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Effect of Substrate Temperature on Structural and Morphological Properties of Ga_2O_3 NPS Thin Films by (PLD) Method

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ABSTRACT

In this study, thin films of Gallium oxide nanoparticles were deposited using the method of pulsed laser deposition (PLD) on a glass substrate under different substrate temperatures (400, 500, and 600 K) before and after annealing. The Nd-YAG laser was utilized at the wavelength (1064 nm) and the frequency (5 Hz) at 130 0C. The effect of substrate temperature value before and after annealing on the Structural and morphological Properties was studied by UV-VIS, X-ray diffraction)XRD), scanning electron microscopy(SEM) and Atomic force microscopy (AFM) . The outcomes XRD showed that the structure of Ga2O3 nanoparticles is a polycrystalline structure of the monoclinic type with Prominent crystal orientations of (-401), (-202), (- 111), (111), and (-312). It is according to JCPDS card No.00-041-1103. Crystallite size for complete models increased with the growth substrate temperature value before and after annealing. The results of (SEM) for gallium oxide nanoparticles prepared with different substrate temperatures (400, 500, and 600 k) before and after annealing showed that the films increase their homogeneity and the voids decrease with increasing temperatures. The energy band gap decreased with increasing substrate temperatures, and the absorption edge was in the UV zone..

Keywords: Gallium oxide Ga_2O_3 nanoparticles, substrate temperature, pulsed laser deposition

INTRODUCTION

There gallium oxide Ga_2O_3 in various forms, α–, β–, γ –, ε–, δ– and κ–phase[2]from all that can be obtained formats, The formula β is the best common forms of Ga_2O_3. β-Gallium oxide is the lone steady polymorph out of all the formats over a extensive temperature scope unto its melting point 1795 0C. The remaining polymorphs are not stable and change to the β formula at temperatures overhead 750-900 0C[3].Ga_2O_3 is a vast band-gap (~5 eV) semiconductor materials, Semiconductor has a band-gap wide 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 Ga2O3 thin film and nanoparticle by pulsed laser deposition(PLD) method on glass substrate for the reason that the effect of the oxidation parameters[7]..

Experimental part

He 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 to have homogenization. Glass substrates (1.5 x 1.5 cm) were utilized for deposition of Ga2O3 film. Distilled water was utilized to clean these glass substrates and remove residual dust and dirt from their surface. The glass substrates were cleaned in alcohol for 5 minutes through an ultrasonic device to remove certain oxides and fat. Hot air was used in this procedure to dry glass substrates, and lastly, soft paper was used to clean the slides An ND:YAG laser was used to deposition the films at (400, 500 and 600 K) by pulsed laser deposition (PLD) method at wavelength (1064 nm), The amount 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 temp. was changed on the Ga2O3 films, 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 the Figure (1).

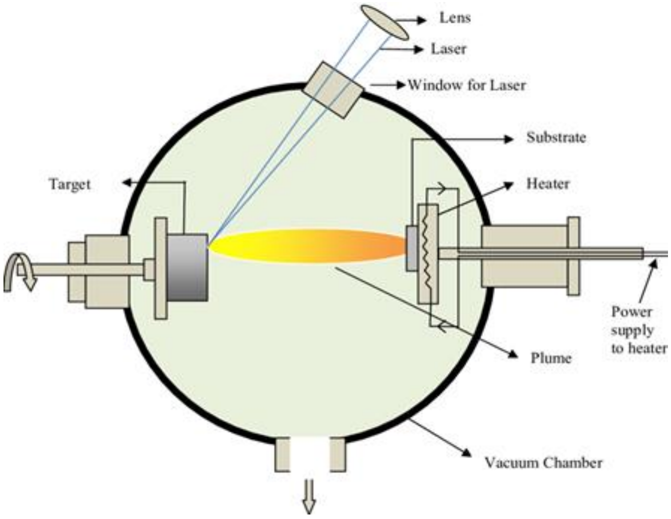

fig (1) Pulsed laser deposition system[8]

$$D = \frac{0.94\,\lambda}{\beta \cos\theta} \quad \text{..........(1)}$$

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

RESULTS AND DISCUSSION

1- X-ray diffraction (XRD)

X-ray diffraction (XRD) spectra of Ga2O3 nanostructure thin films grown at various the temperatures of substrate, 400, 500, and 600 k. All samples of the prepared films of Ga2O3 NPs before and after annealing showed that they had a polycrystalline structure of the monoclinic type with Prominent crystal orientations of (-401), (-202), (-111), (111), and (-312). It is according to JCPDS card No.00-041-1103 as in figures (2) ..

