Indonesian Journal of Material Research
e-ISSN: 2987-1654
Vol. 2, No. 3, November 2024

Research Paper

Study and Characterization ZnO Nanoparticles Prepared by Switched Laser Nd:YAG

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Abstract
In this research, zinc nanoparticles were prepared using pulsed laser ablation in liquids. A pulsed Nd+:YAG laser with wavelength (532 nm) was applied to a pure zinc target immersed in deionized water, and the structural and optical properties of the prepared zinc nanoparticles were studied. The behavior of the UV absorption spectra of zinc nanoparticles was studied as a function of pulse number and ablation energy. The UV-vis absorption spectra showed absorption peaks in the ultraviolet region and in the visible region, the latter being responsible for the formation of zinc nanoparticles, and an increase in the intensity of the absorption peaks with increasing number of laser pulses was observed. Scanning electron microscopy results measured after examining drops of zinc nanoparticle solution showed that the nanoparticles were predominantly spherical in shape with nanoparticle sizes ranging from (42.49, 42.42, and 39.31 nm) respectively, and decreasing in size with increasing ablation pulses, with the best results at higher ablation pulses, the formation of zinc nanoparticles was confirmed by infrared spectroscopy, which confirmed the formation of nanoparticles.

Keywords
Laser, Pulse, Zinc, Nanoparticle, Liquid

Received: 1 September 2024, Accepted: 7 November 2024
https://doi.org/10.26554/ijmr.20242340

1. INTRODUCTION

Nanotechnology has the potential to change some aspects of life in the coming decades, and expectations vary about what will happen and when, but most agree that there is a huge potential for nanotechnology in the future, so nanoscience has now become a prominent feature in many modern sciences (Rai and Duran, 2011). We can define nanoscience as the science that is concerned with the characterization and study of some physical and chemical properties of materials with sizes of (1-100 nm), and what distinguishes nanomaterials from ordinary materials is the most prominent and most influential property, which is the surface area of nanomaterials, as the closer the material approaches the nanoscale, the greater its surface area (Ahmed et al., 2024). The physical and chemical properties of metal nanoparticles are mostly determined by the following parameters: Size, shape and composition (Khan et al., 2019) the control of size, shape and composition is essential to tailor the nanoscale properties. Recent studies have shown the importance of shape control as it allows better tuning of optical properties than other methods. It has become possible to control the shape of metal nanoparticles in liquids, and this has led to the development of many methods and methods of preparation (Sharma, 2014; Muthiah et al., 2020). The methods of preparing nanoparticles (NPs) are numerous and each method has its advantages to serve the purpose for which it was used, and among the common methods are milling method, chemical etching method, laser scraping method, electro migration method, and jetting method (Jasim et al., 2024; Fernandez-Arias et al., 2020). The preparation of fine NPs, for example by ball milling, produces NPs larger than 100 nm without limiting their practical applicability in pharmaceuticals and biomedicine, and to achieve nanoparticles, many techniques have been developed, such as replication, nana analysis and gelation, but such techniques are difficult to control the shape and phase of nanoparticles smaller than (100 nm) (Ganash et al., 2019; Sabri et al., 2024). Therefore, the liquid pulsed laser ablation technique was used, which has several advantages and can be defined as the technique in which the laser pulses falling on the desired target heat the surface of the material at a very high speed, which leads to the formation of a plasma above the surface of the material, and the energy used and the number of pulses determine the amount of material ablated, one of the advantages of producing nanoparticles (NPs) with PLAL technology is that they are free of pollutants and on a large scale. The shape and phase size of these particles can be controlled by adjusting the laser parameters (wavelength, pulse width, pulse number, energy, ambient) (Fernandez-Arias et al., 2020; Ganash et al., 2019; Sabri et al., 2024). Nanoparticles in pulsed laser ablation technology are prepared in liquid, vacuum or gas obtained within the (1−100 nm) nanoscale from several targets and in a wide range and different categories depending on their shape and size and can be in solid target form or in powder form as they are classified as metallic nanoparticles, semiconductor nanoparticles, polymeric nanoparticles, and organic nanoparticles (Korkamaz and Karadag, 2021). Pulsed laser ablation in liquid (PLAL) technique is a simplified and environmentally friendly method for the preparation of nanoparticles (Saleh et al., 2023). The biggest advantage of PLAL is that its products are chemically pure. Several products prepared by PLAL have been studied, such as zinc and alloy nanoparticles (Khashan et al., 2020). When the pulsed laser beam is directed directly at the target material placed in the liquid medium, a thermal evaporation process will result, where plasma and vapor are generated when the interface area between the surface of the target material and the submerged liquid is irradiated by the laser beam (Jasim et al., 2021a; Attallah et al., 2023). The amount of mass evaporated from the surface of the target forms a cloud. Steam moving upward from the target surface with high temperature and pressure, as well as irradiating the target surface in this process, leads to the ejection of the substance in the form of a hot plasma column inside the liquid medium from the target surface due to the interaction of high energy laser pulses with the target (Ishikawa et al., 2006; Yogesh et al., 2021). After that, the stimulated plasma was expanded (Shih et al., 2020). With a laser at a speed exceeding the speed of sound, shock waves are generated under the insulation of the liquid medium due to (vibrating shocks) of the laser plasma, its high temperature and pressure, and the state of thermodynamic imbalance (Al-Douri et al., 2019; Mozaffari and Mahdieh, 2019). To achieve thermodynamic equilibrium, various chemical reactions can occur between the species derived from the target and the molecules of the liquid used in laser plasma (Hassan et al., 2022). Which produces diverse compounds under thermodynamic conditions and can result in induced plasma and nucleation into desired nanostructures in liquid media (Kadhim et al., 2018; Al Baroot et al., 2022).

