# The Optical Properties of GaAs Thin films Prepared by Flash Evaporation Technique

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## Abstract:
A polycrystalline GaAs thin films have prepared by flash evaporation on glass substrate with Thickness ~ 1 μm and substrate temperature ($T_s$) of about 423 K under vacuum of about $10^{-5}$ mbar. The thin films heat treated at different annealing temperatures 423, 473, 523, 573 K. The optical measurements showed that GaAs has direct energy band gap, and the absorption coefficient decreases with increasing the annealing temperatures. The increasing of annealing temperature shifts the peak of transmittance spectrum toward the shorter wavelengths (higher energies) compared with the as-deposited thin film.

## Introduction:
III-V semiconductors are commonly used in the fabrication of optoelectronic devices, e.g. the laser and light emitting diode in the visible spectrum and in the infrared spectrum (gallium arsenide (GaAs)) as used for CD and DVD drives. GaAs is also of interest for high frequency applications. Its electron effective mass is only 1/16 of that of Si, consequently with higher mobility of electrons. This makes GaAs a prospective candidate for the production of future integrated circuits despite its technologically more elaborate processing [1].

### The Experimental Work:
A corning glass slides were used as substrates, they were cleaned by deionized water into ultrasonic vessel for 15 minutes, then for the same period in pure alcohol. Flash evaporation technique is generally used for the evaporation and deposition of the GaAs compound, since the material is evaporated quickly; the decomposition of the compound is minimized [**2**]. In this method the components of the compound in spite of the difference between their vapor pressures but they do not separate through the evaporation process.
Preparation of GaAs thin films by flash evaporation technique by using The Edward E306A coating system, under vacuum of about $10^{-5}$ mbar, the alloy crushed into very small grains (powder), this powder is dropped into a heated boat from the ***feed through*** passing through a guide funnel by manual vibrating handmade system.
The substrate temperature obtained by a tungsten heater and measured by a thermocouple Type ***K***. The optical properties includes transmittance spectrum in the wavelength range 0.3-1.1 μm by UV/Vis Centra 5 spectrometer which is previous to GBC scientific equipment PTY ltd, this spectrometer contains two sources( Deuterium lamp and Tungsten Lamp within the wavelengths (λ□) 190-360 nm and 360-1100 nm of the spectrum respectively). The output data of λ, transmittance (T) and absorbance (A) are used in a computer program to deduce the optical energy band gap ($E_g$) and fundamental optical edge and all optical constants such as absorption coefficient (α)□, extinction coefficient (k) and refractive index (n).

## The Results and discussions:
### 1-The transmittance and absorbance spectra:
The optical properties of 1 μm GaAs thin films at different annealing temperatures have been determined by UV-Visible transmittance spectrum in the region 0.2-1.1 μm on glass substrate.
The transmission spectra of annealed and as-deposited thin films have been illustrated in figure (1). From these plots we can observe that the increasing of annealing temperature shifts the peak of transmittance spectrum toward the shorter wavelengths (higher energies) compared with the as-deposited thin film. This shifting is due to the structural improvement represented by increasing the crystallite grain size [**3**].
The transmittance of GaAs thin films as shown in figure (1) has increased with increasing the annealing temperature. The behavior of the absorbance spectra is opposite completely to that of the transmittance spectra as shown in fig. (2).

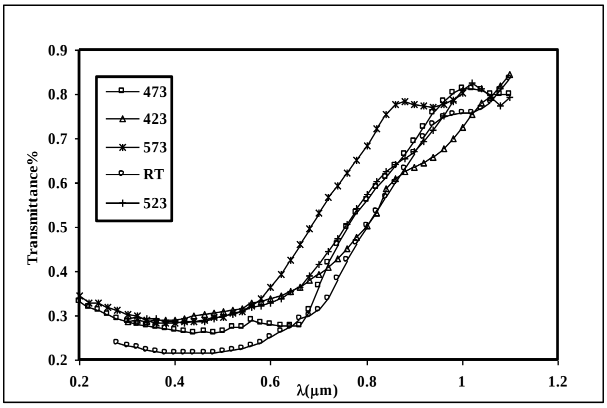


**Fig (1):** The transmittance spectrum at different annealing temperatures for ~ 1 μm GaAs thin films prepared by flash evaporation at $T_s$=423 K

