Studying the structural and morphological properties of ZnO nanoparticles using Pulse Laser Ablation techniquen (PLA) in liquid

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Abstract

In this work, Zno nanoparticles were fabricated by laser ablation of zinc target (purity of 99.99%) immersed in distilled water (DW) prepared on glass substrate by using the radiation of Nd:YAG laser (532 nm) operating at different laser pulses(1000, 1500, 2000) by 1Hz repetition rate, effective beam diameter of 4.8 mm and 10 ns pulse width. Laser energy was kept constant at (800) mJ. The Optimmaum condition of preparation was 2000 pulses with excellent structural (XRD) revealed that 4 with values of 36.32, 45.74, 56.76 and 68.08 degree, and morphology field emission scanning electron miceoscope (FESEM) properties.

Keywords: ZnO nanoparticles, X-ray diffraction, Morphology, FESEM

دراسة الخواص التركيبية لـ ZnO النانوية با استخدام PLA

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الخلاصــة

في هذا البحث تم تحضير جسيمات اوكسيد الخارصين النانوية بأستخدام تقنية الأستئصال بالليزر لهدف الخارصين ذو نقاوه ٩٩,٩٩% المغمور في الماء المقطر والذي أعد على شريحة الزجاج بواسطة تشعيع ليزر الأندياك الذي يعمل بطولا موجي (٥٣٢) نانومتر لنبضات مختلفه (١٠٠٠-١٥٠٠-٢٠٠٠) ضربة ومعدل تكرار نبضه ١ هرتز وقطر حزمه ٤,٨ ملمتر وأمد نبضة ١٠ نانو ثانيه، و ان طاقة الليزر هنا ثابتة مقدارها ٨٠٠ جول .و ان افضل شرط للعملية هو ٢٠٠٠ ضربة الذي يمتلك ٤ قيم للزاويــة ٢Θ وهي ٣٦,٣٢ ،٤٥,٧٤ ،٥٦,٧٦ واخيراً ٦٨,٠٨ درجة وخصائص التشكل المورفولوجية.

Introduction

laser ablation is a typical example of top-down approach to fabrication nanoparticles [1]. Nanoparticles have great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures, at this size, physical, chemical and biological properties of substance are different in comparison with properties in the micrometer and larger scales [2]. By harnessing these new properties, researchers have found that they can develop materials, devices and systems that are superior to those in use today, but smaller in size such as laser ablation in liquid and chemical etching [3]. The concept of the bottom-up approach is that one starts with atoms or molecules, which build up to form larger structures such as pulse laser deposition (PLD) and physical vapor deposition (PVD), however, the top-down approach is not a friendly, inexpensive, and rapid way of producing nanostructures [4]. Nanostructures ZnO materials have received broad attention due to their distinguished performance in electronics, optics and photonics, with reduction in size, novel electrical, mechanical, chemical and optical properties are introduced, which are largely believed to be result of surface and quantum confinement effects [5]. Recently, special attention has been devoted to the morphology, as ZnO can form different nanostructures, such as nanobelts, nanoribbons, nanowires, nanotubes, nanohelixes, nanorods and Nanoparticles [6].

Experimental procedure

The ablation process is done at room temperature. The zinc target (purity of 99.99%) has been immersed in DW and fixed at bottom of glass vessel container. Nd:YAG laser system (type HUAFEI) providing pulses at 532 nm wavelength in the infrared was used for ablation of zinc target with energy per pulse of 800 mJ, pulse duration is 10 ns, repetition rate of 1Hz and effective beam diameter of 4.8 mm. The number of laser pulse that used are (1000, 1500 2000) pulses. When ablation of zinc target, Zno nanoparticles colloidal wasl formed in distilled water. In order to make solution homogeneity the colloidal dispersed with ultrasonically for 15 min and magnetic stirrer for 0.5 h. After this, solution drop casing on clean glass which put on Hotplate stirrer at a temperature (115 °C) for 20 minutes.

Figure (1) shows the experimental setup of laser ablation, whichincludes Nd-YAG laser of 532 nm frequency (1Hz) wavelength were used for laser ablation process.

