# Isochronal Studies of the Structural and Electrical Properties of CdTe Films

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## Abstract:

The paper reports the influence of annealing temperature under vacuum for one hour on the some structural and electrical properties of p-type CdTe thin films were grown at room temperature under high vacuum by using thermal evaporation technique with a mean thickness about 600nm. X-ray diffraction analysis confirms the formation of CdTe cubic phase at all annealing temperature. From investigated the electrical properties of CdTe thin films, the electrical conductivity, the majority carrier concentration, and the Hall mobility were found increase with increasing annealing temperatures.

**Key words: sola, Cell CdTe film, structural CdTe, cds films.**

## Introduction:

The study of polycrystalline II-VI compound semiconductors is important due to their application in semiconductor devices technology, but the unique properties of CdTe make it an ideal material for several applications ranging from photovoltaic conversion, high energy flux detectors- such as X-ray and γ-ray detectors for electronic and optoelectronic devices, and there is interest in growth of high quality CdTe thin films for use as substrate for important infrared detector material HgCdTe, epitaxial layers and quantum well structures[1,2,3] .This material is recognized as one of the most promising semiconductor materials for the production of low-cost solar cells[4,5,6] . CdTe is unique among II-VI series of semiconductor compounds, as it exhibits both n- and p- type's conductivity; this permits the fabrication both homojunction and heterojunction configuration[7] .

In this paper, we study some structural and electrical properties of CdTe thin films annealing at different temperatures.

## Materials and Methods:

A polycrystalline CdTe thin film about 600nm thick were grown onto slides by thermal evaporation of the CdTe powder (purity 99.99%) after weighting CdTe material that required for the deposition. The chamber was evacuated to a pressure nearly $10^{-6}$ Torr. During the evaporation, the temperature of the evaporation source was about 1200K, the substrate temperature was kept at room temperature, so a thermocouple placed in contact with substrate reveal that the substrate temperature remains practically constant during the deposition. The molybdenum source – substrate distance was kept at 15cm and the deposition rate was0.9nm.$sec^{-1}$. When the system was pumped down to

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required vacuum, electric current was allowed to pass through the boat gradually, when the boat temperature reached the required temperature, the current was adjusted such that the compound evaporated completely at the required time, then the current was decreased gradually to zero value. The deposited films were left under high vacuum for, at least, 20 hours. After that the samples had been annealed in vacuum oven at different annealing temperatures (473, 523, and 573) K for one hour. Then films were provided with suitable masks to deposit the aluminum electrodes. It was observed that the result of electrical measurement were the same for both arrangements of the electrodes (over or under the semi conducting films). The structure of CdTe powder and films which prepared and annealed at different temperature have been examined by XRD with Cu-$K_{ά}$ wavelength 1.541Å, the scanning angle has varied in range (20°-50°). For D.C. conductivity measurement the resistance of the films as function of the temperature from (291-495) K at different annealing temperature was carried out, the measurements have been done with sensitive digital electrometer keithley 616 and electrical oven. Hall effect was carried out by using d.c. power supply, and two keithly to measure the passing current (I) and Hall voltage ($V_H$) that emerge after applied constant transverse magnetic field (B=0.257Tasla).

## Result and Discussion:

These results include the X-ray diffraction examination of CdTe powder, CdTe films as deposited, and CdTe films which treated at different annealing temperatures(473,523,573)K, also the result of electrical measurements(d.c. conductivity, Hall effect) of all films have been analyzed.

### Structural Properties

The spectra of CdTe powder as shown in Fig (1.a) exhibited sharp peaks at 2θ equal to 23.95$^o$, 39.55$^o$, and 46.67$^o$, which correspond to reflection from (111), (220),and ( 311) plans with preferential orientation in[111] direction. According to ASTM card 15-0770[8], these reflections represent a cubic structure having a zinc blend type.

Fig. (1.b, c, d, and e) showed the spectra of CdTe thin films deposited at R.T and annealed at (473, 523, and 573) K, which reveal the cubic phase with a preferential orientation in [111] direction. The preferential orientation in [111] of the films deposited on glass may be due to the larger stability of the {111} plans. This stability originates in larger density of bonds [9].

