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Synthesis of silver nanoparticles by Nd:YAG laser and study Optical Limiting Behavior of colloid

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ABSTRACT

In the present work, silver nanoparticle was synthesis by pulse laser ablation by using (Q-switched Nd:YAG) pulse duration10ns and (E=80mJ, λ=532nm) of silver metal target in deionize-water and ethanol. The results of XRD explain that not found any impurity in diffraction peaks in the pattern and Ag nanoparticles have high quality from of crystalline, which evidences the presence of silver particles with FCC structure. The optical properties were studied with Ultraviolet-Visible (UV-Vis) spectrophotometer which showed blue-shaft with pulse number, and atomic force microscope (AFM) indicates the size in nanometer (nm) range abut(40-80)nm.

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تحضير جسيمات الفضة النانوية بواسطة ليزر Nd: YAG ودراسة سلوك المحدد البصري للمحلول الغروي

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الـــخُـــلاصـــة

تم في هذه الدراسة تحضير جسيمات الفضة النانوية باستخدام الاستئصال بالليزر النبضي عن طريق تسليط عدد من النبضات الليزرية على هدف من الفضة في الماء منزوع الأيونات والإيثانول باستخدام المعلمات (E=80mJ, λ=532nm) (Q-switched Nd:YAG) . توضح نتائج XRD ان جسيمات الفضة النانوية ذات تركيب بلوري FCC وبدرجة عالية من البلورية . وتمت دراسة الخواص البصرية باستخدام مطياف (UV-Vis) والتي اشارت الى حدوث ازاحة نحو الاطوال الموجية الزرقاء بزيادة عدد النبضات. وتشير نتائج المجهر الذري (AFM) إلى الحجم في مدى النانومتر من nm (40-80). وتم دراسة المحدد البصري للمحلول الغروي الناتج.

الكلمات المفتاحية:

– ليزر الاجتثاث
– نبضة الليزر
– الفضة النانوية
– المحدد البصري

1. INTRODUCTION

Noble metal nanostructures have appropriately found their application in the Surface Enhanced Raman Scattering or (SERS) sensors since they demonstrate the property of Surface Plasmon resonance or LSPR [1]. Pulse laser ablation in liquid (PLAL) has unique advantages for synthesis of nanostructured particles like high purity, simple, rapid, does not require sophisticated vacuum equipment and does not require chemicals as in wet chemical methods which contaminate the end product and also pollute the environment [2,3]. In this technique, the high energy of laser beam, first, heats up the target surface, which is immersed in liquid, up to the melting and even boiling point, then metallic vapor is generated in the plasma plume immediately, after absorption of latest part of the laser pulse, the plume expands adiabatically; and finally, the condensation occurs, leading to synthesis of nanoparticles [4]. Laser ablation plasma is formed above the surface of the solid target when an intense laser beam strikes the target [4, 5, and 2]. Controlling particle size is a very important factor in the method used for obtaining them, because their properties are very sensitive to their size. In the laser ablation method, the particle size can be controlled by changing the laser wavelength, pulses, energy, ..[3,6]. The laser ablation of metallic targets in liquids is without any contamination of chemical reagent and parasitic ions compared to the chemical ways to produce metallic nanoparticles in solution as for laser ablation in vacuum [7].

The study of the optical limiting (OL) laser radiation in various materials lead the possibility of using these materials as laser shutters for protection against intense laser radiation and is important in investigating the essential properties of nonlinear optical media [8].

In this work, the laser ablation method is studied. The objective of it is to generate nanoparticles, In addition to study how the particle size, and their concentration, change in different experimental conditions such as laser pulse or change liquid.

2. EXPERIMENTAL

Silver nanoparticles (Ag NPs) were synthesized by pulsed laser ablation of silver target in distilled water, and ethanol at room temperature. The silver target (purity of 99.99%) was fixed at bottom of glass vessel containing of 2 ml of double distilled deionized water DDDW. The ablation was achieved using focused output of pulsed Nd: YAG laser (type of laser system (HUAFEI) operating with a repetition rate of 6 Hz and pulse width of 10 ns. Ablation is carried out with laser operating at (E=80mJ, λ=532nm), the number of laser shots applied for the metal target at (100,200,300) pulse. Size and shape measurements investigated by XRD and AFM. The experimental setup of PLAL process was shown as in Fig (1).

