Preparation of Silver and Gold Nanoparticles By Using Nd - YAG Pulse Laser Ablation

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ABSTRACT

Silver and gold nanoparticles were prepared by using nanosecond pulsed laser ablation. Ablation of pure metal targets (Ag and Au) for nanoparticle colloidal production was studied in de-ionized water. The optical properties were studied with Ultraviolet- Visible (UV-Vis) spectrophotometer. The spectra reveal sharp peaks due to surface plasmon absorption peaks at 405 nm and 523 nm for Ag and Au respectively. The size and shape of nanoparticles was investigated by Transmission Electron Microscope (TEM). Spherical shapes with average diameters of 10 nm and 6 nm for silver and gold nanoparticles were found respectively.

Keywords: Silver Nanoparticles, Gold Nanoparticles, Laser Ablation, Colloid.

تحضير جسيمات الفضة والذهب النانوية باستخدام طريقة الاستئصال بليزر الياك النبضي

الخلاصة

تم تحضير جسيمات نانوية من الفضة والذهب باستخدام طريقة الاستئصال بالليزر النبضي .تمت الدراسة لاهداف معدنية نقية من الفضة والذهب لانتاج محلول الجسيمات النانوية في الماء الايوني . درست الخواص البصرية بمطيافية الاشعة فوق البنفسجية (UV-VIS) .بينت الاطياف ظهور ذروات حادة نتيجة الامتصاص السطحي البلازموني عند 405نانومتر و523 نانومتر للفضة والذهب على التوالي. فحص حجم وشكل الجسيمات النانوية بجهاز المجهر الالكتروني النافذ (TEM). وجد ان جسيمات الفضة والذهب كروية الشكل ومعدل اقطارهما 10نانومتر و6 نانومتر لكل منهما على التوالي .

INTRODUCTION

Metal nanoparticles have attracted much attention because of their unique size-dependent optical properties, magnetic properties and catalytic properties [1]. Metal nanoparticles have been intensively studied within the past decade [2]. Nano materials have been an important subject in basic and applied sciences for their application in a wide ranges of different fields, including chemistry, physics, biology, materials science, medicine and catalysis [3]. Metal nanoparticles have been prepared using many methods such as laser ablation technique [3], chemical reduction method or silver salt [4], photo-reduction [5], microorganisms [6], arc-Discharge method [7] and bio surfactant [8].

Laser ablation technique has attracted much growing interest since it is extensively employed for synthesis of new novel materials especially for drilling microvias in the high density printed circuit board in the microelectronic packaging[9]. Laser ablation plasma is formed above the surface of the solid target when an intense laser beam strikes the target. Laser ablation provides a simple and contaminant-free method which can be used for large number of materials [10]. Silver and gold nanoparticles generally exhibit Plasmon absorption bands that depend on their size and shape [11]. Gold nanoparticles have a wide range of potential applications, for instance, an effective drug delivery in cancerous tumors [12], biomedical [13], wide range of cosmetic and beauty applications [14], biosensors [15] and catalysis [16]. Silver nanoparticles have potential to eliminate bacteria and fungi for cosmetic and beauty application with self – cleaning properties [17].

In the present work, we prepared silver and gold nanoparticles as colloidal solutions, from metal silver disc and gold foil in deionized water using Nd-YAG pulse laser ablation method. The average size and the distribution of silver and gold nanoparticles were measured with transmission electron microscope. The UV –Visible absorption spectra of silver and gold nanoparticles was observed at different laser pulse times.

EXPERIMENTAL PROCEDURES

Colloidal of silver and gold nanoparticles (NP's) were synthesized by using pulsed laser ablation (Nd-YAG -1064 nm- 10ns) operating at the fundamental wavelength 1064 nm, and frequency of 10Hz. High purity (99.99%) of commercial grade silver powder was pressed by hydraulic system using stainless steel punch and die with 1cm diameter. The produced pellet with 1cm diameter and 3mm thickness was annealed to 600°C in tube furnace. Then, it was polished with automatic polisher. The silver disc was immersed at the bottom of cylinder with 20ml of deionized water. Laser beam with wavelength of 1064 nm was focused by lens with 5cm focal length. The ablation parameters are: power of 40mj, frequency of 6Hz, and pulse duration of 7ns. Experiments were carried out at different time (5min., 15min., and 30min). Pure gold (commercial grade) was used as another target with size of 1cmx1cmx0.5mm. The gold foil (1cmx1cmx 0.05cm) was ablated in the same manner used with silver and using the same parameters.

