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Electrical Characterisation of CdTe Thin Films

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Abstract: ***We report the results obtained from the Electrical Characterisation of CdTe thin Films grown by Flash Evaporation technique. The objective of this work is to determine its stability for optoelectronics devices and passivation of Mercury cadmium Telluride. Important aspects in CdTe thin films optimisation of deposition conditions and effects of photo thermal annealing in hydrogen environment on the electrical properties are also investigated.***

Keywords: CdTe, Flash Evaporation, Electrical Characterisation, Activation Energy, Thin Films

1. Introduction

Cadmium Telluride Thin films have a very importance place in the semiconductor industry. They have been investigated extensively for the development and production of Photovoltaic (1, 2) optoelectronic (3) and IR devices (4). In recent years CdTe has emerged as a potential material for HgCdTe photo diodes since its a wide gap semiconductor which is nearly lattice matched and chemically compatible to MCT (5, 6). Some work has been carried out on single crystal of CdTe (7, 8). CdTe Epilayers were grown by MOCVD (9-12), Sputtering (13) and Thermal Evaporation (14-15) and Electron Beam Evaporation (16). Unfortunately the preparation of high quality stoichiometric films is very crucial problem with the material and require stringent growth conditions. To overcome this problem, we deposited thin films by Flash Evaporated Technique. Cadmium Telluride thin films were deposited by Flash Evaporation technique which is very simple and convenient method. Since a very little information was available on deposition of CdTe by this technique, a very careful study was under taken on various parameter involved in the deposition of CdTe thin films. For the deposition of CdTe thin films by Flash Evaporation system, the following growth conditions were optimised and used.

1) Vacuum in chamber ~ 10-6 torr
2) Deposition temperature ~ Room Temperature
3) Boat temperature ~ 1400oC
4) Deposition Rate ~10Å/ Sec

In the Flash Evaporation technique a proper selection and control of evaporation boat and substrate temperature provide adequate control of stiochiometry of the films. Here a very small quantity of the CdTe material was dropped into the preheated boat, resulting in its instantaneous (Flash) evaporation. It was observed that a lot of material was lost by splattering if a simple open boat was used for Flash Evaporation. In addition to this the deposited films appeared to be uneven with pin holes. This could be possible due to deposition of some very fine splattered grains of source material which got carried on to the substrate by the stream of evaporated material. It was not possible to reduce splattering by increasing the boat temperature. This problem was, however, overcome by employing a modified design of the evaporation boat. This boat was covered by a cover which had an entrance aperture and a large number of exit apertures. Its size was optimised to ensure that the amount of evaporated material fed into the boat through the hole was minimum. This particular design of boat was found to almost prevent splattering and preferential loss of the more Volatile Components.

2. Experimental Technique

Thin Films of CdTe were deposited on optically polished glass, mica and quartz substrates, under a vacuum of 10-6 torr. Prior to deposition, the glass microslides, quartz and mica substrates were subjected to extensive cleaning. For this purpose, the substrates were initially thoroughly washed with liquid detergent and later rinsed repeatedly in distilled water. These were boiled in 50% nitric acid solution for fifteen minutes followed by thorough washing with deionised water. The substrate was then degreased in vapours of isopropyl alcohol. The substrates were mounted in the rotating substrate holder which was held in the vacuum chamber such that substrates were located at a distance of ~15cm from the evaporation boat. A molybdenum boat with cover having a 3.5mm diameter entrance aperture for the source material and a large number (25) exit apertures of 0.75mm diameter each was used for evaporation. The boat cover was used to minimize the effects of splattering. The material was intermittedly fed by the hopper- vibrator arrangement of the flash evaporation jig, onto the preheated boat. The boat was maintained at ~1400^{0}C. The film growth was continuing till the appropriate thickness was obtained. A quartz crystal monitor was used to control the deposition rate and thickness of the film. The substrate holder was rotated slowly to obtain uniform thick films. The film growth was continued till films with appropriate thickness were obtained. A quartz crystal monitor was used to control the deposition rate and thickness of the film. The starting material was CdTe powder from Balzer‟S 99.9% purity.

