IRAQI Academic Scientific Journals
العراقية المجلات الأكاديمية العلمية
Kut University Journal
ISSN (E): 2616 - 7808 II ISSN (P): 2414 - 7419
www.kutcollegejournal.alkutcollege.edu.iq
k.u.c.j.sci@alkutcollege.edu.iq
Vol. 10 , Issue 1 , June 2025

Effect of the vacuum on Structural and Morphological Properties of Ga_2O_3 NPs Thin Films by (PLD) Technique

Khalid H. Jebur [1]

Abstract

In this study, thin films of Gallium oxide nanoparticles were equipped using the method of pulsed laser deposition (PLD)on a glass substrate under different vacuum conditions (5×10-5, 2×10-2, and 1mbar). The Nd-YAG laser was utilized at a wavelength of 1064 nm and a frequency of 5 Hz at 130 0C. The increase effect of the vacuum value on the optical and structural characteristics was studied by UV-VIS, X-ray diffraction (XRD), scanning electron microscopy (SEM), and Photoluminescence properties (PL). The outcomes XRD showed that the structure of Ga_2O_3 nanoparticles is a polycrystalline structure of the monoclinic type, with Prominent crystal orientations of (001), (201), (400), (-202), (111), and (-112). It is according to JCPDS card No.00-041-1103. Crystallite size for the complete model decreased with the growth of the vacuum value. The (SEM) images showed that Ga_2o_3 nanoparticles are spherical and homogeneous. The energy band gap increased with increasing the vacuum, and the absorption upper was in the UV zone. Similar results were obtained from the researcher MA Yan-Mei et al. [1].

Keywords: Gallium oxide Ga_2O_3 Nanoparticles, The vacuum, Pulsed Laser Deposition

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Paper Info.
Published: Jun. 2025

تأثير قيمة الفراغ على الخواص الهيكلية والصرفية للأغشية الرقيقة Ga_2O_3 NPs بتقنية (PLD)

خالد حميد جبر [1]

المستخلص

في هذه الدراسة، تم تجهيز اغشية رقيقة من جسيمات Ga2O3 النانوية باستخدام طريقة الترسيب بالليزر النبضي (PLD) على طبقة زجاجية تحت فراغ مختلف (5×10^{-5}، 10×2^{-2} و 1 ملي بار) .تم استخدام ليزر Nd-YAG بطول موجي (1064 نانومتر) ومعدل تكرار (5 هيرتز) عند 130 درجة مئوية .تم دراسة تأثير زيادة الفراغ على الخواص البصرية والهيكلية بواسطة الاشعة فوق بنفسجية المرئية (**UV**-VIS)، حيود الاشعة السينية (XRD) ،المسح المجهري الالكتروني (SEM) ،وخصائص التلألؤ الضوئي (PL). اظهرت نتائج XRD ان هيكل الجسيمات النانوية Ga_2O_3 متعدد البلورات من النوع احادي الميل في اتجاهات بلورية بارزة تبلغ (001)، (201)،، (400)، (-202)، (111) و **(-112).** حسب بطاقة JCPDS رقم 00-041-1103. انخفض حجم البلورات لجميع العينات مع زيادة الفراغ . اظهرت صور (SEM) ان الجسيمات النانوية Ga_2O_3 كروية ومتجانسة . زادت فجوة نطاق الطاقة مع زيادة الفراغ، وكانت ذروة الامتصاص في منطقة الاشعة فوق البنفسجية. تم الحصول على نتائج مماثلة مع الباحث MA Yan-Mei et al [1]

