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A Study of Morphological and Optical Properties for ZnO Thin Film by Pulse Laser Deposition

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Abstract:
Pulse laser deposition PLD method that used to make ready ZnO thin films. Thin film was deposited via pulsed laser deposition on glass and p-type silicon substrate for inspection morphological and optical properties. UV-Visible spectrophotometer utilized in the range of (200-1100) nm to determine spectral transmittance of thin film . Many tests were performed for structure and morphological of zinc oxide film such as XRD, FE-SED and AFM.
Keywords: *Zinc oxide thin film; optical properties; Energy gap*.

I. INTRODUCTION

To andate, zinc oxide (ZnO) was been a crucially many sided material in the applications of nanotechnology . ZnO is a very favorable oxide for semiconductor instrument applications [1,2]. It has sundry attractive properties as the direct and wide band gap (3.37 eV) transparent to visible light, high chemical stability and good photoelectric and piezoelectric properties[3,4]. The doping process using to make highly conductive for semiconductor materials[5]. Band-gap of ZnO can be achieved by alloying with CdO or MgO. The metal oxides and Transparent conducting oxides (TCOs) have high electrical conductivity, high optical transparency and low optical absorption. TCOs can be classified as n-type or p-type, for example Zinc oxide (ZnO) is an n-type semiconductor material with large exciton binding energy (60 meV) and hexagonal wurtzite structure as shown in figure (1)[6,7]. It is used in various technological domains such as surface acoustic wave devises, gas sensors, optical devices and transparent window layer in CIS, CGS solar cells[8]. Several techniques were used for preparation ZnO thin film such as sputtering, sol–gel spin coating, thermal oxidation, evaporation, (CVD) chemical vapor deposition, molecular beam epitaxy (MBE), and pulsed laser deposition (PLD) [9-11]. The PLD method enables the growth of high-quality thin films of metal oxide materials at relatively low substrate temperatures compared with other techniques. Also, the method provides synthesizing of multilayers of different compositions with high crystalline perfection. [12-14]. This is due to the high energy of the ablated particles in the laser-produced plasma plume[15].

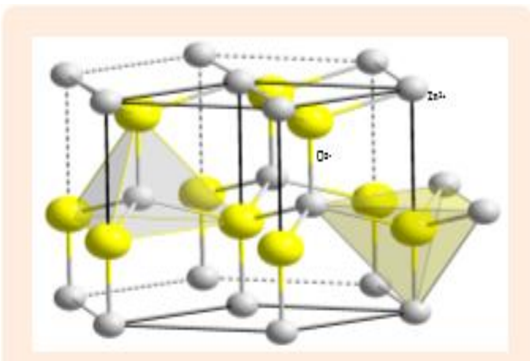

Figure 1. Wurtzite structure of ZnO [16].

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II. EXPERIMENTAL DETAILS

ZnO thin film on glass and silicon substrate was prepare by pulse laser deposition technique, in several steps:

Zinc oxide powder were pressed under a (7 tons) press to form disk shaped (target) with dimension (2.5 , 0.5)cm, respectively. After that, it was dry at 150 0C and 1hr. inside vacuum oven compatible.

The silicon substrate is (100)-oriented, before deposition, for cleaning, the wafer was etched in a 10 % HF for 5 min in order to remove the eventual oxide layer that may form during storage, then rinsed in distilled water and dried by cold air.

ZnO target previously obtained was used for the production of thin film on substrate by PLD method (Nd:YAG laser wavelength 1064 nm), pulse width (10 ns.), repetition rate (6 Hz) this operate at 120 mJ to ablate the target. Power supply, temperature and pressure for deposition are, respectively, (220 v, 250 0C, 10-5 mPa).

After that, annealing thin film at 450 0C for 1.5 hr.

The distance between substrate–target was 3.5 cm. The target is necessary rotated during the deposition for achieve uniform deposition.

III. RESULTS AND DISCUSSION

3.1 X-ray diffraction results

The crystal structure of ZnO films was investigated through X-ray diffraction (XRD).The X-ray diffraction spectrum of ZnO film annealed at 450ºC with prominent reflection planes is shown in figure (2). The peaks in the XRD spectrum correspond to those of the ZnO patterns from the JCPDS data (Powder Diffraction File, Card no: 36-1451), having hexagonal wurtzite structure. No other impurities peaks observed in the XRD diffractograms revealed that the crystalline ZnO formed well for all samples. Thin films deposited on a glass substrate with thickness equal to (160 nm) by pulse laser deposition method at RT. No other impurities peaks observed in the XRD diffractograms revealed that the crystalline ZnO formed well for all samples. The crystallite size of the ZnO films annealed was calculated by using Debye-Scherrer equ. Is used [17]:

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

Where D is the crystallite size, wavelength of the X-ray used is λ =1.54059Å, β is the broadening of diffraction line measured at the half of its maximum intensity in radians and θ is the angle of diffraction[18].