Similar behavior was also observed by Pandey et al. [10], Enriquez et al. [11]and Dawer et al[12].

The diffraction patterns of the films that deposited at R.T showed sharp peaks at 2θ equal to 23.2$^o$, 38.6$^o$, and 45.65$^o$ as shown in Fig. (1.b). While the peaks of film annealed at 200$^0$C appear at 2θ equal to 23.85$^o$, 39.5$^o$, and 46.54$^o$ as shown in fig. (1.c).

The diffraction pattern of the film annealed at 250C$^o$ exhibited sharp peaks at 2θ equal to 23.87$^o$, 39.43$^o$, and 46.58$^o$ as shown in fig. (1.d) and the height of the peaks increased. In addition to these peaks a small peak caused by a small a mount of free Te appeared at 2θ equal to 27.68$^o$. This may be attributed to the probability of re- evaporation Cd leaving an excess of Te on the film, which forms small crystalline grains [9]. Also a small peak cased by the hexagonal phase appeared at 2θ equal to 42.2$^o$ which correspond to diffraction from (103) plane.

The peaks of film annealed at $300^0$C appeared at 2θ equal to $23.95^o$, $39.5^o$, and $46.7^o$ as shown in fig. (1.e). Small peaks caused by Te and hexagonal phase appeared at 2θ equal to $27.62^o$, and $42.2^o$ respectively. The peak due to excess Te of film annealed at $250^0$C was higher than the peak of the films annealed at $200^0$C. This means that the free Te increase with increase annealing temperature. This result is in contrast with Dawar et al[12] who found the height of the peaks increase when the films annealed but they don't detected the hexagonal phase in these films.

## Electrical Properties

It is known that the study of the temperature dependence of the electrical conductivity of semi conducting thin films offers a lot of information about the correlation between the structure and the electrical properties of the films.

In order to study conductivity mechanisms, it is convenient to plot logarithm of the conductivity (In σ), as a function of (1\T).

Figures (2.a, b, c, and d) show the temperature dependence of conductivity of CdTe thin film as deposited and annealed at (473,523,573) K, in the temperature range (291-434) K. It can be observed from these figures that the conductivity is characterized by two stages of σ throughout the heating temperature range.

In this case the first activation energy ($E_{a1}$) occurs at higher temperature, this activation is due to the carrier excited into extended states beyond the mobility edge, while the second activation energy ($E_{a2}$) occur at lower temperature and the conduction mechanism of this stages is due to the carrier transport to the localized states near the valance and the conduction bands.

These two conduction mechanisms mean that the D.C. conductivity is non-linear with temperature [13].

Table (1) shows the conductivity at R.T. ($\sigma_{d.c}$=L\R.W.t), where L is the distance between the electrodes, R is the measured electrical resistance of the film, W is the width of the electrodes, and t is the thickness of film. $\sigma_{d.c}$ is found to increase with increasing the annealing temperature ($T_a$), so it increases from (1.503-22.37) $\times10^{-3}$ $(\Omega.\text{cm})^{-1}$ for CdTe thin films deposited at R.T. and CdTe thin films annealing at 573K respectively. In general the increasing of conductivity may attribute to the change in structure and state of the films as well as to the rearrangement of atoms on the surface of the substrate [14]. Also table (1) shows the values of activation energies ($E_{a1}$, $E_{a2}$) were determined according to the relation $\sigma_{d.c}=\sigma_0\exp\ (-E_a\backslash k_BT)$, where $\sigma_0$ is the minimum electrical conductivity, T is the absolute temperature, and $k_B$ is the Boltzmans constant. We noticed that the value of $E_{a1}$ and $E_{a2}$ have decreased with the increasing of Ta, so $E_{a1}$ decreases from (0.676-0.068) eV and $Ea_2$ decreases from (0.034-0.016) eV for CdTe thin films deposited at R.T. and CdTe thin films annealing at 573K respectively. The decreasing of $E_{a1}$ and $E_{a2}$ may be attributed to creation of localized states by the annealing.

