# Effect of Annealing Temperature on the Structure and Optical Properties of CdS:Cu Thin Films Prepard By Thermal Vacuum Evaporation

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## Abstract:

In this study, we are studying the effect of annealing temperature on the structure and the optical properties of CdS:Cu thin films which were prepared by thermal evaporation technique in vacuum with rate deposition ($4.1A^{o}$/sec) and thickness(≈400nm),all these samples have been annealed at different annealing temperatures (RT,373,423 and 473 K). The structural properties of the films have been studied by using X-ray diffraction. The optical measurements indicate that CdS:Cu films have direct optical energy gap ($E_g^{opt}$), and it decreases from 2.43 eV to 2.37 eV with the increase of annealing temperatures (R.T – 473)K. The optical constants refractive index (n), extinction coefficient (k),absorption coefficient (α) and dielectric constants ($\varepsilon_r$ and $\varepsilon_i$) were also studied.

**Key Words: Effect, Annealing Temperature , Structure, Optical, CdS:Cu.**

## Introduction:

Cadmium Sulfide (CdS) is one of the most studied compounds with a direct band gap of about (2.45eV) [1] which has been used extensively in many applications, including solar cells [2], photo transistors [3], and diodes [4] transparent electrodes [5], gas sensors[6]. Cadmium Sulfide films have been prepared by several methods, such as thermal evaporation ,spray pyrolysis ,chemical bath deposition, gradient recrystallization and growth (GREG), spin coating , pulsed laser deposition, close spaced sublimation[7] and spray pyrolysis deposition (SPD)[8] have been used in the deposition of CdS thin films.

The aim of this paper is to study the effect of annealing treatment on the structure and optical properties of Cadmium Sulfide doped with Copper films deposited by thermal evaporation method.

## Experimental Work:

The films of Cadmium Sulfide doped with Copper were prepared by thermal co-evaporation technique using coating unit in a vacuum about $2\times 10^{-5}$ Torr. A specific weight from Cadmium Sulfide powder (99.9% pure) must be taken and put it in a molybdenum boat, take (1%) from this weight from Copper and put it in other molybdenum boat. the rate of evaporation was $\approx 4.1 A^{o}$/sec and the film thickness in the range of 400 nm was measured by interference method. the substrate glass was placed directly above the source at a distance of nearly 18 cm after cleaned the glass.

The films were annealed in air at different annealing temperatures(373,423.473K) for an hour.

The optical constants absorption coefficient (α) ,extinction coefficient (k) and real ($\varepsilon_r$) and imaginary parts ($\varepsilon_i$) of dielectric constant can be calculated from the following equations[7].

$$\alpha = 2.303\frac{A}{t} \quad \text{.....(1)}$$

Where t is the film thickness and A is the optical absorbance.

$$k = \frac{\alpha\lambda}{4\pi} \quad \text{..... (2)}$$

Where λ: is the wavelength of the incident ray

$$\varepsilon_r = n^2 - k^2 \quad \text{.....(3)}$$
$$\varepsilon_i = 2nk \quad \text{.....(4)}$$

Where n: is the refractive index was obtained from the following relation [9].

$$n = \left[\frac{4R}{(R-1)^2} - k^2\right]^{1/2} - \frac{(R+1)}{(R-1)} \quad \text{.....(5)}$$

## Result And Discussion:

Figure (1) show the XRD spectra obtained at different annealing temperatures for CdS:Cu films. The XRD pattern for Cadmium Sulfide doped with Copper films at different annealing temperatures (RT,373,423,473K) shows a strong peak at the diffraction angles $2\theta^{o}=26.498^{o}$, $2\theta^{o}=26.493^{o}$, $2\theta^{o}= 26.541^{o}$ and $2\theta^{o}=26.476^{o}$ corresponds to the (022) plane, the crystal lattice is hexagonal. This result agrees approximately with the result reported by Ziaul et al [10].

