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The influence of thickness and deposition temperature on the conduction activation energy of $CdSe_{0.2}Te_{0.8}$ thin films

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The electrical conductivity and stability in resistance of $CdSe_{0.2}Te_{0.8}$ thin films in different ambients and deposited at different substrate temperatures were investigated. A reduction in conduction activation energy with increase in film thickness and deposition temperature is accounted for by the fact that in $CdSe_xTe_{1-x}$ inhomogeneous semiconductor thin films, the potential relief inhomogeneity may be reduced with increase in film thickness and substrate temperature, which results in the decrease of conduction activation energy of the films.

1. Introduction

$CdSe_xTe_{1-x}$ solid solution films are extensively used in semiconductor device technology [1–3]. Some of the published data on the electrical conduction mechanism of thin films of this material are in variance [3–5]. Shevchenko *et al.* [4] observed a decrease in electrical resistivity of the films with increase of 'x', where $0 < x < 1$. But Sanitarov *et al.* [5] observed an increase in the resistivity up to $x = 0.5$ and then a steady decrease. Later works [6–9] on the electron transport properties of these films by varying the value of 'x' are not sufficient enough to understand the electrical transport in the thin films of this material.

We have chosen $CdSe_{0.2}Te_{0.8}$ from $CdSe_xTe_{1-x}$ (where $0 < x < 1$) to study extensively the electrical conduction mechanism and stability of the films in different ambients. Through this paper, we try to analyse the dependence of conduction activation energy on thicknesses and deposition temperature of the films. As deposited films were exposed to different ambients to study the stability of the films in these environments. All the measurements were done identically in vacuum, oxygen and atmosphere. Films deposited at different substrate temperatures and for a particular deposition temperature, films of various thickness were studied to understand the modification of activation energy by these parameters. All the measurements were carried out in different ambients with a view to study the effect of heating in these environments on the activation energy and stability of the films. The experimental data is interpreted by considering the fact that $CdSe_{0.2}Te_{0.8}$ is an inhomogeneous semiconductor with deep impurity levels possessing very large potential relief inhomogeneity [9]. This paper correlates the film thickness and deposition temperature of $CdSe_{0.2}Te_{0.8}$ thin films with the potential relief inhomogeneity arising as a result of the microfluctuations in the film composition and barriers at the boundaries of growth figures.

2. Experimental procedure

Preparation of the bulk sample was done by sealing research grade CdSe and CdTe in appropriate quantities into evacuated quartz tubes and heating in a furnace at 950° C for 24 h before quenching in water. Thin glass substrates were used for deposition of the films. Well-cleaned glass substrates were kept at a distance of 20 cm from the source. Precoated Indium was used as contact for resistance measurements. The resistance was measured by a Keithley 610 C electrometer. A radiant heater was used for heating the films uniformally. The substrate temperature was measured using copper-constantan thermocouple. The pressure inside the vacuum chamber was maintained at 10^{-5} torr during deposition as well as measurements. The thickness of the film and deposition rate were controlled using a quartz crystal thickness monitor. The structural characterization was done by X-ray diffractogram method. Different gases were admitted into the vacuum chamber by using a control valve.

3. Results and discussion

The structural analysis of the films by X-ray diffractogram method showed that the film structure is cubic (zinc blende) with the crystallites oriented in the (1 1 1) direction as shown in Fig. 1. Grain size calculations showed an increase in grain size with increase in the film thickness and deposition temperature.

As deposited films were exposed to oxygen and atmosphere to study the stability of the films in these environments. The film resistance remained steady showing that there is no oxygen adsorption on the film surface compared to those films with more CdSe than CdTe percentage, which showed considerable ageing in oxygen and atmosphere [10]. Chan and Hill [11] and Somorjai [12] have reported about the oxygen chemisorption on the CdSe film surface. But CdTe films have not shown any ageing in oxygen or atmosphere. From this study it may be inferred that as the

