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Carbon Nanoparticles Synthesis By Different Nd:Yag Laser Pulse Energy

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ABSTRACT

One of the most important techniques for preparing nanoparticle material is Pulsed Laser Ablation in Liquid technique (PLAL). Carbon nanoparticles were prepared using PLAL, and the carbon target was immersed in Ultrapure water (UPW) then irradiated with Q-switched Nd:YAG laser (1064 nm) and six ns pulse duration. In this process, an Nd:YAG laser beam was focused near the carbon surface. Nanoparticles synthesized using laser irradiation were studied by observing the effects of varying incident laser pulse intensities (250, 500, 750, 1000) mJ on the particle size (20.52, 36.97, 48.72, and 61.53) nm, respectively. In addition, nanoparticles were characterized by means of the Atomic Force Microscopy (AFM) test, pH measurement, and an Electrical Conductivity (EC) test of the nano solution. The smallest particle size was produced with (250) mJ laser pulse energy.

Keywords: Carbon nanoparticles, Pulsed laser ablation technique, Nd:YAG laser

تصنيع جزيئات الكربون النانوية بواسطة طاقة نبضة ليزر Nd:YAG مختلفة

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الخلاصة

عملية اجتثاث الجسيمات بالليزر في السائل واحدة من أهم التقنيات لتحضير الجسيمات النانوية المادية. تم تحضير الجسيمات النانوية الكربونية باستخدام الاجتثاث بالليزر النبضي في تقنية السائل ، وتم غمر الكاربون المطلوب في مياه عالية النقاوة باستخدام جهاز الليزر النبضي بتردد 6 وبطول موجي1064 نانومتر. في هذه العملية ، تم تركيز شعاع ليزر بالقرب من سطح

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الكربون. تمت دراسة جسيمات النانو المُصنَّعة باستخدام إشعاع الليزر من خلال ملاحظة تأثيرات شدة نبضات الليزر العارضة المتغيرة (250 ، 500 ، 750 ، 1000) مللي جول على حجم الجسيمات(20,52، 36,97، 48,72، 61,53)نانو متر. تم تمييز الجسيمات النانوية عن طريق اختبارAFM وقياس pH و واختبار التوصيل الكهربائي (EC) للمحلول النانوي. تم إنتاج أصغر حجم للجسيم باستخدام (250) ميغا جول من طاقة نبضات الليزر.

الكلمات الرئيسية: جسيمات الكربون النانوية, تقنية الاجتثاث بالليزر النبضي ,ليزر YAG:Nd.

1. INTRODUCTION

Nanomaterials have emerged as a fundamental breakthrough in materials manufacturing technology, and this represents a breakthrough in industry and science that enables people to positively improve their condition **(Al-Ali, and Kamoona, 2021)**.

The chemical and physical properties of materials differ greatly when compared between nano to micro-levels. These properties offer big differences from the bulk material of which they are made. Ultra-small metal NPs with a high surface-to-volume ratio and “clean” surface, and thus a high density of active sites exposed to reactants, are significant for heterogeneous catalysis. Preparing metal and metal oxide nanoparticles in a simple technique may be made using Pulsed Laser Ablation in liquid environments (PLAL) **(Alagar, et al., 2012); (Edison and Sethuraman, 2012) and (Parameshwaran, et al., 2013).**

The laser beam characteristics (number of pulses, pulse duration, wavelength, energy) are strongly influenced by the laser ablation (**Lara, et al., 2010; Edison, and Sethuraman, 2012; Nouran, and Haram, 2012; Hu, et al., 2012; Dutta, 2012; Selvam, et al., 2012. Parameshwaran et al., 2013; Makarov, et al., 2014; Nabipour, and Rostamzad, 2012; Elango, and Roopom, 2015; Delma, et al., 2016; Devendra, et al., 2016; Parashar, et al., 2017, and Majeed, et al., 2018).**

The experiments indicate that the ablation rate increases logarithmically with the nano pulse fluence in the case of single metals, semiconductors, and dielectrics **(Majeed, et al., 2018)** used pulsed laser ablation to synthesize ZnOnano colloidal of zinc metal in water. All experiments were performed using a Q-switched Nd-YAG laser operating at fundamental mode 1064nm with 9ns pulse duration at fixed laser output energy (750mJ). A different number of pulses (250, 500, 750, and 1000) was applied to affect the concentration of synthesized ZnO colloidal.