الكلمات المفتاحية: اوكسيد الغاليوم Ga_2O_3، الفراغ، الترسيب بالليزر النبضي

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[1] **المؤلف المراسل**

معلومات البحث
تأريخ النشر : حزيران 2025

Introduction

There are gallium oxide Ga_2O_3 in various forms, α–, β–, γ –, ε–, δ–, and κ–κ-phases [2] from all that can be obtained formats. The formula β is the best common form of Ga_2O_3. β-Gallium oxide is the lone steady polymorph out of all the formats over an extensive temperature range up to its melting point of 1795 ^{0}C. The remaining polymorphs are unstable and change to the β

formula at temperatures over 750-900 ^{0}C [3]. Ga_2O_3 is a vast band-gap (~5 eV) semiconductor material, Semiconductor has a wide band-gap usefulness over polymers now utilized in the discovery of UV blindness sowing to their substantial visual blindness, temperature constancy, and improved radiation hardness [4] and is a promising nominee for new applications in optoelectronic strategies, for example, field effect transistors (FET) [5], gas sensors [6]. It is possible to perform a plain and cheap thermal oxidation operation to produce Ga_2O_3 thin film and nanoparticles by pulsed laser deposition (PLD) method on a glass substrate because of the oxidation parameters [7].

Experimental part

The target was prepared by pressing the powder from gallium oxide using a hydraulic press under 7 tons of pressure, where it was 2 cm in diameter and 2 mm thick. Then it is heated in a convection oven to 600 0C for five hours for homogenization. Glass substrates (1.5x 1.5 cm) were utilized to deposit Ga_2O_3film. Distilled water was utilized to spotlessly clean these glass substrates and remove residual dust and dirt from their surface. The glass substrates were cleaned in alcohol for 5 minutes using an ultrasonic device to remove certain oxides and fat. Hot air was used in this procedure to dries glass substrates, and lastly, soft paper was used to clean the slides. An ND:YAG laser was used to deposition the films at 130 ^{0}Cby pulsed laser deposition (PLD) method at wavelength (1064 nm) at various vacuum values (5×10^{-5}, $2\times10^{-2}$and 1mbar). The number of pulses is 1000 pulses, and the frequency (5 HZ) that happened on the target surface at an angle of 450. The distance between the laser and the target is 3 cm . The vacuum was changed on the Ga_2O_3films, and the optical gap was calculated for it by calculating the absorbance and transmittance spectra using a UV-visible device for the crystallized Gallium oxide films, as shown in Figure (1).

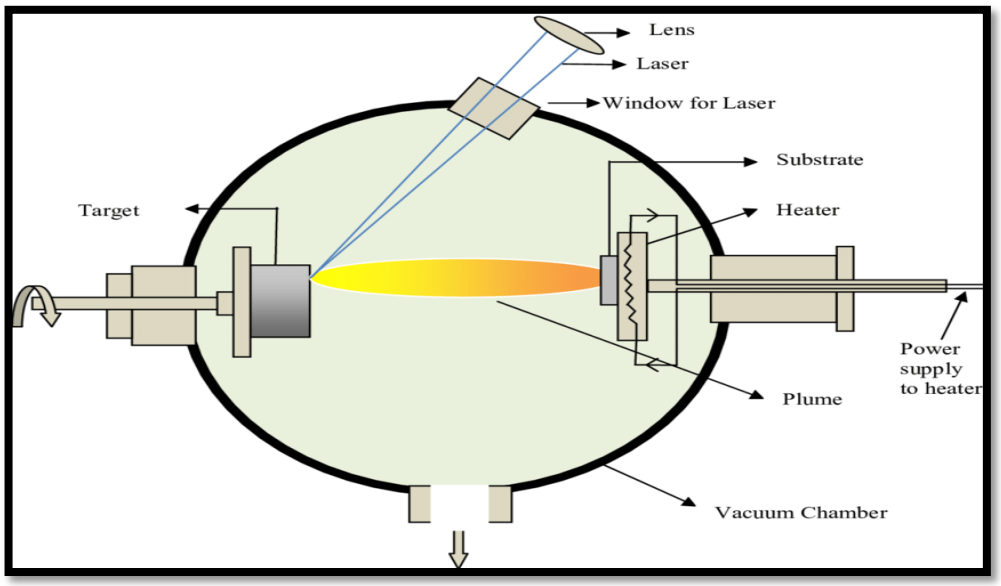

Figure (1) Pulsed laser deposition system [8]

Results of the program

1-X-ray diffraction (XRD)

X-ray diffraction (XRD) range of Ga_2O_3 nanostructures thin films grown at different vacuums (5×10^{-5}, $2\times10^{-2}$and 1mbar). All samples of the prepared films of Ga_2O_3 NPs showed that they had a polycrystalline structure of the monoclinic type, with Prominent crystal orientations of (001), (201), (400), (-202), (111), and (-112). According to JCPDS card No.00-041-1103, as in Figure (2).