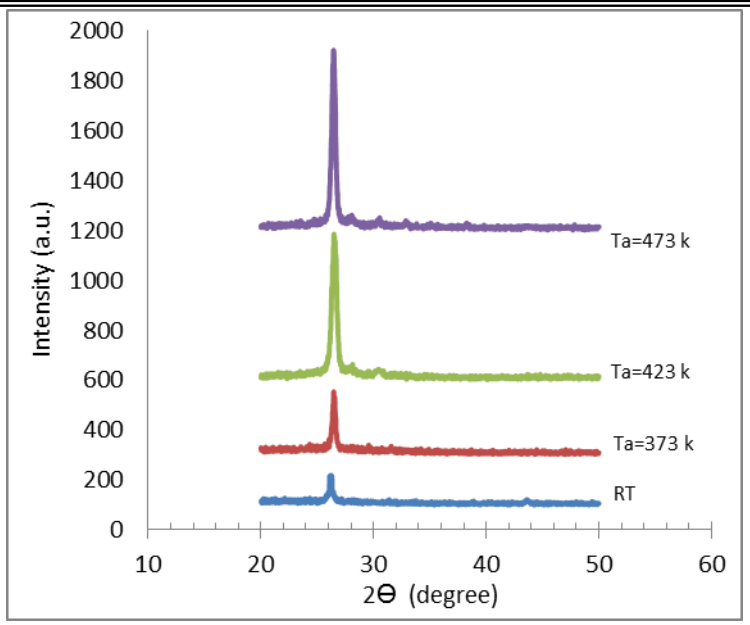
The optical energy gap values ($E_g$) for CdS:Cu films have been determined. A plot of $(\alpha h\nu)^2$ versus photon energy for CdS:Cu films at different annealing temperatures (RT,373,423,473 K) are shown in Fig.(2) and table(1). The plot is linear indicating as direct band gap nature of the film. Extrapolation of the line to the photon energy axis gives the band gap. The values of the optical energy gap for CdS:Cu films are decrease from ( 2.43 eV) to (2.37 eV) when increase the annealing temperatures from (RT - 473 K) . This may be due to the increase of the density of localized states in the $E_g$, which causes a shift to lower values. This result agrees approximately with the result reported by Iqbal et al[7].

The Figure (3) refers to transmission of CdS:Cu films in the range between (500-1100)nm. The transmittance spectra show an increase when the annealing temperature increases. This result similar with the result reported by Pantoja[11].

Figure (4) shows the variations in refractive index as a function of photon energy. It is observed that for films CdS:Cu, the refractive index increases with decreases of the annealing temperatures , this may be return to the effect heat treatment on the nature of films surface in which the reflection would occur and that would lead to the variation of the refractive index[12].

The extinction coefficient (k) increases with the decrease of annealing temperatures for films as shown in Fig.(5) and this may be due to increasing the absorption which shown in Fig.(6).

The dielectric constant real part ($\varepsilon_r$) and imaginary part with the increases annealing temperatures for the films are shown in Fig(7) and in Fig(8) respecitivily. the real part($\varepsilon_r$) decreases with the increase of annealing temperatures, and this attributed to the same reason mentioned previously for the refractive index, also imaginary part ($\varepsilon_i$) decreases with the increase of annealing temperatures and this is due to the similar interpretation discussed previously for the extinction coefficient.




**Figure(1): X-ray diffraction of CdS:Cu films for different annealing temperatures**

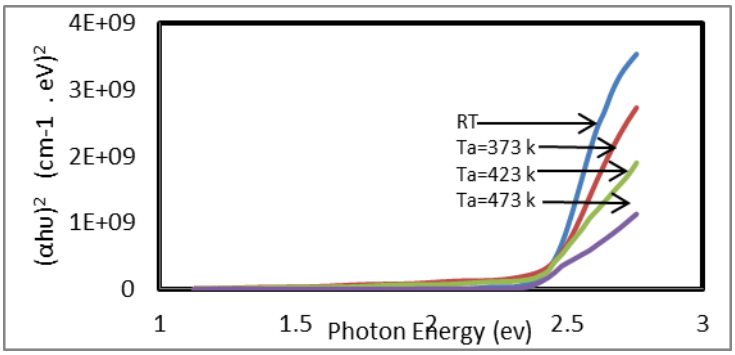



**Figure (2): Variation of energy gap of CdS:Cu films a function at different annealing temperatures**

Table 1: The optical properties parameters of CdS:Cu thin films at different annealing temperatures when λ=500 nm.