RESULTS AND DISCUSSION

Figure (1) shows the silver and gold colloidal solutions prepared by (Nd-YAG) laser ablation (1064 nm). The pale yellow and red colors of silver and gold nanoparticles as shown in figure 1a, 1b, are due to their Plasmon absorption. These two colloidal solutions are further characterized by UV-Vis Spectrophotometer (at Nanotechnology Center / UOT/ Baghdad) and Transmission Electron Microscope (TEM) (at Medical College / Al Nahrain University / Baghdad) as shown below.

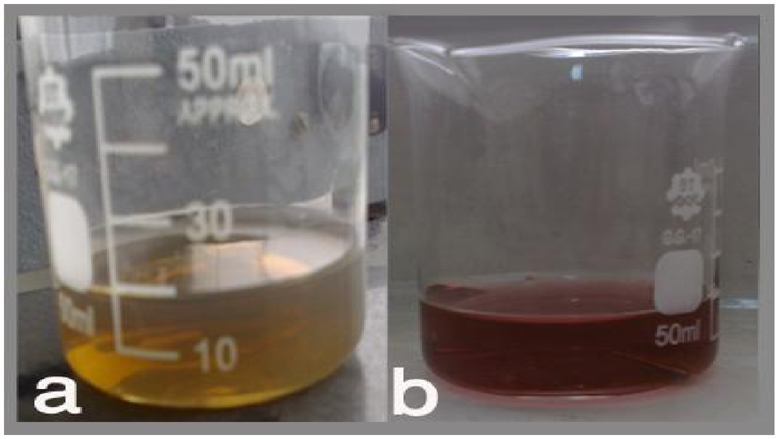

Figure (1) (a) Sliver colloidal (pale yellow); (b) Gold colloidal (pale red).

UV-VIS ANALYSIS

UV-Visible spectra were measured using UV- Cary 100 Cone UV- Visible Spectrophotometer in the range of (200-800) nm. The absorption and transmission spectra for silver and gold colloidal were measured with quartz cell.. The spectral features of different colloidal are characterized by Plasmon absorption peaks. A maximum wavelength (λ_{max}) for maximum absorbance was measured. Figure (2) shows UV-Vis absorption spectra for silver colloidal prepared with different laser pulse time (5 min, 15 min, and 30 min) at a constant laser power (40mJ/pulse). The absorbance increased as a function of time with increasing peak sharpness. This is due to the increase of colloidal concentration. The peaks at 405 nm are due to surface Plasmon of silver. The observed peak broadening at 5 and 15 min pulse times might be due to the small nanoparticle sizes in both cases. The size and shape of gold nanoparticles were measured by TEM as explained in later section.

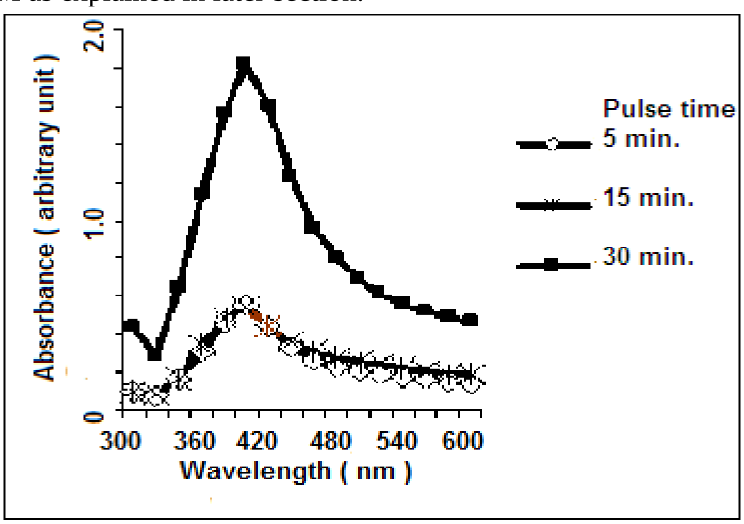

Figure (2) UV-Vis Spectra of silver nanoparticles at different Pulse times: 5 min., 15 min., and 30 min. , respectively.