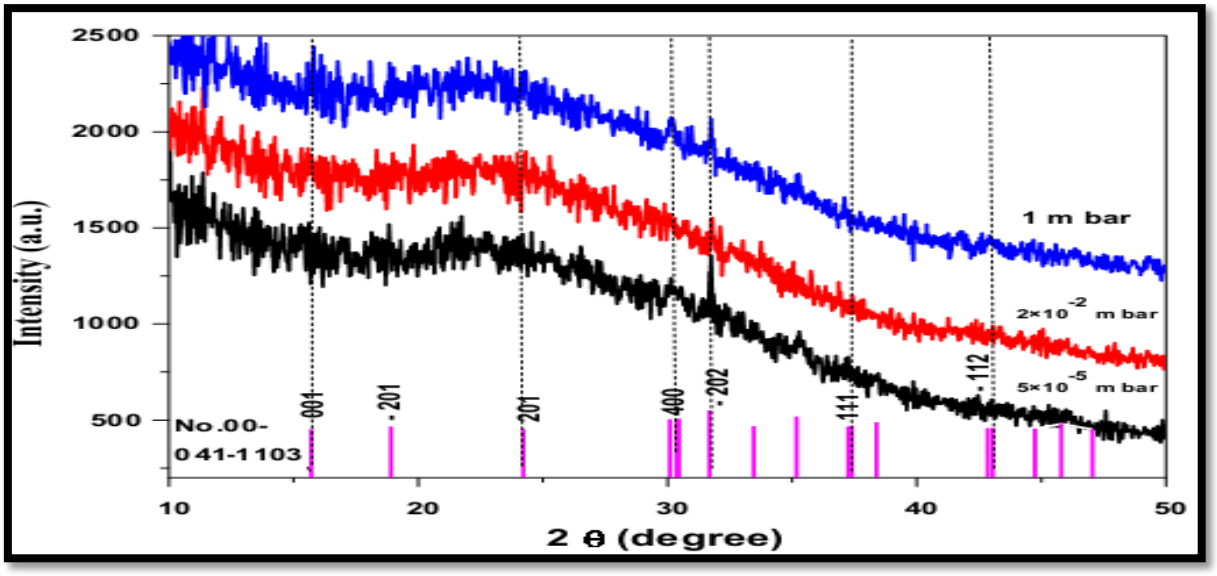

Figure (2) X-ray diffraction patterns of Ga_2O_3 thin films prepared at different the vacuum (5×10^{-5}, 2×10^{-2} and 1mbar)

We note that the material is low in crystallinity at a vacuum of 5×10^{-5} mbar and begins to increase in crystallinity by increasing the intensity of the peaks of crystal levels with increasing the vacuum [9]. The crystallite size of all samples can be calculated at different vacuums, as shown in Table (1) equation (1).

$$D = \frac{0.94\ \lambda}{\beta \cos\theta} \qquad (1)$$

Where (θ) Bragg angle in radians, (D) crystallite size (nm), and (β) (FWHM) full width at half maximum in radians.

Table (1) Crystallite size of Ga_2O_3 NPs at different the vacuum

Vacuum (mbar)	crystallite size (nm)
5×10^{-5}	160.64
2×10^{-2}	53.57
1	32.15

2- Scanning electron microscopy (SEM

In figure (3), (4) and (5), we observe the (SEM) images and (EDS) of Ga_2O_3 nanoparticles at various the vacuum, (5×10^{-5}, 2×10^{-2} and 1mbar) respectively.

