

# Nanofabrication and characterization of gold metal by Pulsed Laser

## Ablation in SDS solution

Raheem Gaayied Kadhim (Corresponding author)  
College of the Science - University of Babylon  
Tel:0964-7801305881  
E-mail: [RaheemAlmorshdy@yahoo.com](mailto:RaheemAlmorshdy@yahoo.com)

Abdurrahman Khalaf Ali  
School of Applied Sciences – University of Technology  
Tel: 0964-7901386884  
E-mail: [Abed\\_ali@yahoo.com](mailto:Abed_ali@yahoo.com)

Maryam Falah Noori  
College of the Science - University of Babylon  
Tel: 0964-7903380791  
E-Mail: [physicallaser@yahoo.com](mailto:physicallaser@yahoo.com)

### Abstract

Gold nanoparticles were synthesized by pulsed laser ablation (Q-switched Nd:YAG,  $\lambda=1064\text{nm}$ , 10 ns pulse duration and  $E=750\text{ mJ}$ ) of pure Au metal plate immersed in double distilled and deionized water DDDW and other aqueous solution of SDS with various concentrations. Absorbance spectra of the produced nanoparticles solution was measured by uv-vis spectrophotometer, which show single and sharp peak around 525 nm, indicating the produced Au nanoparticles with a narrow size ranging from 5 to 50 nm with almost spherical shape. The morphology and size was estimated by SEM.

**Keywords:** Nobel, Pulsed, Nanoparticles, Gold, Liquid, Nd: YAG, SDS solution

### 1. Introduction:

Pulsed laser ablation in liquid media (PLAL) has become an increasingly important alternative approach for synthesis of colloidal suspensions with novel functional properties [1]. Noble metal nanoparticles such as Ag and Au NPs have been a source of great interest due to their novel electrical, optical, physical, chemical and magnetic properties [2,3] and due to their surface plasmon resonance related properties that are potentially useful for their biological applications[1]. Metal nanoparticles have attracted much attention because of their size-dependent physical and chemical properties. In this relation, size-selected nanoparticles with diameters less than 10 nm have been prepared using wet-chemistry techniques. More recently, laser-ablation method has been developed to prepare metal nanoparticles in a solution. This physical method allows us to prepare nanoparticles with ease and without contamination by a reducing agent, but the size distribution of the nanoparticles tends to be broadened because the coagulation processes of atoms can hardly be controlled. [4]. On the other hand, one can effectively produce colloidal metal nanoparticles when the ablation occurs in a liquid environment. However, the laser ablation in pure water generally gives relatively large ~20–300 nm and strongly dispersed ~50–300 nm Particles due to both the postablation agglomeration of nanoclusters and to the ejection of large target fragments, although certain size control can be achieved by a variation of radiation parameters. It has been recently demonstrated that the nanoparticle size can be drastically reduced by the use of aqueous solutions of surfactants, which cover the particles just after their ablation and thus prevent them from further agglomeration. Sodium dodecyl sulfate ~SDS was found to be the most efficient among the surfactants to reduce the mean size of Au nanoparticles down to 5 nm during nanosecond laser ablation of gold [5]. Gold is used for nanoparticle applications because it is unreactive and is not sensitive to air or light [6] The size control of the noble metal nanoparticles fabricated by laser ablation could be achieved by adding

specific molecules to the aqueous fabrication environment, which physically or chemically interact with the surfaces of the forming particles, to limit their growth. Ionic surfactants, [7,8] cyclodextrins, [9] and sodium chloride [10] were successfully used to limit the noble metal particle size. In some cases, the exact mechanism limiting the growth of the particles remains unclear.

As reported in previous literatures, we found that the preparation of metal nanoparticles via PLAL method suffers from low production yields and the rate of NPs generation strongly depends on experimental parameters. Moreover, the size and size distribution of the NPs prepared by PLAL tends to be broadened due to the ejection of large fragments and agglomeration and the process is not controlled.