Elecrical Characteristics

Resistivity measurements of CdTe thin films deposited on glass slides were carried out at room temperature and at 77K using the Van der Pauw method. The films were first annealed in hydrogen atmosphere (with out using the Hg tub) at 100°C, 150°C, 200°C and 250°C for 2, 3, 2 and 1 hours respectively Room temperature resistance was observed to increase from 1.5E4 ohm-cm to 9.4ohm-cm as the annealing temperature was increased from 100 to 250°C. The increase in resistivity was sharper for films annealed between 100 and 200°C and it was less pronounced thereafter at higher temperatures. A graphical representation of these results is made in fig.1. It may be observed that the graph has a steeper slope as

annealing temperature is increased from 100 to 200°C and below and above these temperatures the annealing temperature does not seen to influence the resistivity so much. The resistivity showed a sharp increase of four orders of magnitude, i.e. from 10^4~ 10^8 as the temperature was decreased from room temperature to 77K. The resistivity of the annealed films was higher as compared to the unannealed ones indicating that annealing in hydrogen atmosphere has helped passivate the defects by neutralising the dangling bonds present in the CdTe films Thus we may conclude that annealing in hydrogen atmosphere as carried out by us leads to passivated, better quality films. The variation of resistivity Vs temperature of CdTe deposited films was also measured from 50K to 400K. The CdTe films deposited on mica substrates were annealed in hydrogen atmosphere in the presence of UV photons. The deposited CdTe 5 films were annealed at 80^0C for different durations viz. lh,2h,3hand 4h under the conditions as described above. Resistivity Vs. Temperature plots for different annealing durations are shown in fig. 2. It is observed that the resistivity increases with decrease in measuring temperature. All plots show a small increase in resistivity as the temperature is reduced from 400K to 250K and after this there is a linear increase in resistivity with decrease in temperature from 250K to 50K. The maximum value of resistivity is attained at 50K Results of the resistivity measurements at room temperature and 77K are plotted as a functions of annealing duration in fig.3. It is observed that there is an improvement in resistivity from 2.4E4 ohm-cm to 3.23E5 ohm-cm at room temperature, when the annealing duration is increased from 0h to 4h. Similar observation has been made in the other set of Resistivity Vs Temperature plots at 77K in fig.4, where resistivity increases from 1.03E6ohm-cm to 9.0E6 ohm-cm with increase in annealing duration from Oh to 4h. The CdTe thin films deposited on glass slides were annealed in H2 atmosphere in the Photo CVD unit. All conditions involved in this process are same as those for the results discussed above, only Hg bath is incorporated this time during annealing. The Hg tub is kept at temperature of 100°C. The results of resistivity Vs annealing, where H_2 is bubbled through Hg bath at 100°C is shown in fig.4. It is observed that with the incorporation of Hg at 100°C there is decrease in resistivity from 2.4E4 ohm-cm to 2.4E3 ohm-cm for the unannealed samples to the samples subjected to annealing for 3hours at 80°C. The temperature dependence of the resistivity is given by the expression p = po exp.(w/kT), where w is the activation energy, k is Boltzman's constant and T is the absolute temperature. When In p is plotted as a function of 1/T, the slope of the plot gives w/k. The activation energy 'w' is calculated from this graph of In p Vs. 1/T. The plots of In p against 103/T for different annealing durations in hydrogen are shown in fig.13. All the graphs plotted between In p Vs. 1/T in these figure 5 show two distinct regions having different slopes. These have been classified as region 1 and region 2 in our analysis. Region 1 corresponds to the higher temperature range of characterisation while region 2 corresponds to the observations made when the sample was maintained at the lower range of temperature. The activation energy has been calculated separately for these two regions in each set of samples and noted in table .1. For all sets the calculated value of activation energy shows a decrease as we move from region-1 corresponding to higher temperature to region -2 corresponding to low temperature The value of activation energy as calculated from these plots has been found to decrease with annealing time in both low temperature as well as high temperature activation regions. The two regions of activation energy may be 6 attributed to the presence of two valence bands. The high value of activation energy in high temperature region i.e. Region 1 is due to the fact that number of free electrons for conduction in conduction band at higher temperature are more as compared to low temperature region i.e. Region-2.

3. Conclusions

The decrease in activation energy with increase in hydrogen annealing duration at 80°C in presence UV photons may be due to the improvement in crystallinity (17-18) and short range order in films and also dangling bonds may be assumed to be satisfied, the binding energy to the charge carriers is reduced, resulting in a low value of activation energy. Hence Suitable optimum material for optoelectronics devices.

