Academic Science Journal

Some physical properties of Al nanoparticle Via pulse laser ablation in liquid method (PLAl)

Tahseen H. Mubarak, Nadia M. Jassim and Quds A. Guidan

Department of Physics – College of Science – University of Diyala, Diyla, Iraq

sciphyms2117@uodiyala.edu.iq

Received: 4 July 2022 **Accepted: 19 August 2022**

DOI: https://dx.doi.org/10.24237/ASJ.01.02.631C

Abstract

This examination, pulsed laser ablation in liquids technology was used to synthesis of aluminum nanoparticles. A number of pulsed Nydmium Yak (Nd:YAG) laser with wavelength (1064 nm) , constant ablation energy (600 mJ), frequency (1 Hz) and pulse duration (10 ns), was utilized for an objective of unadulterated aluminum drenched in refined water. The primary, morphological, and optical properties were examined, including XRD for Al NPs has a polycrystalline structure and cubic phase. The planes (111) and (200) corresponding to peaks at (2θ=38.08° and 44.03°) which agreement with the JCPDS standard card no. (004-0787). (111) direction represents the strongest and the preferred peak. We determined the crystallite size found out by utilizing Scherrer's recipe it was (17.52) nm. Estimation of FTIR after effects of the pre-arranged aluminum showed an expansion of the connection between AL-O-H , C - O , C = C, and O-H Which have a place with the water particles utilized in the readiness interaction. Field Emission Scanning Electron Microscopy (FESEM) analysis were carried out.FESEM images of Al NPs prepared at 500 pulse relatively shapes like spherical, cubical and uniform were noted. It is clear from these pictures that the particle size is around (177.4 nm), Al NPs prepared at 600 pulses are in agglomerated form. Due to the agglomeration the particles look much bigger than their real size. It is clear from these pictures that the particle size is around (136.0 nm) and Al NPs prepared at 700 pulses are nearly spherical and cubical in shape with different sizes. The aggregation of Al nanoparticles is due to strong interactions. The average particle size of the NPs observed from FE-SEM images is (123.1 nm). The absorbance spectra of Al NPs at 500, 600 and 700 pulses and laser power 600 mJ was noted that when pulses number of laser increases the SPR shift to smaller wavelength (blue shift) which indicates that the smaller size nanoparticles. Optical absorption spectra of the sample prepared in constant solution at fixed laser power and varying pulses number have a strong feature in the ultraviolet and visible range. The SPR peak absorption increases whenever increases pulses number, accompanied by a slight change in bandwidth and a maximum wavelength of absorption. The peaks position unstable when the pulse number increases, increases the confinement energy. EDS analysis of aluminum nanoparticles prepared by pulsed laser ablation at(600 pulse) showed that the noticeable peaks are oxygen and aluminum.

Keywords: PLAl ,Al nanoparticle ,physical properties.

بعض الخواص الفيزيائية لجسيمات الالمنيوم النانوية المحضرة بطريقة الاجتثاث بالليزر النبضي في السائل (PLAl)

الأسماء باللغة العربية

قسم الفيزياء – كلية العلوم – جامعة ديالى

الخلاصة

تم استخدام استراتيجية تقنية الاجتثاث بالليزر النبضي في السوائل لتخليق دقائق الألمنيوم النانوية. تم استخدام عدد من ليزر النيديميوم-ياك ذو الطول الموجي 1064 نانومتر، وطاقة الاجتثاث الثابتة (600 مللي جول)، والتردد (1 هرتز) ومدة النبض (10 نانوثانية)، لهدف من الألمنيوم النقي المنقوع في ماء منزوع الايونات تم فحص الخصائص التركيبية والمورفولوجية والبصرية، بما في ذلك XRD لـ Al NPs له هيكل متعدد البلورات وطور مكعب. المستويات (1 1 1) و (0 0 2) المقابلة للقمم عند (2θ=38.08° and 44.03°) والتي تتفق مع رقم البطاقة القياسي (JCPDS004-0787). يمثل الاتجاه (1 1 1) الأقوى والذروة المفضلة. حددنا الحجم البلوري الذي تم اكتشافه من خلال استخدام معادلة شيرر وكان (17.52) نانومتر. أظهر تقدير FTIR بعد تأثيرات الألومنيوم المرتب مسبقًا توسعًا في الاتصال بين AL-O-H و C - O و C = C و O-H والتي لها مكان مع جزيئات الماء المستخدمة في تفاعل الاستعداد. تم إجراء تحليل المجهر الإلكتروني لمسح الانبعاث المجال (FESEM)، ولوحظت صور FESEM لـ Al NPs المحضرة في 500 نبضة بأشكال نسبيًا مثل كروية ومكعبية وموحدة. يتضح من هذه الصور أن حجم الجسيمات حوالي (177.4 نانومتر)، Al NPs المحضرة عند 600 نبضة في شكل تكتل. تبدو الجسيمات أكبر بكثير من حجمها الحقيقي يتضح من هذه الصور أن حجم الجسيم حوالي