In this paper, we have reported synthesis of gold NPs by nanosecond Nd: YAG laser ablation of gold target immersed in of double distilled deionized water DDDW and in various concentrations of SDS solution. The optical properties and morphology of colloidal gold NPs prepared at different concentrations were investigated.

## 2. Materials and methods:

Gold NPs were synthesized by pulsed laser ablation of gold target in double distilled and deionized water DDDW and other aqueous solution of SDS with various concentrations at room temperature. The gold target (purity of 99.99%) was fixed at bottom of glass vessel containing of 1 ml of double distilled deionized water DDDW or SDS solution. The ablation was achieved using focused output of pulsed Nd: YAG laser (type HUAFEI) operating with a repetition rate of 1 Hz and pulse width of 10 ns. Ablation is carried out with laser operating at 1064 nm wavelengths at fluence set in 61 J/cm<sup>2</sup>. The spot size of the laser beam on the surface of the metal plate was 1 mm in diameter by the distance between the focusing lens and the metal plate at 10 cm. The pulse energy was (750 mJ/pulse). The liquid thickness was 1mm. The number of laser shots applied for the metal target at 25 pulses. Size and shape measurements investigated by scanning electron microscope SEM (FEL Quanta 200, Netherlands) SEM view of periodic structures formed under scanning laser ablation in SDS solution. The absorbance spectra of the nanoparticles solution measured by UV-VIS double beam spectrophotometer (type CECIL C. 7200). The Experimental setup of PLAL process was shown as in Fig. 1.

## 3. Results and discussion:

Fig.2 shows a typical optical absorption spectrum of gold nanoparticles produced in different concentrations of sodium dodecyl sulphate SDS and pure water respectively. So that the laser ablation in an aqueous solution containing SDS: C<sub>12</sub>H<sub>25</sub>SO<sub>4</sub>Na, (M.W 289), as a surfactant is determined by particle growth in a plume by the laser ablation. The formation mechanism of gold nanoparticles in the solution was examined by changing the concentration of SDS. Laser ablation was carried out with a Nd: YAG laser 1064 nm, maximum energy 750mJ/pulse, during all of the experiments. The gold target was placed on the bottom of a 1ml glass vessel filled with 1 ml of aqueous solution. The focal plane was adjusted to 1 mm beyond the target surface to decrease the radiation intensity on its surface and enlarge the radiation spot. The inset shows the peaks of absorbance of the Au nanoparticles as a function of the SDS concentration corresponding to be the samples shown in same fig. The peak of absorbance tends to increase linearly by addition of SDS, until 30 mM, and then turns to decrease gradually. According to our result the optimum SDS concentration to produce maximum amount of Au nanoparticles is 30 mM. Note that the optimum concentration depends on the experimental parameters. Evidently, SDS plays an important role in determining the stability and size of the nanoparticles, because the termination of the nanoparticles growth is controlled by the diffusion and the attachment rates of SDS on the NPs. For the samples prepared in SDS solution, the particles are covered with surfactant (especially for high SDS concentration). It can be seen that with the increasing of SDS concentration, the size distribution width becomes narrow. Highly negative charged nanoparticles can repel each other more effectively, thus allowing the SDS molecules to cover them before contact occurs. These kinetics considerations are expected to limit the coalescence of the forming clusters, leading to smaller particles. SDS which interact with the nanoparticles during the condensation and, thus, prevent them from further coalescence and agglomeration, have been used to effectively stabilize and reduce the size of Au nanoparticles. It is believed that

convenient amount of SDS in water will enhance the Efficiency of nanoparticles formation, reduce the size, and prevent the aggregation; this fact was also confirmed by Ali [10] for silver nanoparticles.

