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Study the Structural Properties of ZnO Prepared by Pulsed Laser Deposition Technique

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KEYWORDS:
- Zinc oxide
- pulsed laser deposition
- structural properties

ABSTRACT

In this research, ZnO nanostructure films were prepared using pulsed laser deposition method on glass substrates ina room temperature. The ZnO nanostructures were characterized by X-ray diffraction and atomic force microscopy (XRD, AFM). Thegrownthin films have a polycrystalline wurtzite structure, it can be seen that the highest texture coefficient was inplane (101), with grain sizes between (41nm-65nm), morphology of the film wasstudied and showed that the average root mean squareincreases with the thickness of the films, with RMS between (197nm-206nm).

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دراسة الخواص التركيبية الأغشية (ZnO) المحضرة بتقنية الـ(PLD)

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الكلمات المفتاحية:
- أوكسيد الخارصين
- الترسيب بالليزر النبضي
- الخصائص التركيبية

الـــخُـــلاصـــة

تم في هذا البحث، تحضير أغشية ذات تركيب نانو من أكسيد الخارصين باستخدام طريقة الترسيب بالليزر النبضي، وتم ترسيب الاغشية على أرضيات من الزجاج عند درجة حرارة الغرفة، وتم التأكد من التركيب النانو عن طريق حيود الاشعة السينية (XRD)، ومجهر القوة الذرية (AFM)، وكانت الاغشية ذات تركيب سداسي متعدد التبلور، وحجم الحبيبات ما بين (41nm-64nm)، وتبين دراسة مورفولوجيا سطح الغشاء ان متوسط الجذر التربيعي يزداد بزيادة سمك الغشاء، وأن متوسط الجذر التربيعي ما بين (197nm-206nm).

1. Introduction

At the beginning of the 19th century, researchers focused on the semiconductor study because of the advantages of these materials such as changing their Electrical conductivity by heat, light and magnetic field: Because of these properties, semiconductors were extremely important in technological applications[1].One of the most important semiconductors is the so-called transparent conductive oxides, which are abbreviated to

(TCO), a compound semiconductor composed of an oxygen metal called oxide of metals (ZnO, SnO_2, In_2O_3،etc.) [2,3]. Zinc oxide; a chemical compound referred to as the chemical molecular ZnO and be insoluble in almost water or alcohol but it melts in acids and alkalis. It is manufactured in a white powder with hexagonal crystals and is known as zinc white as it is in nature in the form of mineral zincates. Hexagon and its color depends on the presence of impurities and the zinc oxide is characterized by the electro-thermal, characteristic piezoelectric, and the thermochemical effect as its color changes from white to yellow when heated. Zinc oxide is a semiconductor with energy gap of3.37eV at room temperature, which makes it within UV range. So, it's a pipette for the UV energy that's falling on it. [٤,12]. The pulsed laser deposition (PLD) is the process of vapor deposition of the material that gets into the vacuum system, the laser energy intensity of each pulse is sufficient to vaporize or scrape a small amount of material that creates the plasma plume, which in turn moves forward towards the backbone of the meta-growth process [5].In our study (research), zinc oxide thin films were prepared (deposited) by pulsed laser deposition method using Nd-YAG laser with wavelength 1064 nm, the effect of film thickness on the structural, and surface morphology of the film were studied.

2. Experimental details

The targets were manufactured from of the pure zinc oxide powder 99.995%, the product by company chemical Ltd. The targets are made in the form of pills by the compression of the powdered zinc oxide when pressed 10Ton, and these targets with a thickness 3mm and diameter 25 mm and then placed in a thermal oven at atmospheric pressure with temperature of200 ℃ for four hours.

The ZnO films were deposited on glass substrates in the (PLD) system, in which a Nd-YAG type laser pulse device was used. The laser was with wavelength of 1046nm, frequency rate 5Hz, and the laser power density 100mJ/cm2, the distance between substrate and target 4cm, when the vacuum compartment was pressed 0.2 mbar, the films were deposited with a different deposition time (5, 10, 20) min.The thickness of the films was measured using the optical interferometry method (Michelson method). This method was based on the interference of the light beam reflected from the surface of the thin layer and the bottom of the basement. He-Ne laser with wavelength 632.8 nm was used and thickness was determined using the formula [6,12]:

$$t = \left(\frac{\Delta x}{x}\right) \times \frac{\lambda}{2} \text{ - - - } \quad (1)$$

where t: is the films thickness, x is fringe width, Δx is the distance between two fringes and$\lambda$is wavelength of laser light.