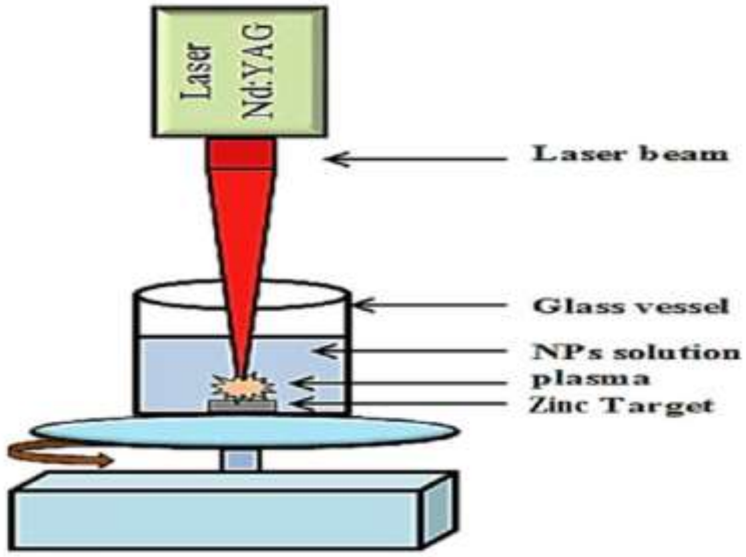


Figure 1: Experimental setup of noanoparticles synthesis by PLA method.

Results and discussions

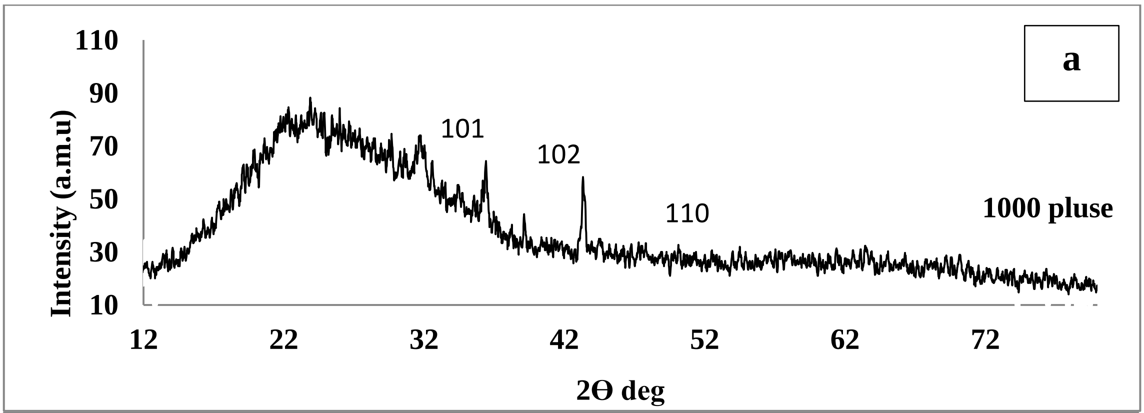
Figure 2(a) reveals that 3 peaks with 2θ values of 36.32, 43.71 and 54.64 degree, corresponding to ZnO crystal planes of (101),(102) and (110) respectively at 1000. Figure 2 (b) revealed that 2 peaks with 2θ values of 47.52 and 56.44 degree, corresponding to ZnO crystal planes of (102) (210) and (110) respectively at 1500 pulses. Figure (c) revealed that 4peaks with 2θ values of 36.32, 45.74, 56.76 and 68.08 degree, corresponding to crystal planes of (101), (102), (110) and (200) respectively at 2000 pulses. A matching of the observed and standard (hkl) planes confirmed that the product is of ZnO having a polycrystalline in nature with tetragonal structure. XRD peaks also revealed that ZnO nanoparticles prefer to grow in the (200) direction since the maximum intensity appeared in this direction. The crystal size of the crystalline material has an important effect in determining the properties of the material and can be estimated through the X-ray spectrum display half way to the middle of the peak (FWHM) which is given to (Debye-Scherrer relation) [7]:

