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Temperature Dependence of Electrical Properties and Thickness of II-VI Solid-Solution of CdTe Thin Films Prepared by Spray Pyrolysis

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Abstract: ***CdTe thin films deposited by using aqueous solution of cadmium chloride and tellurium tetrachloride of 0.02 M of each at differentsubstrate temperature from 300^{0}C to 375^{0}C in the interval of 25^{0}C. Arrhenius plot show the each curve has two segments. At lower temperature region 300 K to 450 K shallow trapping state appears due to the formation of interstitial of cadmium or telluride vacancies are expected to dominate the extrinsic conductivity near room temperature while at higher temperature region 450 K to 573 K deep traps appears to be operative. As the preparation temperature of the films increases, the activation energy also increases. This indicates the increases of grain size of the films which reduces the grain boundary effect. Indicating the formation of polycrystalline films of n-type semiconductor.***

Keywords: CdTe Thin films, Spray pyrolysis, activation energy

1. Introduction

In the last decade, there has been growing interest in the preparation and study of physical properties of CdTe thin films and solid solution crystals. The high resistivity II-VI compounds semiconductor e.g. ZnTe, CdTe, and their alloys $Cd_{1-x}Zn_xTe$ with stoichiometric value 'x' are the potential material used for room temperature X-ray and Gramma-ray detectors, infrared detectors, solar cells,lux meter, switching devices and schottky barrier and other upto electronic devices because it has band gap energy less than 2 eV by controlling stoichiometry. Cadmium telluride is a unique among II-VI series of semiconducting compounds as it shows both n-type and p-type conductivity. It is an especially attractive devices in high efficient tandem structures. At present CdTe substrates are the most favored material for epitaxial deposition of the important infrared detector materials $Hg_{1-x}Cd_xTe$. Moreover, it has been found that the lattice matching among these two solid solution is optimized by using $Cd_{1-x}Zn_xTe$with x=0.04. Thus minimizing the density of defects associated to misfit dislocations.

The increasing interest in the use of CdTe thin films in particular corresponding to band gaps smaller than 2 eV, demands in extensive characterization of all physical properties related to the structural, electrical as well as optical properties relevant for the above mentioned applications. In this work we report the detailed study of electrical properties and thickness dependence with temperature of CdTe thin films. There are several method to prepared thin films of CdTe, such as, vacuum evaporation, flash evaporation,r.f. sputtering chemical vapour deposition, chemical bath deposition and spray, pyrolysis (1-3). We have chosen spray pyrolysis method due cheap, inexpensive and produce on large substrate area.

2. Experimental Details

Aqueous solution of cadmium chloride and tellurium tetrachloride of 0.02 M were prepared in double distilled water. These two solutions was mixed in one in the proportion of 1:2.2 by volume and insert in the sprayer. Chemical were used as AR-grade. Sprayer was mechanically move to and fro to avoid the formation of droplets on the pre-heated glass substrate and insure the instant evaporation from the substrate. Films shows the tellurium deficiency if the ratio of solution of proportion was taken as 1:1 by volume (1-3). The temperature of the substrate were used from 300^{0}C to 375^{0}C by changing in the interval of 25^{0}C. The spray rate was maintained of 3.5 ml/min at the pressure 12 kg/cm^2. Temperature of the substrate was measured by pre-calibrated copper constantan thermocouple. Electrical resistivity were measured by using four probe method. Conductivity of the films was tested by hot probe method.

3. Electrical Properties

Conductivity of the films was tested by hot probe method wasof n-type semiconductor. Fig.1 shows the Arrhenius plot of conductivity verses inverse temperature as depositedCdTe thin film prepared at different substrate temperature.