The thickness of the prepared films which was (150nm, 300nm, 600nm) ± 7nm.The following measurements were conducted:

a. Measurement of structural properties by (CuKα) XRD-6000, Shimadzu X- ray diffractometer at scanning between (20– 80).

b. Topographic surface of the films using the atomic force Microscope (AFM)(Phywe AA 3000).

3. Results and discussion

a. X - ray diffraction (XRD):

X-ray results showed that the films prepared were polycrystalline and hexagonal. Figure 1 shows seven distinct peaks (100), (002), (101),(102), (110), (103), (112) at angles 31.8 °, 34.5 °, 36.3 °, 47.6 °, 56.7 °, 62.9 ° 68 ° respectively, it is clear from these forms that this level (101) is the preferred level of growth compelled with other levels, making it the preferred trend level, and observed that the diffraction intensity at this level and facilities to the angle of deviation 36.3 ° is at the highest possible level, comparing the results with the

American Standard for Testing and Materials Card (ASTM) No. 96-900-8878.

In addition, the d_{hkl} values of the crystalline levels shown in table 1, which were calculated using a Bragg relationship that is also congruent, as the table shows too the rate of grain size found using an equation (Debye-Scherrer's) [7,11]:

$$D = \frac{0.9\lambda}{\beta_{hkl}\cos\theta} --- \qquad (2)$$

Where D: the crystallite size.

λ: the wavelength used in the X-ray radiation.

β_{hkl}: FWHM, θ: angle of Bragg

Table (1): The results of the X-rays and the average crystallite size.

Thickness (nm)	2θ (deg.)	d_{hkl} exp.(Å)	d_{hkl} std. (Å)	FWHM (deg.)	(hkl)	G.S (nm)
150	31.8	2.808	2.814	0.191	(100)	45.101
	34.5	2.599	2.603	0.188	(002)	46.086
	36.3	2.472	2.475	0.212	(101)	41.111
	47.6	1.909	1.911	0.166	(102)	54.42
	56.7	1.623	1.624	0.206	(110)	45.622
	62.9	1.475	1.477	0.17	(103)	57.245
	68	1.378	1.378	0.155	(112)	64.589
300	31.852	2.807	-	0.24	(100)	35.879
	34.5024	2.597	-	0.192	(002)	45.271
	36.3256	2.471	-	0.204	(101)	42.741
	47.6443	1.907	-	0.19	(102)	47.757
	56.6288	1.624	-	0.286	(110)	32.886
	62.9267	1.475	-	0.153	(103)	63.475
	68.0484	1.376	-	0.173	(112)	57.786
600	31.8601	2.806	-	0.194	(100)	44.3387
	34.5145	2.596	-	0.187	(002)	46.359
	36.3423	2.47	-	0.19	(101)	45.886
	47.6434	1.907	-	0.181	(102)	49.938
	56.6816	1.622	-	0.164	(110)	57.435
	62.9434	1.475	-	0.19	(103)	51.219
	68.0331	1.376	-	0.169	(112)	59.146