Figure (3) shows the optical absorption spectra of gold nanoparticles prepared by 1064 nm laser ablation at different periods of time (5 min, 15 min and 30 min.). The ablation process was continuous with average duration of 100 pulses per minute. The UV-Vis spectrum for the colloidal solution of gold nanoparticles prepared shows maximum peaks at 523 nm. These are confirmed by other workers [11], which is due to their surface Plasmon absorption. A small absorption peak appears at 370 nm at 30 nm ablation time as shown in Figure (3). The results shows that the absorption peak intensity decreases with decreasing laser ablation time, (at 15 min.) and disappears at 5 minutes. The shoulder at 370 nm is corresponding to the transverse Plasmon vibration in gold nanoparticles which might be the effect of the particles shape [18, 19]. The presence of single surface Plasmon peak implies that the formed nanoparticles are nearly spherical. In case of ellipsoidal particles, the absorption spectrum would have two plasmon peaks [20].

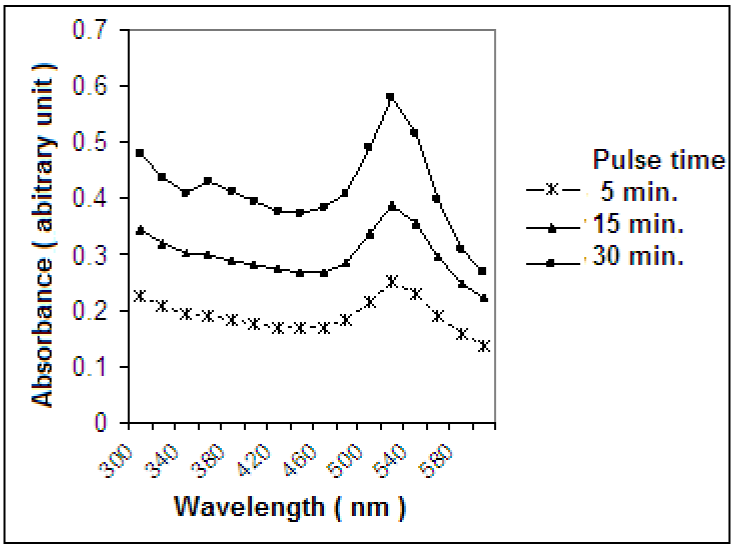

Figure (3) UV-Vis absorption spectra of gold nanoparticles at Different pulse times: 5 min., 15 min., and 30 min. respectively.

TEM MORPHOLOGY

The morphology of silver and gold nanoparticles was studied using Transmission Electron Microscope (TEM, PHILIPS CM10 / Holland) working at 100 kV accelerating voltage. TEM sample for Silver and gold were prepared separately from their colloidal by dropping a single drop on standard (3.05 mm) copper grid and then dried to be ready for imaging. Figure (4a). shows TEM image of silver nanoparticles prepared by 1064 nm laser ablation. Spherical silver nanoparticles with an average diameter of 10 nm were obtained. The spherical shape of silver nanoparticles observed by TEM is consistent with the optical absorption peak around 400 nm which originates from surface Plasmon excitation. This value was found to be consistent with results obtained by other workers for Ag NP's [21]. The size distribution of silver nanoparticles obtained from TEM image is shown in Figure (4b).

