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Synthesis AgO Nanoparticles by Nd:Yag Laser with Different Pulse Energies

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Abstract:

One technique used to prepare nanoparticles material is Pulsed Laser Ablation in Liquid (PLAL), Silver Oxide nanoparticles (AgO) were prepared by using this technique, where silver target was submerged in ultra-pure water (UPW) at room temperature after that Nd:Yag laser which characteristics by 1064 nm wavelength, Q-switched, and 6ns pulse duration was used to irradiated silver target. This preparation method was used to study the effects of laser irradiation on Nanoparticles synthesized by used varying laser pulse energy 1000 mJ, 500 mJ, and 100 mJ, with 500 pulses each time on the particle size. Nanoparticles are characterized using XRD, SEM, AFM, and UV-Visible spectroscopy. All the structural peaks determined by the XRD test can be indexed as face-centered cubic (FCC) type, the stronger crystalline orientation is located in the (111) plane. The nanoscale particles have an almost spherical shape as inferred from the SEM images. In (1000) mJ laser pulse energy the best smallest particle size was produced. According to AFM results of all films, the particle size 32.45nm, 64.3nm, and 67.86nm respectively for 1000 mJ, 500 mJ, and 100 mJ , the surface roughness affected and increased as increase the laser energy because the increase particle size and aggregation of partials. UV-Visible spectroscopy measured the absorbance of the silver nanoparticle prepared which is increased as increase pulsed laser ablation energy at wavelength 440 nm.

Keywords: AgO Nanoparticles, Nd:Yag Laser, Particle size, Pulsed Laser Ablation Technique, UV-Visible spectroscopy.

Introduction:

Physical and chemical materials properties greatly differ between nano to micro size[1]. Metal nanoparticles NPs with a high surface area, high density of active sites exposed to reactants, are significant for heterogeneous catalysis. Preparing metal oxide, metal nanoparticles in a simple technique may be made using Pulsed Laser Ablation in liquid environments (PLAL) [2, 3].

The laser ablation process is affecting strongly with characteristics of a laser beam used (number of pulses, wavelength, pulse duration, and energy) [4 -7] ablation rate direct proportionality with laser pulses number that influenced in the case of dielectrics, semiconductors, and single metals [2, 8-10]. The pulse laser ablation in liquids used for nanomaterial synthesis has many unique advantages compared with other synthesis techniques like synthesis Lu and Sm sesquioxide nanoparticles by using Nd:Yag laser-irradiated for 30 min, spherical particles form with particle size 62.35–75.02 nm was formed[11].

Cu_2O NPs synthesized by used (Nd: Yag laser, 1064 nm, and 7 ns) pulsed laser ablation on a copper plate immersed in liquid media (ultra-pure water), the particle sizes were affected and decreased by increasing the repetition rates of a pulsed laser where characterized by measured (laser-induced breakdown spectroscopy, UV–visible spectroscopy, and X-ray diffraction) [12]
Silver/zinc oxide nanoparticle structure synthesis using a pulsed laser ablation in liquid (PLAL) technique. The concentration of silver was effect by changed time of target ablation from one to five min. the photocatalytic ability of zinc oxide increased by modulation with silver than pure zinc

oxide and facilitated a higher degradation rate of R6G[13].

Ag/Au (core/shell) nanoparticles (NPs) synthesis using pulse laser ablation in water with Q-switch Nd: YAG laser (wavelengths 532nm and 1,064nm ,different energy range 0.2 J to 1J, and repetition rate 1Hz) to create Ag/Au NPs , Ag nano-colloid first prepared via ablation target, this ablation related to Au target at various energies. Surface morphology, Surface Plasmon Resonance (SPR), and average particle size were identified by employing: scanning electron microscopy (SEM), UV-visible spectrophotometer, and transmission electron microscopy (TEM) [14].

Laser ablation defines as a process of removing small masses from the material surface with the laser beam. Laser ablation process is based on many applications like modification surface of materials, nanoparticles formation, and deposition of thin film, chemical analysis, and micromachining. Laser ablation process relies on ablated material properties (optical and thermal) as well as laser parameters [9, 15-21].

Silver (Ag) oxide is used for several applications, used in gas sensing[22], other important applications of silver oxide in biological activity and medical applications [23-26].