Laser ablation is the process of removing material from a target surface by irradiation with a laser beam. Several applications are based on laser ablation, (e.g., nanoparticles formation, surface modification of materials, micromachining, thin film deposition, chemical analysis). Since the process depends on the optical and thermal properties of the target and the laser parameters (**Hu, et al., 2012).** It is necessary to investigate the effects of the parameters and energy transfer to the target material in order to control and optimize the laser-induced material removal process (**Dutta, et al., 2012,** and **Selvam, et al., 2012).**

The nanoparticles, when synthesized in the base fluid, nanofluids offer advantages besides the high thermal conductivity. These advantages include improving heat transfer, miniaturizing systems, etc. Carbon nanoparticles are made because of their higher thermal conductivity (k) in all the axial directions, large surface area, and low density **(Abdullah, and Ibrahim, 2017).**

In this study, the attempt to create new nanoparticles using a pulse ND: YAG laser of a wavelength of 1064 nm with different pulse energy based on the size of the excised carbon particles.

2. Materials and Method

2.1Target Materials

Metals plates Carbon (C) is purchased from Sigma Aldrich, with high purity listed of (99.6 - 99.8%) for C, carbon sheet was used as targets to produce oxide nanoparticles.

Before starting the experiment, the targets were cut into specific dimensions to fit the experimental arrangement**.**

2.2PREPARATION OF CARBON NANOPARTICLES

The colloidal solution of carbon nanoparticles was prepared by the PLAL technique. The required carbon was immersed in UPW (0.45µS/cm) and subjected to different energies (250, 500, 750, and 1000) mJ/pulse Nd:YAG laser (1064 nm, 6Hz, 6ns). Every time 500 pulse was used to produce the carbon nanoparticles. The ablation setup is shown schematically in **Fig.1**

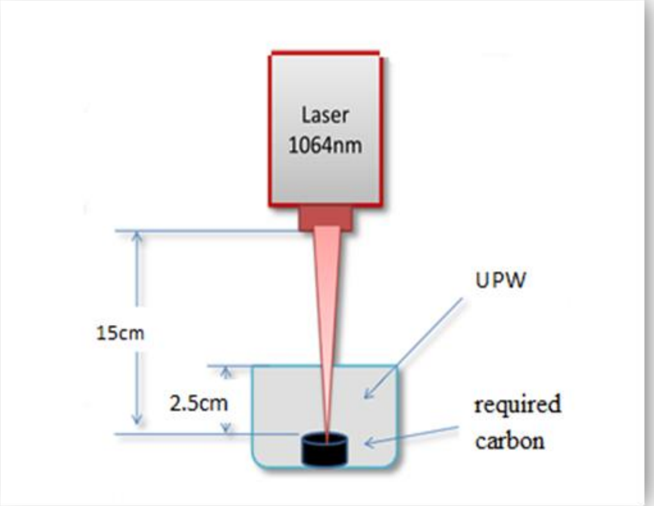

Figure 1. Scheme of the modified PLAL system.

Many inspections were used to analyze the optical, surface morphology, composition, and natural characteristics of the prepared nanoparticles. These inspections are; Atomic Force Microscope (AFM), electrical conductivity (EC), and pH meter.

3. RESULTS AND DISCUSSION

3.1 Atomic Force Microscopy (AFM) Analysis

A thin film of the prepared carbon NPs has been made by deposition on a glass substrate. AFM measurement was made for the evaluation of surface morphology and roughness. The results are displayed in **Fig.2** to **Fig.5**