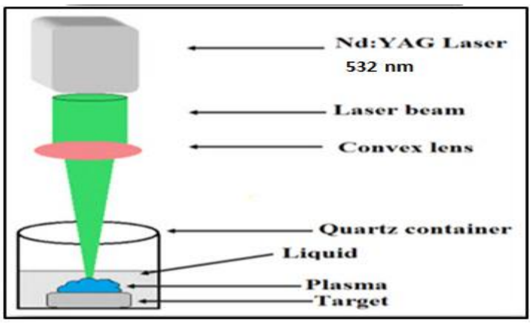


Figure 1: Experimental setup for nanoparticles synthesis by PLAL

3. RESULTS AND DISCUSSION

3-1 X-ray diffraction study

Fig (2) presents the XRD of the sample, The results of XRD explain that not found any impurity in diffraction peaks in the pattern and Ag NPs have high quality from crystalline and the results of XRD appear clear and sharp peak with dominant peaks on 2θ=38.36°, 2θ =44.482°, 2θ =64.671°, 2θ =77.53° corresponding to (111), (200), (220), (311) peaks respectively, Ag NPs with polycrystalline structure was established by (JCPDS card No. (04-0783). which evidences the presence of implanted silver particles with FCC structure of their internal region in agreement with the EXAFS result. The best crystallization will be along the level (111) 2θ =38.36. The average particle size was measured by Debye-Sheerer equation [9].

$$D= (0.89\ \lambda)/ (\beta^* \cos(\theta)) \qquad \ldots\ (1)$$

Where D is grin size, λ=0.154nm, β=FWHM, λ=wavelength, θ is Diffraction angle.

It turns out that the minutes are prepared at an average (38.4, 42.7) nm in DDDW and ethanol respectively.

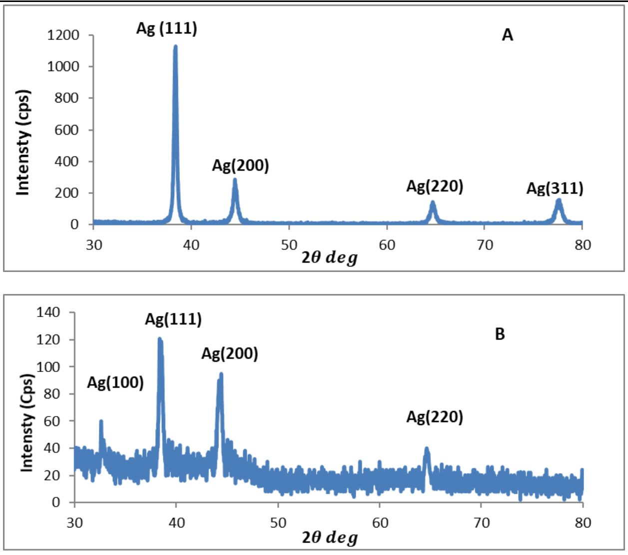
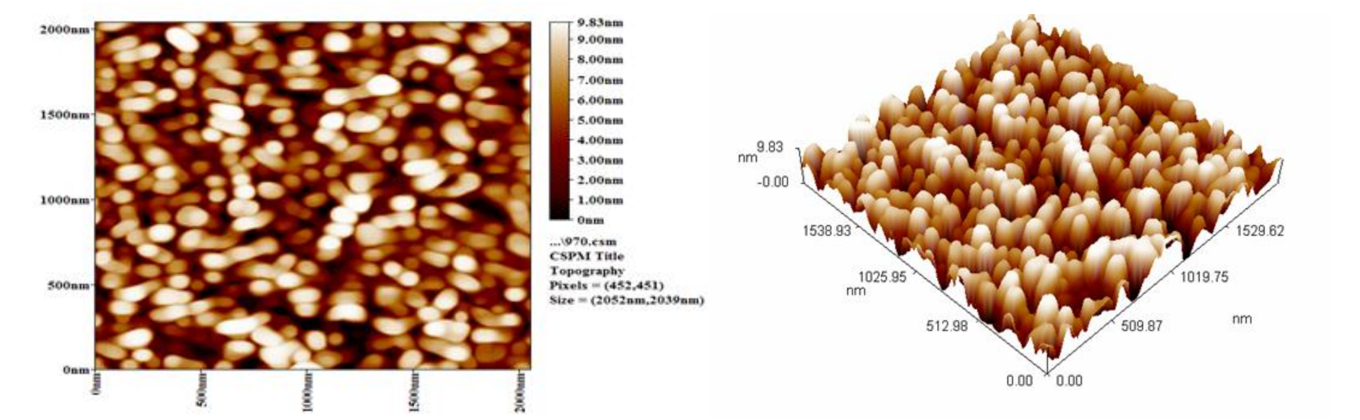


