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Effect of Experimental Parameters on the Fabrication of Silver Nanoparticles by Laser Ablation

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ABSTRACT

In this work, silver nanoparticles has been prepared via ablation of pure Ag metal target in distilled water was accomplished using Q-switched Nd:YAG laser at (1.06 µm) laser wavelength , with different laser energy and number of laser pulses. The effect of these parameters on the optical and surface morphology have been studied , UV-Visible show a red shift in the absorption spectra related to the shift in the energy gap due to increment of the grain of prepared particles size is increased as laser energy. Grain size of the obtained NPs are found to increase with laser energy with rang (20-112) nm as shown by the SEM result.

Keyword: Nanoparticle, Laser Ablation, Surface Morphology, Optical Properties.

تأثير العوامل التجريبية على تشكيل فضه نانوية بعمليه القلع المستحث بأشعة الليزر

الخلاصة

في هذا العمل تم أجراء عملية التبخير بالليزر لشريحة معدنية من الفضة النقي مغمورة بماء مقطر لا أيوني وباستخدام ليزر الندميوم-ياك النبضي بالطولي الموجي(1.06 µm) وكثافة طاقات ليزر مختلفة وبعدد نبضات مختلف. تم دراسة تأثير هذه المعلمات المختلفة على الخصائص البصرية، خصائص طبوغرافية السطح أظهرت نتائج الخصائص البصرية حدوث إزاحة نحو الأطول الموجية الحمراء في طيف الامتصاص للمحاليل المحضرة وذلك نتيجة لإزاحة فجوة الطاقة بسبب زيادة الحجم الحبيبي للدقائق المحضرة مع زيادة طاقة الليزر، بينما لوحظ وجود إزاحة نحو اللون الأزرق مع الزيادة في عدد النبضات. وكذلك وجد أن الحجم الحبيبي للجسيمات النانوية بأنها تزداد مع زيادة طاقة الليزر وبمعدل من 20-112 نانوميتر.

INTRODUCTION

Noble metal nanoparticles such as Ag nanoparticles have got great interests due to their novel electrical, optical, physical, chemical and magnetic properties [1, 2]. So Noble metal nanoparticles were very attractive for biophysical, biochemical, and biotechnological applications due to their unusual physical properties, especially due to their sharp plasmon absorption peak at the visible region. Another important advantage of Ag nanoparticles prepared that by pulsed laser ablation in liquid (PLAL) were chemically stable for a period of months.

Additionally, silver nanoparticles are typically exhibit surface enhanced Raman scattering (SERS) in the visible wavelength range, where they may cause a tremendous increase in various optical cross-sections.

The resonance frequencies strongly depend on a particle shape and size as well as on the optical properties of the material within the near field of the particle [3]. Silver, for example, has been for thousands of years, used as a disinfectant; on the other side, nobody can neglect its value as a catalyst [4].

Nanoparticles have been prepared by a wide variety of techniques such as pulsed laser deposition [5], chemical reduction [6], photo reduction [7], electrochemical reduction [8]...etc. Among them, the pulsed laser ablation in liquid medium (PLAL) has become an increasingly popular top-down approach [9] for producing nanoparticles. 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.

In addition, it has been demonstrated that size of synthesized material can be controlled by changing different parameters such as: laser wavelength, laser pulse duration, changing the PH of the solution [10], all nanoparticles can be captured in liquid [11, 12].

In comparison with the conventional physical methods such as chemical vapor deposition, vapor phase transport, laser ablation in vacuum, etc., liquid–phase laser ablation has distinct features as follows: well crystallized nanoparticles can easily be obtained in one–step procedure without subsequent heat–treatments because of the high energetic state of ablated species [13] The synthesis procedure of the metal nanoparticles affects the final colloidal state and [9] the nanoparticle generation rate is 100 times higher in air compared to water and large quantities of nanoparticles can be synthesized.

The aims of the work are to prepare more stable-dispersed and size-controlled of pure silver nanoparticles to optimize the process and improve the formation rate of nanoparticles by studying the effects of experimental parameters such as number of laser shots, laser energy, that leads to enhancement of ablation efficiency.

EXPERIMENTAL PROCEDURES OF PLAL

Ag NPs synthesized by pulsed laser ablation of silver target in distilled water at room temperature. The silver target (purity of 99.99%) was fixed at bottom of glass vessel containing of 10 ml of double distilled deionized water DDDW. The ablation was achieved using focused output of pulsed Nd: YAG laser (type Huafei Tongda Technology—DIAMOND-288 pattern EPLS)) operating with a repetition rate of 1 Hz and pulse width of 10 ns. Ablation is carried out with laser operating at 1064 nm wave length .The spot size of the laser beam on the surface of the metal plate was 0.75 mm in diameter by the distance between the focusing lens and the metal plate at 13 cm .The pulse energy was 600 and 800 mJ/pulse. The liquid depth was 1mm,the number of laser shots applied for the metal target at (100-800) pulses.