136.0 نانومتر وأن Al NPs المحضرة عند نبضة 700 تكون كروية تقريبًا ومكعبة الشكل بأحجام مختلفة. يرجع تراكم جزيئات النانو إلى التفاعلات القوية. يبلغ متوسط حجم الجسيمات لـ NPs التي لوحظت من صور 123.1 نانومتر. تمت ملاحظة أطياف الامتصاص لـ Al NPs عند نبضات 500 , 600و700 وقوة الليزر 600 مللي جول أنه عندما يزيد عدد نبضات الليزر من تحول SPR إلى طول موجي أصغر (التحول الأزرق) مما يشير إلى أن الجسيمات النانوية أصغر حجمًا. أطياف الامتصاص البصري للعينة المحضرة في محلول ثابت بقوة الليزر الثابتة وعدد النبضات المتغيرة لها ميزة قوية في النطاق المرئي والأشعة فوق البنفسجية. يزيد امتصاص ذروة امتصاص SPR كلما زاد عدد النبضات، مصحوبًا بتغيير طفيف في عرض النطاق وأقصى طول موجي للامتصاص. وضع القمم غير مستقر عندما يزداد عدد النبضات، ويزيد من طاقة الحبس. أظهر تحليل EDS لجسيمات الألومنيوم النانوية المحضرة عن طريق الاجتثاث بالليزر النبضي عند (600 نبضة) أن القمم الملحوظة هي الأوكسجين والألمنيوم.

الكلمات المفتاحية: PLAl، جسيمات النانو، الخصائص الفيزيائية.

