Investigation of Structural, Optical and Electrical Properties of ZnO Prepared Thin Film by PLD

The 5th International Scientific Conference for Nanotechnology and Advanced Materials and Their Applications ICNAMA 2015 (3-4)Nov.2015)

Dr. Samer. Y. Al-Dabag
College of Science for women, University of Baghdad/ Baghdad.
Email: wwss81296@yahoo.com
Dr. Sudad. S. Ahmed
College of Science, University of Baghdad / Baghdad.
Wasan. J. Taher
College of Science for women, University of Baghdad/ Baghdad.

Abstract

In this paper , Zinc Oxide (ZnO) films were grown on glass substrates by Pulsed Laser Deposition (PLD) technique at room temperature under the vacuum pressure of 3×10^{-3} mbar. Employing a Nd:YAG pulses laser at wavelength 1064nm was used in this technique .The effect of number of laser pulses (200,500 and 800) at annealing temperature 450 C ^{o} on the structural, optical and electrical properties was studied. The structure of the ZnO thin films was examined by X-Ray diffraction (XRD), it was found that ZnO thin films are polycrystalline with many peaks, and the results of Atomic Force Microscopy (AFM) indicated that all films have grain size around 90 nm. The optical properties concerning the photoluminescence (PL) spectra were studied for the prepared thin film. From the PL, the optical gap of the ZnO thin film was determined. The Hall effect measurements confirmed that the ZnO thin films are n-type , While the number of laser pulses is increasing, the charge carriers concentration (n) increases, and Hall mobility (μ_H) decreases.

Keywords: Pulsed laser deposition, Zinc oxide thin films, Structural, Optical, Electrical properties.

دراسة الخواص ألتركيبيه، ألبصريه والكهربائية لأغشية اوكسيد النحاس المحضرة بتقنية الترسيب بالليزر النبضي

ألخلاصه:

في هذا البحث تم ترسيب اغشية اوكسيد الزنك الرقيقه بتقنية الليزر النبضي باستخدام ليزر النيدميوم ياك النبضي ذي الطول الموجي 1064nm. تم تلدين الأغشية المرسبة على أرضيات زجاجية بدرجات حرارة (450 ^{O}C) . أظهرت فحوصات حيود الأشعة السينية بأن كل أغشية الـ ZnO متعددة التبلور, ويلاحظ أن حجم الحبيبات يزداد بزيادة عدد النبضات. وتم حساب فجوة الطاقه من خلال نتائج شدة الاستضاءة الفوتونيه للاغشيه ألمصنعه . من حساب تاثير هول وجد ان اغشيه اوكسيد الزنك ألرقيقه هي من نوع ال n-typ وتم ملاحظة ان كثافة حاملات ألشحنه تزداد وتحركية هول تقل بوضوح مع زيادة عدد نبضات الليزر.

الكلمات ألمفتاحيه :- الترسيب بالليزر النبضي, الأغشية ألرقيقه ل ZnO , لخصائص التركيبية, البصرية وللكهربائية .

INTRODUCTION

Zinc Oxide (ZnO) has been attracting much attention due to its unique electrical, and optical properties that together with its low cost, ease of preparation[1] and non toxic [2].In recent years, nano ZnO has found wide ranging applications such as an electrode for dye-sensitized solar cell.[3, 4].

Almost all of the major deposition techniques such as Sputtering, Chemical Vapor Deposition, sol-gel, chemical spraying and electron plasma sputtering, have been employed for the growth of ZnO films. As the pulsed laser deposition (PLD) method has been recognized to offer the potential of growing high quality thin film at relatively lower substrate temperatures than other techniques[5], its use in growing ZnO films .The high melting and boiling points of ZnO allow one to explore a variety of heat treatments required for alloying purposes and device formation. Being an oxide, ZnO also enjoys the extreme stability against the oxidation problem which can severely affect the device performance as in case of some of semiconductors such as GaAs, InAs etc [6]. Other advantages of ZnO are the resistance to high energy radiation, which makes it suitable for space applications, as well as the stability and amenability to wet chemical etching , which can be exploited for the fabrication of small size devices [7]

In this work , the (ZnO) deposit by PLD method using Nd:YAG laser using pulsed Nd:YAG pulse laser at 1064nm wavelength and repetition rate 6Hz . The deposits were characterized by XRD and AFM to observe the surface structure ,PL to investigate and hall effect to examined the state the novelty ρ this work electrical properties of the films.