In this paper, the effects of different pulses energy of Nd:Yag laser beam with wavelength (1064 nm) has been studied to ablated AgO Nanomaterial and the interaction effect.

Materials and Methods:

Synthesis of AgO nanoparticles

The PLAL technique is used to prepare colloidal solution of AgO nanoparticles. Silver metal target is immersed in 50ml of Ultra-Pure Water (UPW) 0.45µS/cm and Nd:Yag laser 1064 nm, 6Hz, 6ns with different pulse laser energies 1000mJ, 500mJ and 100 mJ irradiation on immersed silver metal target . Each time 500 pulses were used to produce the AgO nanoparticles. Fig.1 shows schematically of ablation setup.

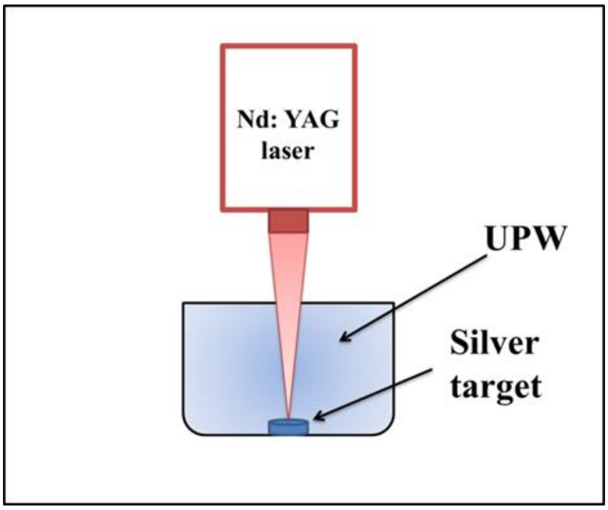

Figure 1. Modified PLAL Ablation Setup.

Some different of measured tests were used to characterize the prepared silver NPs like: SEM, AFM, XRD, and UV-visible spectroscopy.

Results and Discussion:

a) Crystalline Structure Analysis

Growth of silver nanoparticles crystalline structure was characterized and identification by X-ray diffraction (XRD). Diffraction patterns result of prepared AgO nanoparticles is shown in Fig. 2 at different laser energy 1000 mJ, 500 mJ, and 100 mJ respectively. All Silver nanoparticles, which are prepared at room temperature 25°C can be indexed as faced centered cubic (FCC) with strong intensity peak at (111) direction. The peaks give an indication that the product is at high purity.

The average size of the produced AgO nanoparticles can be calculated from the peak broadening using Scherer equation [17]

$$D = \frac{0.9\,\lambda}{\beta_{FWHM}\,\cos\theta_B} \quad ....1$$

Where: D represents the nanoparticles' mean diameter, λ is XRD wavelength = 1.54A°, θ_B refers to Bragg angle and β_{FWHM} is X-ray peaks' full width at half maximum. In addition, diffraction patterns have been used to calculate the lattice constant and the results with particle size values are 5.5 nm, 13nm and 19 nm respectively for laser pulse energy 1000 mJ, 500 mJ, and 100 mJ. Our results show a good agreement with those obtained [27, 28].