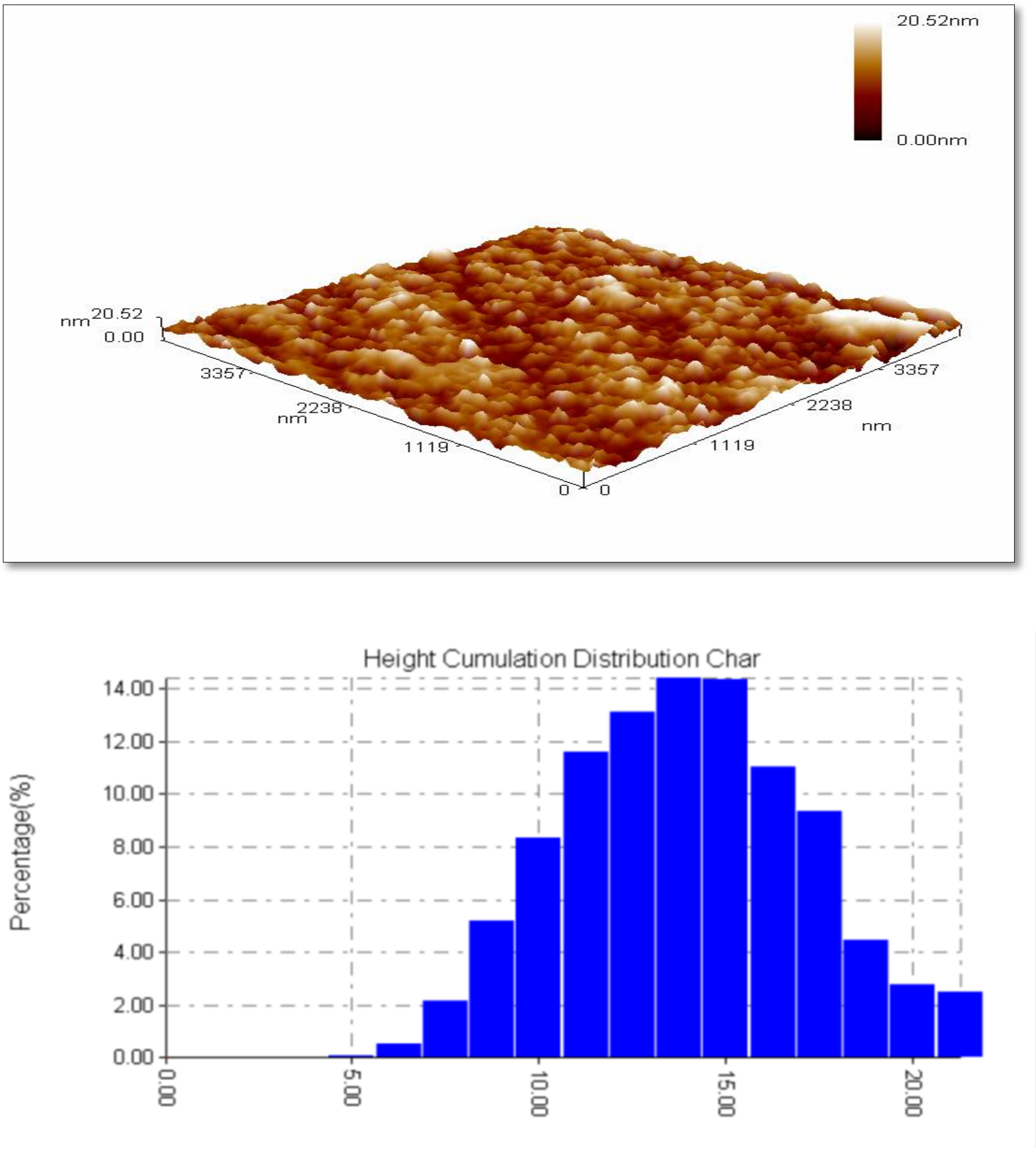

Figure 2.AFM micrograph of the prepared carbon NPs with (250) mJ laser pulse energy.

The 3D AFM image indicates a fine structure with a small grain size of 20.52nm. A widely used parameter in AFM analysis is the Root Mean Square (RMS). In this work the, RMS was 3.28nm, and the average roughness is 2.6nm with peak to peak 20.5 nm, which characterizes the surface roughness.