Experimental Work

Target preparation*:* ZnO powder with high purity 99.9 % powder was pressed under 5 Ton for 7 min.

Laser Source:-

Nd: YAG Laser work at wavelength 1064nm was used for the deposition of ZnO thin film at different number of laser pulses (200, 500, 800) and (energy, frequency,)constant for each pulse: 800mJ, 6Hz, respectively**.** During this work pulse laser deposition (PLD) is used to prepare ZnO thin film. The experimental setup of Pulse Laser Deposition (PLD) system consist of laser source and deposition chamber which include inside it the target, the substrate and the vacuum system.

Electrodes Deposition

Aluminum electrodes were evaporated to mare ohmic controls on the surface of ZnO films using thermal evaporation technique through a mask giving sensitive area as illustrated in figure (1)

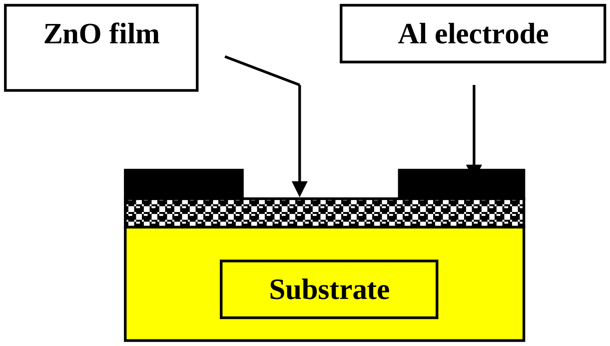


Figure (1) Al electrodes deposited on the surface of ZnO.

Characterization Measurements

The structure of the ZnO are studied by X-ray diffraction (XRD) (SHIMADZU JAPAN, XRD – 6000) with Cu Kα radiation (λ = 1.542 A°) was used, and Atomic Force Microscope (AFM, model AA3000 scanning probe microscope) using tapping mode, the optical testing of the film were investigated by (PL) and electrical testing study by Hall effect.

Result and desiccation:-

Structure measurements:-

X-Ray Diffraction Analysis:-

The XRD pattern of the ZnO powder is studied with the diffraction angle (10˚ - 80˚). All the peaks are in 100% phase matching with the ZnO hexagonal phase of ASTM cared, as shown in Figure (2). There are no other characteristic impurities peaks were present which also confirm that the product obtained is in pure phase. Figure (3) shows XRD patterns of the ZnO thin film at different Number of pulses (200, 500 and 800) of Nd:YAG laser at annealing temperature by 450 °C for 2 h. XRD pattern of synthesized ZnO nanostructures by PLD present all peaks of the obtained product are corresponding to the hexagonal structure of ZnO. The diffraction peaks at scattering angle (2θ) of (31.7^o), (34.4^o), (36.2^o), (47.4^o) and (56.5^o) correspond to the reflections from (100), (002), (101), (012) and (110) crystal planes respectively. These reflections correspond to the standard card ASTM. were observed from figure effect number of laser pulse on intensity suggests that as the increases the diffraction peaks are narrower and exhibit a higher intensity. The average grain sizes were found to be increasing with increasing number of laser pulse as shown in Figure (4), average grain sizes measurement by using Scherrer equation.

