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ELECTRICAL PROPERTIES OF THERMALLY EVAPORATED INDIUM TELLURIDE THIN FILMS

M Saeedur Rahman Khan* and M Rejwan Ali

University of Rajshahi, Rajshahi 6205, Bangladesh

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Indium telluride thin films are prepared by thermal evaporation technique onto glass substrate held at room temperature at deposition pressure $2x10^{-4}$ Pa. Electrical studies of the films annealed in air at 400 K shows semiconducting behaviour. Thickness dependent electrical conductivity, activation energy, aging effect are also being investigated. Activation energy is found to decrease with film thickness. Thickness dependent conductivity is found to follow Fuchs-Sondheimer size effect theory. The Hall and thermoelectric measurements show that the films are p-type semiconductor having high carrier concentration of the order $10^{18}/cm^3$.

Key words: Thermal evaporation, Electrical properties, In_2Te_3, Thin films.

Introduction

In_2Te_3 is a III-VI semiconductor with a band gap of about 1.1 eV (Purkayastha *et al* 1980). The material has technological importance for its potential use in IR detectors, solar cells and optoelectronic devices. Recently its suitability as a memory switch has been reported (Afifi *et al* 1996). $In_2 Te_3$ has two phases α and β (Zaslavskii and Sergeeva 1961). The high temperature β phase has zinc blend structure (lattice parameter a = 6.16 Å) with one third of the indium sites vacant at random (Hahn and Klingler 1949). The α phase is a superlattice with a=18.54 Å (Purkayastha *et al* 1980).

Literature reports physical properties of $In_2 Te_3$ this films produced by thermal and electron beam evaporation techniqeus. Although electrical properties of $In_2 Te_3$ are reported in a number of works, there is significant difference between the order of carrier concentration for films deposited at different substrate temperature conditions. Also that conductivity of both n and p types are reported, but associated thermopower data for both types of films are not available.

In this paper, we present and discuss the systematic study of the film preparation and the effect of temperature on resistivity at varying film thickness. The activation energy, size effect, Hall mobility, carrier concentration and thermoelectric power are also studied.

Experimental

Thin films of indium telluride have been prepared by thermal evaporation of $In_2 Te_3$ powder (purity 99.999%) from a molybdenum boat at a temperature of about 700 K onto glass substrate held at room temperature. The materials were evaporated in an E306A Edwards vacuum coating system at a pressure of about $2x10^{-4}$ pa. Before depositing the films, the glass substrates were first cleaned in chromic acid solution and then washed in distilled water. After washing and drying in hot air, the substrates were again cleaned in acetone and dried in hot air and were then used for deposition. Films of various thickness have been deposited for electrical and optical measurements onto glass substrates. the film tickness was measured by the Tolansky interference method (Tolansky 1948) with an accuracy of $\pm$ 2 nm. Thickness of these samples was in the range 58 to 303 nm. The films were annealed in air for about half an hour at temperature 400 K.

*Author for correspondence

Results and Discussion

Electrical properties. Electrical resistivity ρ was measured as a function of temperature T in the range 303 to 413 K. The glass substrate was heated by a specially designed heater and the temperature was measured by a chromel-alumel thermocouple placed on the middle of the substrate. The resistivity was obtained by applying a dc 8 V bias across the film with silver paste contract and recording the current and voltage simultaneously by using a standard four-probe van-der-Pauw technique (Chopra 1969).

Fig 1 shows the ρ versus T curves for four $In_2 Te_3$ films of thickness 58, 98, 119 and 161 nm respectively. It is seen that the resistivity decreases with increase of temperature indicating semiconducting behaviour.

Activation energy of four annealed films were determined using the following well known formula:

$\sigma = \sigma_o \exp(-E_a/2KT)$.............(1)

Where σ = conductivity at measured temperature

σ_o =conductivity at some reference temperature

E_a=activation energy

Fig 2 reports ln σ~ 1/T graph. The relation is almost linear within the temperature range 303 K to 413 K. The activation energy evaluated from the slopes of the curves are presented in Table 1. The result is smaller than the previous reported work by Zahab et al (1990). It was observed that activation energy decreases with the film thickness.