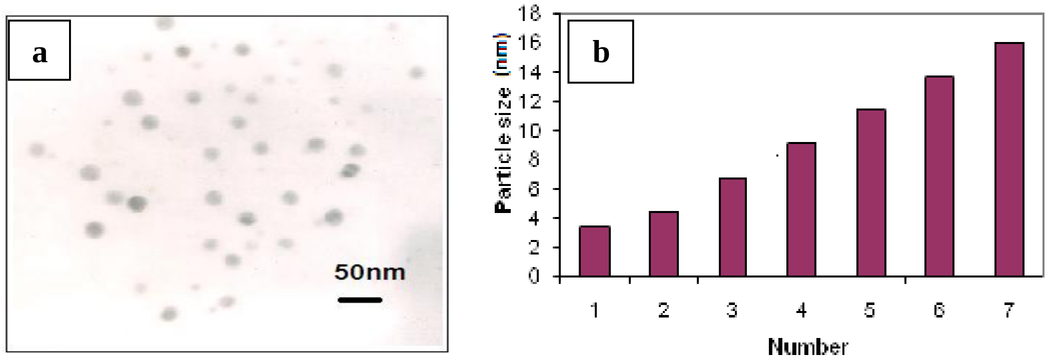

Figure (4) TEM image for spherical silver nanoparticles (a); and the corresponding particle size distribution (b).

Figure (**5)** shows TEM image of spherical gold nanoparticles also prepared by using laser ablation for 5 min with an average diameter of 6 nm. Spherical gold nanoparticles are being formed in various sizes as shown in Figure (5a). With an average diameter of 6 nm. Their absorption spectra were varying with time depending on size and shape of the nanoparticles. The Au nanoparticles size distribution constructed from TEM image is shown in Figure (5b).

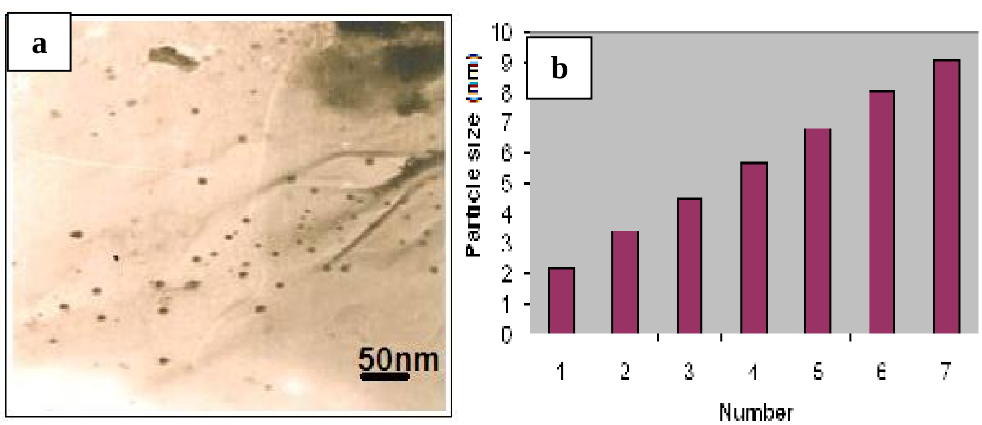

Figure (5) Typical TEM image for spherical gold nanoparticles (a); and the corresponding particle size distribution (b) at 5 min pulse time.

The experimental results of silver and gold nanoparticles using Nd-YAG pulse laser ablation (λ=1064 nm, frequency = 6 Hz, at various periods (5min., 15min., and 30 min.) are listed in Table (1).

Table (1) Experimental results of silver and gold nanoparticles using Nd-YAG pulse laser ablation.

Metal target	Time (min.)	Abs. peak at λ (nm)	Colloidal color	TEM results
Silver (Fig.2)	5	405	Pale yellow	--------
Silver (Fig.2)	15	405	Yellow (Fig.1a)	Fig.4a
Silver (Fig.2)	30	405	Brown yellow	--------
Gold (Fig.3)	5	523	Pale red	
Gold (Fig.3)	15	370 and 523	Red (Fig.1b)	Fig. 4b
Gold (Fig.3)	30	370 and 523	Red	---------

CONCLUSIONS

The preparation method of silver and gold nanoparticles via using (1064 nm) Nd-YAG pulse laser has been successfully developed. The UV-Vis absorption results at different period of time which have been revealed the formation of surface Plasmon absorption for silver and gold nanoparticles at two distinguished peaks at 405 nm and 523 nm respectively. Spherical nanoparticles are formed with various sizes as characterized by TEM images. It was concluded that the absorption spectrum of silver and gold nanoparticles depends on their size and shape as mentioned previously. Also absorption peak intensities increases with increasing laser time ablation (30 min.> 15 min.> 5min.)

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