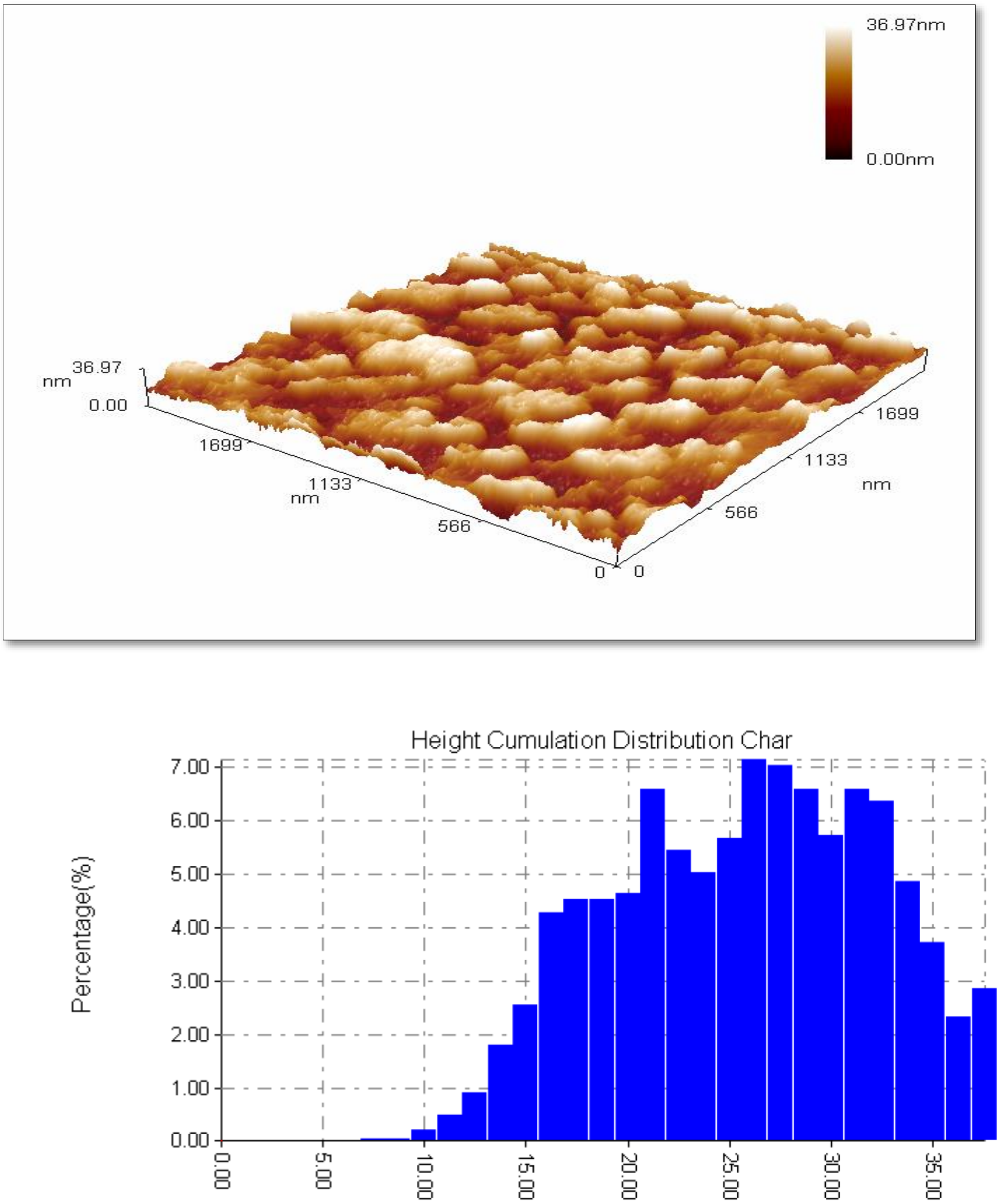

Figure 3. AFM micrograph of the prepared carbon NPs with (500) mJ laser pulse energy.

The 3D AFM image indicates a fine structure with a small grain size of 36.97 nm. A widely used parameter in AFM analysis is the RMS. In this work the, RMS was 6.53 nm, and the average roughness is 5.37 nm with peak-peak 36.2 nm, which characterizes the surface roughness.