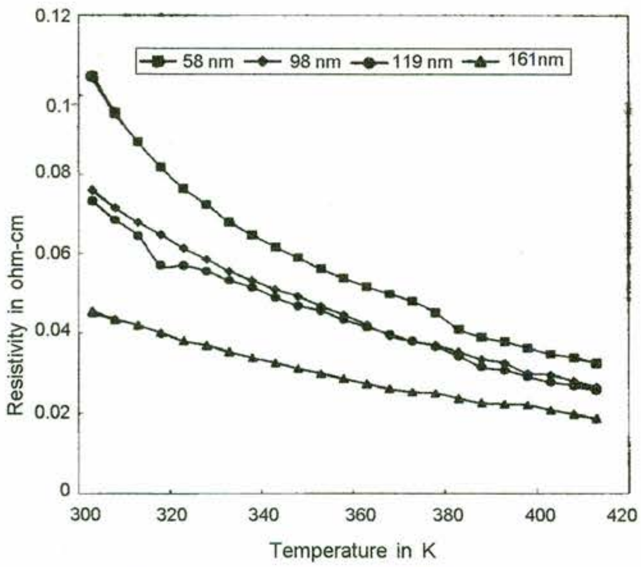

Fig 1. Variation of resistivity with temperature.

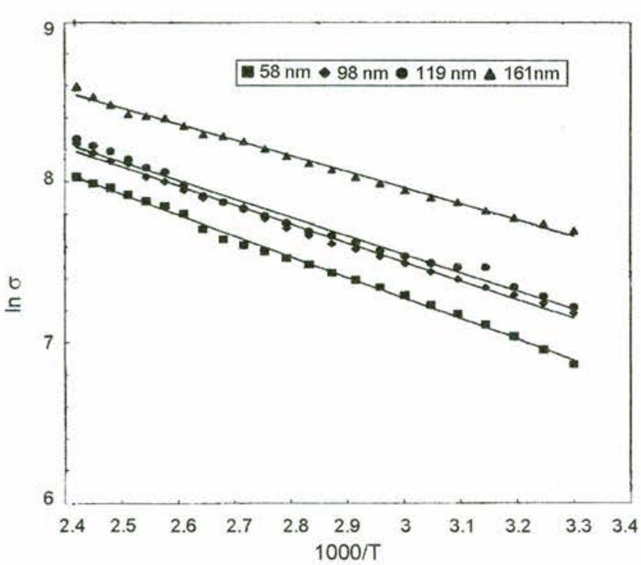

Fig 2. Variation of ln σ with inverse temperature.

Table 1
Activation energy for different film thickness

Deposition pressure	Film thickness in nm	Activation energy in ev
	58	0.22
	98	0.20
2x 10^{-4} Pa	119	0.20
	161	0.17

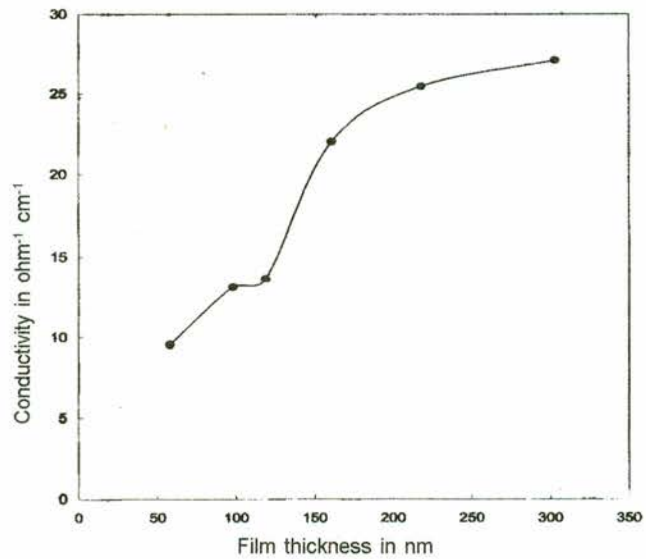

Fig 3. Variation of film conductivity with thickness.