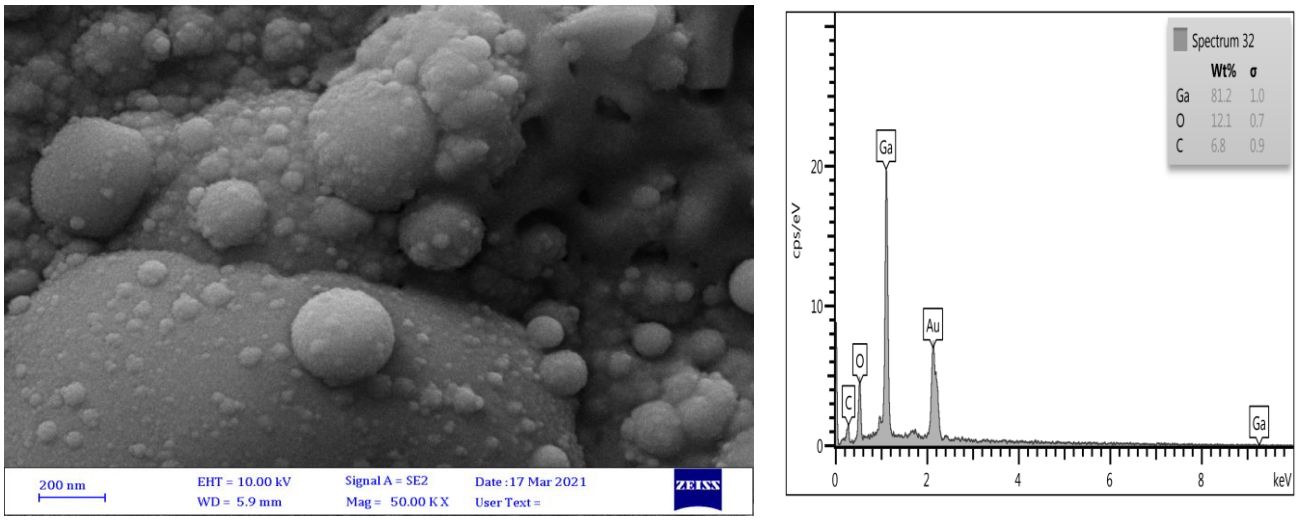

Figure (3) (SEM) and (EDS) image at various vacuum, (5×10^{-5} mbar)

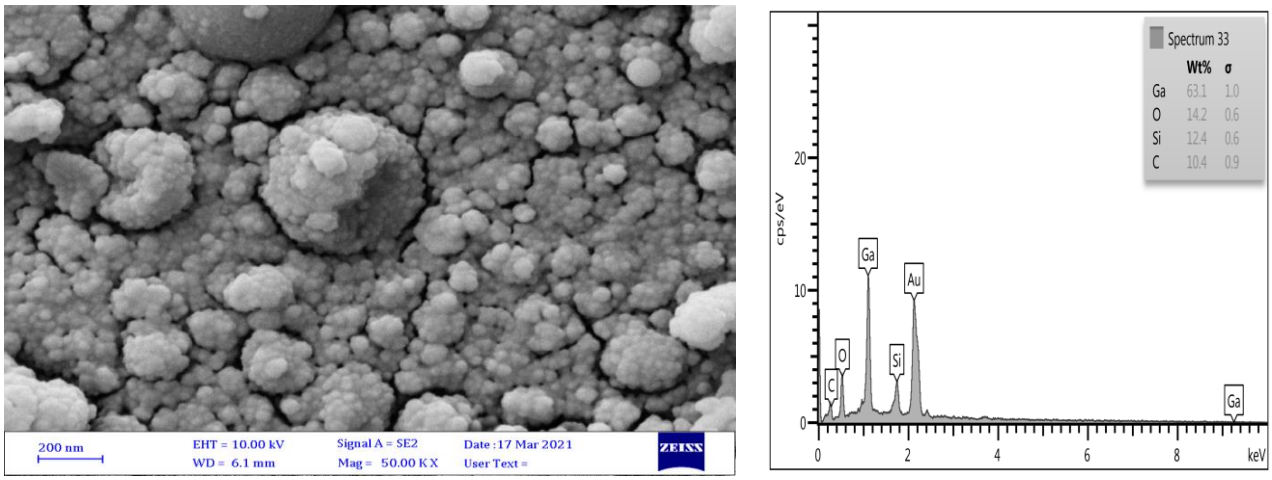

Fig. (4) (SEM) and (EDS) image at various vacuum, (2×10^{-2} mbar)