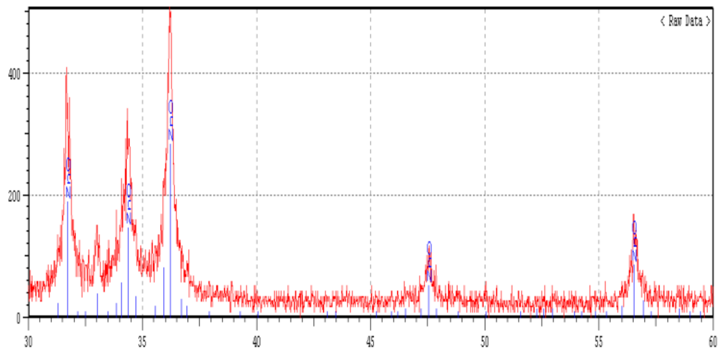

Figure 2. X-ray diffraction spectrum of ZnO film.

Figure (3) shows the EDS spectrum of thin film (ZnO) at the required process parameters, which indicates that the film contains 64.3% O and 35.7% Zn (mass fraction), the structure of the thin film is expected to be crystall. This is exactly what happened. Lower incorporation of nano-particles in thin films can be ascribed to the smaller size of the particles.

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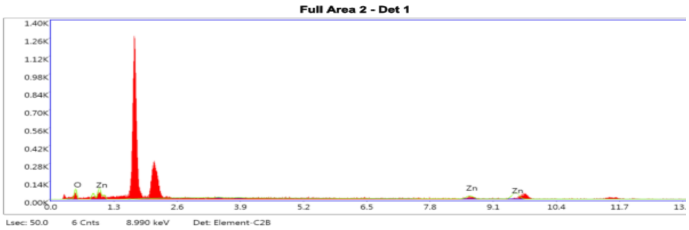

eZAF Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
O K	64.3	88.0	10.2	13.2	0.2740	1.0875	0.3918	1.0000
ZnK	35.7	12.0	7.5	8.3	0.3049	0.8053	1.0423	1.0182

Figure 3. EDS of ZnO film.

3.2 FE-SEM

The morphologies of the generated ZnO particles prepared by pulse laser deposition technique at (450 °C) temperatures was analysed by FE-SEM. Figure (4) is shown image at magnification of 60 Kx for the prepared ZnO NPs. The image reveals that the shape of formed nanoparticle is approximately spherical, and having hexagonal wurtzite structure. The thicknesses of ZnO films measured by Spectroscopic Ellipsometry. Thickness of the prepared films were 113 nm for PLD.

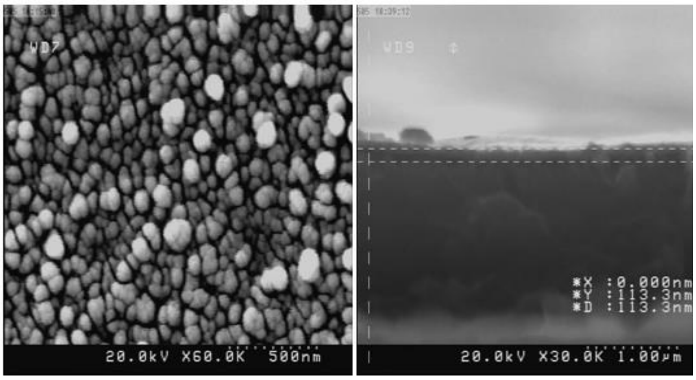

Figure 4. FE-SEM image of surface (A), and cross-section (B) of ZnO film.

3.3 Atomic Force Microscope- AFM

The AFM images of pure ZnO thin films have prepared by pulse laser deposition technique at RT under pressure of 1×10-5 mbar, which are annealed at 450 °C temperature for 2 hours and thicknesses of 113 nm. The AFM images of pure ZnO thin films show a uniform granular surface morphology. From the Fig.(5). Where notice that the roughness average 0.471 nm and root mean square 0.598 nm, also the average grain diameter from 80 nm to 180 nm.