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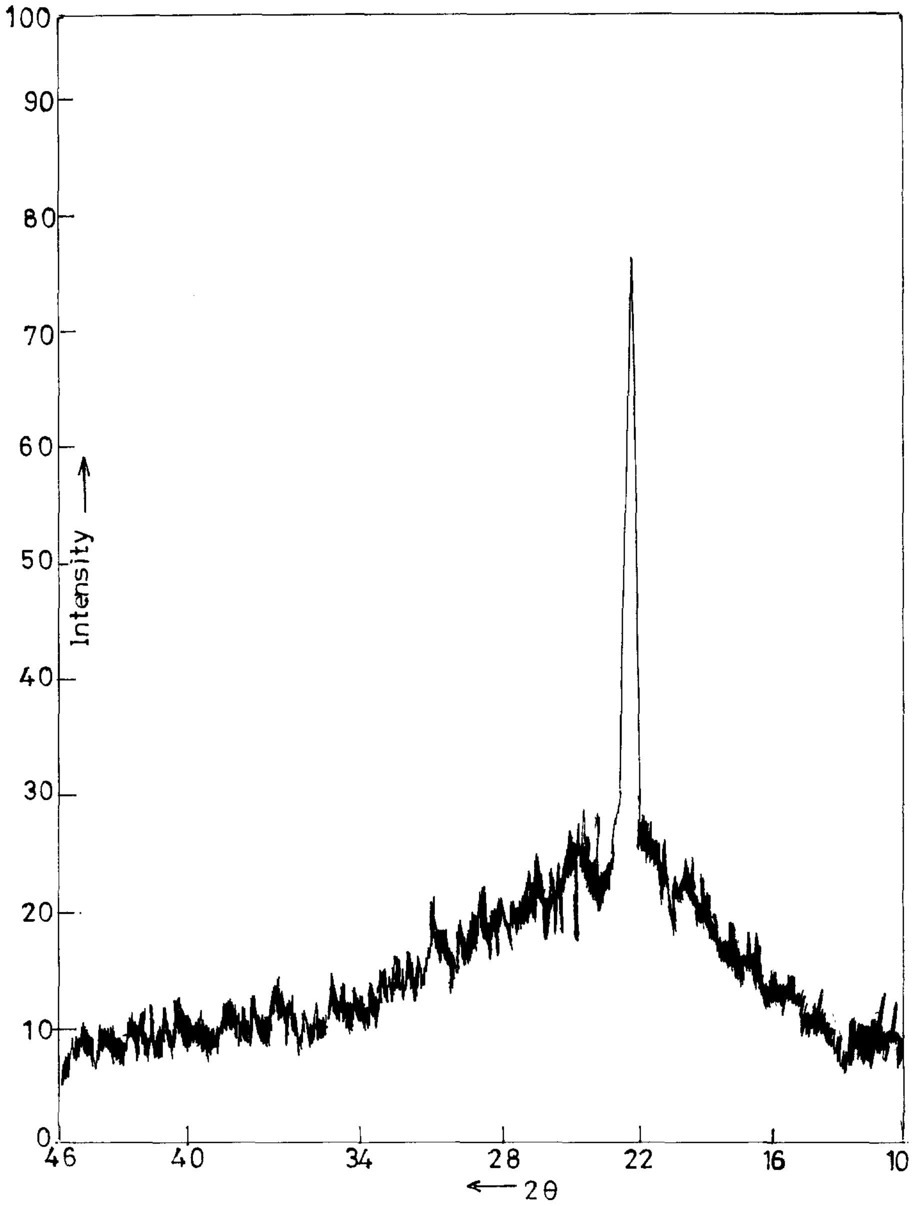

Figure 1 Typical X-ray diffractogram of $CdSe_{0.2}Te_{0.8}$ thin films.

CdSe percentage in $CdSe_xTe_{1-x}$ thin films increases, they become more unstable in oxygen and atmosphere.