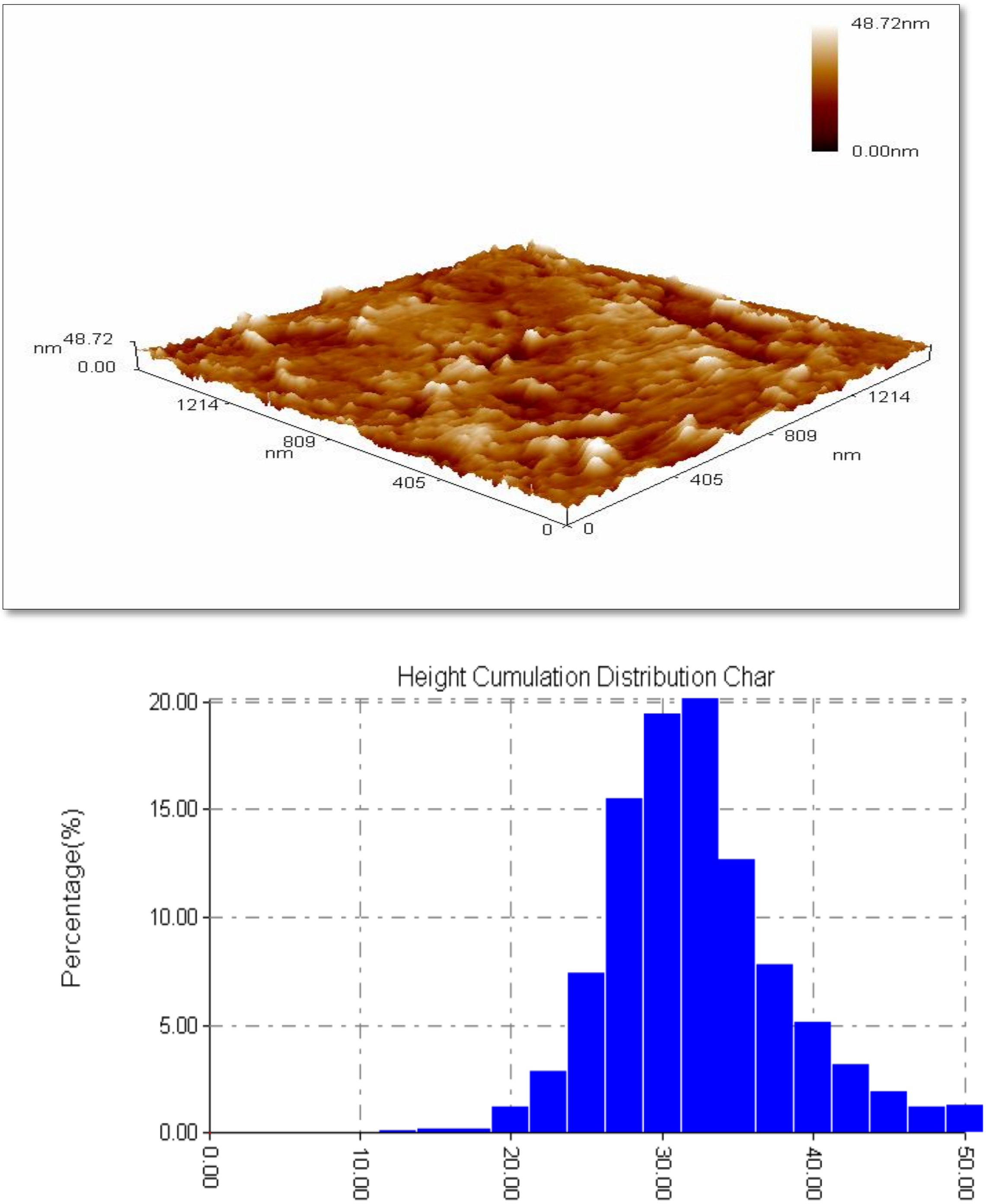

Figure 4. AFM micrograph of the prepared carbon NPs with (750) mJ laser pulse energy.

The 3D AFM image indicates a fine structure with a small grain size of 48.72 nm. A widely used parameter in AFM analysis is the RMS. In this work the, RMS was 5.72 nm, and the average roughness is 4.27nm with peak-peak 46 nm which characterizes the surface roughness.