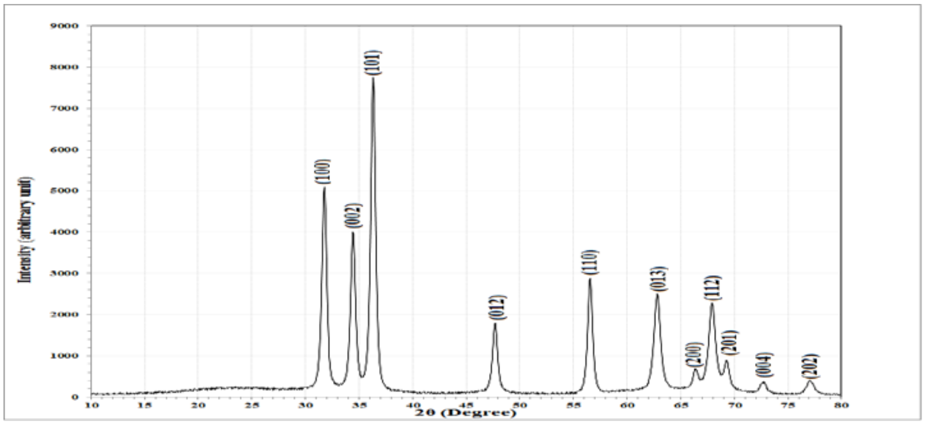


Figure (2) XRD patterns of the ZnO powder.

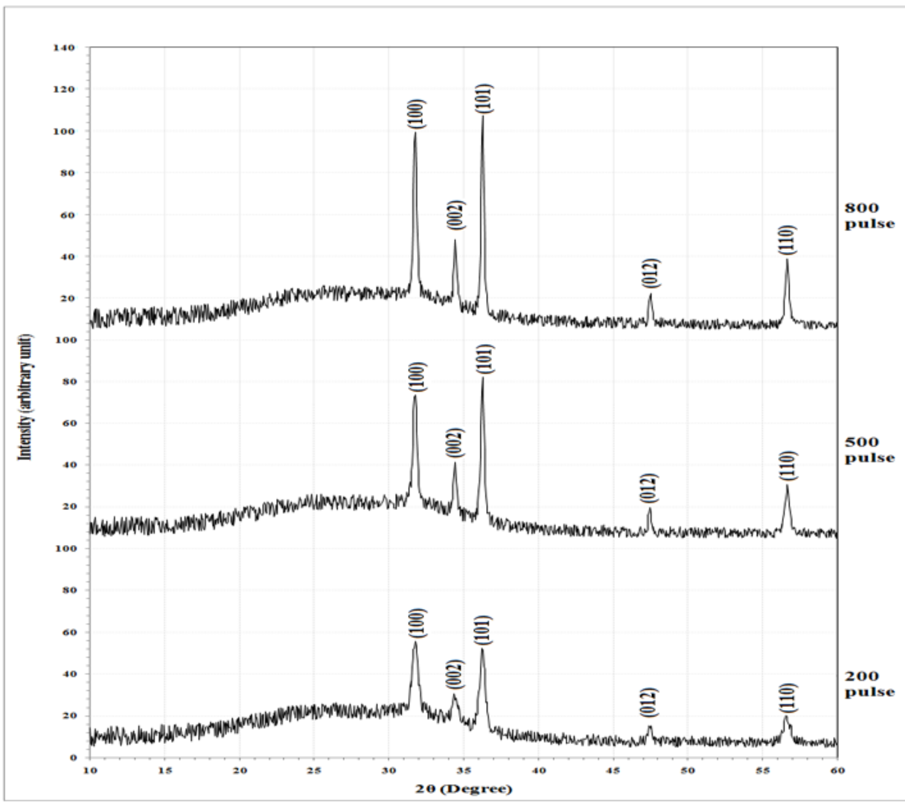


Figure (3) XRD patterns of the ZnO thin film deposited on glass substrate different No. of pulse (200, 500 and 800).