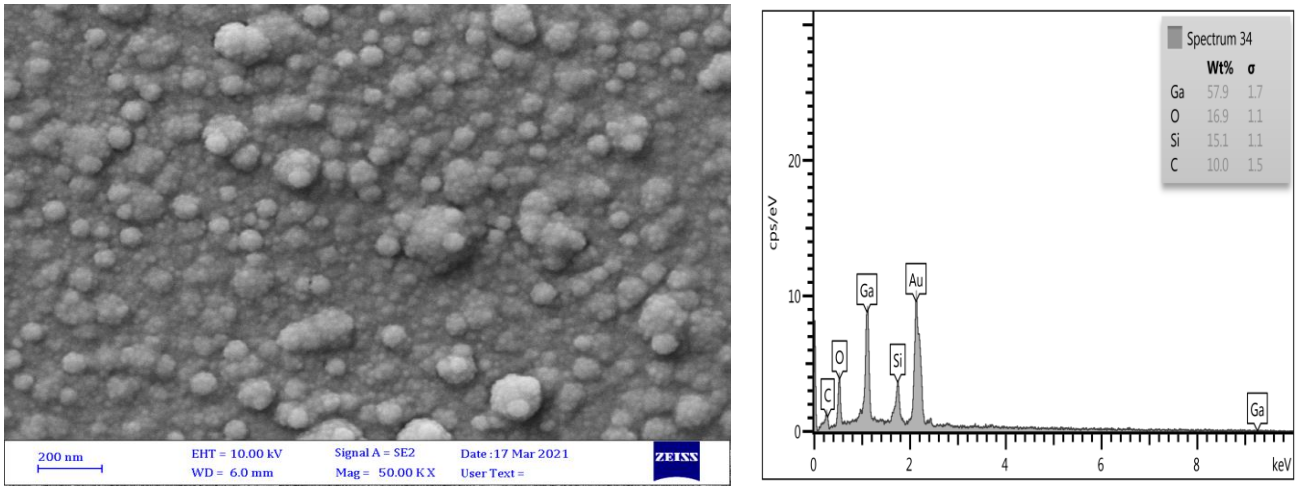

Fig. (5) (SEM) and (EDS) image at various vacuum levels, (1 mbar)

We observe (SEM) images of thin films, Ga_2O_3 particles in nanometer size, and the formation of spherical nanoparticles of as-deposited films from Ga_2O_3. Increasing the vacuum leads to forming small spherical nanoparticles, which is consistent with the crystallite size measurements

of the samples using the (XRD) apparatus. Where we notice that the crystallization process increases and the shape becomes more homogeneous with the increase in the value of the vacuum As for the results of the measurements (EDX), we note that with increasing the value of the vacuum, the oxygen percentage increases and the gallium percentage decreases as a result of oxidation and reduction processes, as the oxygen percentage increases as a result of electron acquisition until it reaches the steady state, this is evidence of good crystallization of the samples[10] as shown in the figure (6).