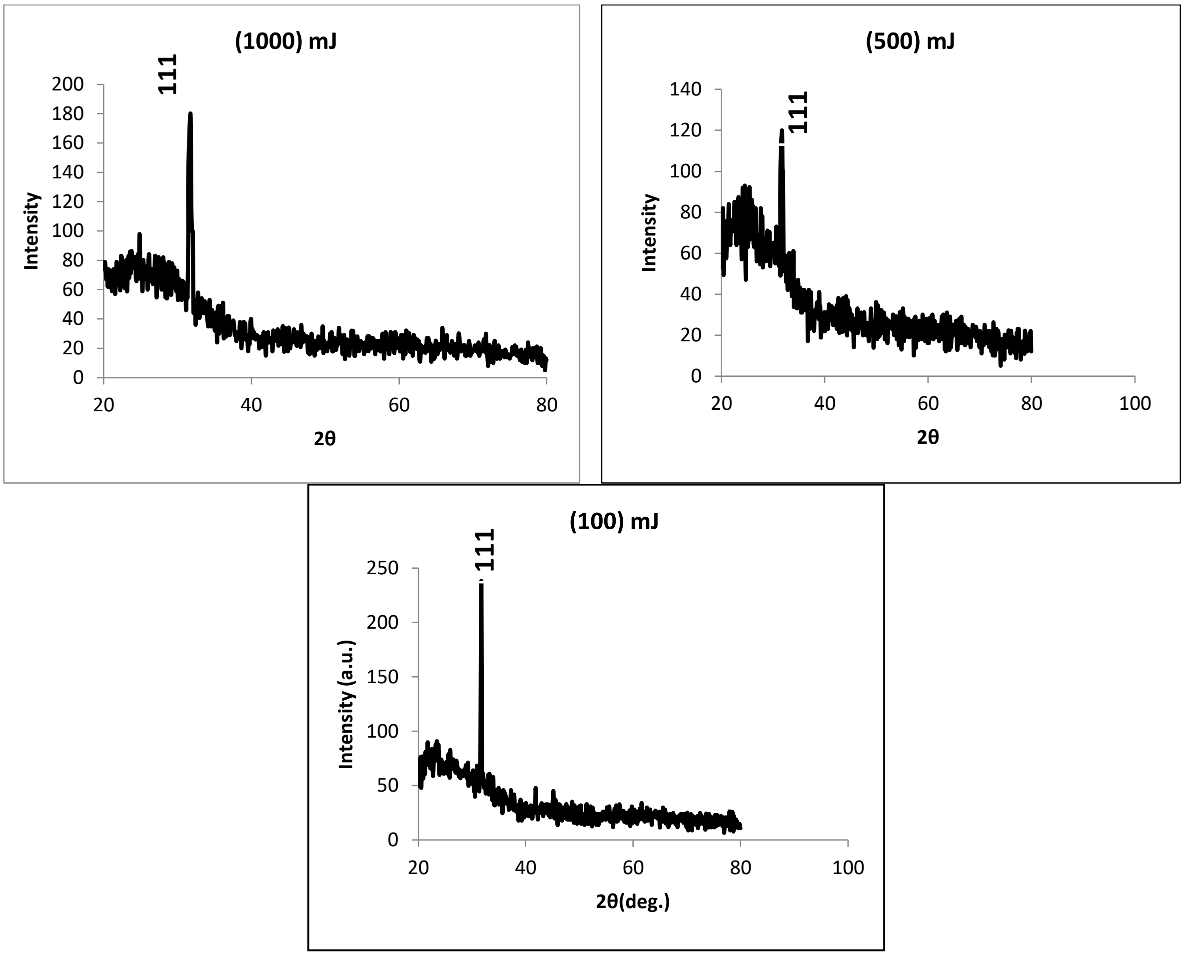

Figure 2. The XRD pattern of AgO NPs prepared with different laser pulse Energies 1000, 500, and 100 mJ.

B) SEM analysis

The micrograph images of morphological studies for AgO nanoparticles done with SEM and obtained results are shown in Figs 3, 4 and 5 respectively for silver NPs prepared with laser pulse energy 1000 mJ, 500 mJ, and 100 mJ. The nanoparticles have almost spherical shape, grow individually, and make a few agglomerates over the surface.