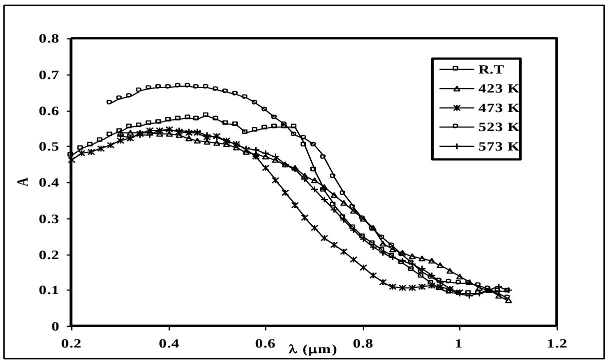


**Fig (2):** The absorption spectrum at different annealing for 1 ~ μm GaAs

**2- The absorption coefficient:**

The absorption coefficient of GaAs thin films have been illustrated in Fig.(3). From this figure, the absorption coefficient of the GaAs thin films are characterized by strong absorption at the shorter wavelengths region between 0.20- 0.62 µm and without sharp edge on the long wavelength side from o.64- 1.1 µm. In the shorter wavelength the absorption coefficient exhibits higher values within the range (1.114-1.193) × $10^4$ $cm^{-1}$, these values of α (>$10^4$) means that there is a large probability of the allowed direct transition **[4]**, then α decreases with increasing λ, the values of α was nearly in agreement with Theye et al (1985) **[5]**. Also the α values have been decreased with increasing the annealing temperatures due to structure improvement and increasing the energy gap **[6]**.

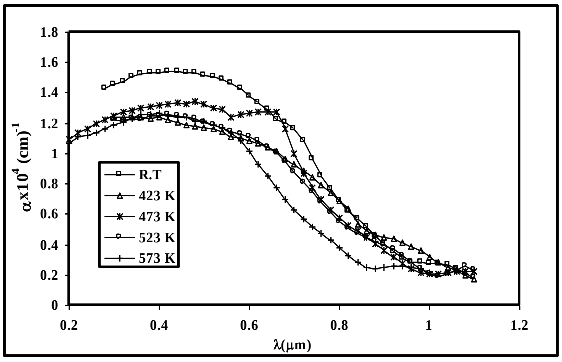


**Fig (3):** The absorption coefficient at different annealing temperature for ~ 1 µm GaAs thin films prepared by flash evaporation at $T_s$=423 K

**3- The optical energy gap:**

To examine the type of the transitions and by plotting $(\alpha h\nu)^2$, $(\alpha h\nu)^{2/3}$, $(\alpha h\nu)^{1/2}$, $(\alpha h\nu)^{1/3}$ as a function of photon energy by using Tuac equation [**7**], the first relation yields a linear dependence which described the allowed direct transition and illustrated in Fig. (4). The $E_g$ values were estimated from the extrapolation to zero absorption in Tauc equation, and lie within the range 1.34 to 1.52 eV and tabulated in table (1). The values of optical energy gaps ($E_g$) increase with increasing the annealing temperature. These results are nearly in agreement with Baker et al (1990) [**6**].The increasing of $E_g$ is due to the improvement in the structure of the thin films as a result of the annealing process which further consolidates the suggestion that $T_a$ enhances the crystalline improvement.

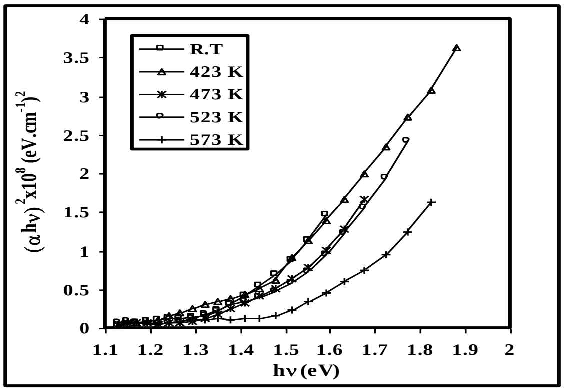


**Fig (4):** The plot of □$(\alpha h\nu)^2$ Vs. hν for a)as prepared as deposited and annealed thin films at 423, 473, 523 and 573 K .

Fig (5) illustrates the variation of energy gap with annealing temperature. The increased of $E_g$ with the annealing temperature ($T_a$) agrees with Narasimhan and Guha (1974) [**8**], Aguir et al (1989) [**9**], Islam and mitra (1986) [**10**] and Bakar et al in 1990 [**6**].

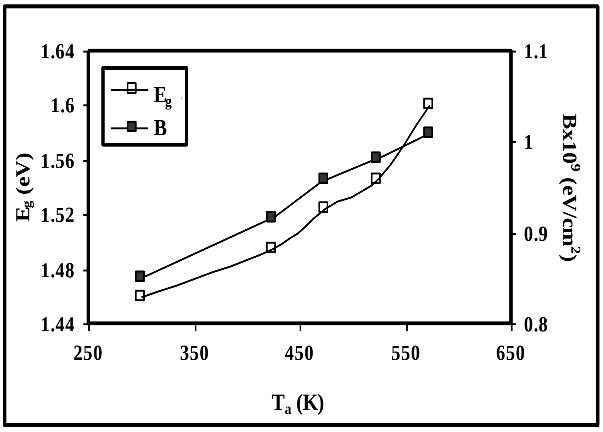


**Fig (5):** The optical energy gap and β Vs annealing temperatures for GaAs thin films

The coefficient β (Tuac slope) in Tuac equation has been obtained from the root square of the straight line slope as in figure (4), where from table (1) we can observe that β is increases with increasing the annealing temperature. We know that β is inversely proportional to amorphousity and width of the band tails [**4**].