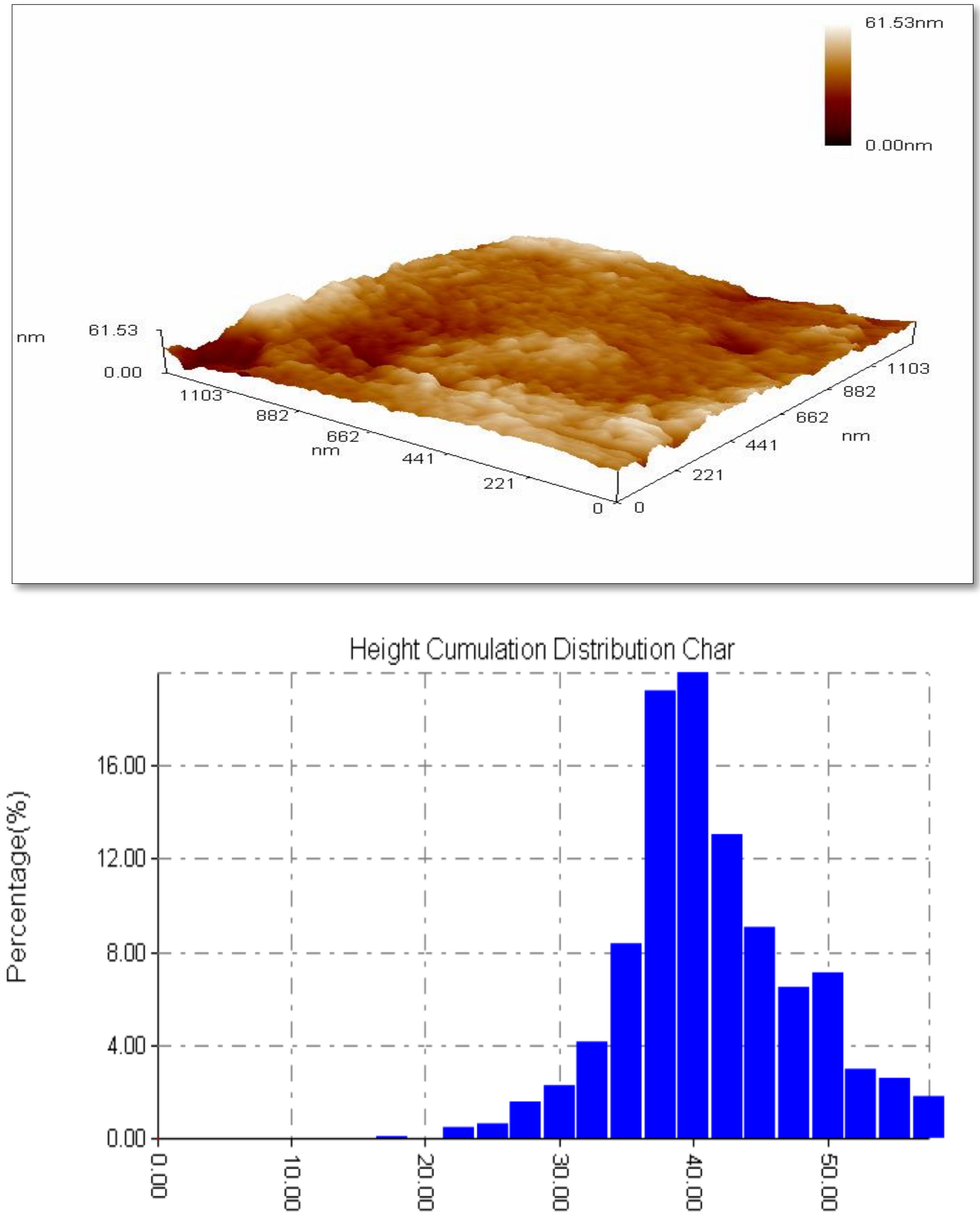

Figure 5. AFM micrograph of the prepared carbon NPs with (1000) mJ laser pulse energy.

The 3D AFM image indicates a fine structure with a small grain size of 61.53 nm. A widely used parameter in AFM analysis is RMS. In this work the, RMS was 6.97 nm, and the average roughness is 5.24 nm with peak-peak 43.6 nm, which characterizes the surface roughness. Therefore, the 3D AFM image indicates a fine structure with a grain size of (20.52, 36.97, 48.72, and 61.53) nm, respectively, because the pulse laser energy used is the parameter that controlled the ablated particle grain size.

3.2 pH and EC measurement of nano-colloidal

Fig.6 shows the evolution of the pH value of synthesized samples as a function of the increasing laser pulse energy. The starting pH value of the nanofluid was 7.52 with regard to the base fluid (water), and then pH value becomes higher or even saturated at approximately 7.8. The differences in pH value increase with increasing laser pulse energy. The pulsed laser energy increment leads to an increase in the amount of nanoparticles, which increased the pH.

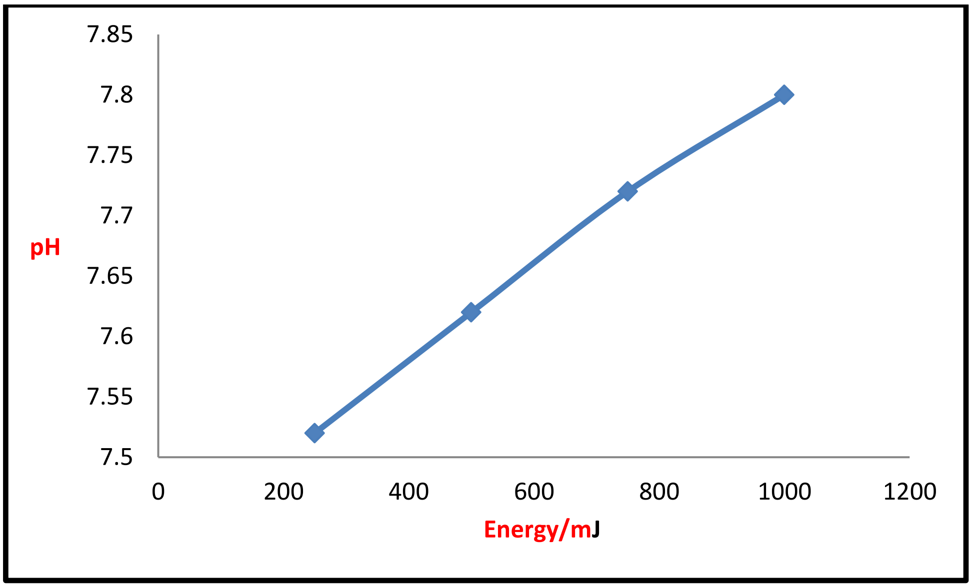

Figure 6.pH value of the nano solution as a function of different laser pulse energy.

Fig.7 shows the evolution of the electrical conductivity of synthesized samples as a function of increasing laser pulse energy. The electrical conductivity value of the nanofluid was increased with increasing laser pulse energy. The pulsed laser energy increment leads to an increase in the amount of nanoparticles, which increased the electrical conductivity.