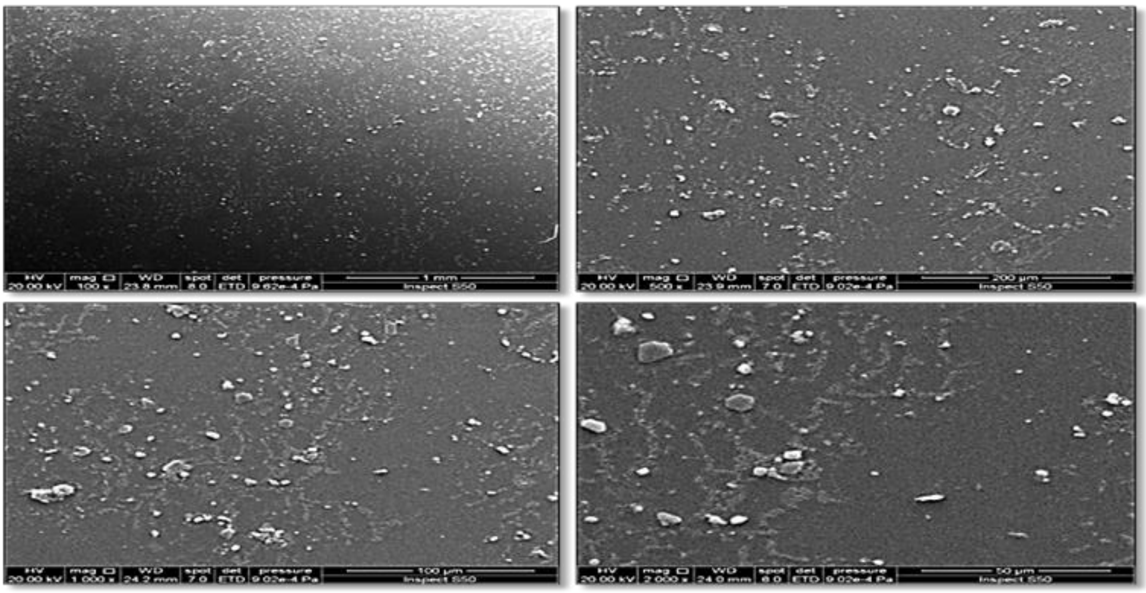

Figure 3. SEM micrograph images of prepared silver NPs with laser pulse 1000 mJ.

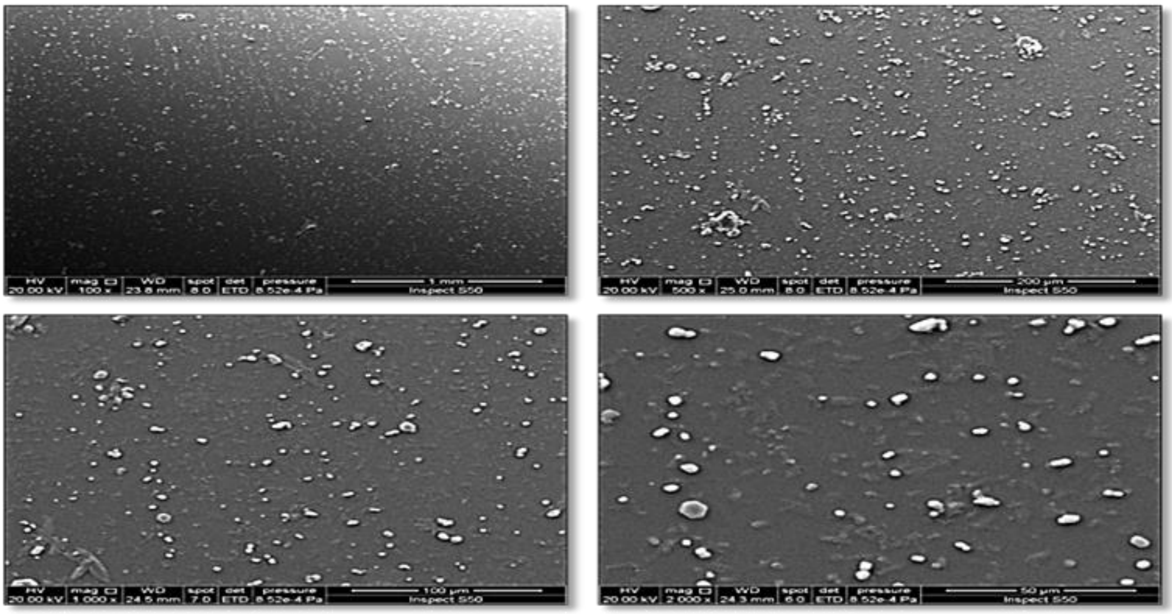

Figure 4. EM micrograph images of prepared silver NPs with laser pulse 500 mJ.