#### 4. Conclusion:

In summary, we successfully demonstrated the synthesis of high purity gold NPs colloid at room temperature by Nd: YAG laser ablation of gold target in SDS solution. The optical properties of SDS are strongly affected by laser fluence and wavelength. The gold NPs exhibited high absorption in visible region and lowered absorption in UV and IR regions. The average size of gold NPs increased with laser fluence. The synthesized gold NPs have spherical shape and the size distribution is nearly Gaussian. The effect of water temperature on characteristics of gold NPs is underway. The nanoparticles obtained by laser ablation were partly oxidized, with Au-O compounds present at the nanoparticles surface. These compounds contribute to the negative surface charge of the nanoparticles. The gold nanoparticles are shifts to a smaller size due to increasing in SDS concentration; slow particle growth is due to SDS coating.

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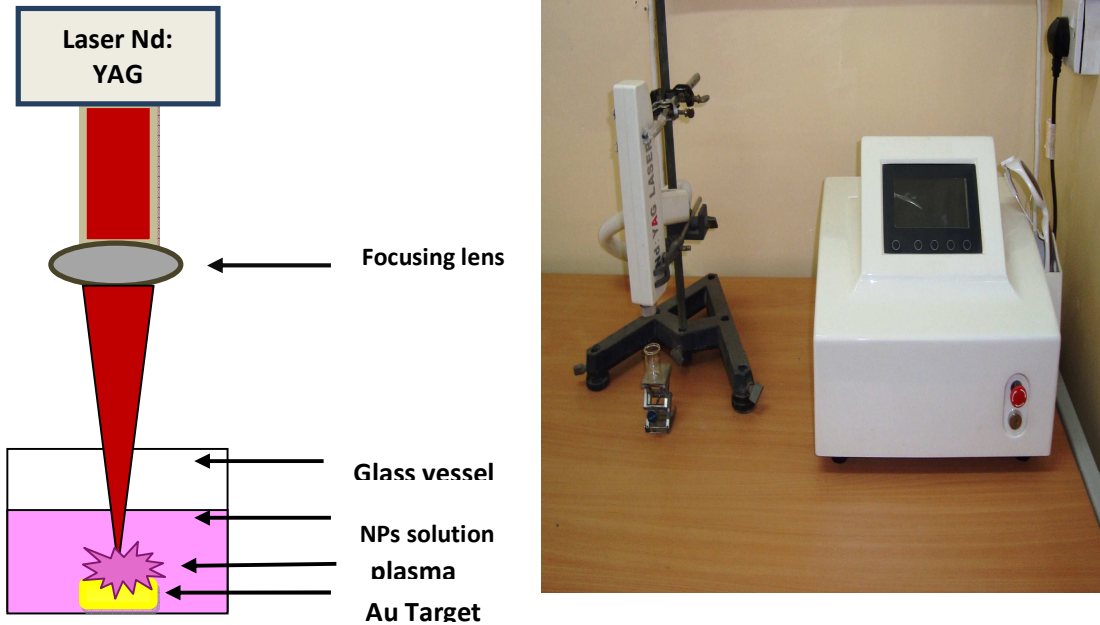


Fig.1: Experimental setup for nanoparticles synthesis by PLAL process.