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Table 1

S.No.	Annealing Time (hours)	Activation Energy Region - 1 (eV)	Activation Energy Region -2 (eV)
1	with out annealing	0.0446	0.00416
2	1	0.03932	0.00330
3	2	0.03905	0.003232
4	3	0.02990	0.003017
5	4	0.00398	0.001293

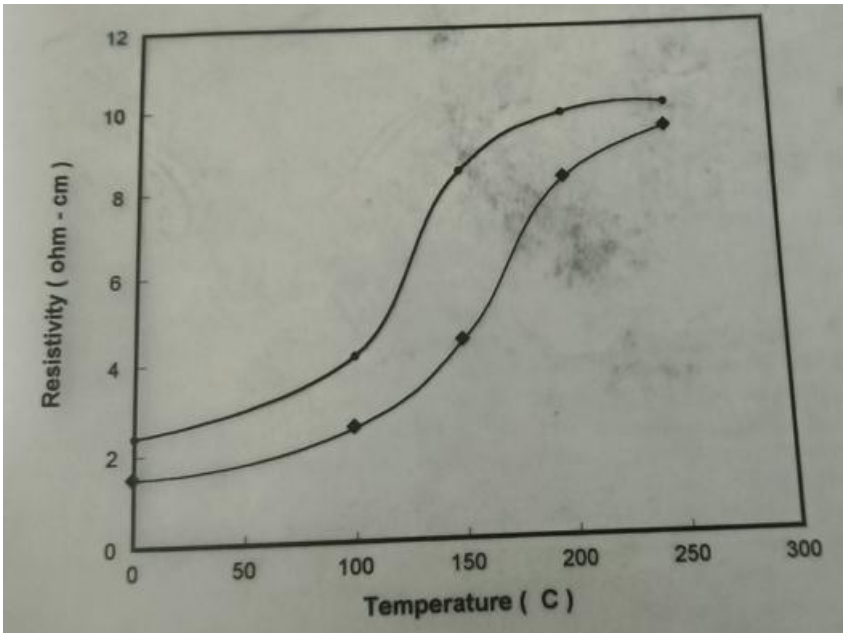

Figure 1: Resistivity VS Hydrogen Annealing Temperature.

