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Effect of Diffusion Temperature on the some Electrical Properties of CdS:In Thin Films Prepared by Vacuum Evaporation

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Abstract:

CdS films were prepared by thermal evaporation technique at thickness 1 µm on glass substrates and these films were doped with indium (3%) by thermal diffusion method. The electrical properties of these have been investigated in the range of diffusion temperature (473-623 K)> Activation energy is increased with diffusion temperature unless at 623 K activation energy had been decreased. Hall effect results have shown that all the films n-type except at 573 and 623 K and with increase diffusion temperature both of concentration and mobility carriers were increased.

Keyword: Thermal diffusion, electrical properties, activation energy, concentration, mobility.

Introduction:

Thin films of CdS have been extensively studied due to the Varity of applications in optoelectronic devices, in particular hetrojunction solar cells with a narrow band gap base and wide band gap window [1, 2]. CdS is widely used as a substance with many advanced technological applications such as CdS/CdTe, CdS/CuInSe and CdS/Si hetrojunction solar cells [3,4].

There are several methods for depositing CdS thin films, such as vacuum evaporation (VE) [5], chemical bath deposition (CBD) [6], spary paralysis (SP) [7], etc. In this CdS films had been prepared with doped in 3% Indium by thermal diffusion method, which is considered as a non-traditional method, and used previously in doping CdS. This method is very important in controlling impurities diffusion and its connect-ratio in thin films. Electrical properties of the polycrystalline CdS and CdS:In thin film had been studied.

Materials and Methods:

Indium of high purity (99.999%) was evaporated on the CdS film of 1µm thickness with 3% ratio and heated in different temperature Td (473, 523, 573, 623 K) by thermal evaporation technique at vacuum ~ $2x10^{-5}$ torr using Balzers Coating Unit (Model: MA510). A molybdenum boat was used as the evaporation source and the substrates were cleaned.

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Glass plates held at room temperature, which were placed directly above the source at a distance of nearly 18 cm. Two Aluminum electrodes contact were thermally deposited on the films with (4mm) space on the surface of the film.

Electrical Measurement

D.C conductivity

D.C power supply PE 1540 was used to measure the conductivity and digital electrometer keithley 616 to measure current and voltage measurement. The receptivity (ρ) of the film has been calculated by using the following relation:

$$\rho = R\frac{wt}{L} ....(1)$$

Where

R: is the resistance of the film

w: is the width of (Al) electrode.

L: is the distance between two (Al) electrod.

t: film thickness, and from the knowledge the value of the resisitivity we can find the value of the conductivity (σ) whwer:

$$\sigma = \frac{1}{\rho} ....(2)$$

The activation energy was calculated by using the values of conductivity at different temperature by the relation [8]

$$\sigma = \sigma_o \exp(-E_a / K_B T) ....(3)$$

Hall Effect

We can know the type and concentration of the electric charge carrier by studding the Hall effect. Determine the value of the Hall coefficient (R_H) using the relation:

$$R_H = \left(\frac{V_H}{I}\right)\left(\frac{t}{B}\right) ....(4)$$

The charge carrier concentration of the film was measured using the relation:

$$n = \frac{1}{|R_H|.e} ....(5)$$

Where (e) is the electron charge.

The Hall mobility (μ_H) of the prepared thin films was calculated according to the equ. [9]:

$$\mu_H = |R_H|.\sigma_{R.T} ....(6)$$

Results and Discussion:

Variation of the electrical conductivity with reciprocal temperature was measured for CdS film of 1 µm thickness at different diffusion temperature as shown in Fig. (1). The activation energy for the film was increased with diffusion temperatures increasing except at 623 K it is decreased as in Fig. (2). This attributed to substitute In (III) with higher covalent into Cd atoms, and behave as a donor when incorporate with (II-VI) group atoms (ex. CdS). This result is in a good agreement with other works [10, 11]. Conductivity mechanism for the films content two regions. That means the conduction I film is due to the thermally assisted tunneling and of the charge carriers through the grain boundary barrier but in second region the conductivity will change to hopping conductivity [12], and carrier transition from acceptor level to conduction band and the energy gap will change.

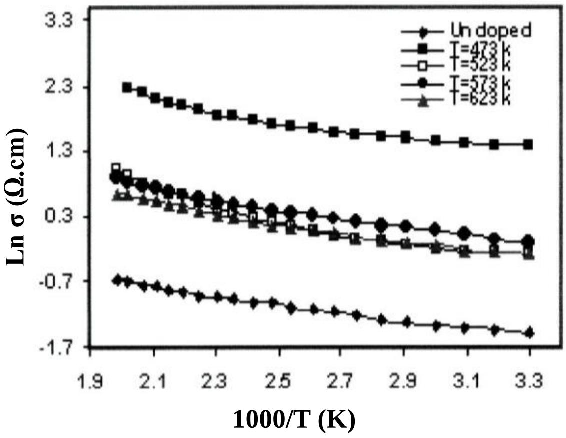

Figure 1. Variation of the lnσ with 1000/T for CdS thin films with different diffusion temperature