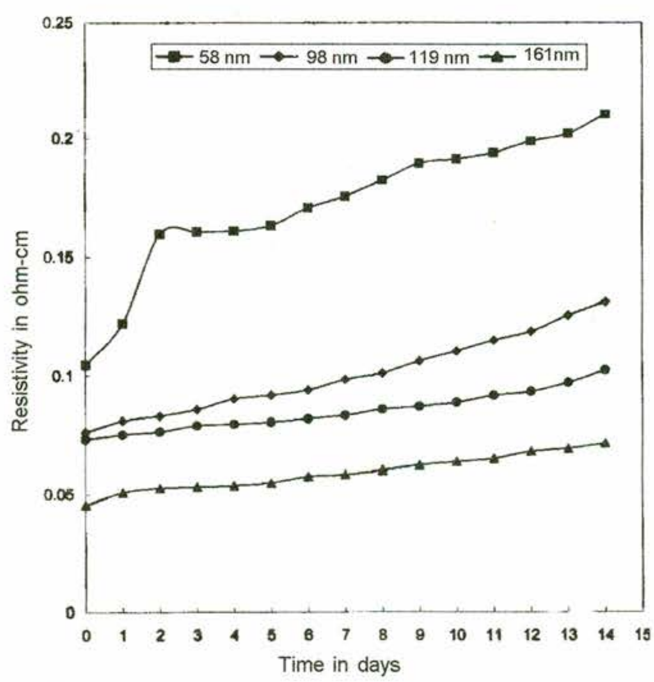

Fig 4. Variation of resistivity with time

Size effect. Variation of electrical conductivity with film thickness is shown in Fig 3. It is observed that the conductivity increases with thickness and attains an almost constant value 27.1 $\Omega^{-1}cm^{-1}$ at d ≈ 300 nm. The thickness dependence of conductivity is well in conformity with the Fuchs-Sondheimer theory (Sondheimer 1950). The conductivity decreases sharply below 58 nm which is probably due to the discontinuous structure of the film.