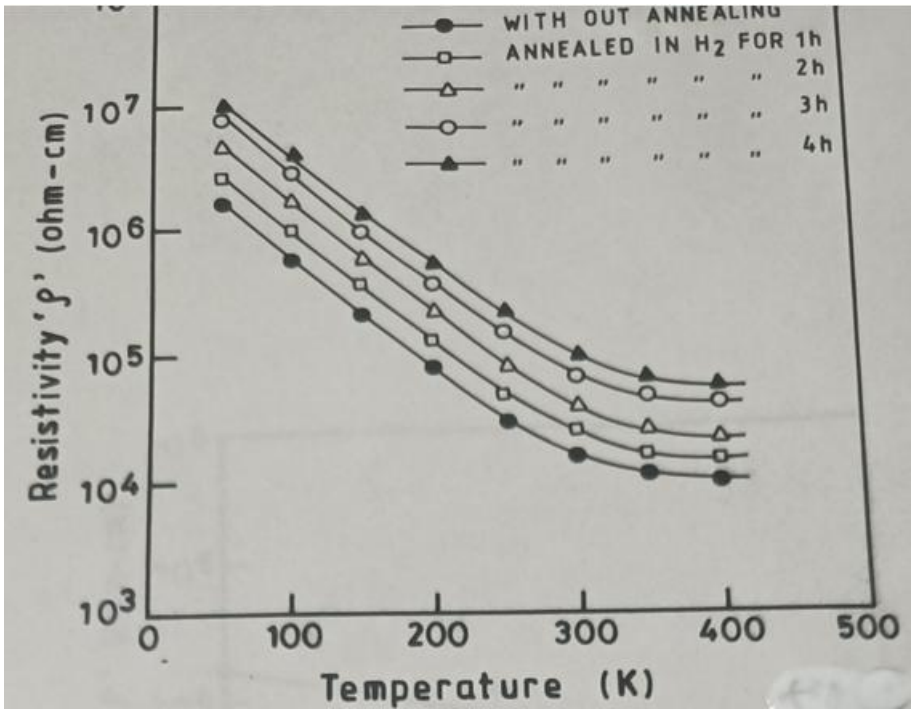

Figure 2: Variations of Resistivity vs. Temperature

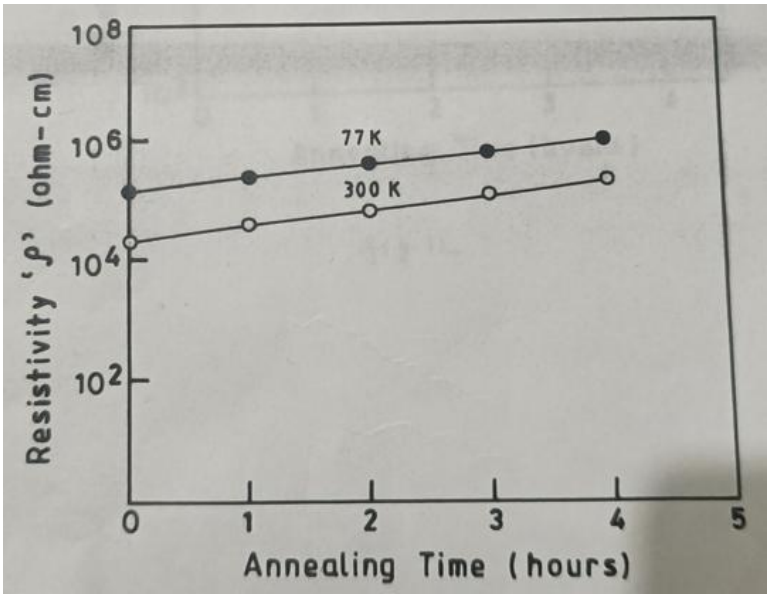

Figure 3: Variation of Resistivity VS Hydrogen Annealing

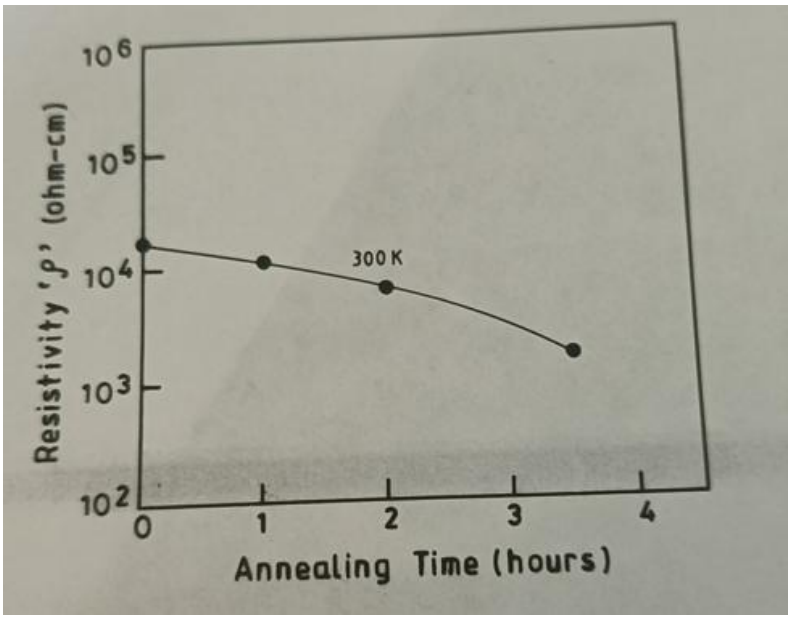

Figure 4: Variation of Resistivity VS Hydrogen Annealing. During annealing, the hydrogen was bubbled through Hg Tub. maintained at 100°C.

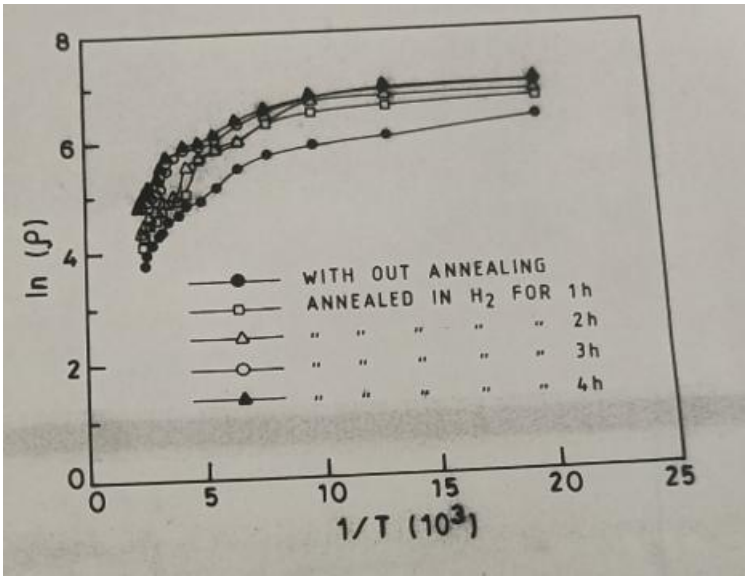

Figure 5: Plots of In p against 10^3/ T for CdTe films annealed for different annealing durations in hydrogen