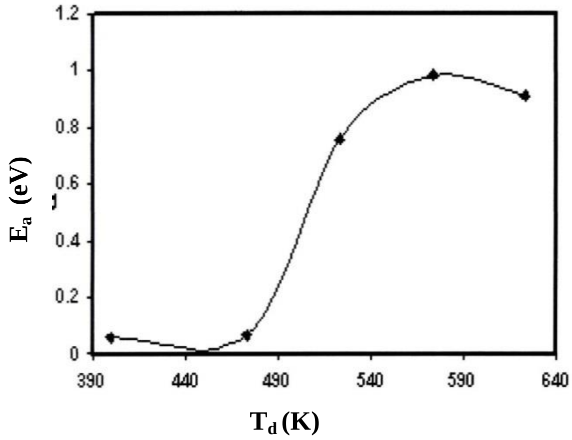

Figure 2. Variation of E_a with T_d for CdS thin films with different diffusion temperature

Fig. (3) is illustrated the Hall measurement for the films. We can see all the films n-type except at T_d=573 and 623 K. These results are due to re distribution the impurity level in the energy gap [11]. The carrier concentration and mobility calculated from this figures. The result is shown in Fig. (4). We can conclude that with increasing diffusion temperature, concentration and mobility increase. This result is due to improve the electrical properties and decrease the defect in the energy band gap. There are some lattice defects, geometrical and physical imperfection randomly distributed on the surface and the volume of the chalcogenide film [12].

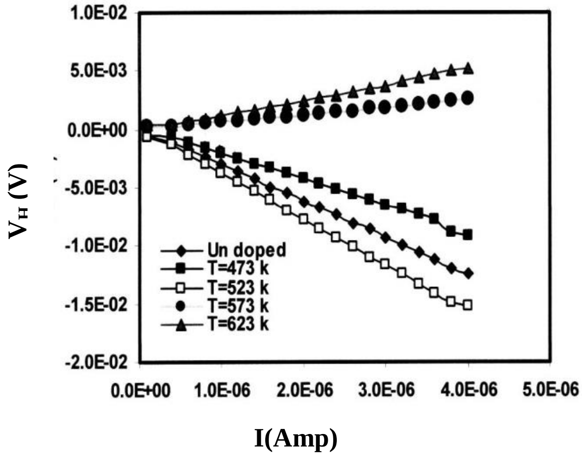

Figure 3. Hall measurements for CdS thin films with different diffusion temperature

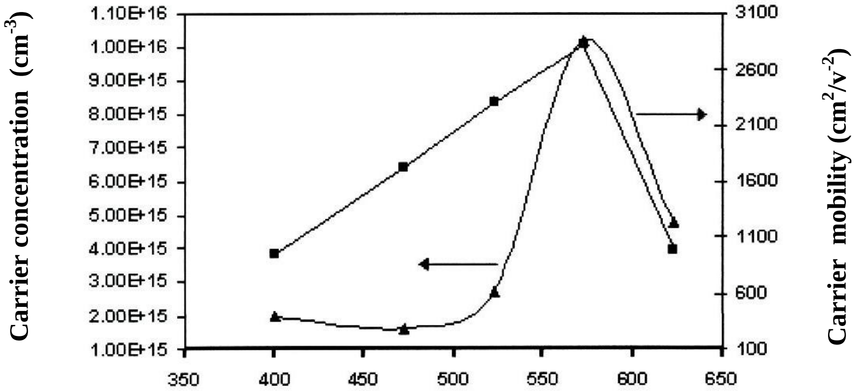

Figure 4. Variation of the concentration and mobility for CdS thin films with different diffusion temperature

Conclusions:

1. CdS films have been deposited by thermal evaporation technique.
2. The effects of Indium doped on the electrical properties were studied in the range of diffusion temperature Td (473-623 K).
3. The activation energy increased with Td and conductivity mechanism for the films content two regions.
4. The Hall measurement showed all the films n-type except at 573 and the carriers concentration and mobility increasing with diffusion temperature.

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تأثير درجة الانتشار على بعض الخصائص الكهربائية لغشاء CdS:In المحضر بطريقة التبخير الحراري

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الخلاصة:

حضرت اغشية المركب CdS:In بسمك 1 µm باستعمال تقنية التبخير الحراري على ارضية زجاجية وقد طعمت بالانديوم بنسة (3%) باستعمال طريقة الانتشار الحراري. تم دراسة الخصائص الكهربائية في مدى درجات حرارة الانتشار (K 473-623) ووجد زيادة طاقة التنشيط مع درجة الحرارة ولكن عند درجة حرارة 623 K اخذت الطاقة بالنقصان. واظهرت نتائج تاثير هول ان جميع الافلام من نوع n-type ماعدا 623 K و 573 وان مع زيادة درجة حرارة الانتشار يزداد كل من تركيز وتحركية الحاملات.

الكلمات المفتاحية: الأنتشار الحراري، الخصائص الكهربائية، طاقة التنشيط ، التركيز، الحركية.