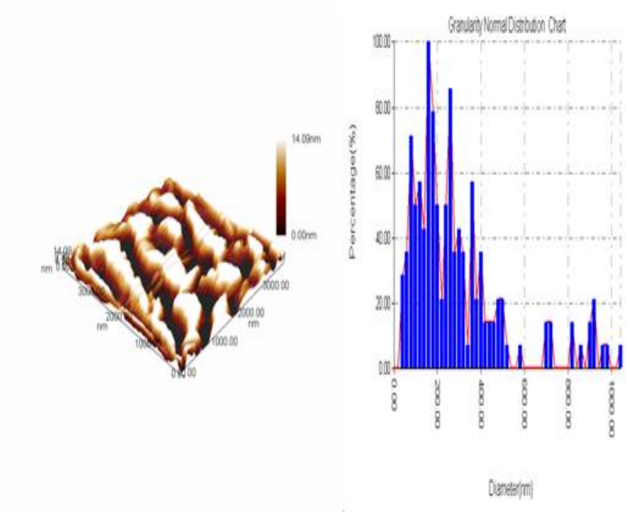

Figure 5. AFM images of pure ZnO thin films at thickness 160 nm and annealing temperature 450 °C.

3.4 Optical measurements

The absorbance, absorbance coefficient and transmittance for thin films of ZnO onto glass substrate obtained by pulse laser deposition technique at RT, which are annealed at 450 °C temperature for 2 hours and thicknesses of 113 nm, were measured by using instrument measuring the spectrum, made by (Shemadzo) company, Japan 1800 UV visible.

The absorbance spectrum as a function of the wavelength in the range (200-1100) nm for ZnO thin films are shown in figure (6). Spectrum of ZnO revealed that ZnO thin films have high response in the UV region and decreases exponentially with the increasing of wavelength in the visible region while glass spectrum is transparent at visible region. This is mean that the emitted photons from ZnO will not suffer from any absorption during passing through the thin film. This is except in the wavelength of 364 nm were there is a peak of small absorption. The band gap (Eg) of ZnO were calculated by using the formula $E= hc/\lambda$ where h is plank's constant, c is

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the velocity of light and λ is the wavelength. It can determined from the plot of (αhν)2 with photon energy (hν) indicates. The band gap of ZnO was found to be 3.374 eV.

The value of the absorption coefficient for ZnO thin film are found to be > 104 cm-1 in the visible region which means that the film has a direct optical energy gap. The variation of the absorption coefficient of ZnO thin film is shown in Fig. (7) as a function of the wavelength.

Figure (8) shows the transmission spectra of ZnO thin film deposited onto glass substrates in the wavelengths range of 200 - 1100 nm. All the measurements are realized at room temperature.

As can be seen, the average optical transmittance of the samples in the visible range is amount 70%. In addition, it is important to notice that the film has a suitable thickness (113 nm), leading to a good optical quality of the produced ZnO materials which is in good agreement with the literature report [17].

The ZnO thin film was electrically characterized using Hall Effect measurements. The film of 113 nm thickness shows semiconductor of n-type behavior, which means that the charge carries are electrons.

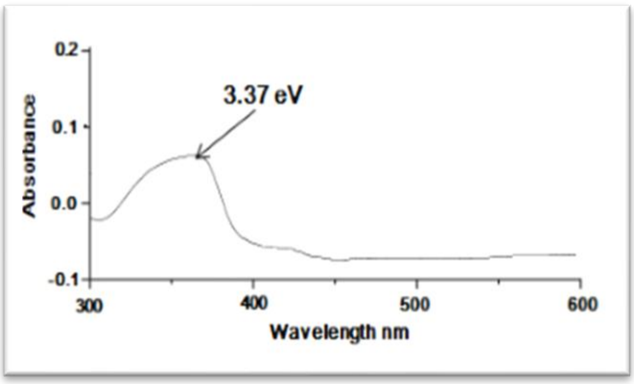

Figure 6. The absorbance spectra as a function of wavelength of ZnO thin films.