The films were deposited at substrate temperatures varying from room temperature to 100° C on well cleaned glass substrates. The films deposited at higher substrate temperatures were cooled down to room temperature and further heating and cooling cycles showed the same behaviour. Thin films of different thicknesses varying from 390 nm to 1130 nm were deposited on glass at a substrate temperature of 348 K and the temperature response of resistance was recorded using the electrometer. The conduction activation energy was calculated from $\ln R$ against $1/T$ plot, where R is the resistance of the film and T, the film temperature in degree kelvin. The observed variation is shown in Fig. 2. From the figure, it is obvious that $\ln R$ against $1/T$ plot is linear throughout the temperature range (room temperature to 100° C). But from Fig. 2 and Table I we can see the variation of conduction activation energy with thickness of the film. Table I gives the observed variation of conduction activation energy with thickness of the films deposited at 348 K. From Table I one can see that activation energy decreased with increase in thickness of the film. The same measurements were carried out in films of a particular thickness (420 nm) deposited at substrate temperatures varying from room temperature to 100° C. In the latter case also one is able to find a decrease in activation energy with increase in deposition temperature. The observed variation is shown in Fig. 3 and Table II. The same measurements were repeated again in oxygen and atmosphere to find

TABLE I Variation of conduction activation energy with thickness in vacuum of the films deposited at 348 k

d(nm)	E_a (eV)
390	0.43
420	0.33
1030	0.17
1130	0.11

TABLE II Variation of conduction activation energy with deposition temperature in vacuum of a film thickness 420 nm