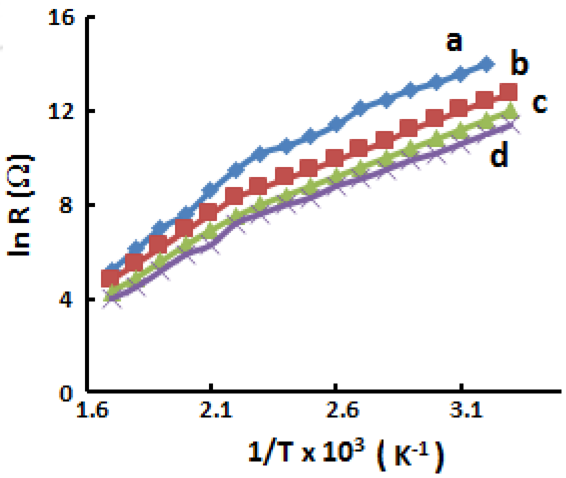

Figure 1: Arrhenius plot of conductivity verses inverse temperature ofas depositedCdTe thin film for a) 300^{0}C b) 325^{0}C C) 350^{0}C & 375^{0}C.

The thin films of CdTe were prepared at different temperature a) 300^0C b) 325^0C C) 350^0C & 375^0C.

Electrical resistivity of the films was calculated by using four probe method (4) given by,

$$\varrho = 2\pi s\ V/I\ /G_7\ (t/s) \quad (1)$$

$$\text{and } G_7\ (t/s) = 2s/t\ \ln \quad (2)$$

Where s-the distance between the probes, t-be the thickness of the films I be the current generated from constant current source between the inner probes, V-the voltage between outer probes.

The temperature dependence of conductivity was studied from 300 K to 573 K and it is given by the relation,

$$\sigma = \sigma_0 \exp(-Ea/kT) \quad (2)$$

Where σ_0-the pre-expontial terms, k-the Boltzmann constant, T-the absolute temperature, Ea- the activation energy measured from the bottom of conduction band. Fig.1 shows the Arrhenius plot of conductivity for different prepared temperature. Each curves shows the two conduction region, a) 300 K to 450 K b) 450 K to 573 K. The slope is small in the low temperature region but it increases if the further temperature increases. From the slope of each curve the activation energies were calculated and tabulated in table.1. It was observed that increase the temperature of the films, thickness of the films as well as activation energy increases upto the optimised temperature 350^0C. But increase the temperature further increase, the thickness of the films decreases but increase of activation energy takes place. This shows that grain size of the films increases, which reduces the grain boundary effect. This is due to the formation of n-type semiconducting polycrystalline films of nearly stoichiometric in nature. This results are well agree with the results reported by the other workers (5,6) for the different preparation technique ofCdTe thin films. The higher the conductivity value at lower temperature is an evidence of the adsorption-desorption phenomenon whereas a saturation of conductivity value at higher temperature is a consequence of homogeneous nucleation and diffusion controlled process.

Similar observation also observed in ZnSe thin films prepared by the spray pyrolysis (7). They stated that activation energy increases at higher temperature may be due to the attributed to the increase of optical band gap. Hence the grain size of the films increase, which reduces the grain boundary effect. Hence it is evident that in CdTe thin films the possibility of shallow trapping state due to the interstitials of cadmium or telluride vacancies are expected to dominates the extrinsic conductivity near the room temperature.Whereas at higher temperature deep traps states influence are probable appears.

Table 1

Temperature $T(^0C)$	Activation energy Ea (meV) 300 K-450 K	450 K-573 K	Thickness $t(\mu m)$
300	70	90	0.136
325	100	578	0.153
350	190	780	0.185
375	300	860	0.170

From the table-1 it is clear that if the preparation temperature of the films increases, the continuous activation energy increases which indicates that optical band gap energy increases. This suggest that grain size of the films increases which reduces the grain boundary effect. This indicate the CdTe thin films have good stoichiometric with polycrystalline n-type semiconductor.

4. Conclusion

It is evident that if the preparation temperature increases, the activation energy also increase, this increases the grain size of the films which reduces the grain boundary effect. From the Arrhenius plot at lower temperature (300 K to 450 K) shallow trapping state due to the formation of interstitial of cadmium or telluride vacancies are present. But which at higher temperature (450 K-573 K) deep traps states influence are probable appears.

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