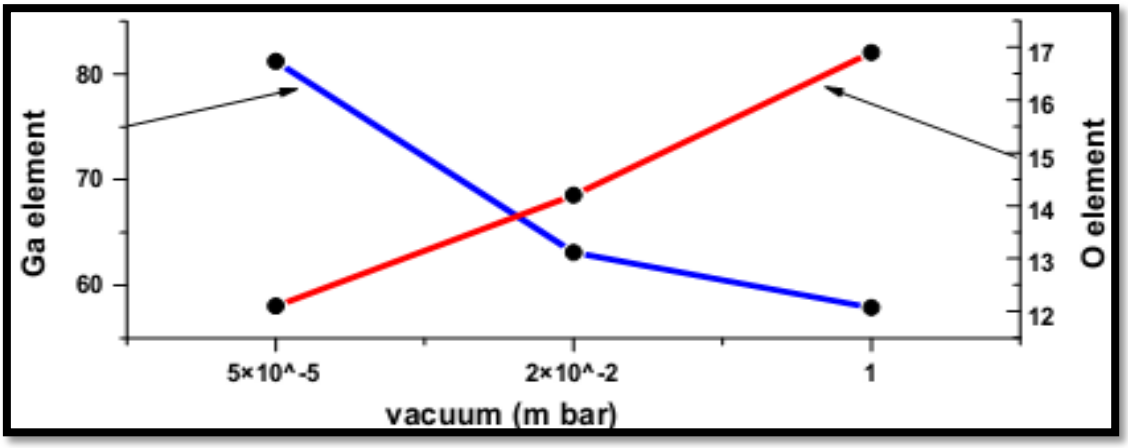

Figure (6) Oxygen and the Gallium percentage at various vacuum levels

3- UV-VIS measurement

The absorbance and transmittance spectra were determined as a cursor of the wavelength in a zone between (200-1100) nm for thin films with Ga_2O_3 nanostructures with increasing the vacuum in the range (5×10^{-5}, 2×10^{-2}, and one mbar), as in figures (7) and (8).