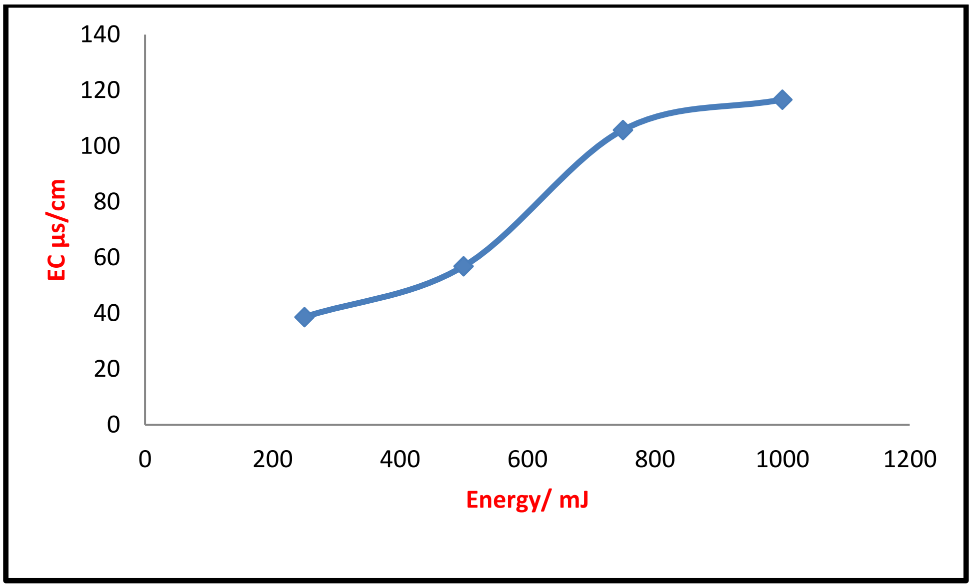

Figure 7. Electrical conductivity of the nano solution as a function of different laser pulse energy.

Fig. 8 shows that the particle size of carbon NPs synthesized by PLALwas increased as a function of the increasing laser pulse energy. With stable wavelength, frequency, and the number of pulses, the change in the pulse energy is the parameter that only influences the nanoparticle size, which is described as the tool of particle size production.

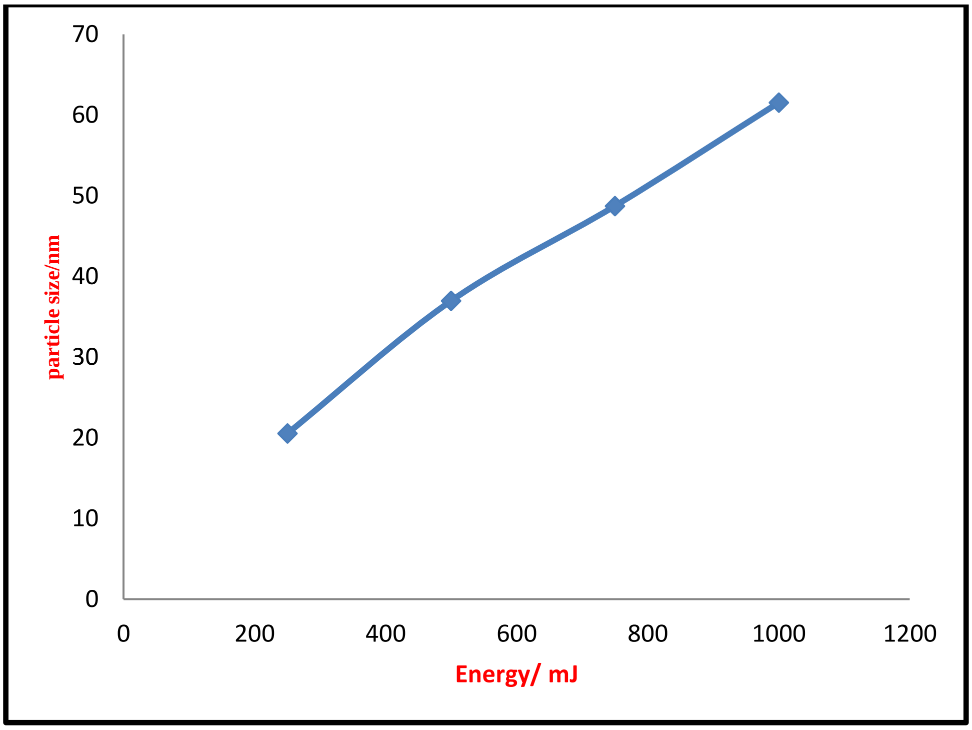

Figure 8. Particle size as a function of different laser pulse energy.

Fig.9, and **Fig. 10** show that the pH meter and electrical conductivity of synthesized samples were increased as a function of the particle size for the carbon NPs.