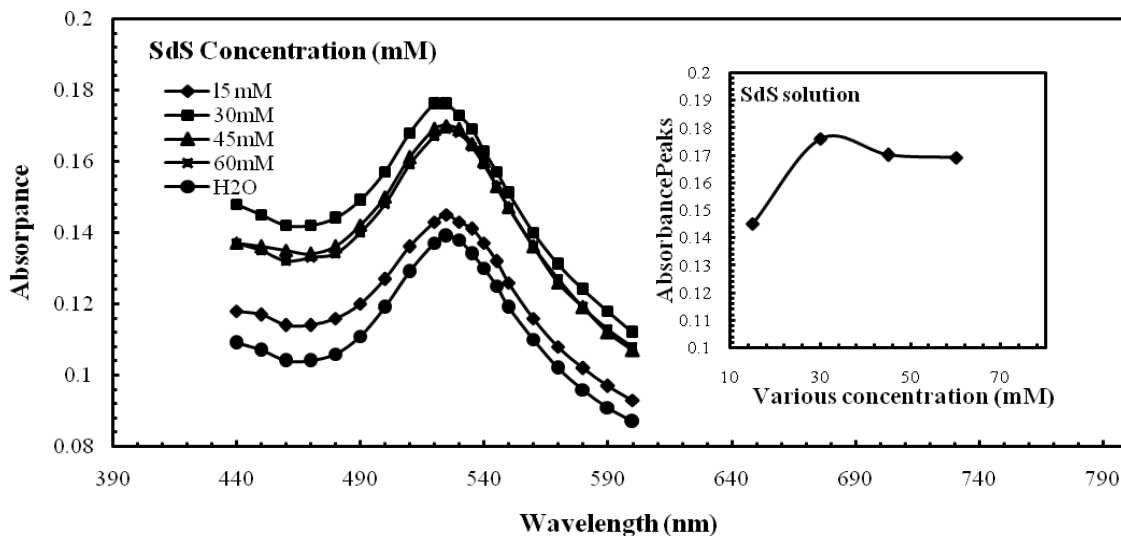


Fig.2: Absorbance spectra of gold colloids prepared by laser ablation of a gold plate immersed in DDDW and SDS solutions at various concentrations (15, 30, 45 and 60 mM). The pulsed laser parameters are ( $E=750$  mJ/pulse,  $\lambda=1064$  nm and 25 laser pulses). The inset shows intensity of the SPE peak as a function of SDS concentrations (15-60 mM).

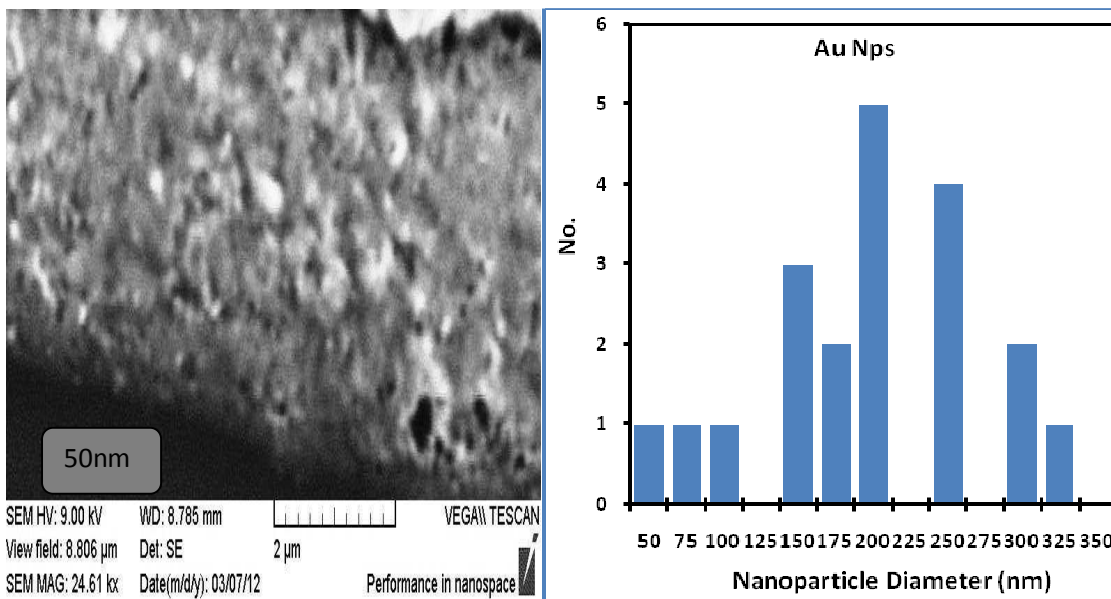


Fig.3: SEM images and size distributions of gold nanoparticles, produced by laser ablation of metal plates immersed in SDS solution, ( $\lambda=1064$  nm and laser shots of 25 pulses). The laser energies are 750mJ/pulse.

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