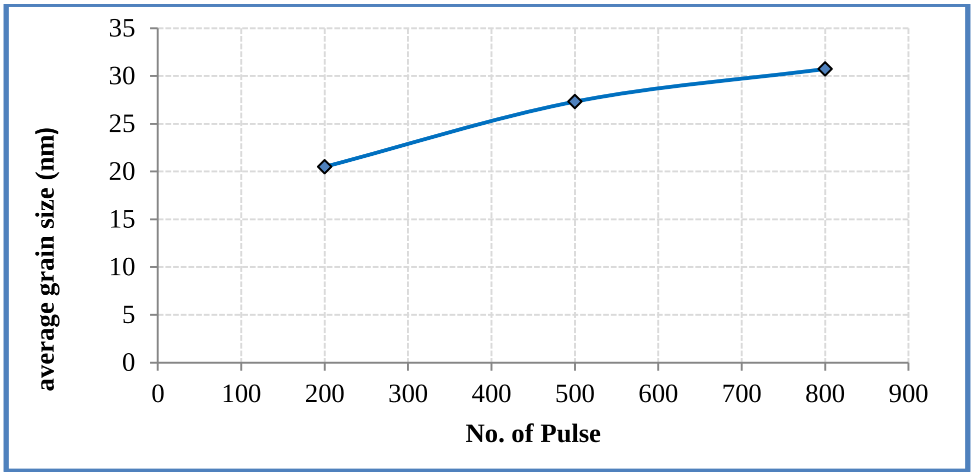


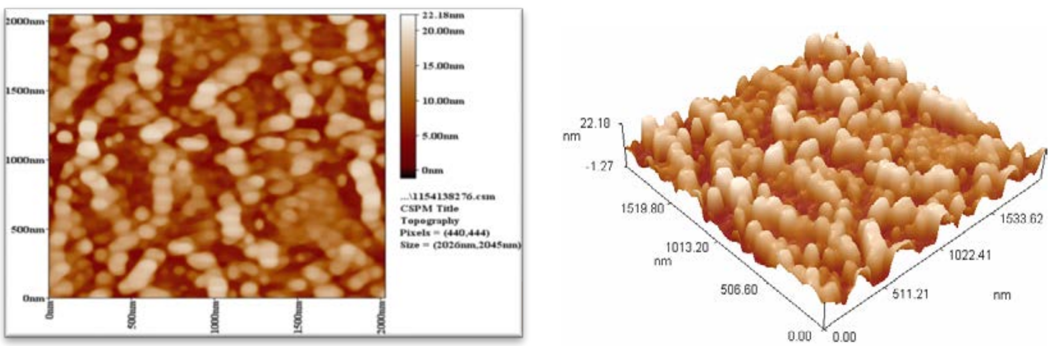
Figure (4):- illustrated the relation-ship between the average grain size (nm) and No. of pulse (200, 500 and 800)

AFM Analysis

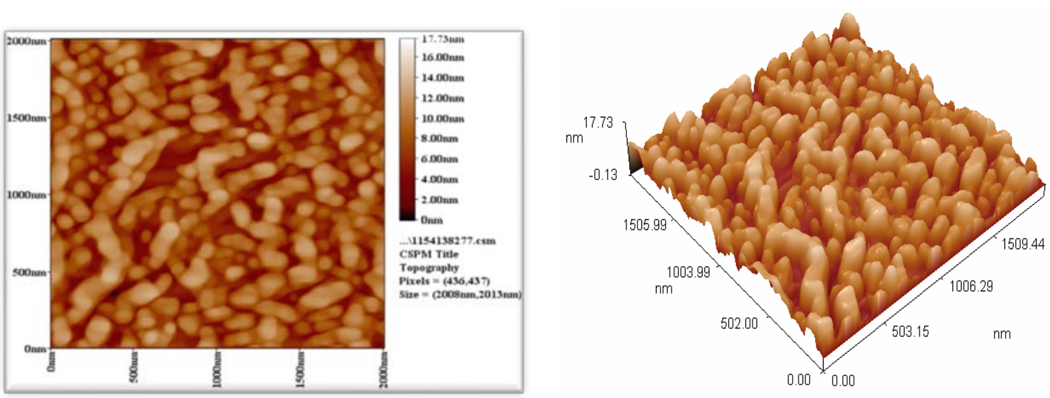
The surface morphology of the ZnO thin films was investigated using Atomic Force Microscopy (AFM) with different No. of pulses (200, 500 and 800) at annealing by 450 °C for 2 h as shown in figure (5). Average grain size and surface roughness values were listed in Table (1). The result of the AFM analysis illustrated the average grain size and roughness increase with increasing number of laser pulse because of increasing the thickness of the film.

Table (1) Grain size and surface roughness of nanostructure ZnO for different No. of pulse (200, 500 and 800).