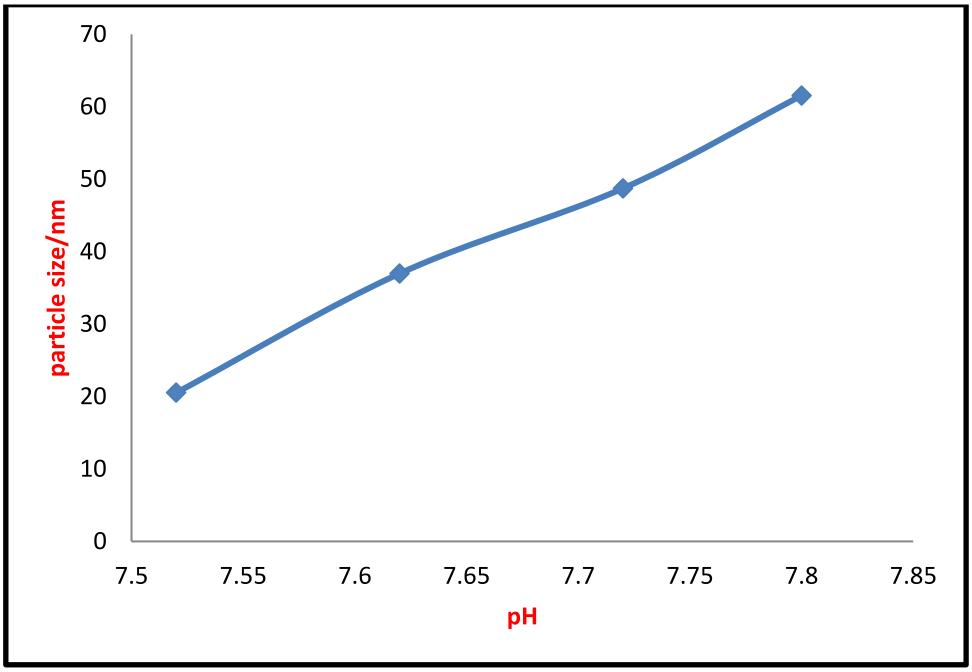

Figure 9.The pH of the nano solution as a function of particle size.

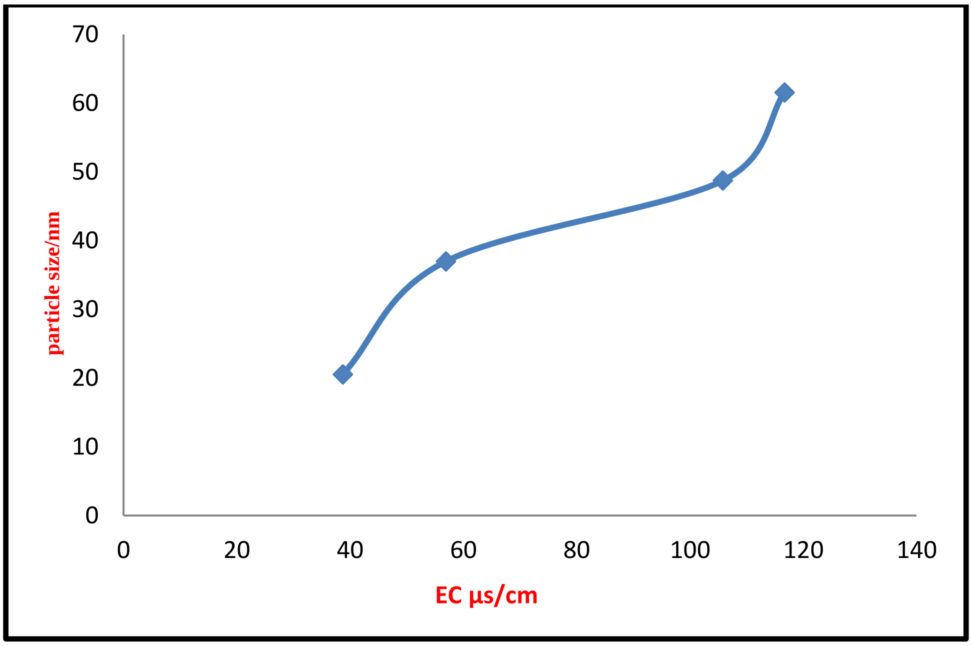

Figure 10. Electrical conductivity as a function of particle size.

4. CONCLUSIONS

The size, electrical properties, and morphology of carbon nanoparticles were studied with different laser pulse energy for 1064nm wavelength of an Nd:YAG laser with an exerted 500 Pulse. Pulse energy is a fundamental and adaptable approach to contcontrolling colloidal carbon nanoparticles'e dispersal and security of The variation of laser pulse energy(250, 500, 750, and 1000) influenced the particle size (20.52, 36.97, 48.72, and 61.53) nm, respectively, and morphologies of the carbon NPs obtained in (PLAL) technique. The electrical conductivity of the carbon nano colloids increased with particle size and laser pulse energy increasing while the smallest nanoparticles size were for the lowest laser pulse energy. The pulse energy is a simple and flexible way to control carbon colloidal nanoparticles' size appropriation and strength.

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