

## Conduction Studies on ZnTe Thin Films

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**Abstract:** Zinc Telluride (ZnTe) is a II-VI compound semiconductor with zinc-blende structure. Due to its wide, direct band gap, ZnTe is of considerable interest for potential application in optoelectronic devices. It has been extensively studied for application as back contact for CdTe in CdTe/CdS heterojunction solar cells. The ZnTe thin film was deposited onto well-cleaned glass substrate in between aluminium electrodes to form the MSM structure under the vacuum of 10<sup>-5</sup> Torr. The thickness of the film was measured by multiple beam interferometer (MBI) technique. From X-ray analysis, it has been found that ZnTe thin film possesses crystalline structure. The transport mechanism in these films under a.c. fields was studied in the frequency range 12 Hz to 100 kHz, at different temperatures (303-483 K). The dependence of capacitance and loss factor on frequency, for different temperatures was investigated and results are discussed. The process of a.c. conduction has been explained on the basis of hopping conduction mechanism. The dielectric constant ( $\epsilon'$ ), temperature co-efficient of capacitance (TCC) and temperature co-efficient of permittivity (TCP) were estimated. The dependences of activation energy on frequency and thickness were also studied.

**Keywords:** ZnTe thin films, semiconductors, Dielectric, Optoelectronic devices, X-ray diffraction

### 1. INTRODUCTION

Zinc Telluride (ZnTe), is one of the important II-VI compound semiconducting materials which has potential applications in a variety of solid-state devices such as solar cells, photodetectors and light emitting diodes [1,2]. Zinc telluride has a direct bandgap of 2.21 to 2.26 eV at room temperature. ZnTe is used as a substrate for the growth of CdTe and the heterostructures based on ZnTe and HgTe are used for infrared optics [3]. When doped with vanadium, ZnTe becomes a photorefractive semiconducting material [3] and has good potential applications for optical power limiting applications. Also ZnTe has been investigated for its uses as visible light-emitting semiconductor laser [4]. It has been extensively studied for application as back contact for CdTe in CdTe/CdS heterojunction solar cells [5-9].

Several workers [10-17] have made a detailed study of the crystal structure of ZnTe thin films. They have observed that these films deposited on glass substrates kept at room temperature have cubic zinc blende type structure. Semiconducting thin films have been extensively studied for a long time, because of their high technical value. In recent years, owing to a number of practical

applications in the field of micro-electronics and opto-electronics a great deal of interest has been shown in the study of the dielectric and conduction behaviour of various semiconducting materials [18-21]. Most of the experimental work carried out so far relates to d.c. which give information about the nature of transport processes. Studies on space charge and thermally stimulated currents in ZnTe thin films have been carried out by Taro Hino and Ken Yamashita [22]. Parakh and Grag [23] have studied the conduction mechanisms in vacuum evaporated ZnTe thin films and they found that the type of conduction is Poole-Frenkel. Conduction mechanisms in the off state of ZnTe thin films have been studied by Marc Burgelman [24] and they applied this aspect for the fabrication of switching devices. No work is found in the literature about conduction studies of ZnTe films under a.c. fields. Hence the present paper discusses the structure and a.c. conduction mechanism in vacuum evaporated Zinc Telluride thin films.

### 2 EXPERIMENTAL DETAILS

#### 2.1. Film Preparation

Using the conventional 12A4 Hind Hivac coating unit, pure (99.999%) aluminium was evaporated from a tungsten filament onto well-cleaned glass substrates through suitable masks to form

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Table 1. Structural parameters of Vacuum Deposited Zinc Telluride Thin films

Thickness of the film (t) in Å	2θ		Crystallite size (D) in Å	Strain (ε) in lines-m <sup>-2</sup>	Dislocation density (ρ) lines/min <sup>2</sup>	lattice spacing (d) in Å
	In XRD	In JCPDS				
3300	25.13	25.427	54.083	64.118 x 10 <sup>-4</sup>	3.4188x10 <sup>16</sup>	3.9172
7700	25.21	25.427	54.332	63.823 x 10 <sup>-4</sup>	3.3875x10 <sup>16</sup>	3.5329