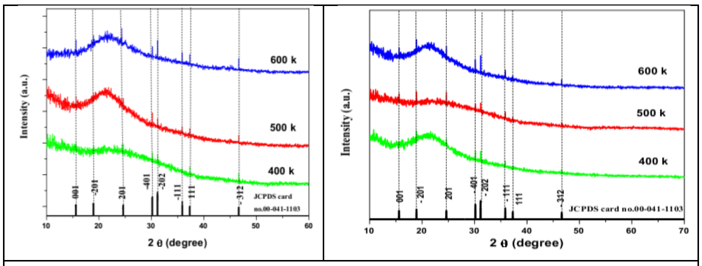

Fig. (2) X-ray diffraction patterns of Ga_2O_3 thin films prepared at different temperatures of the substrate before and after annealing.

TABLE I TABLE (1) CRYSTALLITE SIZE OF GA2O3 NPS BEFORE AND AFTER ANNEALING

Temperature (k)	crystallite size (nm) before annealing	crystallite size (nm) after annealing	Temperature (k)
400	32.01	53.34	400
500	53. 35	80.09	500
600	106.6	106.69	600

Table (2) surface roughness and (RMS) of Ga2O3 NPs before and after annealing

Temperature (k)	Surface Roughness		RMS	
	before annealing	After annealing	before annealing	After annealing
400	14.4	2.69	23.6	3.94
500	16	23.5	26	36.3
600	25.9	37.3	36.8	44.8

2- Atomic force microscopy (AFM)

The (AFM) images give some data about the surface roughness (R), the average grain size (D) and the maximum height of the Ga2O3 NPs thin films were infectious at various temperature (400, 500, and 600 K) before and after annealing as shown in the figures (3)

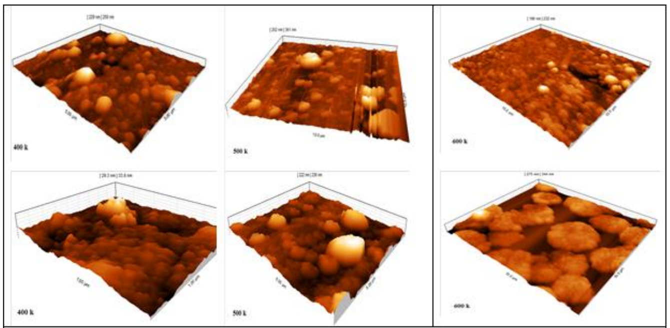

Fig. (3): AFM images at various substrate temperature (400, 500 and 600 K) before and after annealing

The minimum value of surface roughness and (RMS) of films after annealing at 400 k and increases with increasing temperature, as shown in Table (2) indicating that the temperature increases growth and makes the surface of films free of voids and homogeneous distribution for grains.

After annealing, the surface roughness value and (RMS) will increase, and the grain size becomes larger. The reason for this is that high annealing temperature facilitates the coalescence of the surface grains and therefore a rougher surface , and thus an increase in the grain size.

Scanning electron microscopy (SEM)

In Figure (4) before and after annealing, we observe the (SEM) images and (EDS) of Ga2O3 nanoparticles at various substrate temperatures (400, 500, and 600 K) respectively

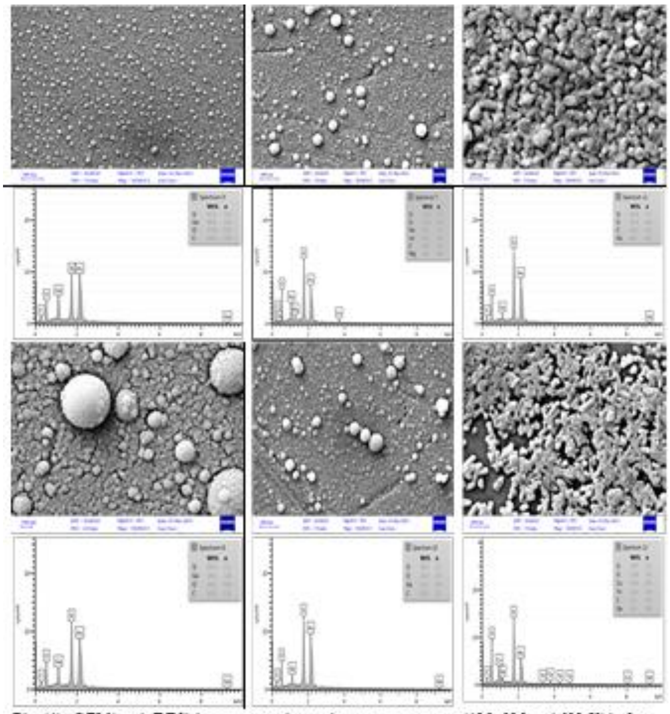

Fig. (4): (SEM) and (EDS) images at various substrate temperature (400, 500 and 600 K) before and after annealing

The results of (SEM) for gallium oxide nanoparticles and prepared with different substrate temperatures (400, 500 and 600 k) before and after annealing showed that the films increase their homogeneity and the voids decrease with increasing temperatures, as well as when the films are annealed, as the crystal growth process is clearly completed and this corresponds to the increase in crystal size diagnosed through X-ray diffraction.