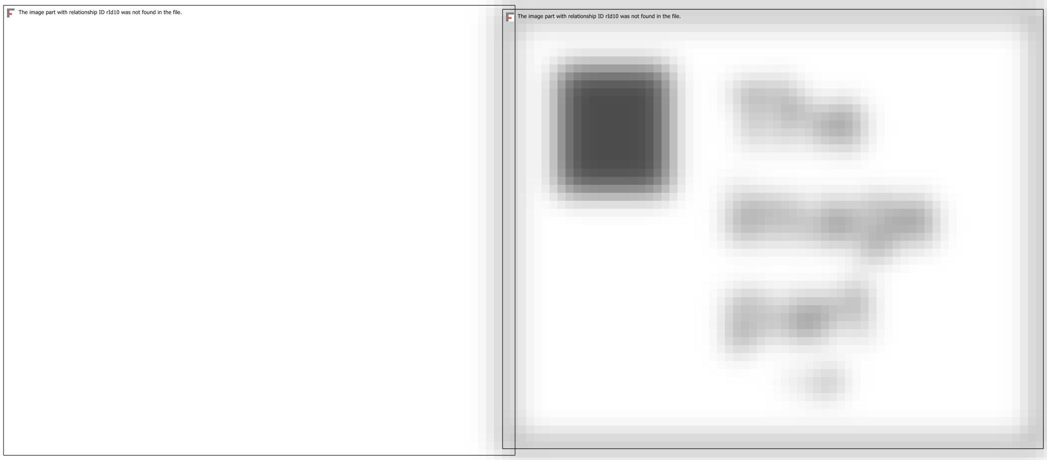
Introduction

The application of nanoscale materials and plans, for the most part going from 1 to 100 nm, is an emerging area of nanoscience and nanotechnology [1]. Nanoparticles show phenomenal properties that stood out from the mass metals in this way a lot of investigation work has represented the mix and uses of metal nanoparticles [2]. Physical and manufactured properties of aluminum (Al) and especially its nanoparticles, are adequately ideal to make them relevant in various applications, for instance, composite powder metallurgy parts for cars and planes, heat defending coatings of planes, disintegration, protected, conductive and heat reflecting paints, conductive and fancy plastics, affixing and termite welding, firecrackers and military applications (rocket fuel, igniter, smokes, and tracers) [3]. Nanoscale Al particles are moreover focused as high-limit hydrogen limit materials [4]. Laser Ablation in Liquid (LAL) for the making of nanostructures relies upon the release of material by a laser beat lighting serious areas of strength for a lowered in liquid. The laser matter correspondence and the ensuing evacuation are unequivocally dependent upon the irradiance and the length of the beat, on the establishment liquid, the model math and morphology as well as on the focusing condition. Laser blend of colloids, filled areas of strength for by, power lasers, radiates an impression of being a key enabling cycle that is artificially flawless and innocuous to the environment, and connecting with for present day gathering of utilitarian nanomaterials while being important in different locales, for instance, hydrogen age, hydrogen limit, heterogeneous catalysis using colloidal high-entropy composite NPs, anticancer and antimicrobial assessment, drug checking, added substance manufacturing applications, and nonlinear nano photonics. NPs organized by the Laser Ablation in Liquids (LAL) have been used for various and novel applications like scouring decline, sun arranged nanofluids, optical limiting devices, and so on. The time of NPs with LAL really makes them challenge points of view, similar to the production of NPs with a specific size and shape, the diminishing of polydispersity and the augmentation of productivity. Despite a couple of odd issues of a physical, compound and concentrated nature, a couple of strategies have been proposed to vanquish the above issues, including the decision of the reasonable liquid or settling trained professional, the upgrade of the focusing conditions and liquid levels, as well as the gathering of sifting and fluid components methodology by different liquid managing plans and the post irradiation of colloids [5,6]. The aim of this research is to prepare nanoparticles of aluminum by using a pulsed laser ablation.

Experimental Details

preparation method

The colloidal arrangements of nanoparticles of metals were arranged utilizing high immaculateness (99.9 %) silver and titanium targets, utilizing the beat laser removal method (PLAL) in fluid and at room temperature. the metal targets were cleaned and cleaned when every destruction cycle by washing them with ethanol and afterward with refined water utilizing an ultrasound gadget (Ultrasonic way), and afterward cleaning the objectives to dispose of the debasements. Then, at that point, the objective was put at the least of a glass compartment and lowered in refined water (DW) and the volume of water utilized in all destruction tasks was (5 ml) and the level of the fluid over the objective surface is (3mm). In the ongoing review, the number of laser beats was changed as a component of the energies of each heartbeat. The energy utilized is (600 mJ) per beat. Where the quantity of laser beats that besieged the outer layer of the metal targets was (500, 600, 700,800 and 900) beats at a proper laser energy of (600mJ). In the current work, the distance between the objective and the laser focal point was (7cm) for all objectives utilized, and the width of the laser shaft on the outer layer of the metal objective was (2 mm). The objectives were besieged with an (Nd: YAG) laser of frequency (1064 nm) with a heartbeat season of (10 ns) and a recurrence of (1 Hz) to get shaded colloidal arrangements containing the nanoparticles of the metal focus on that were taken out as the water changed variety after the destruction process. Figure (1) shows cutting common aluminum and nano-aluminum.



(a) **(b)**

Figure 1:(a) shows cutting ordinary aluminum and (b) nano-aluminum.

Results And Measurements

XRD analysis of Al NPs

The X-beam diffraction design: were recorded utilizing XRD-6000 with CuKα (λ=1.5406A°) with speeding up voltage of 220/50HZ which is created by SHIMADZU organization.The colloidal solution of Al NPs dried on a glass substrate was used for X-ray diffraction (XRD) measurement. Figure (2) illustrated XRD of the Al NPs prepared by pulsed laser ablation method, at laser power 600 mJ/pulse-600 pulse. The XRD pattern shows that Al NPs has a polycrystalline structure and a cubic phase. The planes (111) and (200) corresponding to peaks at (2θ=38.08° and 44.03°) which agreement with the JCPDS standard card no. (004-0787). (111) direction represents the strongest and the preferred peak. . We determined the crystallite size found by utilizing Scherrer's displayed in condition (1) it was (17.52) nm.