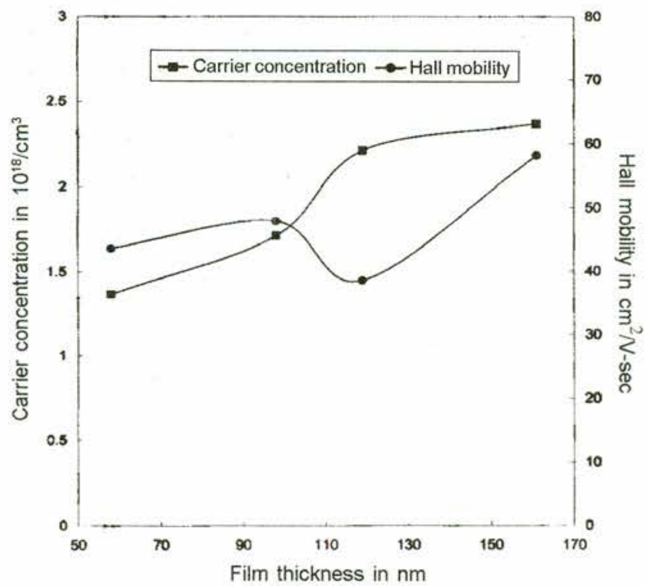

Fig 5. Variation of carrier concentration and Hall mobility with film thickness

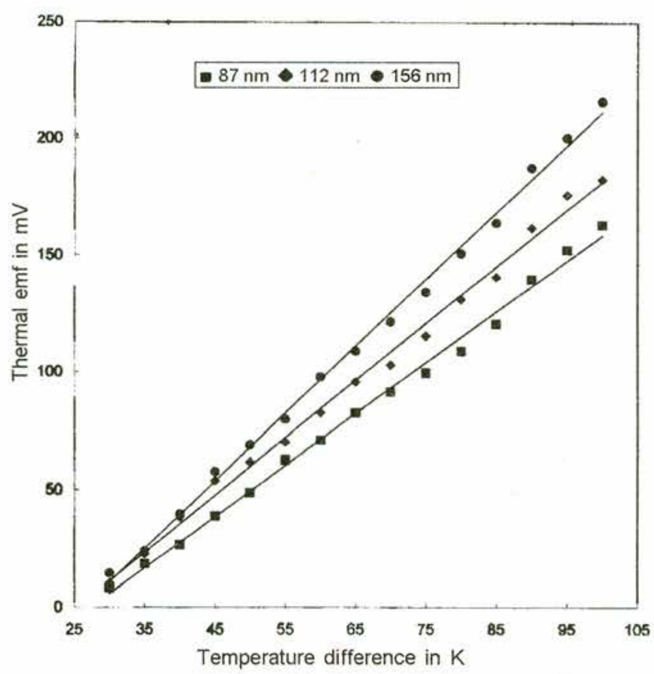

Fig 6. Variation of thermal emf with temperature difference.

Aging effect. The natural aging room temperature for annealed In_2Te_3 films of thickness 58, 89, 119 and 161 nm respectively was investigated and data for electrical resistivity versus time are shown in Fig 4. The resistivity of these films was measured at room temperature as function of time exposing them to laboratory atmosphere for two weeks. The graph indicates that adsorbed atoms have affinity for electrons resulting in increase in resistivity. Larger change in resistivity for film of thickness 58 nm can be for viod and discontinous island structure.

Hall effect. Hall measurements were done on four In_2Te_3 annealed thin films using van-der-Pauw method (Chopra 1969). The measurement was carried out at room temperature using a field of 0.28 Tesla. Geometrical effects on the Hall measurement were almost eliminated as the length-to-width ratio of the films were 2.5. Four films of thickness 58, 98, 119, 168 nm annealed at temperature about 400 K showed positive Hall coefficient indicating p-type nature of the semiconductor. The thickness versus carrier concentration and Hall mobility curves have been presented in Fig 5.

The results for carrier concentration and Hall mobility are much larger than the previous recorded work by Mathur *et al* (1982) while the order is in excellent conformity with the work in which films grown at substrate temperature 423~453 K (Purkayastha *et al* 1980). The results strongly suggests stoichiometric α -phase structure for In_2Te_3 thin films annealed at about 400 K.

Thermoelectric power. The thermo-emf measurement was carried out by the integral method (Das and Mohanty 1983). In this method the temperature of one end of the film was increased gradually step by step and the thermo-emf developed at each step was recorded. For the thermo-emf measurement one end of the specimen was held at 273 K (ice) and the other end was heated by a specially designed nichrome heater. The measurement was carried between the temperature range 303~373 K. Fine copper-constantan thermocouple were used as measuring leads for the thermo-emf. The emf was measured with a high impedence (> 10 M Ω)digital multimeter.

Fig 6 shows the thermo-emf against the temperature difference of the hot and cold ends for three In_2Te_3 annealed films of thickness 87, 112 and 156 nm. The curves are found to be straight lines indicating that the thermoelectric power is dependent on temperature at a particular thickness. The thermo-emf is found to be positive indicating that the films are p-type. Similar result is recorded by Purkayastha *et al* (1980). The reference electrode material used for thermo-emf measurement was lead.

Conclusion

Indium telluride thin films of different thickness have been prepared. The electrical, thermo-emf and Hall measurement showed thermally evaporated In_2Te_3 thin films annealed in air at 400 K is a p-type semiconductor with high carrier concentration of order $10^{18}/cm^3$. Thickness dependent conductivity, activation energy and aging effect have also been studied. The thickness dependent conductivity is well in conformity with the Fuchs-Sondheimer theory. Activation energy is found to decrease with film thickness. Hall and thermoelectric measurements showed p-type conductivity. Natural aging of films showed adsorbed atoms and impurities have affinity for electrons.

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