| Ta (K) | Eg (eV) | α ($cm^{-1}$) | n | K | $\varepsilon_r$ | $\varepsilon_i$ |
|---|---|---|---|---|---|---|
| RT | 2.43 | 6149.01 | 7.25 | 0.024 | 52.56 | 0.36 |
| 373 | 2.41 | 3684.80 | 5.96 | 0.014 | 35.61 | 0.17 |
| 423 | 2.39 | 2732.89 | 4.94 | 0.011 | 24.46 | 0.11 |
| 473 | 2.37 | 1711.89 | 3.67 | 0.007 | 13.47 | 0.05 |

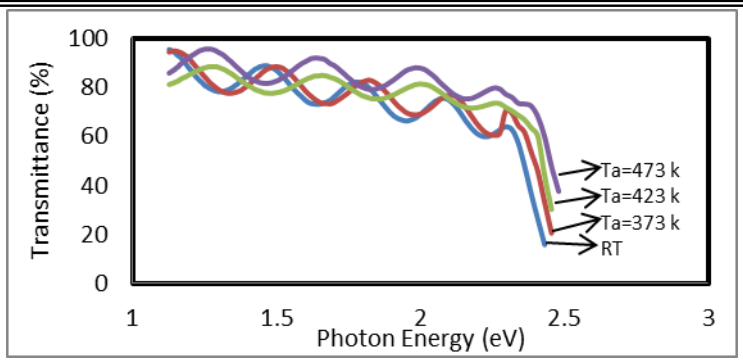



**Figure (3): The optical transmission as a function of photon energy for CdS:Cu films at different annealing temperatures**