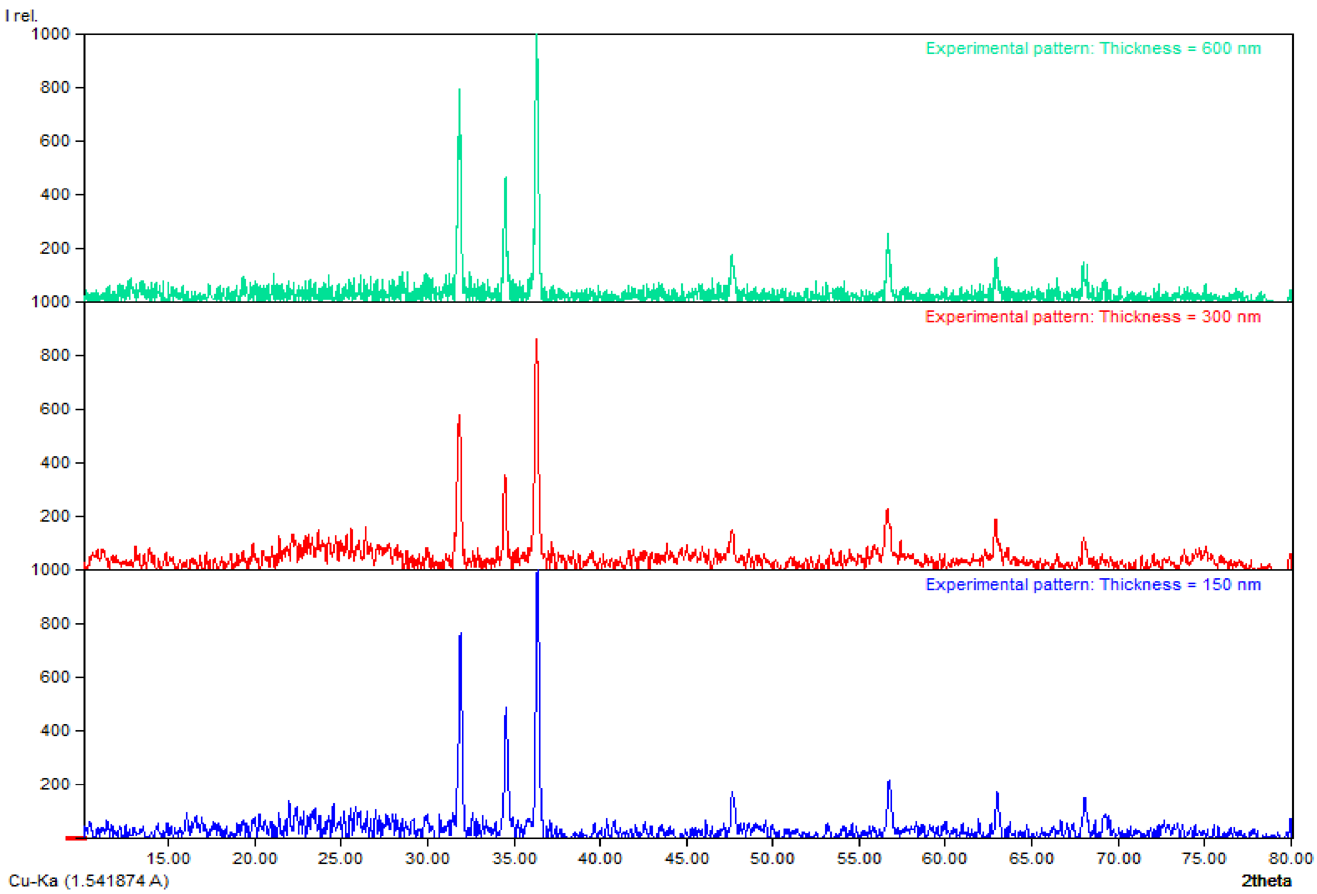

Figure (1): X-ray diffraction patterns of zinc oxide films of different thickness.