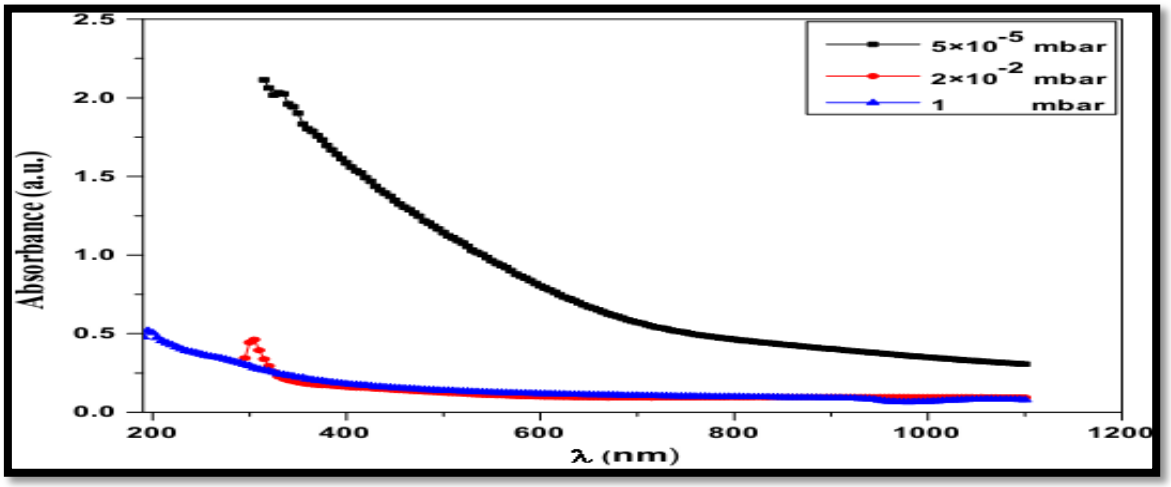

Figure (7) absorbance spectra of Ga_2O_3 nanoparticles thin film

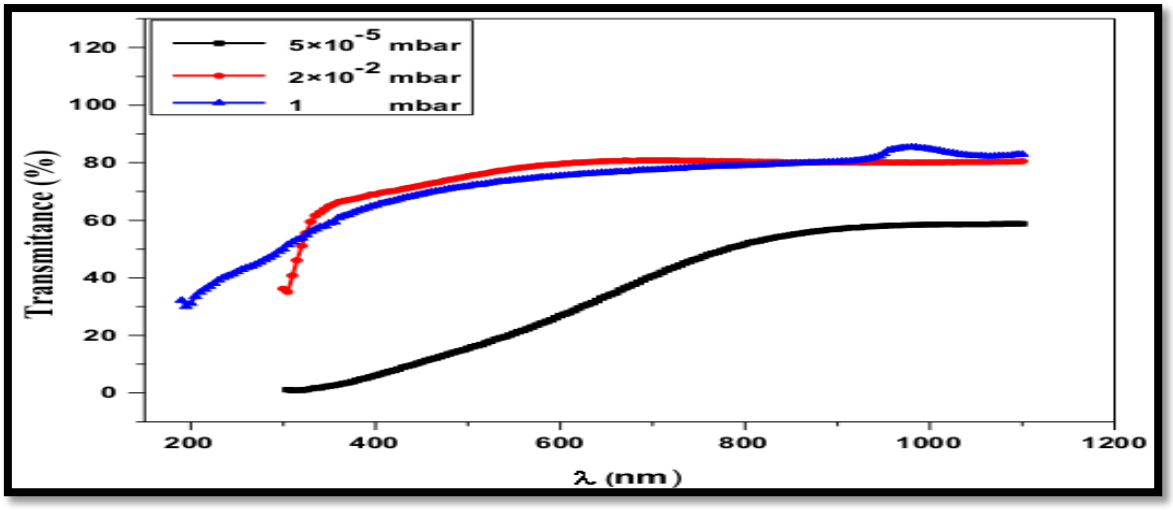

Figure (8) Transmittance spectra of Ga_2O_3 nanoparticles thin film

In figures (7) and (8), the prepared samples had a transmittance of approximately 55% in the vacuum (5×10^{-5}) and this value increased to reach 80% in the vacuum (1mbar) in the UV region. The transmittance decreases sharply to below 350 nm due to the strong absorption of the films in this region. With the increase in the vacuum value, the transmittance value increases, and the absorption value decreases [11]. The energy gap of all models can be calculated at different vacuums as shown in the table (2) and figure (9) by the calculation (2).

$$\alpha\, h\upsilon = B\,(h\upsilon - E_g)^n \qquad (2)$$

(B) The transition static is equal to one, (α) absorption coefficient, (n) equal (bold 1 over bold 2) at allowed direct transition, and (n) equal ($\frac{3}{2}$) at forbidden direct transition.

Table (2) Energy band gap of Ga2O3 NPs at different vacuums

Vacuum (mbar)	Energy band gap (eV)
5×10^{-5}	2.2
2×10^{-2}	3.7
1	4.92

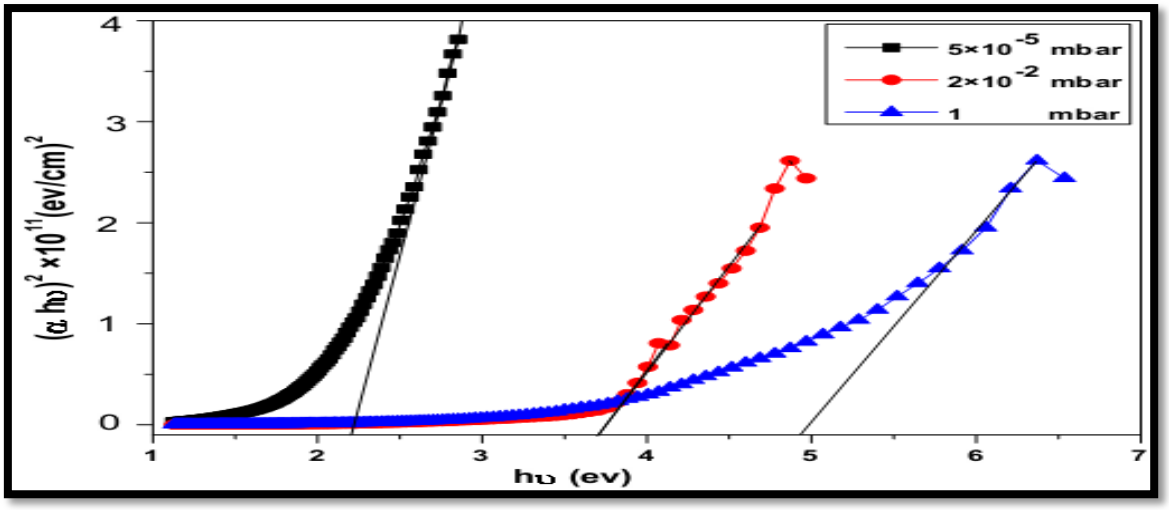

Figure (9) the optical band gap of Ga_2O_3 nanoparticles thin film at different the vacuum (5×10^{-5} , 2×10^{-2} and 1mbar)