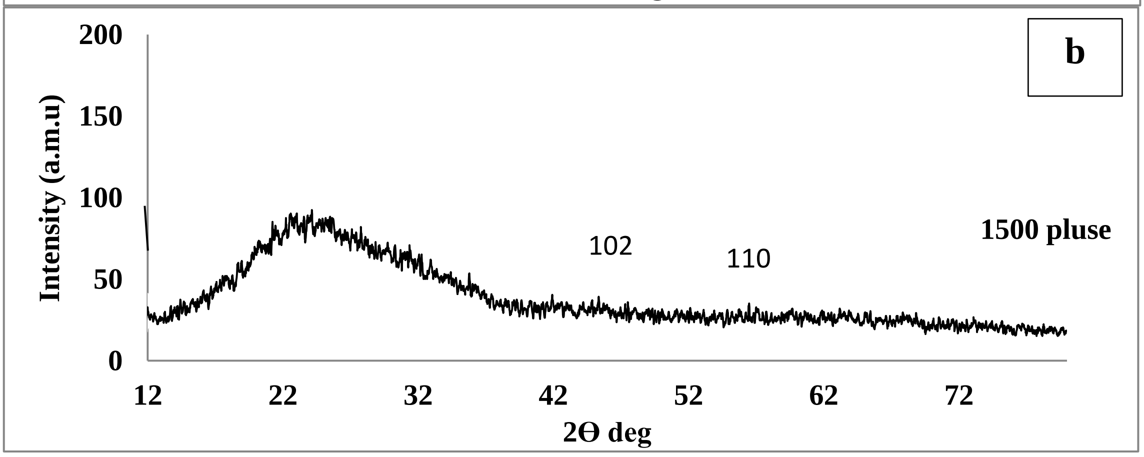
$$D_g = \frac{0.9\,\lambda}{\beta\, cos\theta_B} \quad \text{..........} \ (1)$$

Where D_g: is the crystal size, 0.9 is the Scherrer constant, λ: is the X-ray wavelength, β: is the full width at half maximum of the diffraction peak, and θ_B: is the Bragg diffraction angle of the diffraction peaks.

Table 1: FWHM, (D) crystallite size and (d) interplane distance of ZnO NPs films at (1000, 1500, 2000) pulses after heating temperature 115 (°C).

Zno	2θ (deg.)	Plane (hkl)	FWHM (deg.)	Crystal size (D) (nm)	d (A)
١٠٠٠	36.32	(101)	0.39000	20.2453	2.47272
	43	(102)	0.53000	14.8975	2.0875
	54	(110)	0.20000	36.9883	1.67932
١٥٠٠	47.52	(102)	0.0300	25.32	1.9314
	56.44	(110)	0.0600	12.193	1.610
٢٠٠٠	36.32	101	0.3333	23.667	2.4710
	45.74	102	0.1000	76.496	1.9795
	56.76	110	0.3000	24.340	1.6220
	68.08	200	0.1200	**57.331**	1.3672





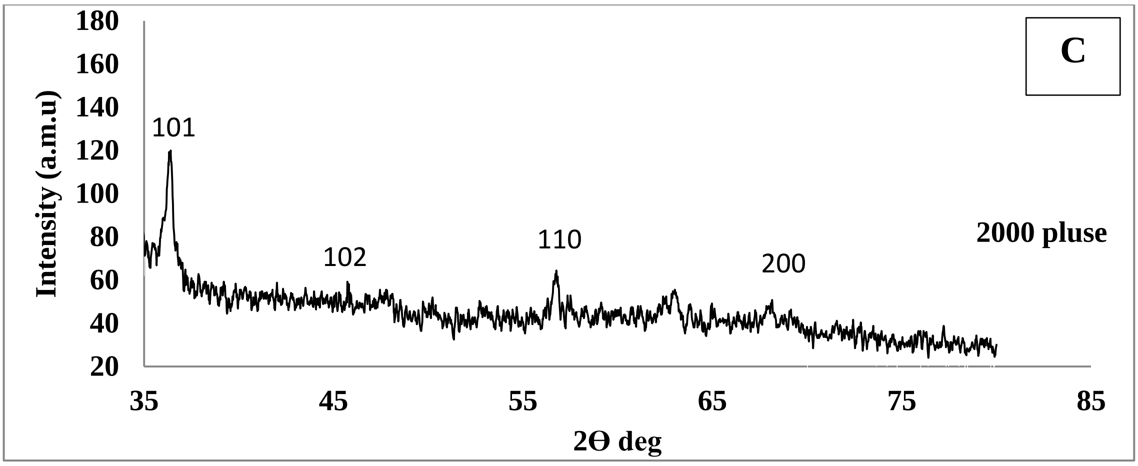


Figure 2 : XRD peakes of ZnO NPs films at (1000, 1500, 2000) pulses after heating temperature 115 (°C) for 20 minute.

FESEM images of ZnO nanoparticles prepared in DW at Optimmaum conditions as shown in figure (5). From figure 5 (a, b, c) results shown that nanoparticles seem to have irregular shape due to low number of pulses that leads to low fragmentation mechanism at initial stage from laser light. Also, DW density plays an important role information of ZnO nanoparticles structure polycrystalline.