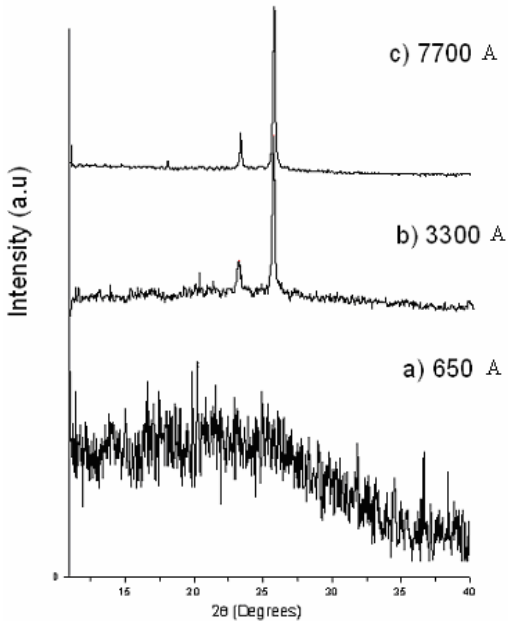


Figure 1. X-ray diffractogram of ZnTe thin films of various thicknesses a) 650 Å, b) 3300 Å and c) 7700 Å.

the base electrode. Pure (99.99%) ZnTe (Aldrich chemicals company, USA) was then evaporated from a molybdenum boat to form the dielectric layer. An aluminium counter electrode was evaporated onto the dielectric through suitable masks to complete the aluminium-zinc telluride-aluminium (metal-semiconductor-metal structure) device. A working pressure of 10<sup>-3</sup> m.bar was maintained in all the evaporation processes. For the structural analysis, the ZnTe films were deposited on the plane glass substrates.

## 2.2. Measurements

Thickness of the films was measured through quartz crystal monitor ("Hind Hivac" Digital Thickness Monitor Model-DTM-101), and verified by multiple beam interferometer (MBI) technique by forming Fizeau fringes [25]. The structural aspects of the films were analyzed, using X-ray diffractometer with filtered CuKα radiation (λ = 1.5418 Å). The capacitors were stabilized in vacuum at about 373 K for 10 hrs. Measurements of series capacitance and the dissipation factor in the frequency range 12Hz-100KHz were carried out at various temperatures (303-483 K) in a rotary vacuum (10<sup>-3</sup> m.bar) using digital LCR meter (LCR-819, GW instek, Good will Instrument company Ltd., Taiwan). The dielectric constant ε' was evaluated from the capacitance data from the known area and thickness of the dielectric films. The parallel equivalent conductance (G<sub>p</sub> = ωC<sub>p</sub>tanδ) was calculated at different temperatures from the measured values of C and tan δ.

## 3. RESULTS AND DISCUSSION

### 3.1. Structure

The X-ray diffractogram of ZnTe thin film of thickness 650 Å is shown in Fig. 1a. The absence of peaks in the diffractogram clearly shows that the structure of the film is amorphous in nature. Fig. 1b and c represents the X-ray diffractogram of ZnTe thin film of thickness 3300 and 7700 Å respectively and the presence of sharp peaks reveals that the films are crystalline in nature. A strong peak is observed around at 2θ = 25.13 which corresponds to prepared orientation along (111) plane of cubic phase. It is good agreement with the standard JCPDS-ICDD (01-0582) data of cubic ZnTe. The increases in grain size of the films with increase in thickness are clearly exhibited by intense sharp peaks in the diffractogram, which are in good agreement with the reported values [10,11]. It is observed that with the increase of film thickness particle size increases due to coalescence of small crystals. The crystallite size (D), strain (ε), dislocation density (ρ) and lattice spacing were estimated and presented in Table 1.

The lattice parameters of the films were calculated using the Bragg's formula

$$2d \sin \theta = n\lambda \quad (1)$$

The grain size of the films was calculated from the XRD using Scherer's relation [26],

$$D = \frac{k\lambda}{\beta \cos \theta} \quad (2)$$

Where

k is the constant = 0.94, λ - the wavelength of radiation

β - the full width half maximum and θ - the diffraction angle.

