150 °C, 300 °C for different current values is shown in Fig. (2), (3). The activation energy was calculated by taking the slope and using corresponding equation,

$$\frac{E_g}{2K} = \frac{\log \rho}{1/T}$$

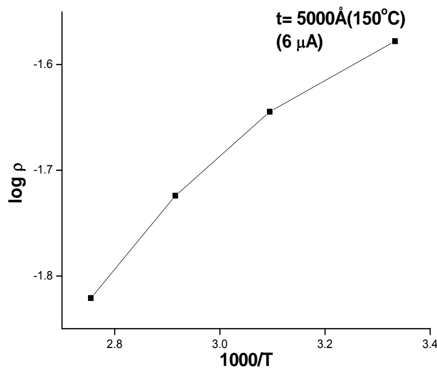
where E_g - Band gap energy, ρ- resistivity,K- Boltzmann constant (1.38×10^{-23}),T- temperature. The activation energy was found to be decreases when the current value increases for films of thickness 5000 Å annealed at 150 °C, 300 ° C is shown in Table 2. In the process of heat treatment the unsaturated defects are gradually annealed out [12], producing a large number of saturated bonds.

Table 2. Annealed thickness (Å) and activation energy (eV) for different current values (μA).

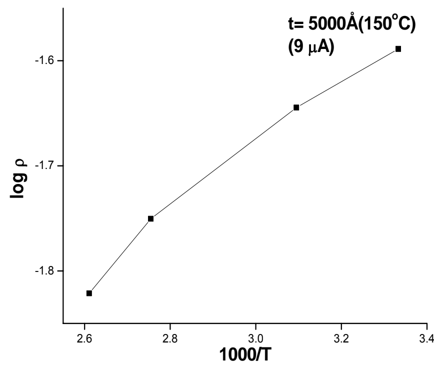
Thickness in Å	Annealed at Temperature	Activation Energy (eV)		
		3μA	6μA	9μA
5000Å	150°C	0.1805	0.1652	0.1635
	300°C	0.1527	0.1429	0.1322



(a)



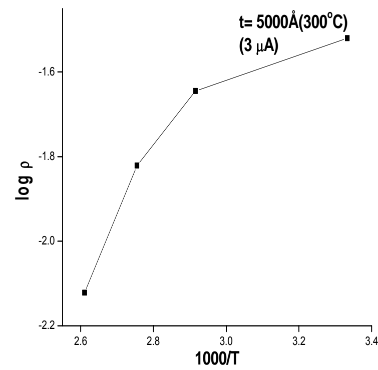
(b)



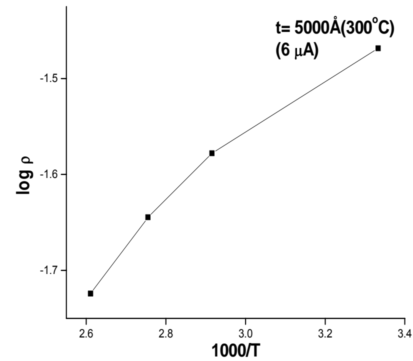
(c)

Fig. 2. Plot of log ρ Vs 1000/T of 150°C annealed In_2Te_3 thin films for different current values: (a) 3μA; (b) 6μA; (c) 9μA.

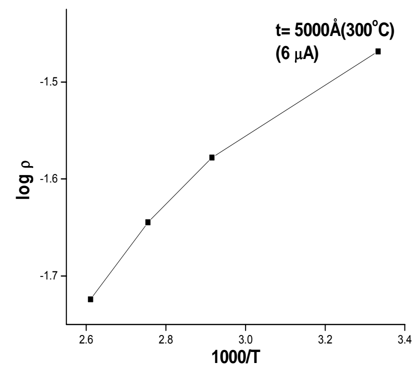
The reduction in the number of unsaturated defects decreases the density of localized states in the bond structure and consequently increases the conductivity value. Due to this increase in conductivity the resistivity decreases, which indicates that the indium telluride thin films exhibit semi conducting nature.



(a)



(b)



(c)

Fig. 3. Plot of log ρ Vs 1000/T of 300°C annealed In_2Te_3 thin films for different current values: (a) 3μA; (b) 6μA; (c) 9μA.

4. Conclusions

Indium telluride thin films of thickness 5000Å were prepared by thermal evaporation technique and annealed at 150°C, 300°C. XRD analysis confirmed that the annealed indium telluride thin films exhibit polycrystalline β-phase structure. The various structural parameters such as crystalline size, Dislocation density and strain in the film have been estimated for the annealed films at different temperature. From the Resistivity analysis, it is confirmed that prepared indium telluride thin films exhibit the semi conducting behavior.

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