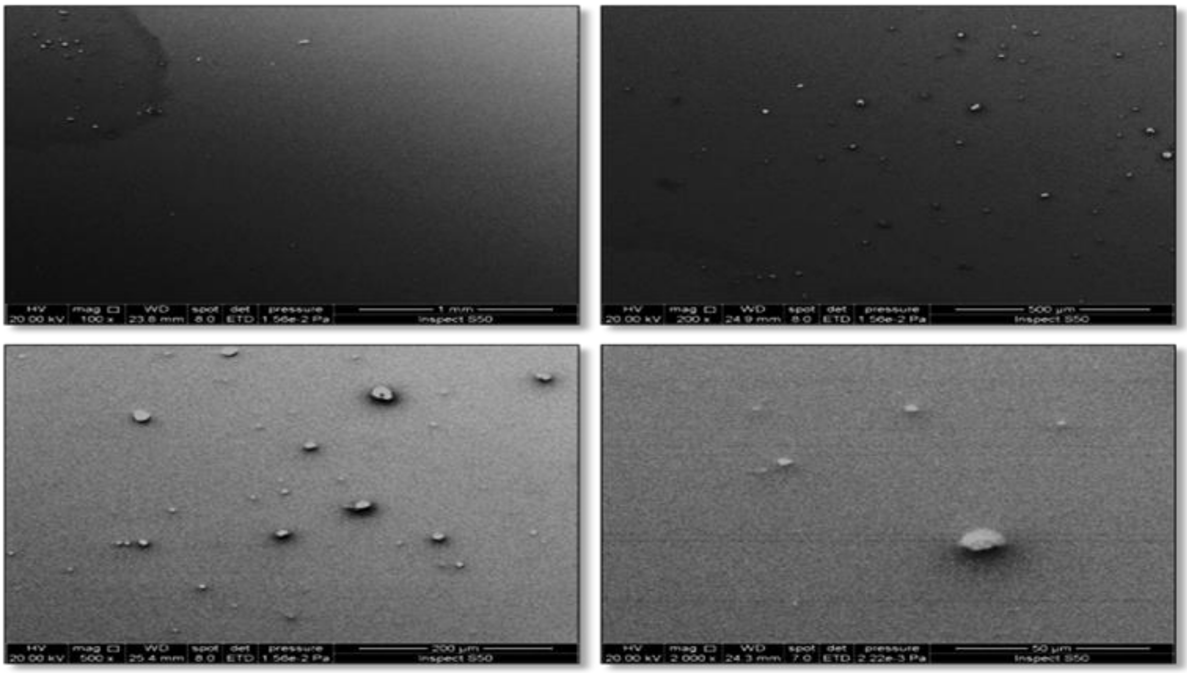

Figure 5. SEM micrograph images of prepared silver NPs with laser pulse 100 mJ.

c) Atomic Force Microscope (AFM) analysis

Surface morphology, particle size, and roughness of the surface for prepared silver NPs was studied by AFM (SPM AA2000, Angstrom advanced, and used contact mode) under normal atmospheric conditions. Fig. 6 displayed Surface morphology result at 1000mJ pulse energy. A 3D image shows fine particles, small particle size of 32.45nm, and the histogram of granularity cumulation distribution appearing that 50% of particle size was 30 nm. A surface roughness analyzing determined by AFM, surface roughness RMS (Root Mean Square) was 2.62 nm and average roughness was 1.96 nm and a cross section curve show regular distribution for particles in height and smooth surface roughness.