$$\mathbf{D_{ave} = K\lambda/\beta \cos\theta} \quad \text{.......} \quad \mathbf{(1)}$$

where K is the Scherrer constant, λ is wave length of the X-ray beam used (1.54,184 Å), β is the Full width at half maximum (FWHM) of the peak and θ is the Bragg angle.The crystal lattice constant (**a_o=b_o=c_o**) was calculated for the aluminum nanoparticles prepared by laser ablation method using the relationship (2). The lattice constant (**a_o**) is calculated from the plane (111). It was found that the value of the lattice constant is connecting with the value in the international card (004-0787), we calculated crystal lattice it was 4.0898A° [7].

$$\mathbf{a = dhkl\,(h^2 + k^2 + l^2)^{1/2}} \quad \text{.......} \quad \mathbf{(2)}$$

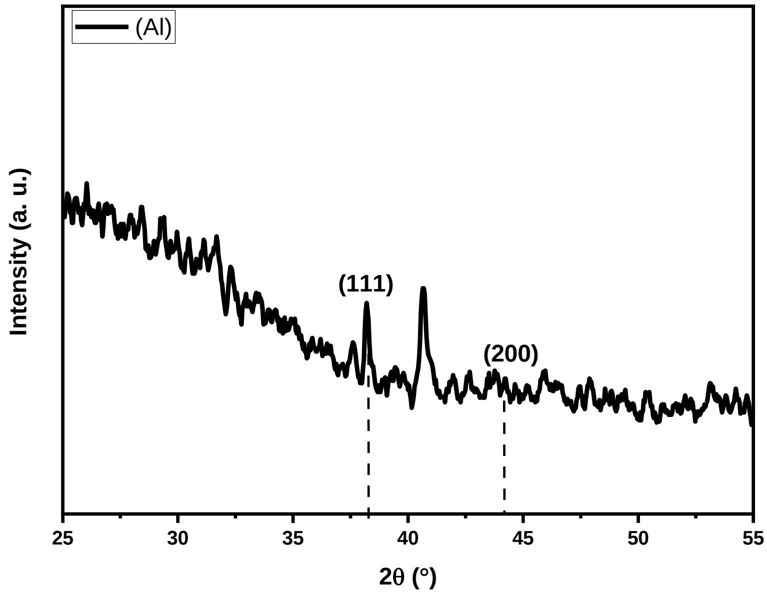


Figure 2: XRD pattern for Al NPs at energy of (600) mJ.

Absorbance

UV-Vis Spectrometer: utilizing Device (UV-Visible 1800 twofold bar spectrophotometer) Factory by an organization (Shimadzu, Japanes). The absorbance spectra of Al NPs at 500, 600 and 700 pulses and laser power 600 mJ are shown in figure (3), it was noted that when pulses number of laser increases the SPR shift to smaller wavelength (blue shift) which indicates that the smaller size nanoparticles.

Optical absorption spectra of the sample prepared in constant solution at fixed laser power and varying pulses number have a strong feature in the ultraviolet and visible range. The SPR peak absorption increases whenever increases pulses number, accompanied by a slight change in bandwidth and a maximum wavelength of absorption. The peaks position unstable when the pulse number increases. Table (1) shows peaks position of Al nanoparticles at various pulses numbers.

Figure 3: Optical absorbance as a function of wavelength for Al NPs Colloidal Solution.

Table 1: Peak position for SPR of Al NPs in DW at different pulses and laser power 600 mJ.

Metal	SPR		
	500 pulses	600 pulses	700 pulses
Al	250	250	245
	440	410	400

FTIR analysis of Al nanoparticles

Fourier Transform Infrared Spectroscopy (FTIR): FTIR spectra of arranged examples were recorded by utilizing Shimadzu, IRAffinity-1, Japan. The FT-IR Characterization is used to find the molecules and their functional group present in the synthesized metallic nanoparticles. The consequences of the examination of the metallic nano Al test (FTIR) at room temperature show that the field energy of the pinnacles of TOM (cross over optical mode) and LOM (longitudinal optical mode) change over a wide temperature range. The elements of the communication of the synthesis component Al with different compound components and utilitarian gatherings additionally shown [8,9]. The FTIR range of a metallic nano Al compound is displayed in Figure (4). In the range of the metallic aluminum test, cross over and longitudinal examples of 419.18 and 443.27 cm^{-1} AL-O-H retention groups are seen at low frequencies. 1637.93 cm^{-1} in aluminum that of (C−O). 2076.25 cm^{-1} in aluminum that of (C=C). The solid top at 3466.02 cm^{-1} compares to the O-H extending [10].