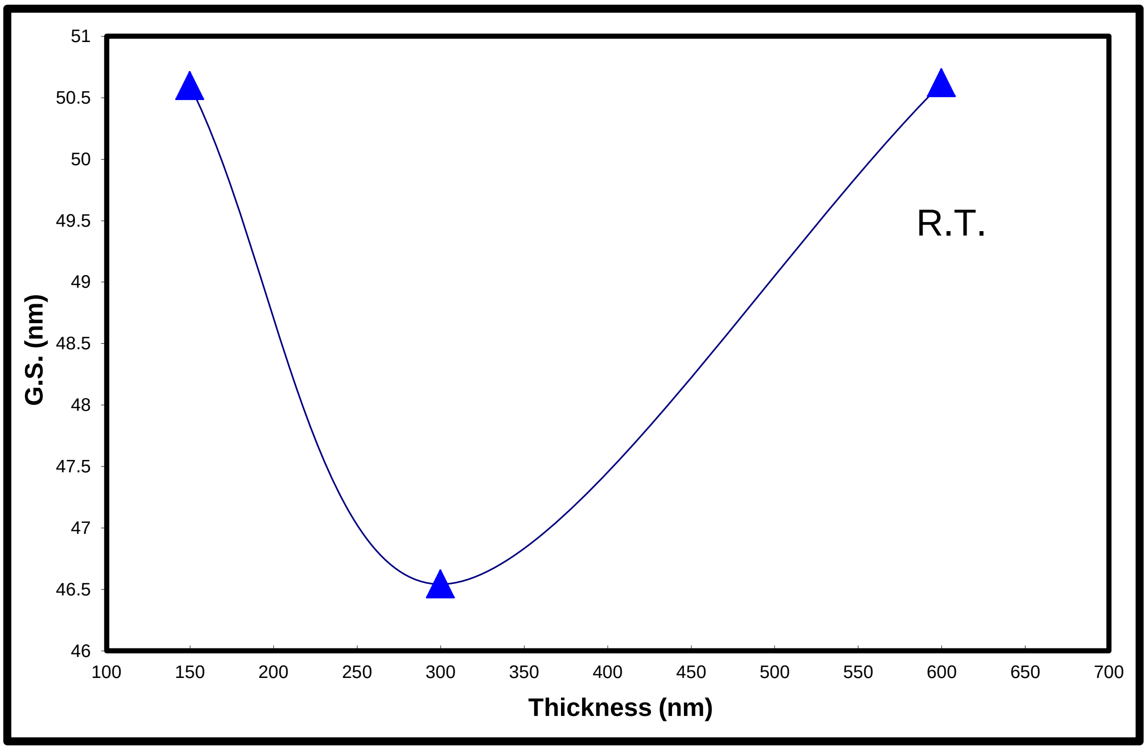

Figure (2):Variants of average grain size with film thickness.

The lattice parameter was calculated in the direction (100) and direction (200) through the following relationship [7,11]:

$$\frac{1}{d^2} = \frac{4}{3}\left(\frac{h^2 + hk + k^2}{a^2}\right) + \left(\frac{l^2}{c^2}\right) - (3)$$

where (hkl): Miller indices.

lattice parameter was compared with international Card (ASTM) numbered (96-900-8878) and were identical as in table 2.

Table (2): The lattice Parameters with different thickness of films.

Thickness (nm)	a (Å) (exp.)	c (Å) (exp.)	a (Å) (exp.)	c (Å) (exp.)
150	3.242	5.198	3.2498	5.206
300	3.241	5.194	-	-
600	3.24	5.193	-	-

Also, the texture coefficient was calculated through the following relationship [8]:

$$T_c = \frac{I(hkl)/I_\circ(hkl)}{N^{-1}\sum I(hkl)/I_\circ(hkl)} - - - \quad (4)$$

where the Tc: the texture coefficient

I(hkl): measuring density at the level of (hkl).

$I_{\circ(hkl)}$: the standard severity of the level (hkl) taken from the ASTM card.

N^{-1}: The number of peaks is visible in X-ray diffraction.

The micro strain was calculated using the following relationship [9,11]:

$$\text{strain} = \frac{|C_{ASTM} - C_{XRD}|}{C_{ASTM}} \times 100\% - (5)$$

Where C_{ASTM} : is taken from the ASTM card.

C_{XRD}: The amount of lattice parameter of x-ray.

The dislocation density was calculated through the following relationship [7,10]:

$$\delta = \frac{1}{D^2} - - - (6)$$

The number of crystals was also calculated from the following relationship [10]:

$$N_\circ = \frac{t}{D^3} - - - (7)$$

The results listed in Table 3 show that the texture coefficient (TC ≪1) shows that direction (101) are the preferred trend for crystal growth of the prepared films. And so, by increasing the thickness Leads increasing to The micro strain, the dislocation density and the number of crystals are increasing too.

Table (3): Structure parameters of zinc oxide thin films.

Thickness (nm)	**T_C (hkl)**	**micro strain**	**$\delta(cm^{-2}) \times 10^{14}$**	**$N_\circ(cm^{-2}) \times 10^{15}$**
150	1.096	0.001	4.167	1.453
300	1.181	0.002	5.318	3.926
600	1.189	0.003	4.028	4.923

b. Surface Topographic:

Through the diagnosis of the Atomic Force Microscope (AFM), it turns out that the pure films material is homogenous distribution through three-dimensional diagnosis with note that there are no irregular physical pools or blanks on the surface of the films as in Figure (5).