The micro strain (ε) and the dislocation density (ρ) of the as grown films were estimated using the equations

$$\varepsilon = \frac{(\beta \cos \theta)}{4} \quad (3)$$

and

$$\rho = \frac{1}{D^2} \quad (4)$$

The crystallite size (D), strain (ε), dislocation density (ρ) and d-spacing were estimated and presented in Table 1. From the table it is observed that the strain, dislocation density and lattice spacing decreases with increase in film thickness.

### 3.2. Dielectric Properties

#### 3.2.1. Annealing

Since freshly prepared films may contain many defects such as voids, grain boundaries, pinholes, etc. The attainment of stability and reproducibility was considered as an indispensable prerequisite and is achieved by careful preparation, heat treatment, and storage of the films in controlled ambient. The stabilization of

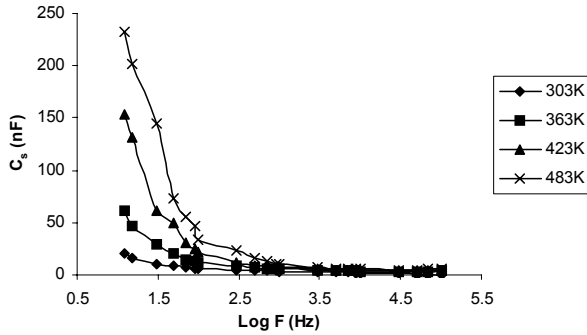


Figure 2. Change of capacitance with log frequency at different temperatures for ZnTe thin film of thickness 7700Å

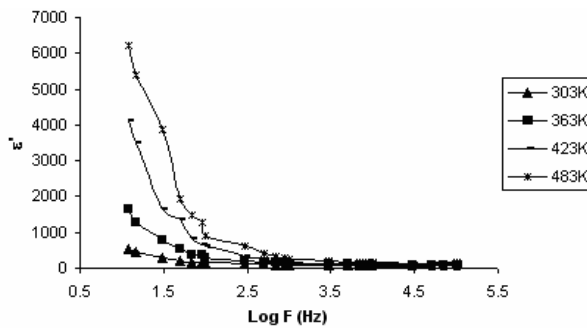


Figure 3. Variation of dielectric constant with log frequency at different temperatures for ZnTe thin film of thickness 7700Å

these capacitors could be achieved by annealing at about 373 K in vacuum for 10 hrs.

### 3.2.2. Frequency effect

The variation of capacitance with frequency for typical film of thickness 7700 Å in the frequency range 12Hz – 100 kHz for different temperatures is shown in Fig. 2. The capacitance decreases with increase in frequency. This effect is believed due to the screening of the electric field across the film by charge redistribution [27-29]. At low frequencies, the charges on defects are more readily redistributed, such that defects closer to the positive side of the applied field become negatively charged while the defects closer to the negative side of the field become positively charged. As the frequency is increased, in all cases the capacitance decreases to the same limit, as the charges on the defects no longer have time to rearrange in response to the applied voltage. At a given frequency, higher the temperature more effective is the screening because of the increase in thermal activation of charges as observed in the earlier work [30].

Fig. 3 presents the dependence of dielectric constant ( $\epsilon'$ ) on frequency. The dielectric constant also decreases with frequency at all temperatures exhibiting a similar trend as that of the capacitance. These curves closely resemble those predicted by the Debye relaxation model for orientational polarization [31].