2. EXPERIMENTAL SECTION

2.1 Materials

A zinc oxide plate with a purity of 99% was used. The large plate is cut into small pieces with dimensions of about (10 mm × 10 mm × 0.2 mm), then polished and then cleaned with distilled water and ethanol C_2H_6O, and the plate is placed at the bottom of a quartz glass vessel immersed in deionized water, where the height of the liquid above the target surface is (3 mm) during the ablation process and the amount of liquid used in preparing each sample is (5 mL). This led to the appearance of sticky zinc NPs in the deionized water, which gradually changes colour during ablation to a pale yellow colour as in Figure 1. The target was bombarded by a pulsed Nd:YAG laser with a wavelength of (532 nm) at a frequency of (3 Hz) frequency and pulse duration (12 ns) with a constant ablation energy (700 mJ) at a pulse rate of (100, 200 and 300 pulse/sec).

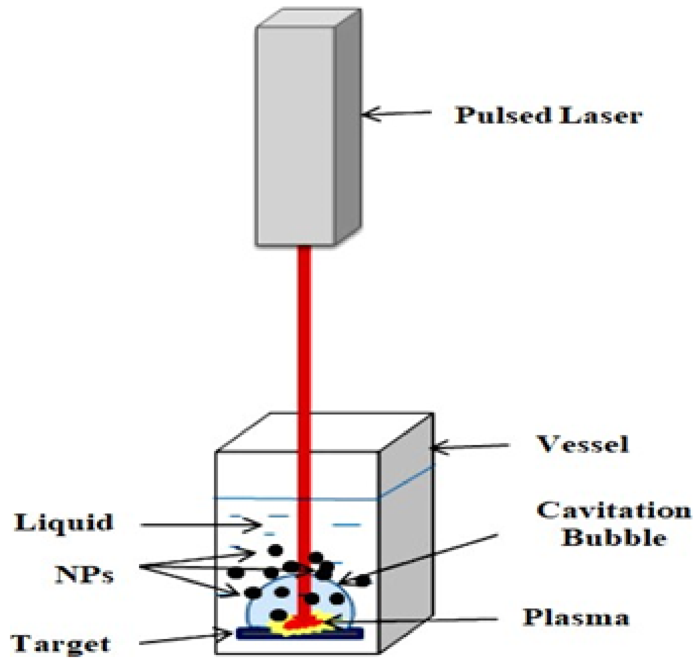
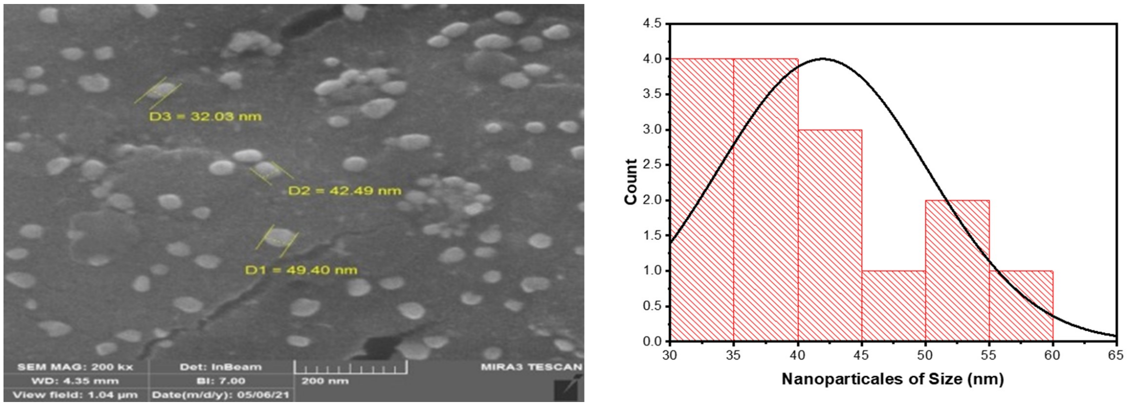