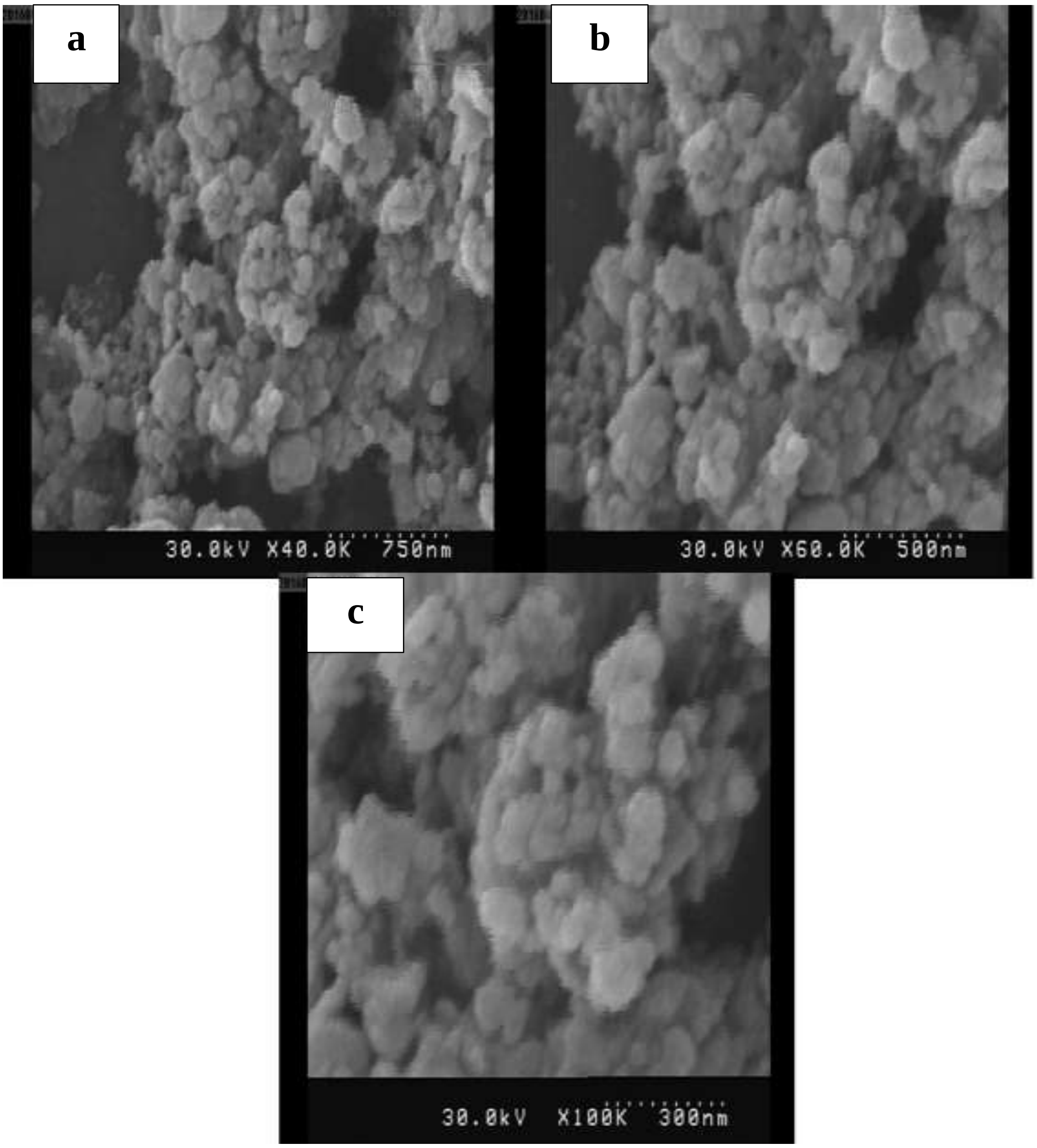


Figure 3: FESEM images of ZnO NPS films after heating temperature 115^{o}C for 20 minutes 2000 pulses.its the best of the conditions to get the nanoparticalsin Distile water(DW) preperd with 2000 pulse at (a) 750 nm (b) 500 nm (c)300nm.

Conclusions

Laser ablation in liquid provides a simple, flexible, controllable process and less expensive way for fabrication of ZnO nanoparticles. From the x-ray characteristics for as-prepared samples showed that amorphous structure of ZnO NPs films, but after annealing film show that is polycrystalline with tetragonal structure without any trace of an extra phase with preferential orientation in the (200) direction. From FESEM technique the formation rate ZnO nanoparticles suspensions, mean particle size could be controlled by proper selection of the laser parameters and liquid media. The NPs in liquids have an almost perfect spherical shape, agglomerated and some presented chains of welded particles.

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