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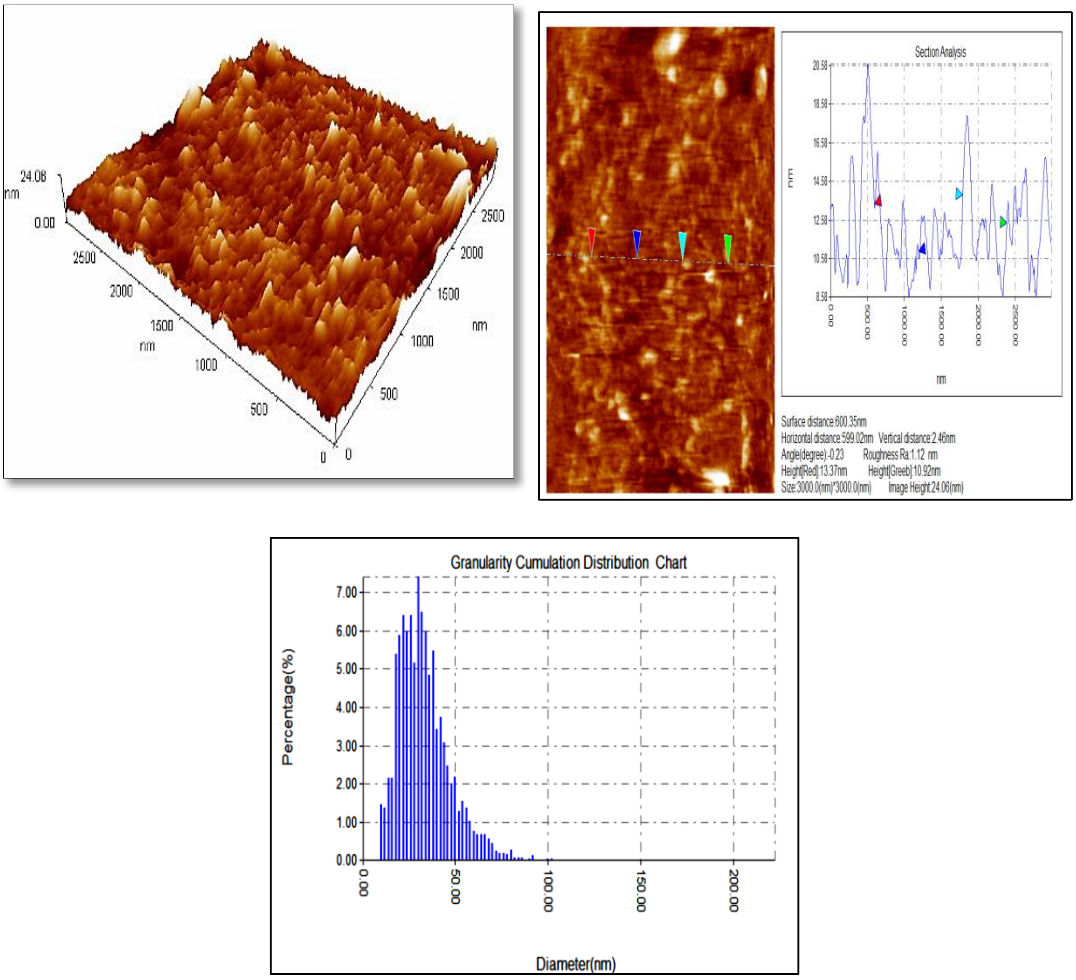

Figure 6. AFM Surface Morphology: 3D, Cross section and cumulation distribution chart for silver NPs prepared by 1000 mJ laser pulse energy.

At 500 mJ, Fig.7, the 3D AFM image shows particle size of about 64.3nm and from the distribution histogram appeared that 50% of diameter was 50 nm. Surface roughness (RMS) was 2.81 nm and average roughness was 2.11nm. The cross section curve show distribution for particles in range 9 - 21nm in height and peaks rather wide in width and the aggregation was appearance by the height and width of peaks.

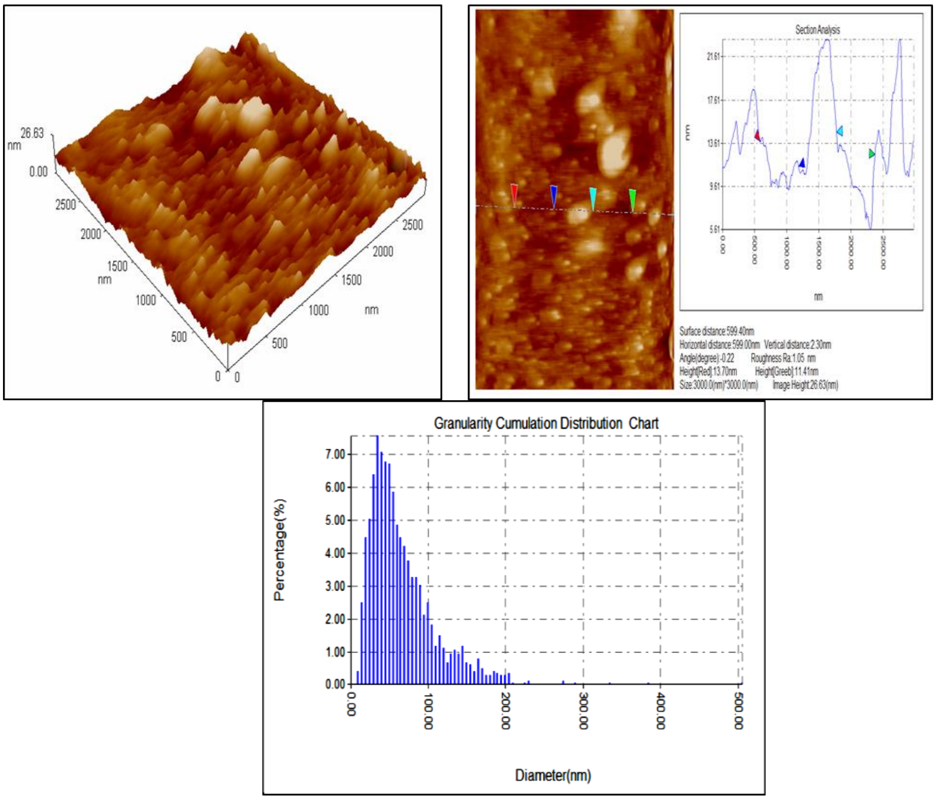

Figure 7. AFM 3D, Cross section and cumulation distribution chart for silver NPs prepared by 500 mJ laser pulse energy.