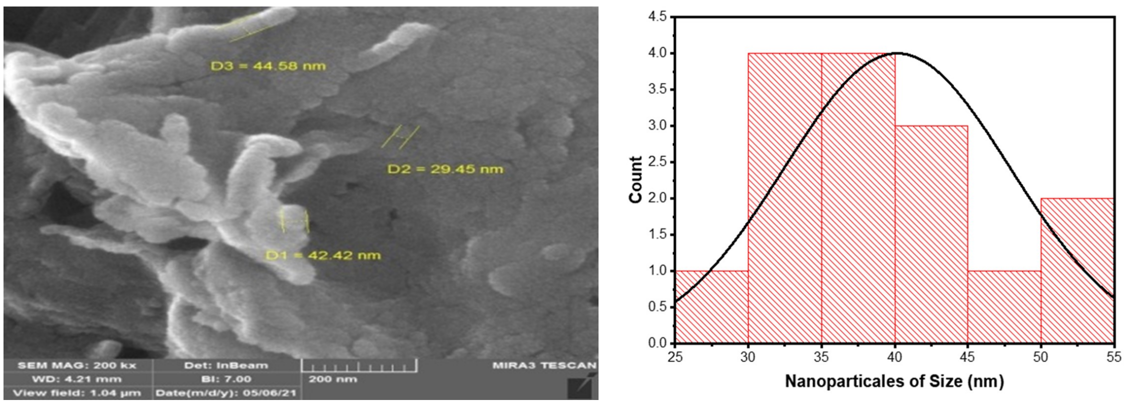
Figure 1. Schematic Illustration of the Experimental Set-up of Laser Ablation Method

2.2 Characterization Nanoparticles

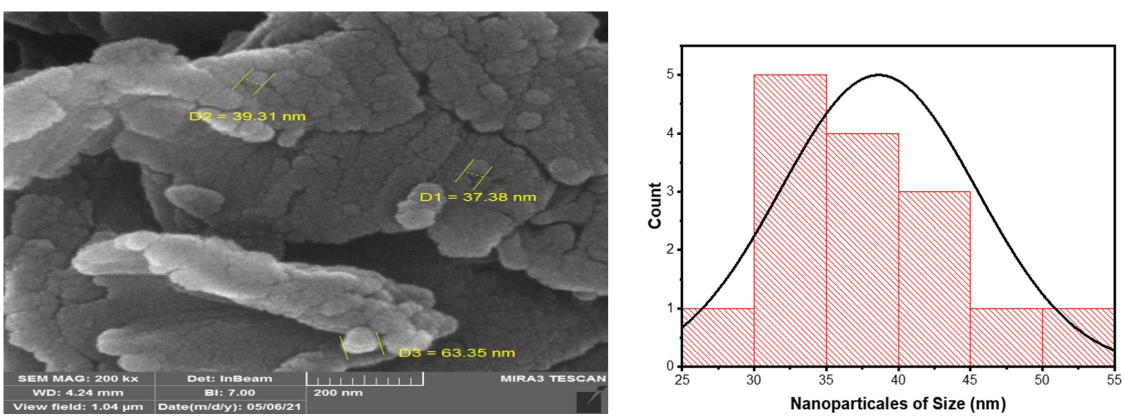
The physical properties of the nanoparticle structures prepared by the pulsed laser ablation method were studied and the size and shape of the particles were determined by performing (FE-SEM) of the prepared samples, the device used was a (FEL-Model Nova Nano450), which is a modern technique used to diagnose nanoparticles and measure their size to obtain a three-dimensional stereoscopic image of the sample surface by obtaining a magnification of up to (100,000) times, The absorbance was measured in the UV-Visible region as the colloidal solution is placed in a quartz cell with an optical path difference of (1 cm) and the cell is placed in the device, where the absorbance spectrum on the (Y) axis and the wavelength on the (X) axis, which is in the range (200-1100 nm), where the UV-visible meter is important to know the absorbance of nanoparticles (NPs) and show their peaks at certain wavelengths. The prepared zinc nanoparticles were also examined by infrared spectroscopy (FT-IR fourier transform 2002 infrared spectrophotometer) using (kbr) discs with a range of (400-4000 cm^{-1}) the liquids used are distilled water and deionized water, which are necessary for the preparation of all samples and solutions in this work. Although this water is completely pure, it is contaminated with ions of salts, dissolved gases and dissolved substances. Deionized water was prepared by ion exchange process, dissolved gases were