Fig. 4 shows the typical variation of  $\tan \delta$  with frequency at vari-

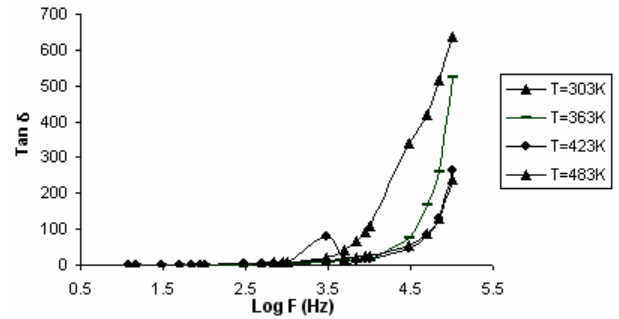


Figure 4. Variation of dielectric loss with log frequency at different temperatures for ZnTe thin film of thickness 7700Å

ous temperatures for a film thickness of 7700 Å. The loss factor is found to increase with increasing frequency whereas it decreases with increase in temperature at higher frequency region, which may be due to the effect of lead resistances.

### 3.2.3. Temperature effect

The temperature coefficient of capacitance (TCC) is an important parameter for assessing the expected behaviour in thin film circuits. The growing interest in the choice of material for application as capacitors suggests that the temperature coefficient of capacitance of dielectrics is to be investigated thoroughly. Temperature dependence of the capacitance and permittivity at the frequency of 1 kHz for different thicknesses has been shown in Fig. 5 (A & B) respectively. The capacitance was found to increase with increasing temperature.

The temperature coefficient of capacitance (TCC) and permittivity (TCP) have been evaluated using the expressions

$$TCC = \frac{1}{C_s} \frac{dC}{dT} \quad (5)$$

$$TCP = \frac{1}{\epsilon'} \frac{d\epsilon'}{dT} \quad (6)$$

Table 2 summarizes the estimated TCC and TCP values for the films of different thicknesses at a frequency of 1 kHz. It is found that the TCC and TCP values increase with increase in thickness.

### 3.3. A.C. Conduction studies

The a.c. conductance  $G_p = \omega C_p \tan \delta$  was calculated at different temperatures from the measured values of capacitance and loss factor. The plot of a.c. conductance versus frequency is shown in Fig.6. The a.c. conductance has been found to vary according to the relation  $G_p \propto f^n$ , where the value of n depends on the temperature and frequency. The curves exhibit two dispersion regions one below 100 Hz and the other above 100 Hz. At room temperature n values range from 0.9 to 1.2. In the second region ( $> 100$  Hz), nearly all the curves approximate to a square law dependence on frequency and show less dependence on temperature at higher frequencies. A strong frequency dependence tending towards a square law at high frequencies suggests the electronic hopping mechanism for the conduction. A similar behaviour has been observed by various investigators [32-34] on insulating dielectric thin films. In the

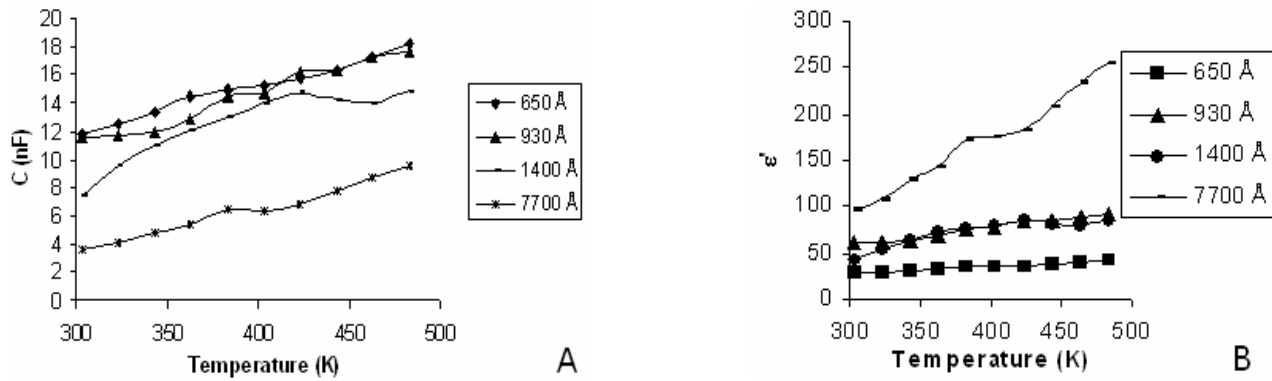


Figure 5. (A & B) showing the variation of capacitance and permittivity with temperature for ZnTe thin films different thickness at a frequency of 1 kHz.