Hall measurement shows that the CdTe films at different $T_a$ are p-type i.e., the conduction is dominated by holes, Bayhan et al. [15], and Sundari et al. [5] have found the same results, it is attributed to the presence of Cd vacant sites which form shallow acceptor levels[16]. Table (1) also shown the variation of carrier concentration ($n_H$ =1\$R_H$.e), where $R_H$ is the Hall coefficient [$R_H$= ($V_H$\I)×($t_h$\B)], and e is the electron charge, and also shown the variation of Hall mobility ($\mu_H=\sigma|R_H|$) with $T_a$ for

CdTe films, it can be seen that the $n_H$ increases with increasing Ta from (8.636-26.249) ×$10^{14}$ cm$^{-3}$, and also we can observe that the μH increases with increasing Ta from (10.877-53.262) cm$^2$\V.sec. This increasing of the $\mu_H$, and $n_H$ is due to the reduction of scattering of the carrier from the surface and the ionized impurities scattering gradually takes over, which agree with Ohmer[17] .

## Conclusion:

In the paper the influence of thermal annealing at (200,250, 300)$^0$C was investigated on the some structural and electrical properties for CdTe films evaporated on to unheated glass substrate by using thermal evaporation technique. The obtained data reveal that the structure and electrical properties of these films are influenced by the annealing treatment. The crystal structure of CdTe films at R.T, and 200$^0$C was of zinc blend type with the preferential orientation of (111) plan normal to the substrate. As the annealing temperature increase to (250, 300)$^0$C, the degree of preferential orientation toward the (111) plan increases, but the hexagonal crystalline phase coexists with the cubic phase. From electrical measurements we noticed that the carrier concentration (n) and electrical conductivity (σ) were modified by the film annealing.