(a)



(b)



(c)

Figure 2. Result FESEM Images for Zn NPs: (a) 100 pulses/sec, (b) 200 pulses/sec, (c) 300 pulses/sec

removed by boiling the water at (100 °C) for (10 min), and filter papers were used to filter and remove particulate matter.

3. RESULTS AND DISCUSSION

3.1 FESEM Analysis

The physical properties of the nanoparticle structures prepared by the laser ablation method were studied and the shape and diameter of the particles were determined by performing FESEM examination of samples prepared with different laser pulses (100,

Table 1. Results FESEM for ZnO NPs

ZnO	Pulse of Number		
	100 Pulse/sec	200 Pulse/sec	300 Pulse/sec
Rienge NPs	32.3 - 59.4 nm	29.45 - 54.58 nm	27.38 to 53.35 nm
Averge size	42.42 nm	42.42 nm	39.31 nm
Ship NPs	Sperchal	Semispherical and rod	Semispherical and rod

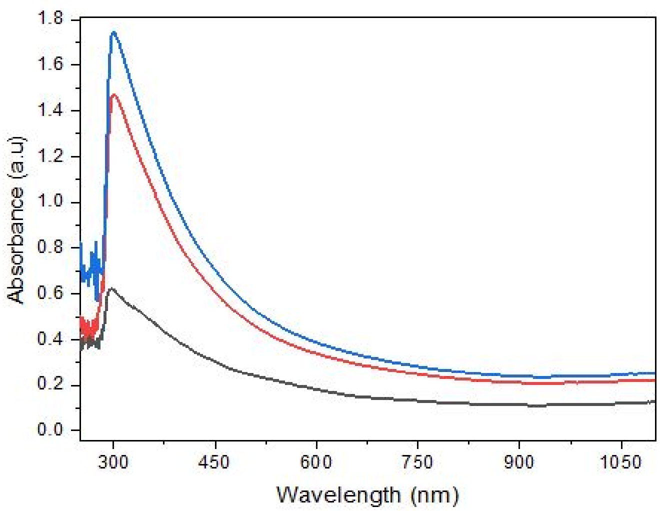


Figure 3. UV-Vis Spectra Absorption and Transmittance of Zn NPs at Pulses of Numbers