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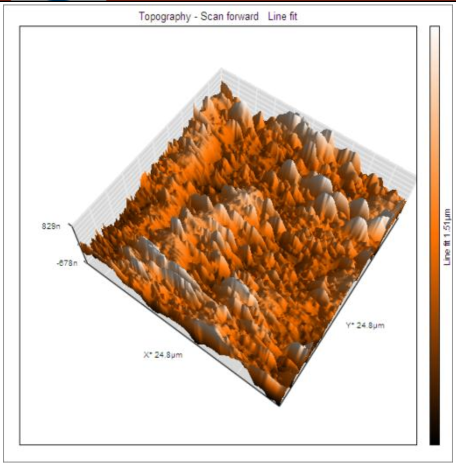
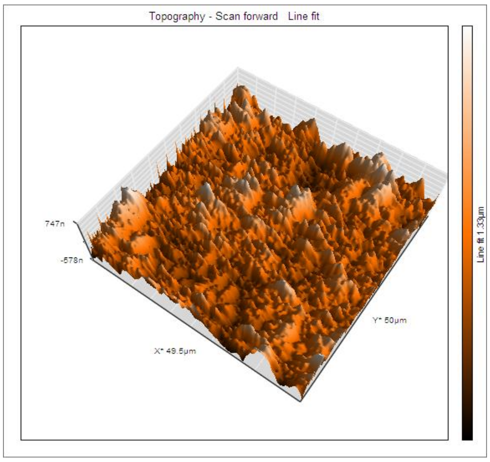
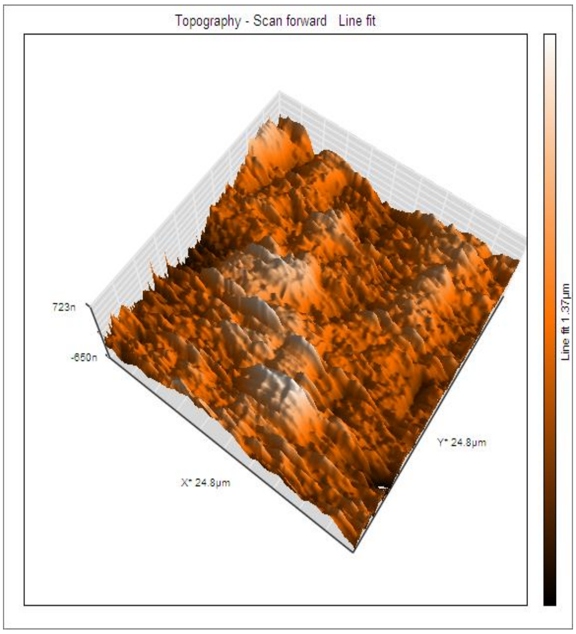


Thickness (600nm)



Thickness (300nm)



Thickness (150nm)

Figure(5): 3D Atomic force Microscopy images of zinc oxide films with thickness (150,300,600) nm.

The results in Table (4) show that the root mean square increases with the thickness of the films.

Table (4): RMS values for pure ZnO films.

Thickness (nm)	RMS (nm)
150	197
300	200
600	206

4. Conclusions:

According to the results, it was observed that we could produce zinc oxide films using a pulsed laser deposition (PLD), where we observed that polycrystalline with a hexagonal structure of x-ray technology and that observed variation in structure properties varies according to thickness of films.

References

[1] G.L Pearson and W. H. Brattain, “History of semiconductor research”, Proc. IRE, vol. 43,(1999).

[2] A. Roth, D. Williams, “Properties of ZnO films Prepared by Oxidation of diethyl zinc”, J. Appl. Phys., Vol. 52, No.11, PP.6685, (1989).

[3] Granqvist, C. G., "Transparent conductors as solar energy materials: A panoramic review". Sol. Energy Mat. Sol. Cells, PP.1529–1598, (2007).

[4] Ü. Özgür, Ya. I. Alivov, C. Liu, A. Teke, M. A. Reshchikov, S. Doğan, V. Avrutin, S.-J. Cho, and H. Morkoç,“A Comprehensive Review of ZnO Materials and Devices”, Journal Applied Physics, Vol.98, No.4, PP. 41301,(2005).

[5] Z. Jin, T. Fukumura and M. Kawasaki, “Hightthrouput fabrication of transition – metal doped epitaxial ZnO thin films: A series of oxide-diluted magnetic semiconductors and their properties”, J. Appl. Phys., let., vol. 78, no. 24, PP.3824, (2001).

[6] D. Chrisey, G.K. Hubler, "Pulsed Laser Deposition of THIN Films", Wiley-Interscience,1Edition, (1999).

[7] Khaled Z.Yahya, "Characterization of Pure and dopant TiO2 thin films for gas sensors applications", Ph.D. thesis, University of Technology, June, (2010).

[8] J. Taus in, “Amorphous and Liquid Semiconductors”, Ed. by J. Taus, Plenum Press, London, (2012).

[9] C. Barred, T. B. Massalski, “Structure of Metals” , Pergamon Press, Oxford, (1980).

[10] M. Ohring, “The Materials Science of Thin Films", Academic Press, (1992).

[11] E. Muchuweni, T. S. Sathiaraj, H. Nyakotyo,“Synthesis and characterization of zinc oxide thin films for optoelectronic applications”,Heliyon,vol.3,no.4,PP.1-18,(2017).

[12] Maysar A. Salim, “Effect of thickness on the optical properties of ZnO thin films prepared by pulsed laser deposition technique (PLD)”, Iraqi Journal of Physics, Vol.15, No.32, PP. 114-121, (2017).