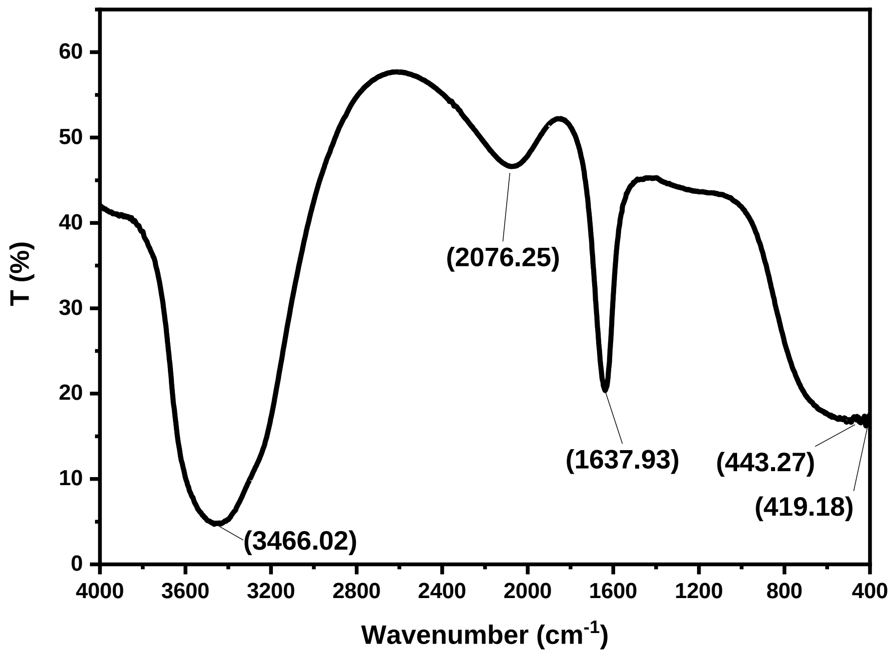


Figure 4: FTIR spectrum for Al nanoparticles

Field Emission Scanning Electron Microscopy (FESEM)

The Field Emission Scanning Electron Microscopy (FESEM): the gadget utilized was of the sort (Model-FEL 450 Nova Nano).

Figure (4- a) shows that the Al NPs prepared at 500 pulses relatively shapes like spherical, cubical and uniform were noted. It is clear from these pictures that the particle size is around (177.4 nm).

Figure (4-b) shows that the Al NPs prepared at 600 pulses are in agglomerated form. Due to the agglomeration the particles look much bigger than their real size. It is clear from these pictures that the particle size is around (136.0 nm).

Figure (4-c) shows that the Al NPs prepared at 700 pulses are nearly spherical and cubical in shape with different sizes. The aggregation of Al nanoparticles is due to strong interactions. The average particle size of the NPs observed from FE-SEM images is (123.1 nm).

To corroborate the chemical analysis of Al NPs, chemical analysis using the Energy dispersive spectroscopy (EDS) technique was used.

Figure (5) shows EDS of the prepared nano Aluminum by laser ablation method. The figure shows that the visible peaks are only for oxygen (O) and aluminum (Al), contributing to total atomic percentages of 85.2% and 14.8% respectively. Appearance high percentage oxygen element attributed to the oxidation of thin film through preparation process.