Figure 2: X-Ray diffraction (A) Ag target before ablation (B) Ag NPs DDDW.

3-2 AFM Morphology

Figures (3) (4) Shown the AFM images show that Ag NPs has semi-spherical shapes and from graphical (2D and 3D) we see that the number and particles distribution decreases with decreasing in number of pulses, the average diameter of the prepared nanoparticles rang between (40-80) nm in DDDW and ethanol respectively, and there is gradient in color ice species indicate grain growth is sequentially, so this color represent the formation of agglomerated grains one on the top of the other.



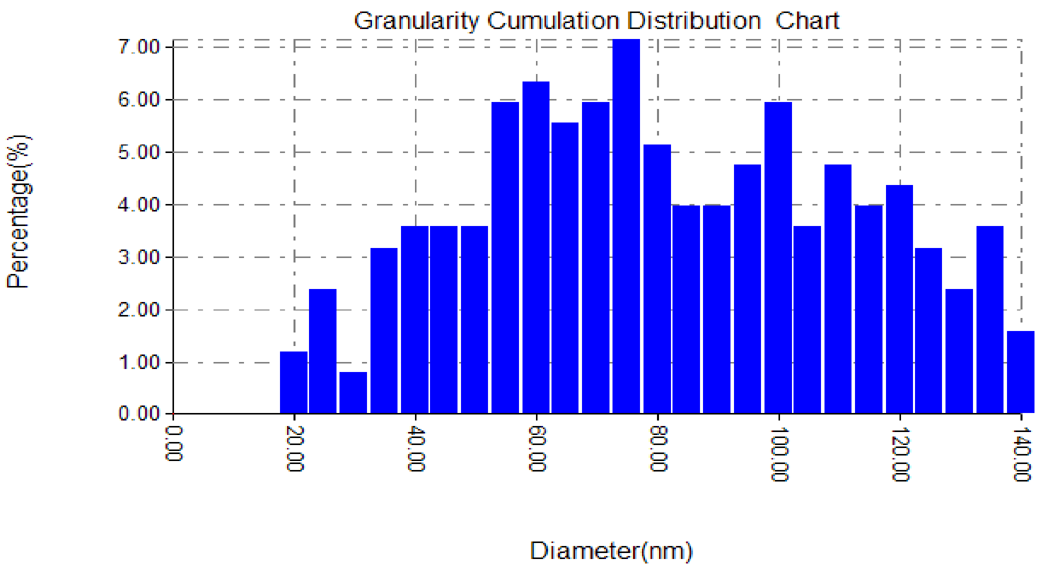


Figure 3: 2D, 3D AFM image and size distribution of Ag NPs in DDDW.