T_s (K)	E_a (eV)
308	0.40
323	0.35
348	0.33
373	0.16

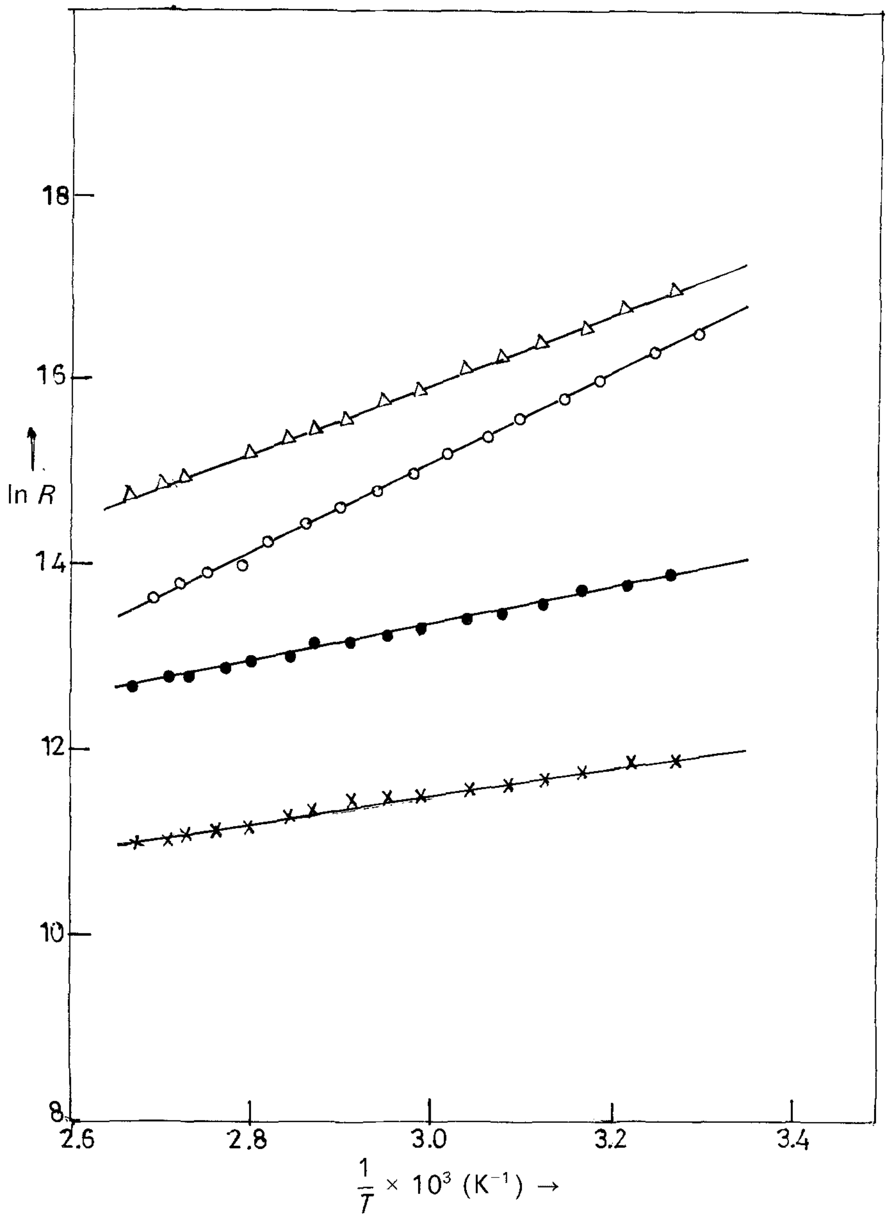

Figure 2 ln R against $1/T$ plot in vacuum of the films deposited at 348 K; O390 nm, △ 420 nm, ● 1030 nm, × 1130 nm.

out any effect of gas adsorption on the film surface. But we ended up with the same type of behaviour as observed in vacuum. In the tables given below, 'd' is the thickness of the films in nm, T_s is the deposition temperature in degree kelvin and E_a is the conduction activation energies in electron volts for the films heated in vacuum. From the same values of activation energy for films heated in vacuum as well as in oxygen, it may be concluded that there is no oxygen adsorption on the film surface, which would have changed the value of activation energy. The effect of oxygen adsorption on the film surface has resulted in a variation of activation energy in the case of films with the amount of CdSe more than that of CdTe in the solid solution. This behaviour has been observed in $CdSe_{0.6}Te_{0.4}$ thin films [10]. This result shows that it is the amount of CdSe present in the solid solution films which controls the ageing of the films in oxygen and atmosphere.

Belyaev and Kalinkin [9] have done studies on the electrical conduction mechanism in $CdSe_xTe_{1-x}$ thin films. They have found out that $CdSe_xTe_{1-x}$ thin films are inhomogeneous semiconductors with deep impurity levels possessing large values of potential relief inhomogeneity associated with the impurity zone as well as the intrinsic zones. If the potential relief is of large scale, then conduction in these semiconductors is effected by electrons excited to the percolation level [9] and is described by

$$\sigma = \sigma_0 \exp\left[\frac{E_p - E_f}{kT}\right] \qquad (1)$$

where 'E_p' is the percolation level and 'E_f' is the fermi level. But in films with $x < 0.3$, the inhomogeneity in potential relief is so great that tunnelling effects cannot be neglected [9]. So at high temperatures the conduction in films with $x < 0.3$ is effected by electrons excited to the mobility edge [9], and is given by

$$\sigma = \sigma_m \exp\left[-\frac{E_m - E_f}{kT}\right] \qquad (2)$$

where E_m is the mobility edge. The large values of activation energy obtained for $CdSe_{0.2}Te_{0.8}$ thin films (refer tables) agrees well with Belyaev and Kalinkin's [9], observation that as the percentage of CdSe in the compound decreases, the potential relief inhomogeneity becomes large scale in nature, hence the