At 100 mJ pulse laser energy, Fig. 8, AFM 3D image shows a distribution of particles and particle size of 67.86 nm. The distribution histogram shows that 50% of diameter was 55nm. Surface roughness (RMS) was 2.96 nm and average roughness was 2.12nm that characterizes the surface roughness. The cross section curve show distribution of particles as peaks and the surface roughness in middle.

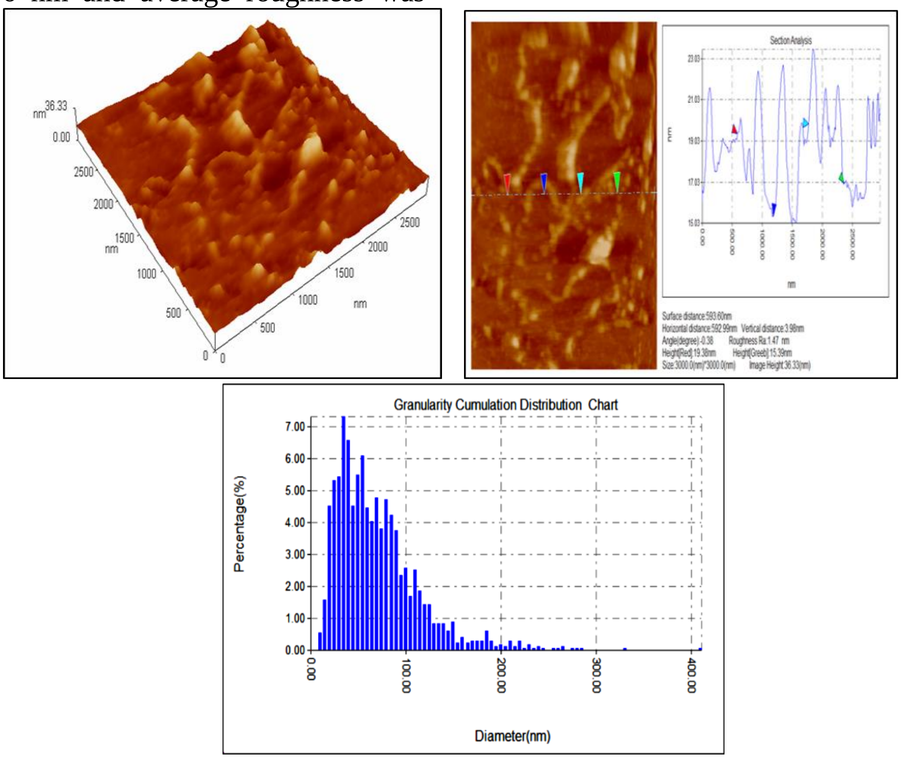

Figure 8. AFM 3D, Cross section, and cumulation distribution chart for silver NPs prepared by 100 mJ laser pulse energy.

d) Optical Measurement: UV-visible analysis

Fig. 9 shows the absorption spectra of prepared silver NPs at wavelength 440nm for pulse energies 1000, 500, and 100 mJ, Optical properties measured by Shimadzu UV- 1650 PC UV-Visible Spectrophotometer at wavelength range of 340 –550 nm. The decrease of pulse laser energy leads to increase silver nanoparticles particle size and the optical absorption spectra that due to Surface Plasmon Resonances (SPR) phenomenon where the particle size and aggregation of nanoparticles effected on the absorbance of incident light than the intensity and lead to increase optical absorption [29].