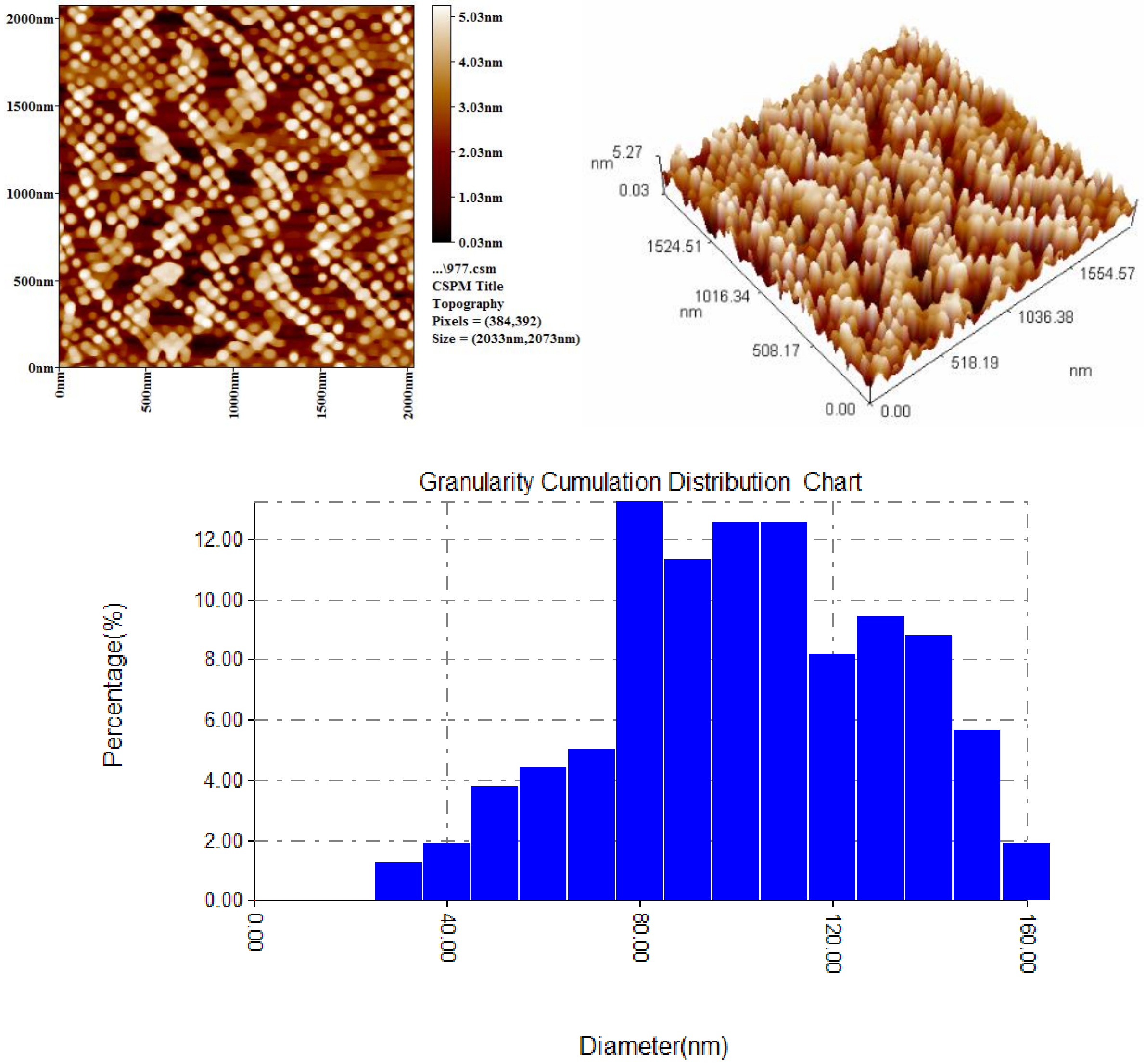


Figure 4: 2D, 3D AFM image and size distribution of Ag NPs in ethanol.

3-3 Optical properties

The absorbance spectra Ag NPs in DDDW and ethanol at different pulses (100,200,300) pulses; the intensity of absorption increased, this is due to the increase of Ag NPs concentration shown that in figures (5) (6) the absorption peaks Ag NPs increase by increasing the number of pulses is max value equal (0.211, 0.250) at 300 pulse in the DDDW and Ethanol respectively. Efficiency of laser ablation increased with larger number of laser pulses this is consistent with previous studies [2, 3, and 10]. The peak will shift toward the short wavelength (blue shifting) this shifting may due to the decreasing of the silver nanoparticle size this agree with previous studies [11, 12].Since ethanol has higher uptake than distilled water, this indicates an increased concentration of Ag NPS, this agree with [13].