Size and shape measurements investigated by Scanning Electron Microscope SEM (TESCAN-VEGA/USA). The absorbance spectra of the nanoparticles solution measured by UV-VIS double beam spectrophotometer (type: AA 6300 / Shimadzu /Japan).The Experimental setup of PLAL process was shown as in Figure (1).

RESULTS AND DISCUSSION

Figure (2) shows UV–visible absorption spectra of Ag-NPs, immediately after ablation. Absorption peaks of Ag NPs can be varied at given wavelength by factors depend on the value of laser energy (up to saturation) and by number of pulses.

For optical absorbance of the colloidal suspension, and it has been found that Ag-NPs exaction absorption peaks located at rang (309.37- 411.64) nm wavelengths as shown in Table (1). These peaks have light red shift with the increase of laser energy this result proved by other work [14, 15] in general a slight increase in the optical absorption as a function of incident light wavelength can be recognized with increasing in laser energy due to the increase in laser ablation efficiency that means increase in the amount of ablated material.

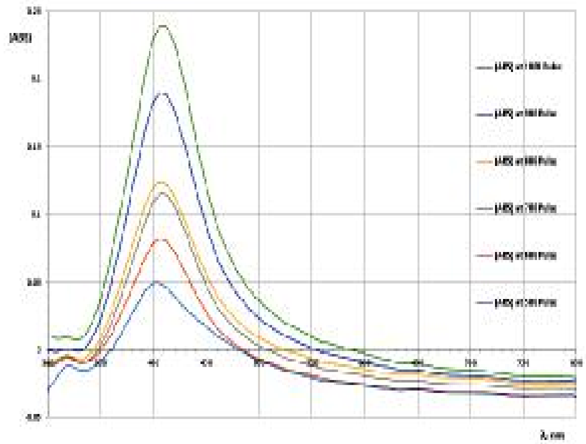
Figure (3) shows the SEM micrographs of Ag NPs prepared at different laser energy. It is clearly obvious that the increase in particles size with increasing laser energy is attributed to the effect of laser energy on the states of plasma during the laser ablation process in liquid and this result agreed with other work [16]. This is related to the overall process of the oxide nanostructure formation mechanism. This mechanism comprises three different but almost instantaneous processes.

The first one is the instantaneous initiation, short- lived persistence and rapid annihilation of the local plasma with (high temperature and high pressure).

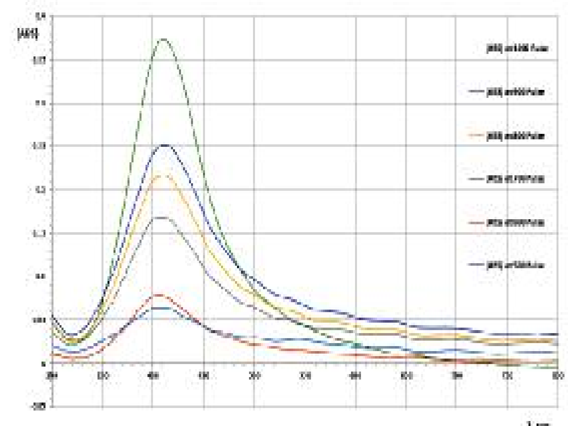
The second is the nucleation and growth of the species during and after the annihilating period. The last one is the aqueous oxidation and quenching of the formed clusters.

It can be seen that the state of plasma plays a basic and decisive role in such instantaneous formation mode. Morphology is controlled by laser energy, and this has an effect on the state of plasma, especially the lifetime and intensity of plasma [17]. In case of low laser energy figure (3-a,b) the plasma plume is weak and has a relatively low temperature and pressure. In addition to space distribution of laser energy and environmental disturbance, inhomogeneous density distribution in plasma plume becomes more obvious.

Figure (1) Experimental setup for nanoparticles synthesis by PLAL.



at E=600 mJ, 1 HZ and λ=1064 nm



at E=800 mJ, 1 HZ and λ=1064 nm

Figure (2) Absorbance spectra of Ag colloids at various pulsed laser and (E=600 and 800 mJ/pulse, λ=1064 nm).

Table (1) Peak of Absorbance for Ag NPs at various pulsed laser and (E=600 and 800 mJ/pulse ,λ=1064 nm).

