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SYNTHESIZE OF GOLD NANOPARTICLES WITH 532 NM AND 1064 NM PULSE LASER ABLATION

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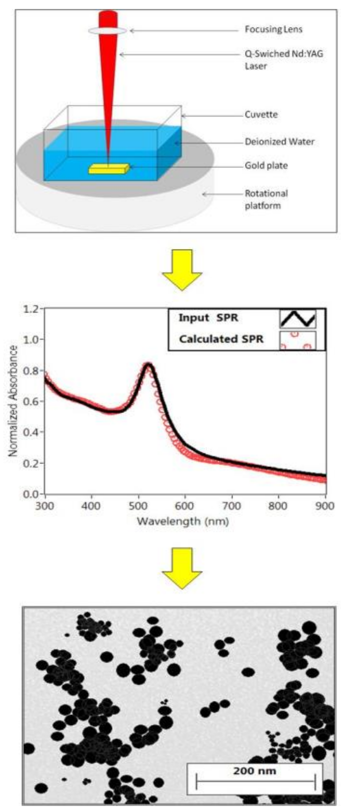
Graphical Abstract



Abstract

The effect of laser wavelength on gold nanoparticle fabrication is reported. Colloidal solutions of gold nanoparticles were prepared by pulsed laser ablation technique in deionized water. A Q-switched Nd:YAG laser with constant energy of 65mJ and operation at fundamental wavelength and second harmonic generation was utilized as a source of energy. Fabricated particles were characterized by using Smart Nanoparticles Measurements (SNM) system. The average diameters of gold nanoparticles achieved as19 nm and 12 nm corresponding to 1064 nm and 532 nm respectively. The fragmentation of colloidal particles by self-absorption of laser pulses is the responsible mechanism to cause for reduction.

Keywords: Laser ablation, gold, nanoparticles, metal colloids, deionized water, laser wavelength

Abstrak

Kesan panjang gelombang terhadap fabrikasi nanopartikel emas dilaporkan. Larutan koloid nanopartikel emas telah disediakan dengan menggunakan teknik ablasi laser berdenyut di dalam air ternyah ion. Satu laser Nd:YAG bersuis-Q dengan tenaga berterusan sebanyak 65 mJ dan beroperasi pada panjang gelombang asas dan penjanaan harmonic kedua telah digunakan sebagai sumber tenaga. Partikel yang difabrikasi telah dicirikan dengan menggunakan system pengukuran bijak nanopartikel (SNM). Purata diameter nanopartikel emas didapati pada 19 nm dan 12 nm sepadan masing-masing dengan 1064 nm dan 532 nm. Pemecahan zarah koloid oleh penyerapan denyutan laser itu sendiri adalah mekanisma yang bertanggungjawab menyebabkan pengurangan tersebut

Kata kunci: Ablasi Laser, Emas; Nanopartikel, Logam Koloid, Air Ternyah Ion, Panjang Gelombang Laser

1.0 INTRODUCTION

Today, a lot of effort in fabrication of nano-sized materials to discover their novelty functions. Synthesize of noble metal of gold nanoparticles has become an important research area recently. Gold is unreactive metal and not sensitive to air and light [1]. Therefore, gold is widely used in nanotechnology industry and medical field. The gold nanoparticles can be synthezised by chemical or physical method [2].

Laser ablation is generally performed in the vacuum phase or air but recently, it has been proved that laser ablation in solution is a promising technique to obtain nano-size metal colloids [3]. One advantage of laser ablation which applied physical method is contaminant-free compared to other chemical method. Therefore, laser ablation can synthesize nanoparticles with high purity [4, 5]. Another advantage of gold nanoparticles prepared by pulse laser ablation (PLAL) technique was stable for a period of month [6]. In this method, nanoparticles generation results from ablation of solid target placed in liquid medium is a simple procedure. Such simplicity also offers to fabricate for others material [7]. The pulse laser ablation has become popular top-down fabrication for producing metallic colloids. This method is starting where smaller fragments or nanomaterials are broken and remove from bulk materials [8]. In particular, the gold nanoparticles has size in range less than 30 nm and strongly absorb light around 520 nm because of the presence of surface plasmon resonance. Thus, the shape and size are very important for further applications [9]. The gold, nanoparticles fabrication can be enhanced by simply changing the wavelength, spot size, laser fluence, pulse duration, repetition rate and liquid medium [10-12].

In this work, gold colloids were prepared by pulsed laser ablation of high purity gold plate immersed in deionized water. Pulsed Q-switched Nd:YAG was employed to irradiate the gold surface during the ablation process. The absorption profile as well as the size and shape of gold nanoparticles produced were measured based on Smart Nanoparticles Measurement (SNM) system respectively [13]. Here, we demonstrated that the effect of the wavelength on absorption spectrum of gold nanoparticles was investigated.

2.0 EXPERIMENTAL

The whole experimental set up is shown in Figure 1. Q-switched Nd:YAG laser manufactured by FP Medical Technology Co., Ltd. model AL-114 (energy 65 mJ/pulse and repetition rate = 1 Hz) was used for ablation. It is operating at fundamental wavelength of 1064 nm and also second harmonic generation of 532 nm. Gold plate (99.99% purity) was immersed at the bottom of a cuvette with dimension – 3 x 3 x 3 cm^3) which filled with 12 ml deionized water. The laser light was focused to the surface target for duration of 50 minutes. The solution was rotated at 10 rpm to achieve homogenous mixture during ablation process. Prior for ablation, the gold plate was cleaned in a Branson ultrasonic bath and then washed with acetone in order to remove organic contamination. It follows by rinsing it with distilled water. The fabricated gold colloids were characterized by using Smart Nanoparticles Measurements (SNM) system [13].