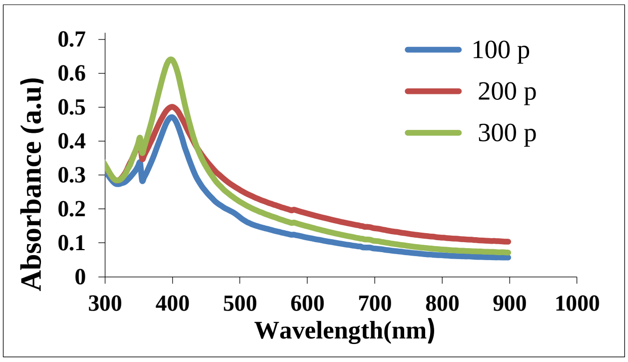


Figure 5: the absorbance spectra Ag NPs in DDDW

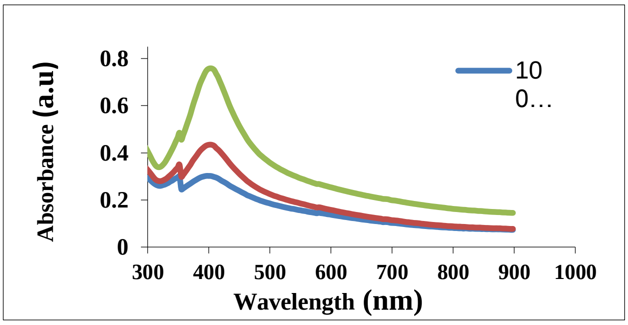


Figure6: the absorbance spectra of Ag NPs in ethanol

4. OPTICAL LIMITER

We made a study to optical power limiter for Ag NPs solution in DDDW and ethanol at different pulses (100,200,300) by use Z-scan technique and diode laser CW at 650 nm with power rang (5-50) mw. The figures (7) (8) shows the input power in the range (5,10,15,20,25.30,35,40,45) mw , the output power was increased with increasing input power until the limiting threshold where the output power is constant at (30mw ,25mw) in samples of DDDW and ethanol respectively. These results are quite encouraging for possible applications in nonlinear optical devices.

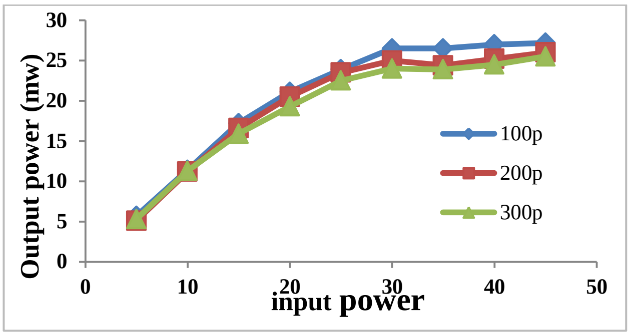


Figure 7: Optical Limiter for Ag NPs colloid in DDDW at different pulses.

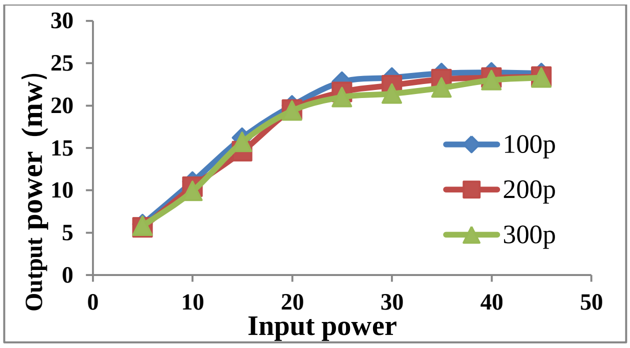


Figure 8: Optical Limiter for Ag NPs colloid in ethanol at different pulses.

5. CONCLUSION

1. X-ray diffraction patterns shows that Ag thin films are polycrystalline.
2. AFM images showed that the number and particles distribution increases with increasing in number of pulses, and average diameter rang (40-80) nm.
3. The absorption peak will shift toward the short wavelength (blue shifting) and this shifting may due to the decreasing of the silver nanoparticle size
4. The results limiter is quite encouraging for possible applications in nonlinear optical devices.

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