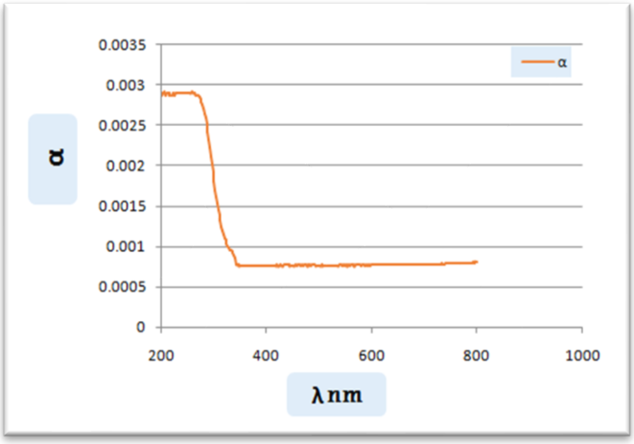

Fig.(7) The absorbance coefficient as a function of wavelength of ZnO thin film

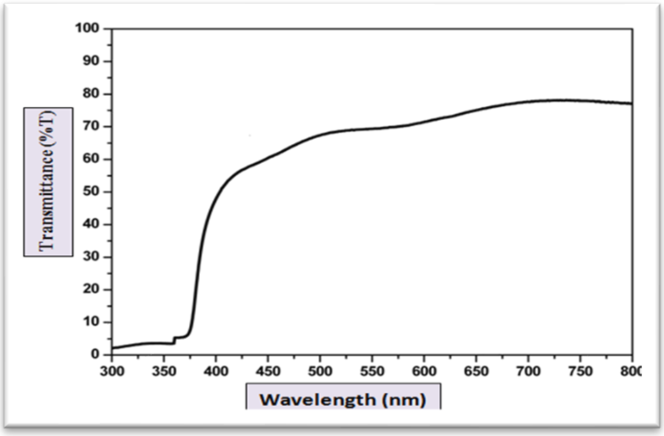

Figure 8. The transmittance as a function of wavelength of ZnO thin film

IV. CONCLUSIONS

The crystalline is satisfied with a hexagonal wurtzite structure and preferential orientation in the (002) direction along the c axis, from XRD examination. A uniform granular surface shows morphology of the atomic force microscope (AFM) images of thin films. The optical measurement shows that the pure ZnO thin film has allowed direct energy gap. The transmission of the ZnO films is about 70% and the deduced value of their optical band gap is 3.23 eV. There are intrinsic cor- relations between the structural, optical and morphological properties of the ZnO thin films, which are important for future study and application of TCO and solar cells thin films.

REFERENCE

[1] S. B. Ogale (2005), Thin Films and Heterostructures for Oxide Electronics (New York: Springer).

[2] N. H. Nickel and E Terukov (2005), Zinc Oxide A Material for Micro- and Optoelectronic Applications (Netherlands: Springer).

[3] C. Jagadish and S. J. Pearton (2006), Zinc Oxide Bulk, Thin Films, and Nanostructures (New York: Elsevier).

[4] A. Mang, K. Reimann and R.¨ubenacke (1995), Solid State Commun. 94-251.

[5] M. Dosmailov, L.N. Leonat, J. Patek, D. Roth, P. Bauer, M.C. Scharber, N.S. Sariciftci, J.D. Pedarnig (2015), Thin Solid Films 591, 97–104.

[6] M. Samadi, M. Zirak, A. Naseri, E. Khorashadizade, AZ. Moshfegh (2016), Recent progress on doped ZnO nanostructures for visible-light photocatalysis. Thin Solid Films 605: 2-19.

[7] AA. Othman, MA. Ali, EM. Ibrahim, MA. Osman (2016), Influence of Cu doping on structural, morphological, photoluminescence, and electrical properties of ZnO nanostructures synthesized by ice-bath assisted sonochemical method, Journal of Alloys and Compounds 683: 399-411.

[8] M. G. Tsoutsouva, C. N. Panagopoulos1, D. Papadimitriou, I. Fasaki, M. Kompitsas, N. Galanis, D. E. Manolakos (2010), ZnO Thin Films Prepared by Pulsed Laser Deposition.

[9] M. Alauddin, J.K. Song, S.M. Park (2010), Appl. Phys. A 101, 707–711.

[10] H. Kim, A. Pique ´, J.S. Horwitz, H. Murata, Z.H. Kafafi, C.M. Gilmore, D.B. Chrisey (2000), Thin Solid Films 377–378, 798–802.

[11] J.H. Lee, T. Lu, S. Cho, F. Khatkhatay, L. Chen, H. Wang (2012), Thin Solid Films 524, 320–327.

[12] F.K. Shan, Y.S. Yu, J. Eur. Ceram. Soc. 24, 1869–1872 (2004).

[13] A. Suzuki, T. Matsushita, N. Wada, Y. Sakamoto, M. Okuda (1996), Jpn. J. Appl. Phys. 35, L56–L59.

[14] F.K. Shan, B.C. Shin, S.C. Kim, Y.S. Yu (2003), J. Korean Phys. Soc. 42, 1374–1377.

[15] S.S. Kim, B.T. Lee (2004), Thin Solid Films, 446, 307.

[16] https://en.wikipedia.org/wiki/Zinc_oxide.

[17] C. Gumus, O.M. Ozkendir, H. Kavak (2006) , Structural and optical properties of zinc oxide thin films prepared by spray pyrolysis method. J. Optoelectronics and Advanced Materials, 8, 299-303.

[18] M. Inoguchi, K. Suzuki, N. Tanaka, K. Kageyama, & H. Takagi (2009), Structural and optical properties of nanocrystalline ZnO thin films derived from clear emulsion of monodispersed ZnO nanocrystals. Journal of Materials Research , 24, 2243-2251.

[19] L. Wang, L. Meng, V. Teixeira, S. Song, Z. Xu and X. Xu (2009), Structure and Optical Properties of ZnO:V Thin Films with Different Doping Concentrations, Thin Solid Films, Vol. 517, No. 13, 3721-3725.