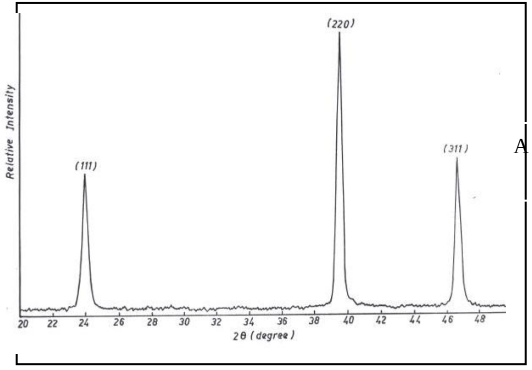


**Fig.1(a): X-ray diffraction pattern of CdTe powder.**

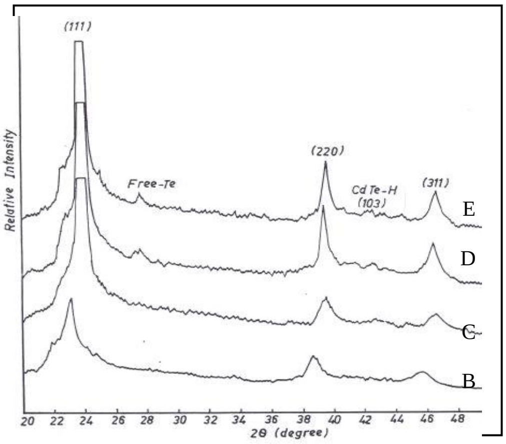
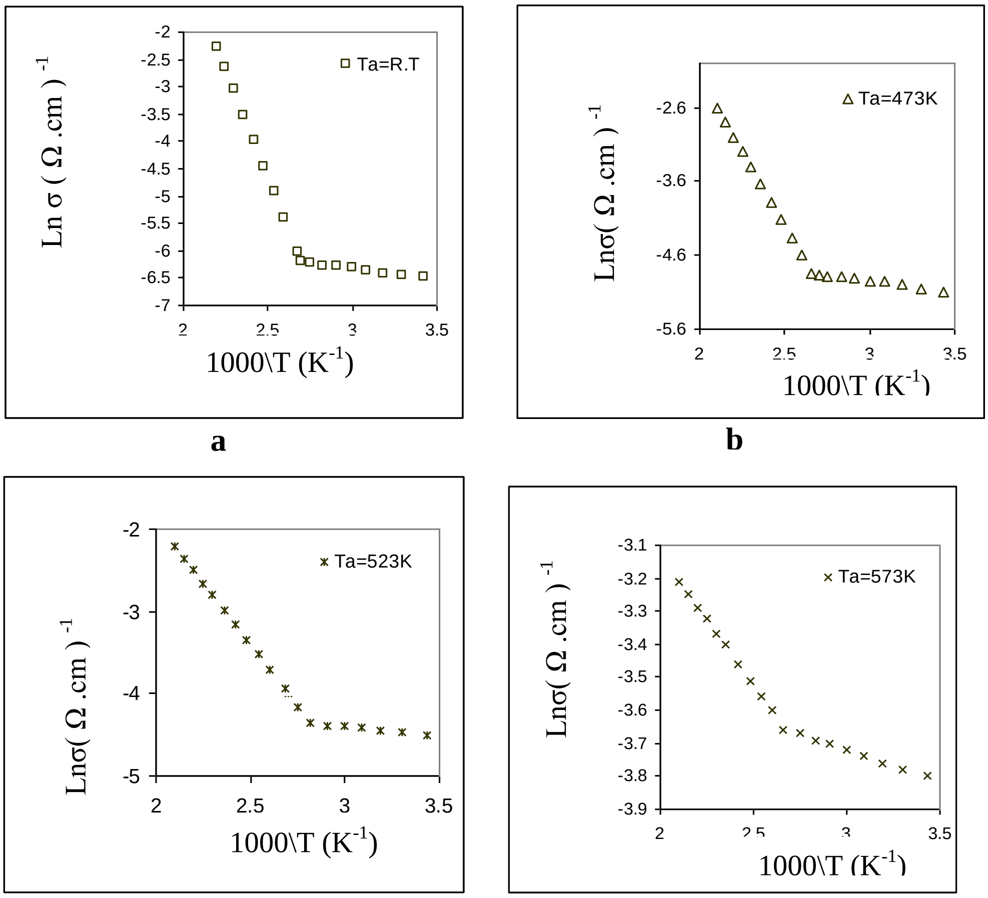


**Fig.1(b, c, d , e): X-ray pattern of CdTe at : R.T, $T_a$=473, 523, and 573 K.**

**Table (1): The experimental electrical parameters of CdTe thin films.**

| $T_a$ (K) | ($\sigma_{d.c}$) (Ω.cm)$^{-1}$ ×$10^{-3}$ | $E_{a1}$ (eV) | $E_{a2}$ (eV) | $R_H$ (cm$^{-3}$.C$^{-1}$) ×$10^3$ | $n_H$(cm$^{-3}$) ×$10^{14}$ | $_H$[cm$^2$.(V.sec)$^{-1}$] |
|---|---|---|---|---|---|---|
| R.T | 1.503 | 0.676 | 0.034 | 7.237 | 8.636 | 10.877 |
| 473 | 5.516 | 0.344 | 0.027 | 5.673 | 11.017 | 31.292 |
| 523 | 11.197 | 0.258 | 0.018 | 4.365 | 14.318 | 48.874 |
| 573 | 22.37 | 0.068 | 0.016 | 2.381 | 26.249 | 53.262 |