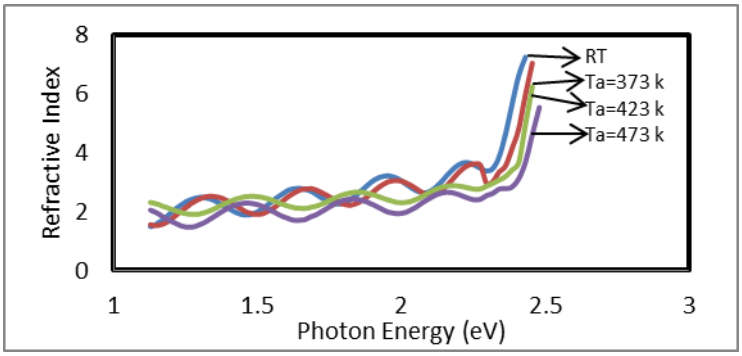



**Figure (4): Refractive index as a function of photon energy for CdS:Cu films annealing temperatures**

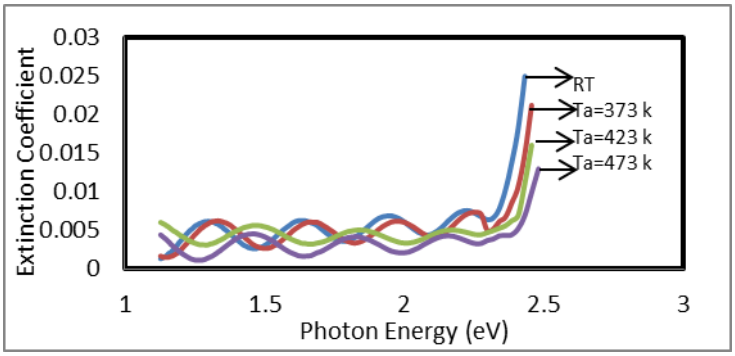



**Figure (5): Extinction coefficient as a function of photon energy for CdS:Cu films at annealing temperatures**

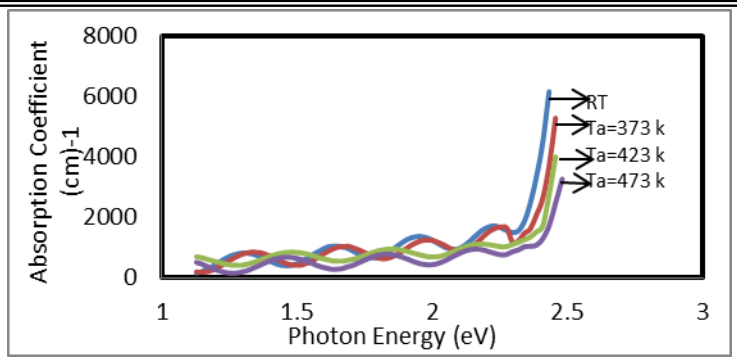



**Figure (6): Absorption coefficient as a function of photon energy for CdS:Cu films at annealing temperatures**

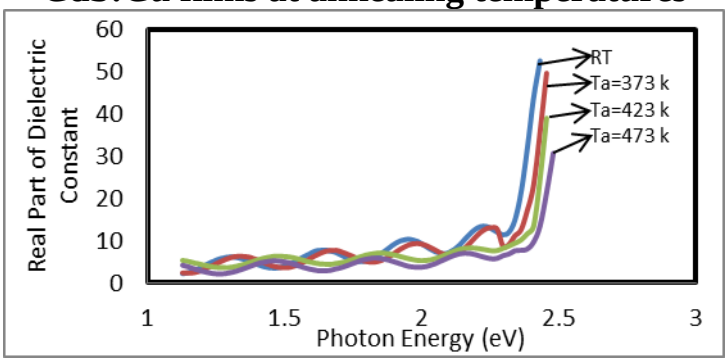



**Figure (7): Real Part of Dielectric Constant as a function of photon energy for CdS:Cu films at annealing temperatures**

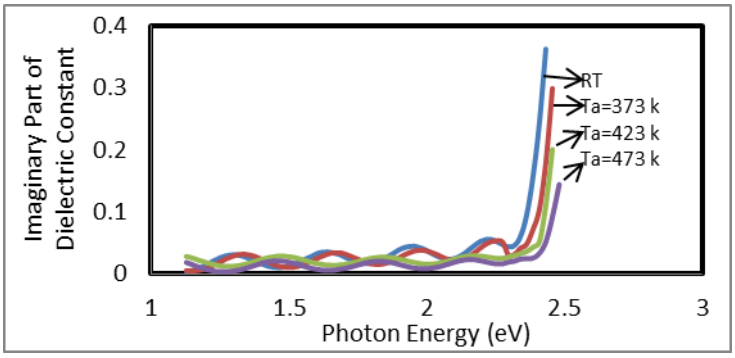



**Figure (8): Imaginary Part of Dielectric Constant as a function of photon energy for CdS:Cu films at annealing temperatures**

## Conclusion:

The effect of annealing treatment on the structure and optical properties of CdS:Cu thin films deposited by thermal evaporation technique were studied. The structure of all films at different temperature is hexagonal, the films show a direct optical energy gap ($E_g^{opt}$), and it decreases with the increase of annealing temperature. All films exhibit high transmittance. The transmittance spectra and extinction coefficient show an increase when the annealing temperature increases, while the refractive index, dielectric constant real part ($\varepsilon_r$) and imaginary part ($\varepsilon_i$) decreases with the increase of annealing temperatures.

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# تأثير درجة حرارة التلدين على الخواص التركيبية والبصرية لأغشية CdS:Cu الرقيقة المحضرة بواسطة التبخير الحراري بالفراغ

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**الخلاصـــــــــة:**

في هذه الدراسة, درسنا تأثير درجة حرارة التلدين على الخواص التركيبية والبصرية لأغشية كبريتيد الكادميوم المشوبة بـالنحاس الرقيقة, والتي حضرت بتقنية التبخير الحراري في الفراغ وبمعدل ترسيب($4.1A^o/sec$) وسمك ($\approx$400nm),جميع العينات لدنت بدرجات حرارة مختلفة ( RT,373,423 and 473K).درست الخواص التركيبية باستخدام حيود الأشعة السينية. بينت القياسات البصرية لأغشية الـ CdS:Cu بأنها تمتلك فجوة طاقة ($E_g^{opt}$) مباشرة, تقل من 2.43 eV الى 2.37 eV مع زيادة درجة حرارة التلدين (RT,373,423 and 473 K) . و درست الثوابت البصرية وهي معامل الانكسار (n) ومعامل الخمود (k) ومعامل الامتصاص ($\alpha$) وثابت العزل بجزئيه الحقيقي والخيالي ($\varepsilon_r$ , $\varepsilon_i$) .

**الكلمات المفتاحية:** تاثير, حرارة التلدين, تركيبية, بصرية, CdS:Cu.