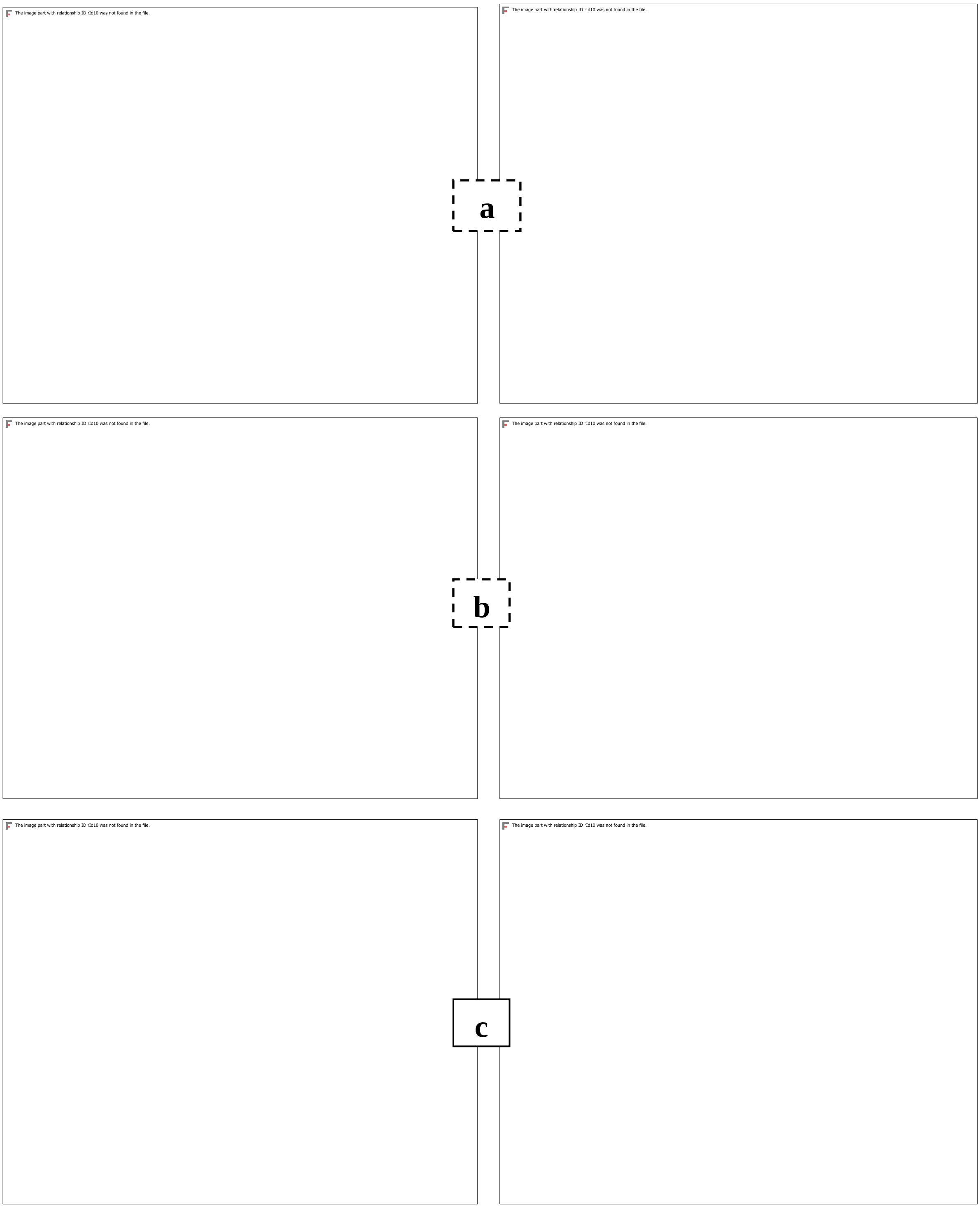


Figure 4: FESEM images for Al NPs at a) 500 pulses, b) 600 pulse and c) 700 pulses.

Figure 5: EDS image of Al NPs at 600 pulses

Dynamic Light Scattering (DLS)

This estimation was made to decide the molecule size by estimating the arbitrary changes in the power of the dispersed light from aluminum nanoparticles arranged by beat laser removal technique in refined water utilizing the quantity of heartbeat 600. Dynamic light dispersing is the estimation of variances in the force of dissipated light over the long haul. These changes in power emerge because of the irregular Brownian movement of nanoparticles, so the factual way of behaving of these vacillations in the dispersed thickness can be connected with the molecule dissemination. Since bigger particles dissipate more leisurely than little particles, molecule size can undoubtedly be connected to estimated variances in light dispersing force [11].

1. Measurement of the dynamic light scattering results of nanoparticles according to the intensity

Figure (6) shows the volume circulation as indicated by the thickness of aluminum nanoparticles arranged by beat laser removal at a beat of 600 and at a temperature of 25°C, and that the consistency is 0.8872 cp. The Z-Average was 174.4 r.nm , It shows the typical molecule size 523.275 r.nm, the biggest molecule size was 5000 r.nm, and the littlest molecule size was 0.2 r.nm and the table (2) shows the radii of aluminum nanoparticles.