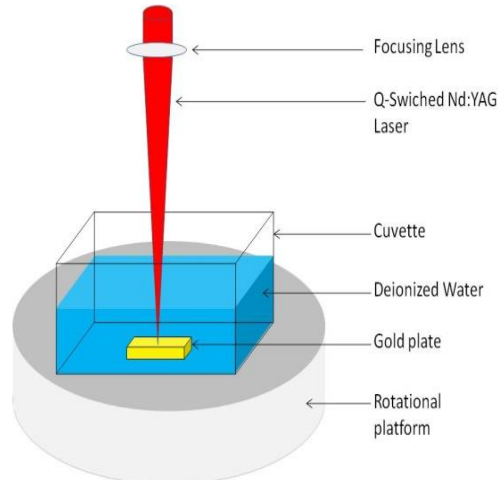


Figure 1 Experimental set up for gold colloid preparation by laser ablation in solution

3.0 RESULTS AND DISCUSSION

Figure 2 indicates the absorption spectra of gold colloidal solutions prepared by ablating gold target in deionized water with 1064 nm and 532 nm laser light. The laser energy was remained constant at 65 mJ. The ablation was performed for 50 minutes.

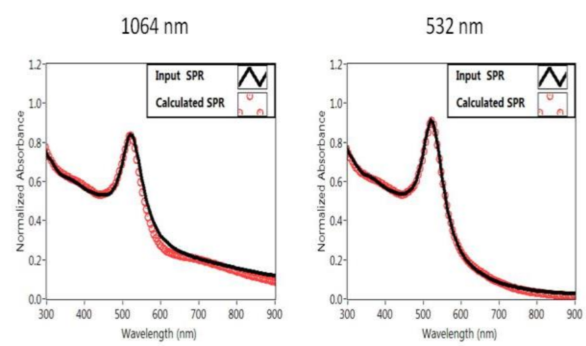


Figure 2 Absorption spectra of gold colloidal solutions prepared by laser ablation

Figure 2 shows that the surface plasmon resonance is centered at λ_{max} of 520 nm. The shape of the surface plasmon curve changed with wavelength of ablation light. The broadening of the surface plasmon bands is suggested that the morphology of colloids changes with respect to wavelength of ablation light. It is realized that the absorbance increases with wavelength of ablation light. The presence of single surface plasmon curve is also an indicator for the formed of nanoparticles in spherical shape [14].

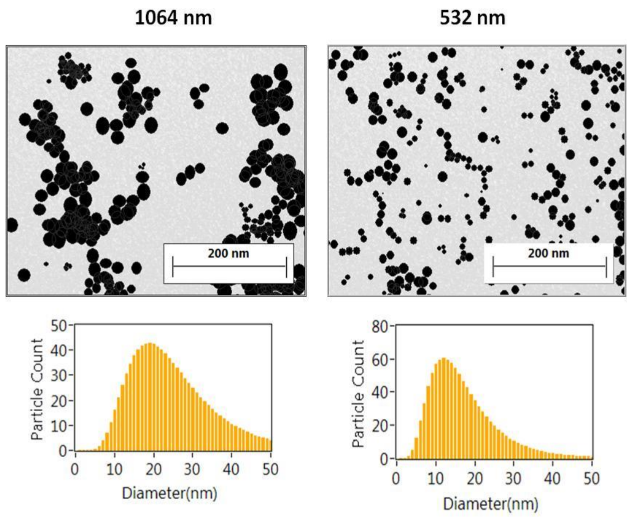


Figure 3 Image gold nanoparticles after exposure by laser at 1064 nm and 532 nm

Figure 3 shows images of gold nanoparticles in deionized water were characterized by using SNM system. The average diameters of particles based on both laser wavelengths are summarized in Table 1. The results of this study clearly showed that the size of particles is < less than 100 nm. It should be noted that the size distribution of the gold nanoparticles strongly dependent on laser wavelength. The average diameter and the size distribution decreases with wavelength. Shorter wavelength of Nd: YAG laser the smaller the size particle. In particular the colloids prepared by 1064 nm, have greater than > 20 nm in diameter, meanwhile most of the nanoparticles prepared by 532 nm laser are > in the average of 10 nm in diameter.

Table 1 Size distribution of gold particles prepared by laser ablation in deionized water

Laser wavelength, (nm)	Average diameter, (nm)
1064	19
532	12

Based on the experimental data shown in Figure 2, there is a strong correlation between the ablation efficiency and the particles size of gold colloids. The ablation efficiency of the smaller gold colloids which prepared by shorter wavelength lasers is lower than that of larger colloids which prepared by longer wavelength lasers. This suggests that nanoparticle size of colloids prepared by laser ablation in liquid medium is significantly affected by self-absorption. The effect of self-absorption can reduce the intensity of laser light which reaches to the surface of target. The absorbed energy of laser light can thermally excite the lattice of metal particles, leading the fragmentation of particles. Hence, irradiation of laser light onto the colloidal solution can reduce the nanoparticle size due to the particle fragmentation [15].

4.0 CONCLUSION

Gold nanoparticles in deionized water were fabricated by using 1064 nm and 532 nm laser. Based on Smart Nanoparticle Measurement (SNM) system indicated the mean gold nanoparticles size decreases from 19 nm to 12 nm corresponding to the decreasing the laser wavelength. The fragmentations of nanoparticles by self-absorption are the reason for such reduction. The finding stated that the gold nanoparticles size can be controlled by using laser wavelength at 1064 nm and 532 nm. This technique will be useful to prepared desired size colloids in solutions for any noble metal to further applications.

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