No. of Pulse	Average Grain size (nm) ZnO	Roughness (nm) ZnO
200	91.71	4.02
500	94.29	5.11
800	98.21	8.89



(a)



(b)

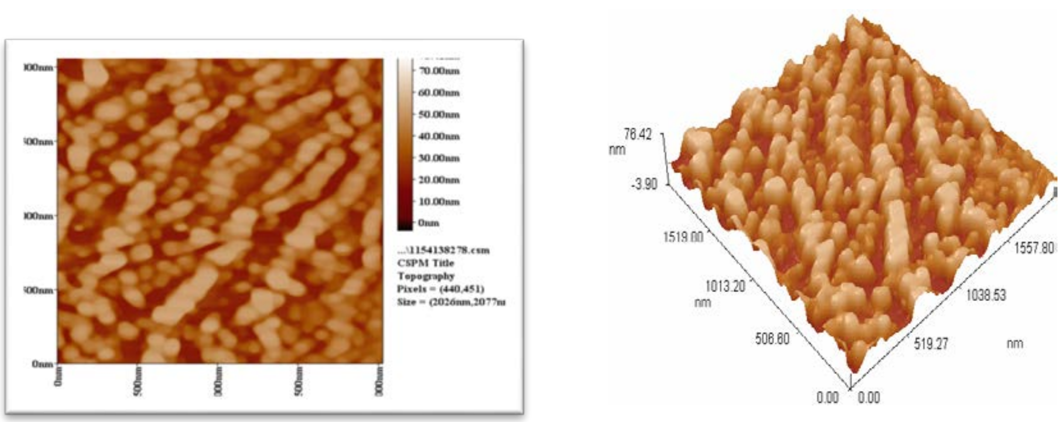


Figure (5) Two-dimensional and three-dimensional AFM of nanostructure ZnO films deposited on galas plate with different No. of pulses {A(200), B(500), C(800)}

Photoluminescence (PL)

Figure (6) shows the PL spectrum of ZnO thin film deposited on glass substrata at different number of pulses (200, 500 and 800) at annealing temperature at 450ºC. Typical luminescence behavior with two emission peaks: a sharp peak of UV emission (a band-edge luminescence band and a broad peak of Deep Level Emissions (DLE). PL characteristics of ZnO thin films showed strong relation to the number of pulse. The intensity of the two peaks increases markedly with the increase of numbers of pulse reached to 5500 (a.u) at temperature 450 °C , due to the large exciton bending energy of thin film. Shorter wavelength (higher energy) excitation photons cause more phonons to be emitted before luminescence occurs. If the excitation energy is less than the energy difference between the ground state and the first excited state, then no optical absorption will occur, resulting in no PL. Table (2) shows the peak values and the intensity of the luminescence spectrum of ZnO.