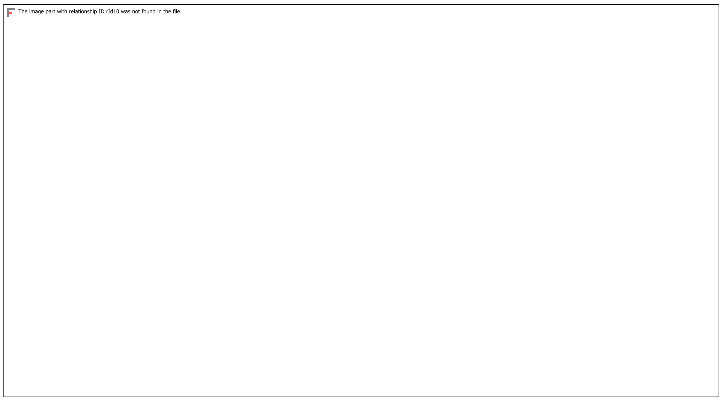


Figure 6: Size distribution analysis by dynamic light scattering of aluminum nanoparticles prepared by pulsed laser ablation at pulse 600 according to intensity.

Table 2: Volumetric distribution results for aluminum nanoparticles according to intensity

Pulse count	Diameter (nm)	Intensity%	Width (nm)
600	105.2	54.7	42.83
	376.1	39.3	139.4
	2631	5.9	217.7

Figure (7) shows the factual dispersion of aluminum nanoparticles by thickness, which showed that the most noteworthy power is at (82.09-96.07 r.nm) and how much Z-Average 348.7995 nm. Furthermore, the aluminum nanoparticles showed a dissemination in the reach from (39.41-859.2 r.nm).

Figure 7: Statistical distribution of the size of the aluminum nanoparticles prepared at the 600 pulse according to the density

2. Measurement results of dynamic light scattering of nanoparticles according to size

Dynamic light dispersing estimation was utilized to decide the volume of aluminum nanoparticles in the fluid arrangement. Figure 8 shows the volume conveyance by the size of aluminum nanoparticles arranged at 600 heartbeats and a temperature of 25°C, and how much thickness of 0.8872 cp. What's more, how much Z-Average 174.4 r.nm . It shows the typical molecule size 523.275 r.nm, the biggest molecule size was 5000 r.nm , and the littlest molecule size was 0.2 r.nm Table (3) volumetric dispersion results for aluminum nanoparticles as indicated by size.

Figure 8: Statistical distribution of the size of the aluminum nanoparticles prepared at the 600 pulse according to the size

Table 3: Volumetric distribution results for aluminum nanoparticles according to size

Pulse count	Diameter (nm)	Volume٪	Width (nm)
600	92.51	24.7	38.04
	473.3	65.5	164.2
	2693	9.8	337.3

Figure 9 shows the measurable dissemination of aluminum nanoparticles by size, and it showed that the most noteworthy force is at 563.2 r.nm at how much Z-Avrage is 348.7995 nm. Furthermore, the aluminum nanoparticles showed dispersion in the reach from (34.0-995.1 r.nm).

The image part with relationship ID rId10 was not found in the file.

Figure 9: Statistical distribution of the size of the aluminum nanoparticles prepared at the 600 pulse according to the size

3. Measurement results of dynamic light scattering of nanoparticles according to number

Figure 10 shows the volume dissemination as per the thickness of aluminum nanoparticles arranged by beat laser removal at a beat of 600 and a temperature of 25°C, and that the consistency is 0.8872 cp. The Z-Average was 174.4 r.nm , It shows the typical molecule size 523.275 r.nm, the biggest molecule size was 5000 r.nm , and the littlest molecule size was 0.2 r.nm and the table (4) shows the radii of aluminum nanoparticles.

The image part with relationship ID rId10 was not found in the file.