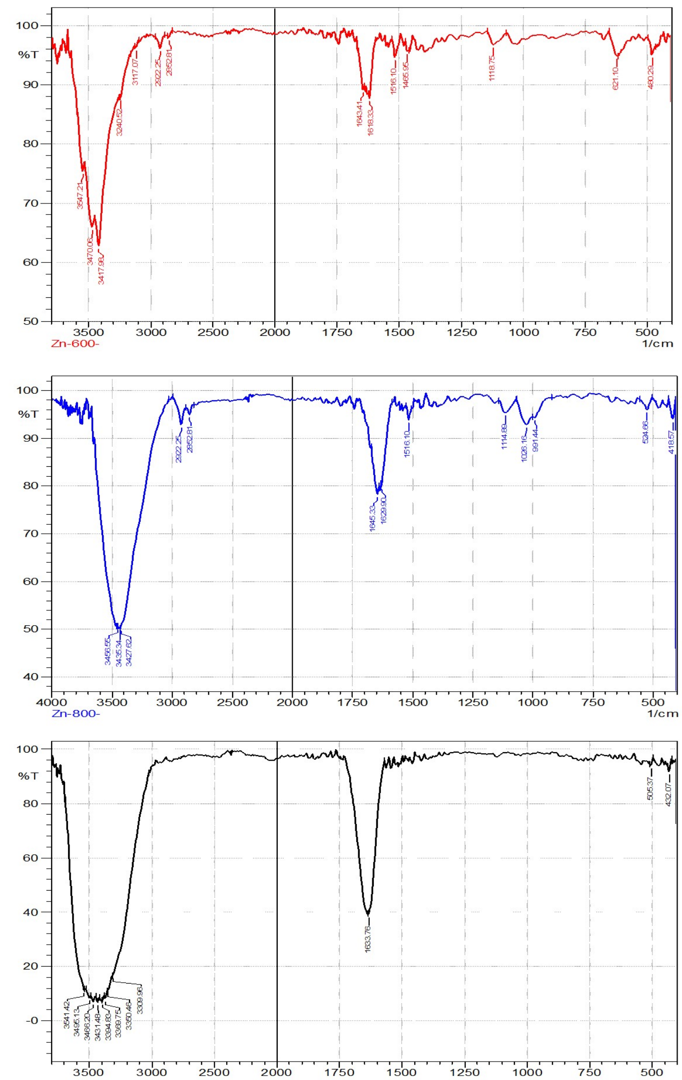


Figure 4. FTIR Spectra of Zn NPs at Pulses of Numbers

200 and 300 Pulse/sec) and ablation energy (700 mJ) and the zinc nanoparticles prepared by PLAL technique varies with the number of laser pulses, as the higher the number of laser pulses, the lower the diameter rate as shown in Table 1 where the FESEM images show the shapes of the nanoparticles and their average diameters. Figure 2 shows the FESEM image of the Zn NPs samples prepared at (100, 200 and 300 Pulse/sec) respectively and ablation energy (700 mJ), where particles were obtained in the nanoparticles ranging from (32.3 to 59.4 nm) with an average diameter of (42.49 nm) and particles were obtained in the range of (29.45 to 54.58 nm) with an average diameter of (42.42 nm) and particles were obtained in the range of (37.38 to 53.35 nm) with an average diameter of (39.31 nm) and samples were almost spherical, semispherical, and rod in shape.

3.2 UV-Visible Spectrum Results

Figure 3 shows the optical absorption spectrum of colloidal solutions containing zinc nanoparticles obtained by laser ablation of the Zinc target with different number of pulses (400, 600 and 800 pulses/second). Examination of the absorption spectrum showed that the changes are within the visible and UV region, and the results of the surface plasmon resonance (SPR) spectrum and absorbance intensity showed that the increase in the laser pulses led to an increase in the absorbance intensity and an increase in the intensity of the peaks (SPR). The increase in laser pulses led to an increase in the absorbance intensity and an increase in the intensity of the SPR peaks, and the width and height of the absorption peaks depended on the number of laser pulses and the spectral change indicates an increase in the abundance of nanoparticles and a change in the colour of the solution to pale yellow by laser irradiation, it was also observed that there is a single surface plasmon peak located around (297, 299, and 300 nm) respectively. indicating that the shape of the nanoparticles is approximately spherical, as in ref. (Jasim et al., 2021b; Rashid et al., 2021).

3.3 FTIR Analysis

Figure 4 represents the FTIR analysis of Zn NPs obtained at (700 mJ) and the number of pulses (400, 600 and 800 pulse/sec) respectively, where the FTIR spectra in both figures showed no fingerprint bands, few bands, no bond formation with Zn NPs, absorption peaks corresponding to the hydroxyl group (O−H), as well as the appearance of absorption peaks corresponding to the carboxyl group (C=O) in the synthesis of nanoparticles, we can see from the figures that the number of pulses affects the value of the absorption peaks, as well as the appearance and disappearance of some of them, as the number of pulses has an effect on the concentration of the solutions (Moradi et al., 2016; Khudiar et al., 2021).

4. CONCLUSIONS

In this study, an easy and simple one-step method was used in the preparation of ZnO particles using different number of pulses (100, 200, and 300 pulse/sec) at energy (200 mJ), where the results showed (FESEM) obtaining a lower particle rate as the number of pulses increases, and also the results of optical properties showed by (UV-Vis) increasing the number of pulses obtained an increase in the SPR peak, as well as the formation of a displacement towards a larger wavelength (297, 299, and 300 nm) respectively, due to increasing the number of pulses. As well as the formation of a displacement towards the greater facial length due to the increase in the number of pulses, and also obtaining a width in the lower half of the intensity below the peak, all these changes are due to the increase in the number of pulses, and FTIR showed peaks, correlations, and ranges of correlations, and there was a slight difference in the intensity of the peaks with increasing number of pulses. and that such particles are useful in many applications such as sensors or photo catalysts or in the medical field as antibacterial agents.

5. ACKNOWLEDGEMENT

Thanks and appreciation to the College of Science, Department of Physics for agreeing to work in the college's laboratories.

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