Name method	λ, nm	Peak (ABS) at Pulse → E, mJ ↓	Number of shots					
			500 pulse	600 pulse	700 pulse	800 pulse	900 pulse	1000 pulse
PLAL at First Harmonic at 1HZ	1064 nm	600 mJ	0.0501 At 402.73 nm	0.0784 At 407.10 nm	0.1257 At 407.10 nm	0.1900 At 407.10 nm	0.2150 At 406.57 nm	0.2401 At 409.37 nm
		800 mJ	0.0638 At 403.95 nm	0.0818 At 406.57 nm	0.1684 At 409.37 nm	0.2269 At 411.64 nm	0.2512 At 411.64 nm	0.3731 At 409.37 nm

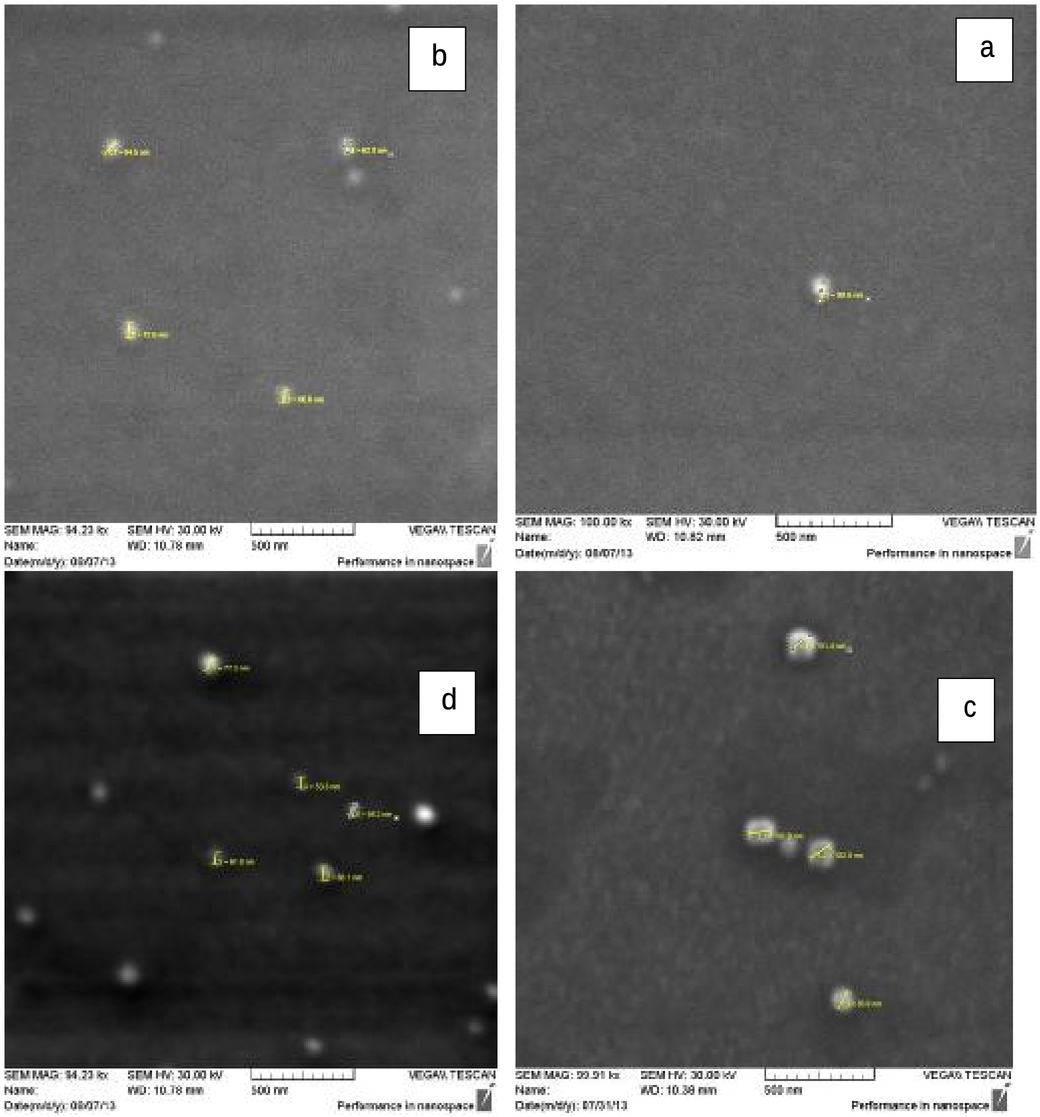


Figure (3) SEM image of Ag NPs prepared at 1.06 µm laser wavelength and different laser energy (a-100, b-200 and c-600 d-800) m J and 100 pulse.

CONCLUSIONS

Efficiency of laser ablation increased with larger number of laser pulses, and higher laser energy. Red shifts results from high laser energy due to increment of the grain of prepared particles size is increased. Particles size could be controlled by laser energy and number of laser pulse.

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