Energy-dispersive X-ray spectroscopy (EDX) system was used to determine the approximate ratio of the elements that make up the thin film from the measurements obtained for each temperature for all samples. As for the results of (EDX) before and after annealing, we note that as the temperature of the substrate increases, the proportion of gallium atoms decreases and the proportion of oxygen atoms increases, as shown in figure (4).

4- Optical Properties measurements

The absorbance and transmittance spectra were determined as a function of wavelength in the zone between (190-1100) nm for thin films with Ga2O3 nanostructures with increasing substrate temperature in the range (400, 500 , and 600 K) before and after annealing, as in Figure (5).

With increasing temperatures of the substrate, the absorption edge of the Ga2O3 films shifted towards the short wavelength zone gradually (blue shift) .

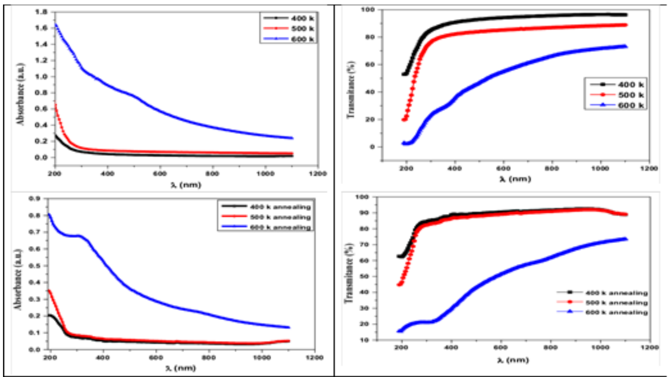

Fig (5) transmittance and absorbance spectra of Ga_2O_3 nanoparticles thin film at different substrate temperature (400, 500 and 600 k) before and after annealing

Before annealing, the prepared samples had a transmittance of more than 90% at wavelengths longer than 280 nm in the UV zone. The sharp transmittance happening at the band edge shows that the Ga2O3 thin films grown at 400–500 K possess a crystalline nature. Also, the feature of transmittance for the Ga2O3 film grown at 600 K was much changed from that of the other films. The 600 K grown film possessed a transmittance spectrum with a smooth but not sharp absorption edge near 450 nm and relatively lower transmittance (< 60%) in the calculated wavelength range. This is because of the incomplete growth structure within the 600 K grown film.

The energy gap of all models can be calculated at different substrate temperature (400, 500 and 600 k) before and after annealing as shown in the table (3) and figure (6) by the calculation:

$\alpha h \upsilon = B (h \upsilon - Eg)^n$….. (2)

(B) the transition static is equal to one, (α) absorption coefficient, (n) equal (1/2) at allowed direct transition and (n) equal (3/2) at forbidden direct transition

Table (3) band gap value of Ga2O3 NPs before and after annealing.

Temperature k	*band gap before annealing*	*band gap after annealing*
400	*5.2 ev*	*5.04 ev*
500	*5.1 ev*	*4.4 ev*
600	*3.7 ev*	*2.7 ev*

The band gap values of Ga2O3 decrease as the substrate temperature increases due to the increase in temperature which causes the particles to fuse with each other and then agglomerate and become with a large crystal size, thus the optical band gap decreases with increasing temperature

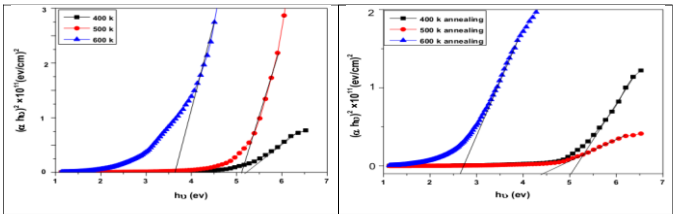

fig. (6) the optical band gap of Ga_2O_3 NPs thin films at varies substrate temperature (400, 500 and 600 k) before after and annealing.

CONCLUSION

1. The crystallites size increases when the different substrate temperatures before and after annealing increase.
2. When the value of substrate temperatures before and after annealing increases, the oxygen percentage increases, and the gallium percentage decreases.

3. The increase in the substrate temperatures before and after annealing, the transmittance value decreases, and the absorption value increases.
4. The increase in the substrate temperatures before and after annealing, the energy gap decreases.
5. This indicates that the film crystallizes while the blue shift..

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