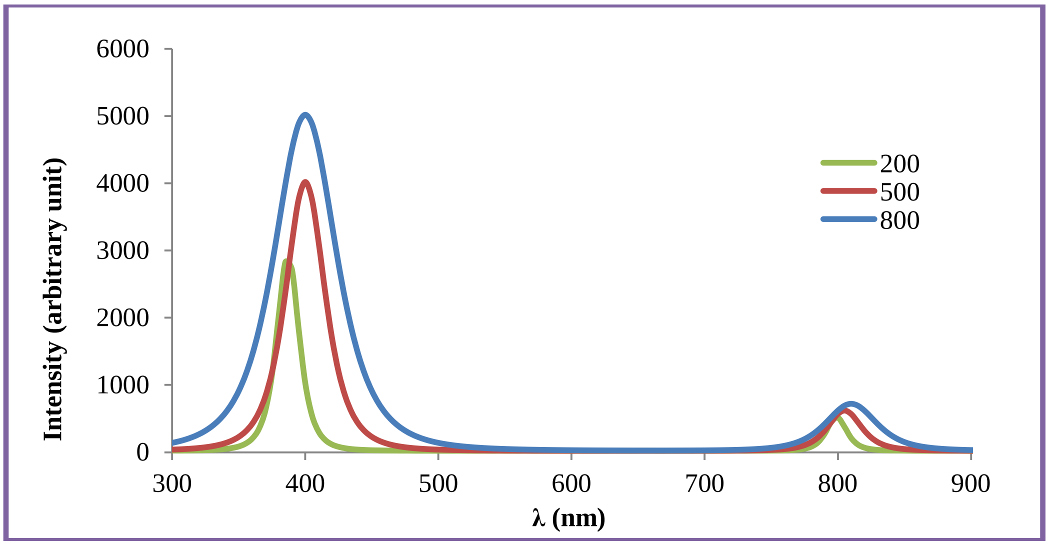


Figure (6) PL spectram of ZnO thin films on glass substrate for different No. of pulse (200, 500 and 800).

Table (2) Wavelength and energy values of photoluminescence peaks at different No. of pulse at 450 ^{o}C of the ZnO.

No. of pulse	Wavelength (1) (nm)	Energy (1) (ev)	Wavelength (2) (nm)	Energy (2) (ev)
200	387	3.20	799	1.55
500	400	3.10	805	1.54
800	400	3.1	810	1.53

Electrical testing

Hall Effect

From the Hall Effect measurements, the resistivity (ρ), carrier concentration (N_H) and carrier mobility (μ_H) values were calculated and listed in table (3). The negative sign of Hall coefficient indicates the conductivity nature of the film is n-type this result agreement with reframes .From figure (7 and 8) can be a plot of the variations of n_H, μ_H with different number of pulse (200, 500 and 800).Hall measurement indicates that the as grown films are high resistance, which is usually attributed to poor crystal quality.

The carrier concentration of ZnO thin films increased with increasing number of pulses. This is attributed to the improved crystallinity and increase grain sizes that weakens inter crystallite boundary scattering and increases carrier lifetime. The n_H was calculated by using the equation

$$\frac{(1)}{q \times R_H} \qquad \ldots (1)$$

Where

q is the electron charge.

Table (3) Hall effect measurements of ZnO at 450 °C for different number of pulse.

NO. Of pulse	$\sigma_H x10^{-6}$ $(\Omega.cm)^{-1}$	R_H x10^{10} (cm^2/C)	n_H $(cm^{-2})*10^{11}$	μ_H $(cm^2/V.s)$ X 10^2	Type of conductance
200	2.496	9.863	6.336	6.445	n-type
500	5.374	8.016	7.796	4.192	n-type
800	7.973	3.522	17.745	2.462	n-type

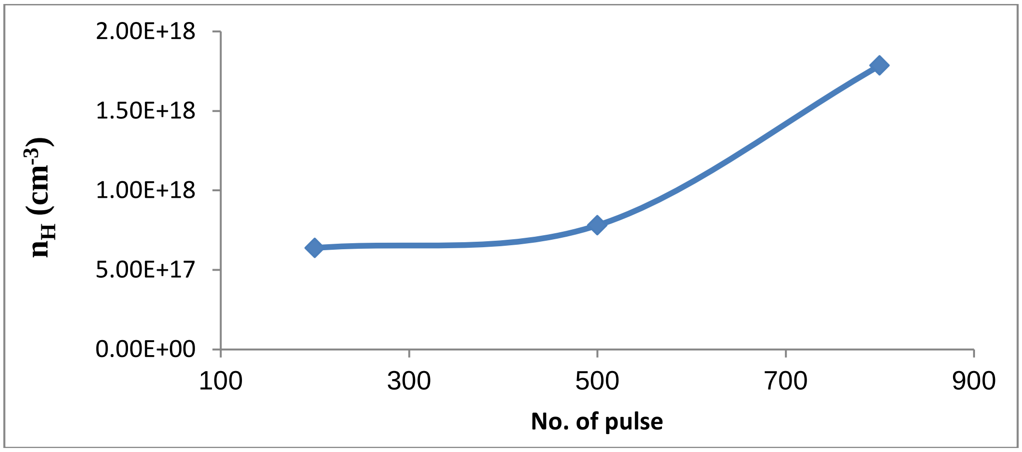


Figure (7) The relation-ship between the n_H of ZnO thin film and No. of pulses (200, 500 and 800) of Nd:YAG laser.