**a** **b**

**c** **d**

**Fig (2): The plots of Ln σ vs. 1000\T for CdTe thin films at: a- R.T b- $T_a$= 473 K c- $T_a$= 523 K d- $T_a$= 573 K**

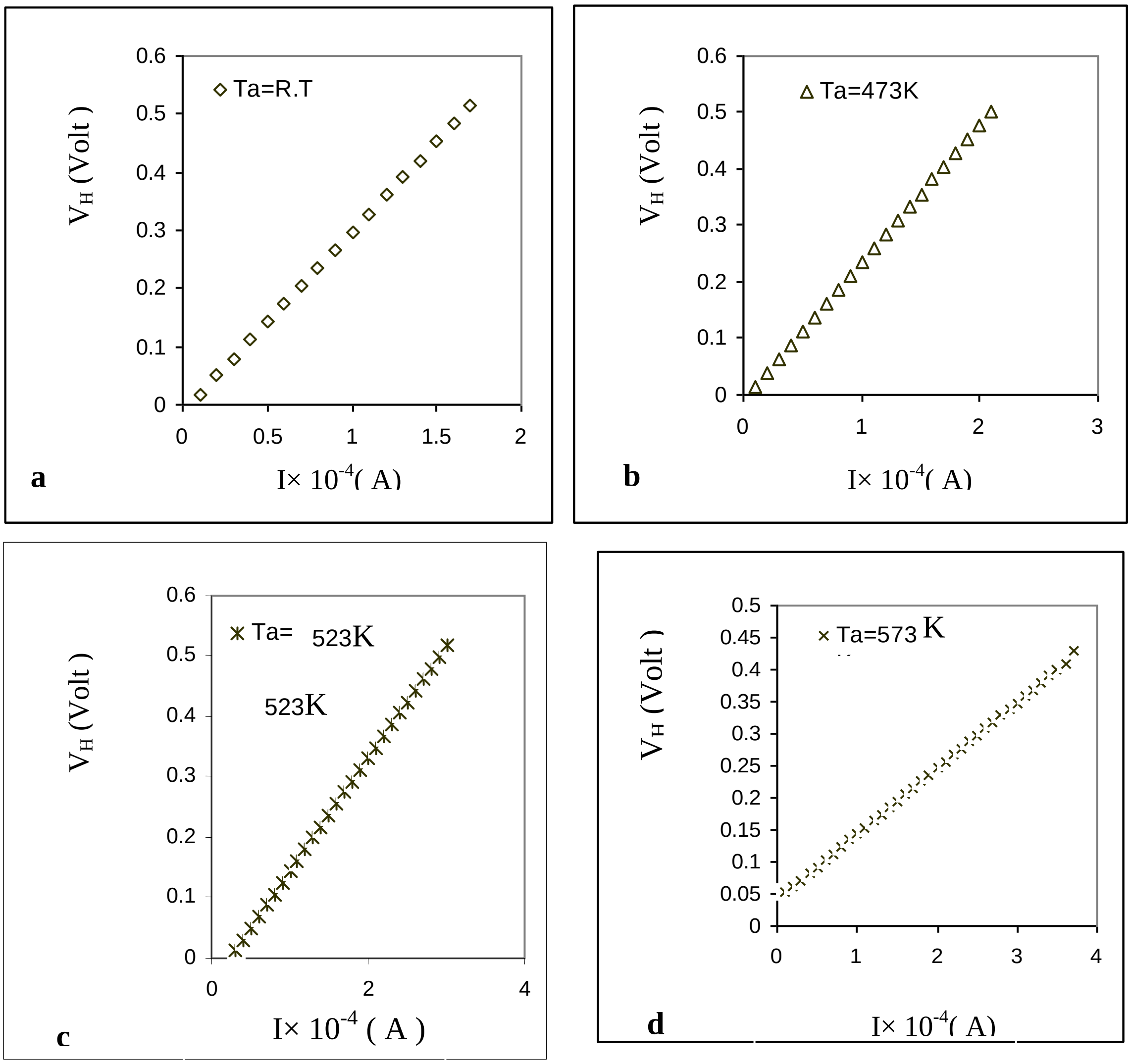


**Fig.(3): The relationship between Hall voltage and passing current for CdTe thin films at :a- R.T b- $T_a$ =473 K c- $T_a$= 523 K d- $T_a$= 573 K**

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# دراسة تأثير التلدين في الخواص التركيبية والكهربائية لأغشية الـCdTe

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## الخلاصة:

يبين البحث تأثير درجة حرارة التلدين في الفراغ ولمدة ساعة في بعض الخواص التركيبية والكهربائية لاغشية تيليرايد الكادميوم من النوع الموجب المرسبة على ارضيات زجاجية وبدرجة حرارة الغرفة والمحضرة بسمك 600nm باستعمال تقنية التبخير الحراري في الفراغ ويؤكد تحليل الاشعة السينية تكون الطور المكعبي لاغشية تيليرايد الكادميوم ولجميع درجات حرارة التلدين . ومن خلال البحث في الخواص الكهربائية وجدنا ان تركيز حاملات الشحنة الاغلبية ، وتحركية هول ، والتوصيلية الكهربائية المستمرة تزداد مع زيادة درجة حرارة التلدين.