Figure 10: Statistical distribution of the size of the aluminum nanoparticles prepared at the 600 pulse according to the number

Table 4: Volumetric distribution results for aluminum nanoparticles according to number

Pulse count	Diameter (nm)	Number٪	Width (nm)
600	64.07	100.0	43.04
	0.000	0.0	0.000
	0.000	0.0	0.000

With respect to the figure 11, it shows the factual conveyance of aluminum nanoparticles by size, and it shows that the most elevated force is at 45.64 r.nm how much Z-Average 348.7995 nm and that the particles showed dispersion in the reach from (34.0-553.2 r.nm).

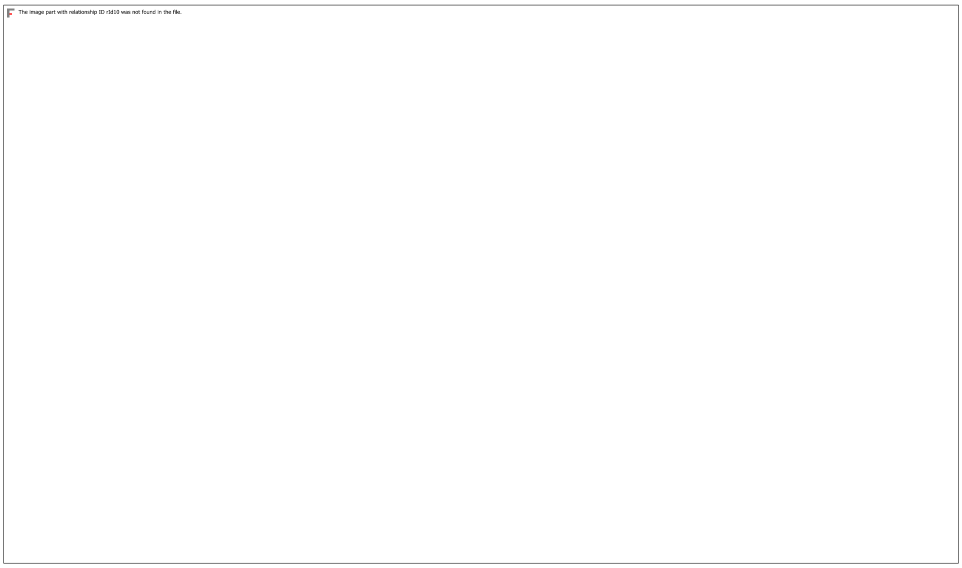


Figure 11: Statistical distribution of the size of the aluminum nanoparticles prepared at the 600 pulse according to the number

Conclusions

Aluminum nanoparticles were prepared successfully in distilled water with various parameters including wavelength (1064 nm), different pulse number (500, 600 and 700 Pulse/sec), constant ablation energy (500 mJ) and obtaining crystallite size of about (17.52 nm).

Reference

1. D. Mandal, M. E. Bolander, D. Mukhopadhyay, G. Sarkar, P. Mukherjee, Appl Microbiol Biotechnol., 69, 485(2006)
2. S. Chandra, A. Kumar, P. K. Tomar, Spectrochimica Acta Part A, 92, 392–397(2012)
3. A. Baladi, R. S. Mamoory, Applied Surface Science 256, 7559–7564(2010)
4. H. Li, M. J. Meziani, F. Lu, C. E. Bunker, E. A. Guliants, Y. Sun, J. Phys. Chem. C, 113, 20539–20542(2009)
5. R. Torres-Mendieta, R. Mondragón, V. Puerto-Belda, O. Mendoza-Yero, J. Lancis, J. E. Juliá, G. Mínguez-Vega, ChemPhysChem.,18,1055–1060(2017)
6. G. González-Rubio, A. Guerrero-Martínez, L. M. Liz-Marzán, Chem. Res., 49,678–686(2016)
7. Z. T. Khodair, M.A. Al-Jubbori, and A.M. Shano, Chemistry of Data Collection, 28, 1–7(2020)
8. R. Romero, F. Martin, J. Ramos-Barrado, D. Leinen, Thin Solid Films, 518, 4499–4502(2010)
9. N. Ahammed, M. S. Hassan, M. Hassan, Materials Science-Poland, 36, 419-426(2018)
10. M. Sangeetha, S. Rajendran, J. Sathiyabama, P. Prabhakar, Journal Natural Product Plant Recourse, 2, 601-610(2012)
11. A. Kumar, C. K. Dixit, Adavances in nanomedicine for the delivery of therapeutic nucleic acids, 43-58(2017)