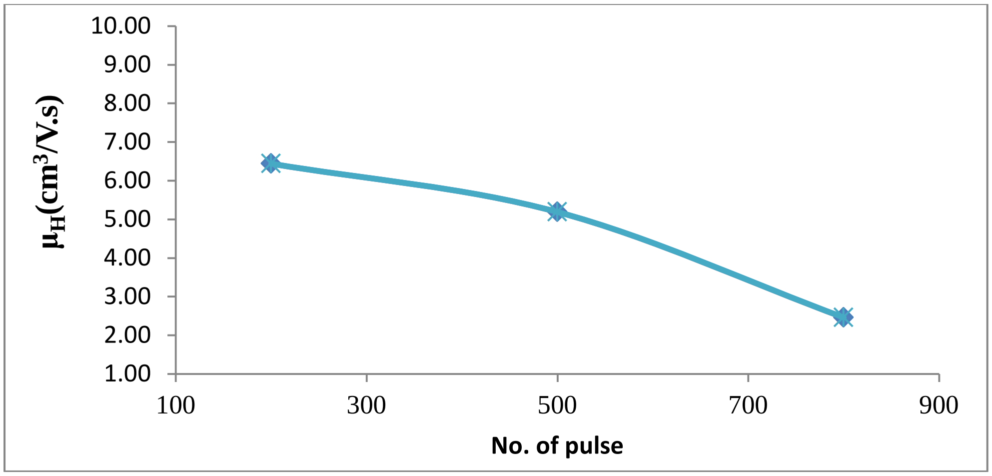


Figure (8) The relation-ship between the μ_H of ZnO thin film and No. of pulses (200, 500 and 800) of Nd:YAG laser.

Conclusion

- XRD analysis indicated that the structure ZnO thin film polycrystalline of the annealed to 450 C^o. And the intensity of peaks increased as No. of pulsed increasing from 200 to 800 pulse.
- The grain size and roughness increase of ZnO thin film as the number of Nd:YAG laser pulse increase.

- Hall Effect measurement proves that ZnO is N- type semiconductor.
- As the number of Nd:YAG laser pulse increase the n_H increase while the mobility μ_H decrease.
- PL characteristics of ZnO thin films showed strong relation to the temperature and number of pulses. The intensity of the two peaks increases markedly with the increase of numbers of pulses.

Reference

[1] A. Peiro, P. Ravirajan, K. Govender, D. Boyle, P. Brien, D. Bradiey, J. Nelson and J. Durrant, “Hybrid Polymer/Metal Oxide Solar Cell Based on ZnO Columnar Structures” journal of materials chemistry, Vol. 16, PP: 2088-2096, (2006).
[2] H. Reza, S. Mahboobeh and M. Ali, “Synthesis of ZnO Nanoparticles by Spray Pyrolysis Method” Iran. J. Chem. Chem. Eng. Vol. 30, No. 1, (2011).
[3] Z. Wang, “ Zinc Oxide Nanostructures: Growth, Properties and Applications “, Journal of Physics: Condensed Matter, Vol. 16, (2004).
[4] J. Mosnier , R. Haire, E. McGlynn, M. Henry, S. Donnell, M. Boyle and K. McGuigan, “ ZnO Films Grown by Pulsed Laser Deposition on Soda Lime Glass Substrates for the Ultraviolet Inactivation of Staphylococcus Eepidermidis Biofilms”, Sci. Technol. Adv. Mater. Vol. 10,PP: 045003, (2009) .
[5] A. Dikovska, P. Atanasov, C. Vasileva, G. Dimitrov, T. Stoyanchov, “Thin ZnO Films Produces by Pulsed Laser Depositions” Journal of Optoelectronics and Advanced Materials, Vol. 7, No. 3, PP: 1329 - 1334 , (2005),
[6] D. Sridev and K. Rajendran, “Synthesis and Optical Characteristics of ZnO Nanocrystals” Indian Academy of Sciences, Vol. 32, No. 2, pp: 165–168, (2009).
[7] I. Volintiru, "Remote Plasma Deposition of Metal Oxides: Routes for Controlling the Film Growth", Eindhoven: Technische Universities Eindhoven, (2008).