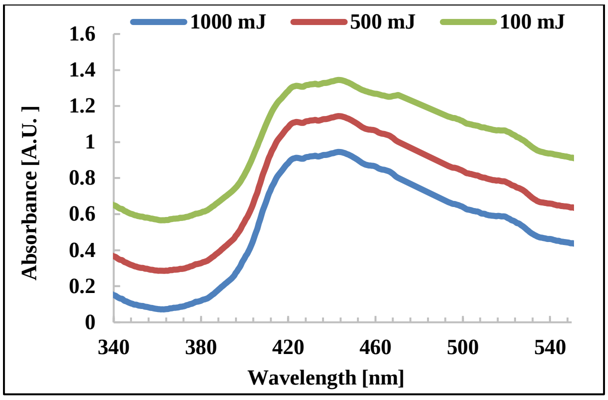

Figure 9. The absorbance spectra of prepared silver NPs with 1000 mJ, 500mJ, and 100mJ laser pulse energy.

Conclusion:

Pulsed Laser Ablation in Liquid (PLAL) process by using Nd:Yag laser (1064 nm wavelength, Q-switched, and 6ns pulse duration) with various pulses energy 1000 mJ, 500 mJ, and 100 mJ, 500 pulses used to synthesis silver oxide nanoparticles .The structural peaks for silver oxide nanoparticles indexed as face-centered cubic (FCC) type and crystalline orientation (111) plane. The particle size increased 32.45, 64.3, and 67.86 nm respectively for 1000, 500, and 100 mJ, this affected on optical properties of nano particles, the absorption spectra increased as decrease in pulse laser energy because of the increase of particle size and aggregation of partials. As a pulse laser energy increased, the particle size decreased.

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Authors' Declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Al-Nahrain University.

Authors' Contributions Statement:

M. S. M., Sh. M. M., R. M. R., and Alaa Adnan Rashad are contributed to the design and implementation of the research, in the results analysis and to the writing of the manuscript.

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تحضير جسيمات اوكسيد الفضة النانوي باستخدام ليزر إن دي ياج وبطاقات نبضة مختلفة

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الخلاصة:

تستخدم تقنية الاستئصال بالليزر النبضي في السائل (PLAL) لتحضير مواد الجسيمات النانوية ، وجسيمات الفضة النانوية (AgO) في هذا البحث تم تحضيرها باستخدام هذه التقنية ، حيث تم غمر هدف الفضة في ماء ذو نقاوة عالية في درجة حرارة الغرفة ثم قصفها بواسطة ليزر ان دي ياج (طول موجي 1064 نانومتر ، فترة النبضة 6 نانوثانية). في هذه العملية يتم دراسة تاثير اشعة الليزر على الجسيمات النانوية التي تم تحضيرها باستخدام طاقات مختلفة 100 ملي جول ، ملي جول 500 ، 1000 ملي جول , مع 500 نبضة في كل مرة على حجم الجسيمات. الجسيمات النانوية المنتجة يتم فحصها باستخدام الفحوصات التالية UV- Visible AFM, SEM, XRD spectroscopy, . يمكن تحديد البنية البلورية لجميع الجسيمات النانوية المحضرة بواسطة قياس حيود الاشعة السينية(XRD) وقد تبين ان البنية البلورية كانت من نوع مكعب مركزي الوجه (FCC) ويقع الاتجاه البلوري الأقوى في المستوى (111). الجسيمات النانوية اغلبها ذو شكل كروي كما تبين من صور المجهرالالكتروني الماسح(SEM). حسب نتائج حجم الذرات التي تم فحصها بجهاز مجهر القوى الذرية (AFM) تبين ان في طاقة نبضة الليزر (1000) ملي جول تم إنتاج أفضل واصغرحجم و ان حجم الجسيمات كانت 32.45 نانو متر, 64.3 نانومتر و 67.86 نانومتر على التوالي ل 1000 ملي جول ، 500 ملي جول و 100 ملي جول و ان خشونة السطح سوف تتاثر وتزدراد مع زيادة الطاقة وذلك بسبب زيادة الحجم والتجمعات للذرات. وقد تم قياس امتصاص جسيمات الفضة النانوية المحضرة بواسطة جهاز مطيافية الأشعة المرئية وفوق البنفسجية حيث ظهرت زيادة بالامتصاصية مع زيادة طاقة الاستئصال بالليزر النبضي عند الطول الموجي 440 نانومتر.

الكلمات المفتاحية: جسيمات الفضة النانوية, ليزر إن دي ياج ,حجم الجزيئة, تقنية الاستئصال بالليزر النبضي في السائل ,مطيافية الأشعة المرئية وفوق البنفسجية.