4 Photoluminescence properties (PL)

Optical luminescence spectra were calculated at room temperature in the zone of 200-900 nm with an excitation wavelength of about 250 nm using a PL spectrometer. Figure (10) illustrates the emission spectra of the samples. PL measurements were achieved to assess the optical properties of Ga_2O_3 thin films prepared at various vacuum levels. The figure shows three peaks concentrated around 339 nm, 387 nm, and 421 nm, respectively. The first peak indicates the near energy band gap, and the second and third peaks are the blue emission. The visible emission can be radiative recombination through the point defects, such as vacancies. The PL intensity for all peaks of UV emission at 339 nm is clear. This indicates that the film crystallizes, while the blue emission expansion indicates defects in the films, the amplitude and blue shift in the emission peaks towards the bottom reveal that the particle size is in the nanoscale [12].

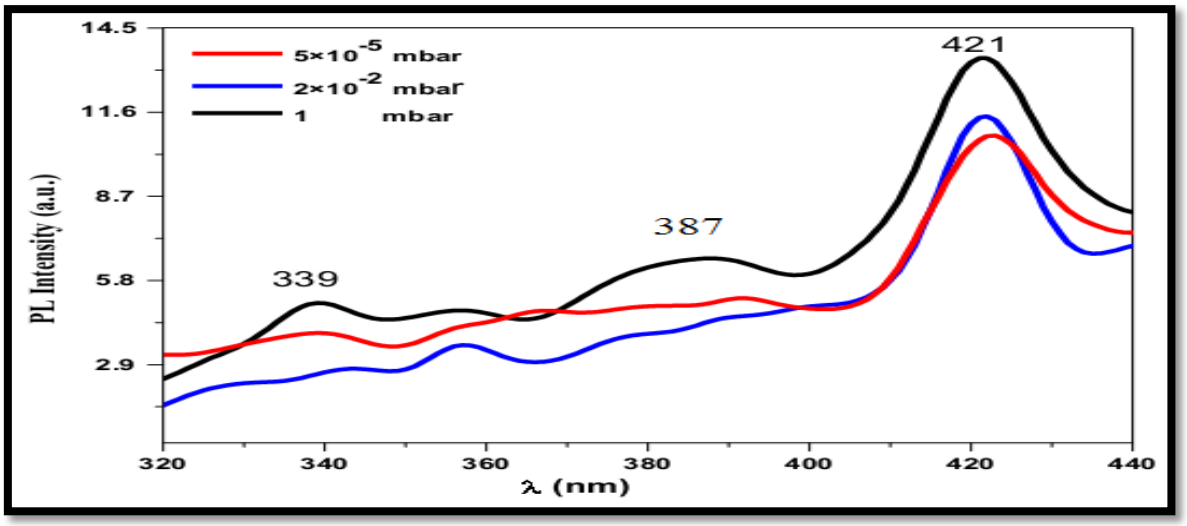

Figure (10) Photoluminescence at various vacuums (510×-5, ×210-2, and 1mbar).

Conclusion

1- The crystallite size increases when the vacuum increases.
2- As the value of the vacuum increases, the oxygen percentage increases and the gallium percentage decreases.
3- The increase in the vacuum, the transmittance value increases, and the absorption value decreases.
4- The increase in the vacuum results in an increase in the energy gap.
5- This indicates that the film crystallizes while emitting blue.

ACKNOWLEDGMENTS

This work was done with the possibilities available in the thin film laboratory of the Physics Department at the Faculty of Science, University of Mustansiriya / Iraq / Baghdad.

Highlights:

- ❖ When the vacuum is increased, there is a blue shift.
- ❖ To obtain the best nanomaterial under a vacuum of 1 mbar.

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