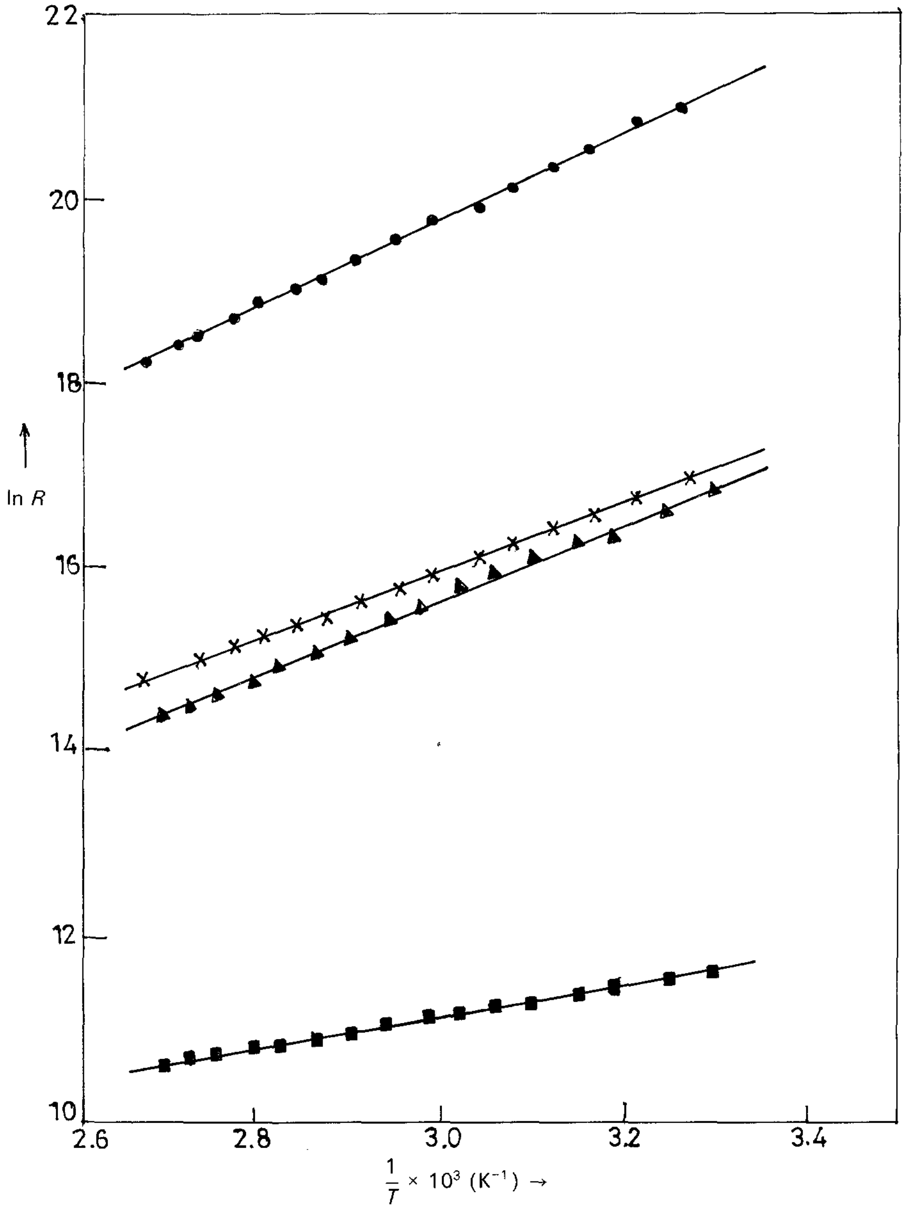

Figure 3 ln R against $1/T$ plot in vacuum of the films (4200 nm) deposited at different substrate temperatures ● 308 K, ▲ 323 K, x 348 K, ■ 373 K.

conduction activation energy increases. In these films the potential relief inhomogeneity associated with the impurity zone is formed by barriers at the boundaries of growth figures [9]. It has been established that as the film thickness and deposition temperature increases the crystallinity improves very much, which results in the reduction of barrier width. This will reduce the energy needed to activate the charge carriers to the mobility edge of $CdSe_{0.2}Te_{0.8}$ thin films. So, as the film thickness and deposition temperature increase, the conduction activation energy decreases in $CdSe_{0.2}Te_{0.8}$ thin films. This variation in conduction activation energy is shown in Tables I and II and in Figs 2 and 3. The same value of activation energy obtained in vacuum and oxygen shows that there is no oxygen adsorption on the film surface.

4. Conclusion

$CdSe_{0.2}Te_{0.8}$ thin films are stable in vacuum as well as in oxygen and atmosphere. The observed reduction in conduction activation energy with increase in film thickness and deposition temperature is explained by the fact that the potential relief inhomogeneity associated with the impurity zone may be reduced with increase in film thickness and deposition temperature. The film conductivity was found improving with increase in thickness and deposition temperature.

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