**4- Refractive Index:**

Table (1) and Fig.(6) show the variation of refractive index at different annealing temperatures, the values of n for GaAs thin films have been measured at 0.84 µm, we can observe that n decreases with increasing $T_a$ by factor of 1.2 within the range 2.518- 2.079. also we can observe that the curves shift to shorter wavelengths (higher energies) versus increasing the annealing temperature, this is due to the increasing in the energy gap which causes the lattice to expand and the grain size to grow and as a consequence to the decrease of defect states[6].

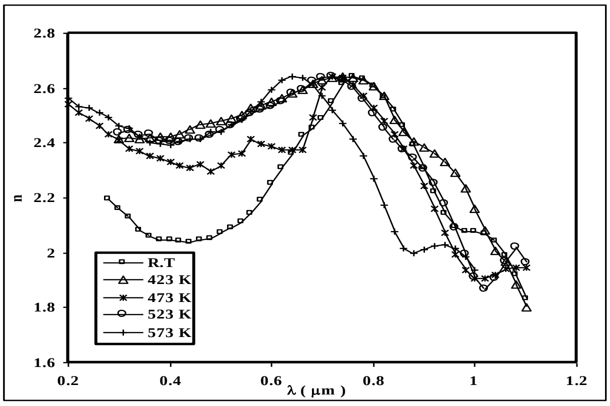


**Fig (6):** Refractive index versus annealing temperature for ~ 1 µm GaAs thin films prepared by flash evaporation at $T_s$=423 K.

**5- Extinction Coefficient:**

The behavior of k is nearly similar to the corresponding α as in Fig. (7) for GaAs thin films at different $T_a$, we can see from this figure and table (1) that k for GaAs thin films decrease with increasing $T_a$ by factor 2 within the range 0.3778 to 0.1877 due to the increasing of α as mentioned at absorption coefficient item.

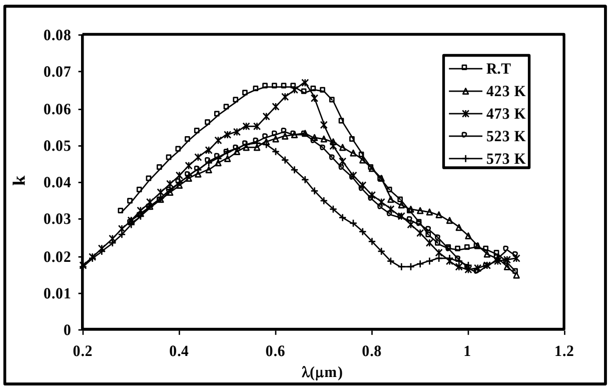


**Fig (7):** k Vs. $T_a$ for ~ 1 µm GaAs thin films prepared by flash evaporation at $T_s$=423 K

**Table (1):** The optical constants of GaAs thin films

| $T_a$(K) | $\alpha x10^4$ $(cm)^{-1}$ | $E_g$(eV) | $\beta x10^9$ $(eV/cm^2)$ | n | k |
|---|---|---|---|---|---|
| R.T | 0.565 | 1.34 | 0.851 | 2.518 | 0.038 |
| 423 | 0.531 | 1.365 | 0.917 | 2.483 | 0.035 |
| 473 | 0.488 | 1.38 | 0.959 | 2.433 | 0.032 |
| 523 | 0.470 | 1.44 | 0.982 | 2.409 | 0.031 |
| 573 | 0.281 | 1.52 | 1.009 | 2.079 | 0.019 |

## The conclusions :

The peak of the transmission spectra of annealed thin films have been shifted toward the shorter wavelengths (higher energies) compared with the as-deposited thin film. The values of α, n and k decreased with increasing the annealing temperatures. The prepared GaAs thin films have direct band gap, and its value increased with increasing the annealing temperature.

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# الخصائص البصرية لغشاء زرنيخات الكاليوم المحضرة بطريقة التبخير الفراغي الوميضي


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**الملخص:**

تم تحضير أغشية زرنيخات الكاليوم متعددة البلورات بسمك ~ ١ مايكرومتر على أرضيات زجاجية بواسطة تقنية التبخير ألوميضي في فراغ حوالي $١٠^{-٥}$ ملي بار وبدرجة حرارة أرضية ٤٢٣ مطلقة، حيث تم معاملتها حراريا بدرجات تلدين مختلفة ٤٢٣، ٤٧٣، ٥٢٣ و٥٧٣ مطلقة.

أظهرت دراسة القياسات البصرية بأن اغشية زرنيخات الكاليوم تمتلك فجوة طاقة مباشرة و التي تزداد مع زيادة درجة حرارة التلدين. ان معامل الامتصاص يقل بزيادة درجات حرارة التلدين، و تزحف قمة طيف النفاذية نحو الاطوال الموجية القصيرة (الطاقات العالية) بزيادة درجة حرارة التلدين مقارنة مع النموذج غير الملدن.