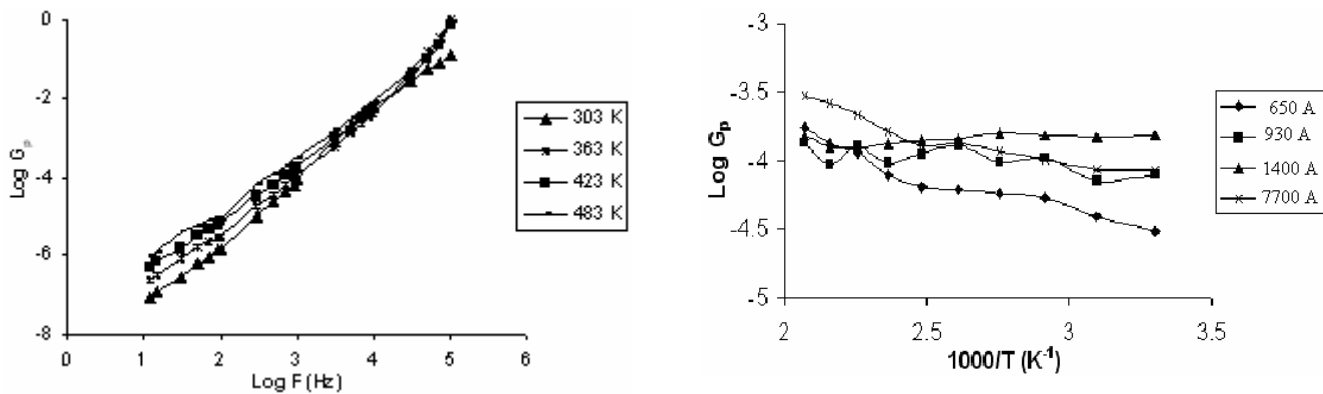


Figure 6. Dependence of conductance on frequency at different temperatures for ZnTe thin film of thickness 7700 Å

Table 2. Thickness dependence of TCC and TCP values

S.No.	Thickness in Å	TCC in ppm/K	TCP in ppm/K
1.	650	1355	2611
2.	930	3053	3125
3.	1400	4285	3355
4.	7700	5172	5128

Table 3. Dependence of Activation energy on thickness

S.No.	Thickness in Å	Activation Energy in eV
1.	650	0.059
2.	930	0.044
3.	1400	0.024
4.	7700	0.013

first region (<100 Hz), the slopes of the curves are less than two and are found to be temperature sensitive. Jonscher [35] accounted for this behaviour on the basis of easy and difficult hops of the carriers between the possible sites. The value of  $n$  decreases as the temperature increases. The contributions to conductivity from the carrier movement (carrier movement between and within the defect wells) at different temperatures are different, thereby resulting in

Figure 7. Variation of dielectric constant with log frequency at different temperatures for ZnTe thin film of thickness 7700 Å

the decrease of  $n$  with increase of temperature. This behaviour suggests that the mechanism responsible for a.c. conduction is of the hopping type and is consistent with the result reported on various hopping systems.

Fig. 7 exhibits the thickness dependence of conductance at 10 kHz and the estimated activation energy is presented in Table 3. As seen in the table, the activation energy decreases as the thickness increases. The observed low value of activation energy suggests that the conduction mechanism in these films may be due to the hopping of electrons, which is in accordance with earlier investigations on other semiconducting films [33, 35-37].

#### 4. CONCLUSION

Zinc Telluride thin films formed by vacuum evaporation technique possess crystalline structure. In the low frequencies and at higher temperatures, the capacitance is dependent both on temperature and frequency whereas it is independent of frequency at low temperature and high frequencies. But the loss factor always shows a dependence on frequency and temperature. The large value of TCC and TCP of the material is suitable for capacitor applications. The a.c. conduction mechanism in the films has been explained on the basis of hopping of charge carriers.

## 5. ACKNOWLEDGMENTS

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