A Study to Compare the Properties of Nano-Gold Suspension Fabricated by Spark Discharge System in Different Dielectric Media

Der Chi Tien, Kuo Hsiung Tseng, Chih Yu Liao, Jen-Chuen Huang and Tsing Tshih Tsung

Abstract—**In this paper a process of spark discharge system (SDS) for creating gold nanoparticles in two different dielectric medium (pure ethanol / deionized water) is proposed. Unlike conventional methods of nanoparticle synthesis, SDS does not require traditional chemical surfactants. The crystallography of SDS-produced gold nanoparticles was observed by Transmission Electron Microscopy (TEM). The microstructure of the nanoscale gold particles was investigated by using X-ray diffraction (XRD). Furthermore Zeta potential measurements depicted that negative charges on the particle surface may be contributing to the stability of the colloidal suspension. The experiment's results demonstrate that using SDS to fabricate gold nanoparticles suspension with different particle sizes and shapes in different media without any added surfactant has been successfully accomplished.**

Index Terms—**Gold, nanoparticle, nanomaterials, spark discharge system, electron microscopy, crystal structure.**

I. Introduction

Gold colloids have novel physical and chemical properties because of their distinctive size and shape. They are extensively used for many chemical reactions because of their exceptional catalytic properties [1]-[3]. The electrochemical properties of gold colloids have led their widespread use in a chemical science and technologies in the past decade [4]-[6]. Several techniques are available for the preparing gold nanoparticles, with different size, shape, and UV-Vis absorption spectra. Current techniques used to create gold nanoparticles are categorized into chemical and physical methods. Chemical methods regularly involve toxic materials [7]. Physical methods include UV [8], [9] and gamma radiation [10] and aerosol technology [11]. Unfortunately, although these methods can be used to successfully produce pure gold nanoparticles, they are relatively expensive to implement and are also create great risks to the environment concern. There is no scientific literature describing the production of gold nanoparticles in ethanol / water using the spark discharge system (SDS). After tedious experiments with different liquid, ethanol and water were chosen as the most typical organic and inorganic dielectric media, due to its chemical and physical variety for different purpose of applications. Research has shown that colloidal gold preparation using SDS in ethanol / water is a rather inexpensive and most likely environmental friendly process.

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II. Experimental Setup

A. Materials preparation

Gold wires (Gredmann, 99.99%, 1 mm in diameter) were used as electrodes sunken in ethanol (J.T. Baker, ethanol absolute anhydrous, 9000-03) or deionized water (pH = 6.5, conductivity = 0.8-0.9 μS/cm) for colloidal gold production.

B. Spark discharge system setup

The spark discharge system (SDS) apparatus includes four main parts: (i) the servo control system, which controls the gap distance between electrodes; (ii) the power supply system, which regulates a stable pulse voltage through the electrodes in order to ionize the medium between them; (iii) a dielectric medium (ethanol / water), which is used to create the gold nanoparticles suspension and to facilitate gold nanoparticles dispersion; (iv) a magnetic stirrer and stirring bar. These are demonstrated in Fig. 1a. The gold electrodes were placed at the center of the container and sunken in ethanol / water at room temperature. The gap distance between the electrodes was controlled by setting up constant current using an electro-mechanical servo feedback system according to the applied voltage and properties of dielectric constant of the medium.

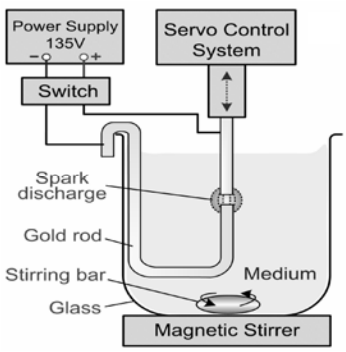
C. Key parameters for spark discharge system

The gold nanoparticles suspension fabricated by SDS is based on basic parameters including initial voltage, peak current, on-off pulse duration, atmospheric pressure during work, volume of medium, dielectric constant, and processing time, as shown in Table 1.

Table 1. Key parameters for colloidal gold production

	Dielectric medium	
Key parameters	**Ethanol**	**Water**
Initial voltage	135 V	135 V
Peak current	6.4 A	4 A
On-pulse duration	50 µs	10 µs
Off-pulse duration	50 µs	50 µs
Temperature of medium	25 ℃	25 ℃
Dielectric constant	24.3	80
Volume of medium	100 ml	100 ml
Fabrication pressure	1 atm	1 atm
Fabrication time	1 min	1 min

With these parameters, the dielectric breakdown in medium (ethanol / water) will occur at a voltage of around 135 V. After the dielectric breakdown, the applied voltage drops down to 18 V. The peak current may reach roughly 6.4 A in ethanol (Fig. 1b) and 4 A in water (Fig. 1c), with on duration time of 20-40 µs and 6-8 µs, respectively. During discharge, the gap between the electrodes is maintained at about 20-40 µm by the servo feedback control system base on alteration to the parameters above. These parameters were determined to be optimal, and as a result the gold nanoparticles suspension was successfully produced.



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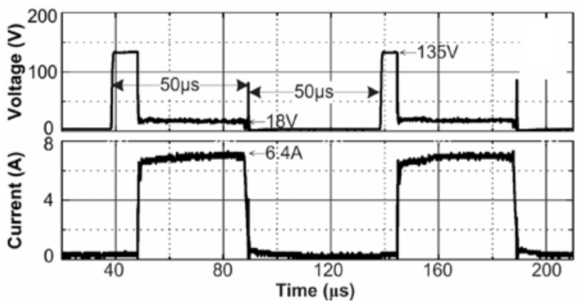

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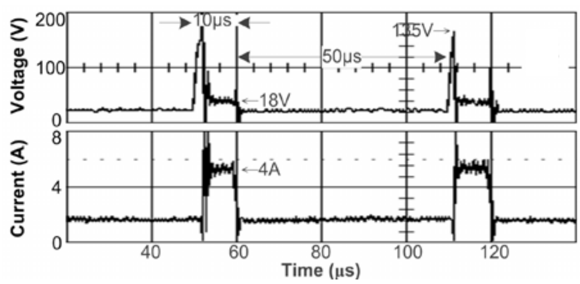

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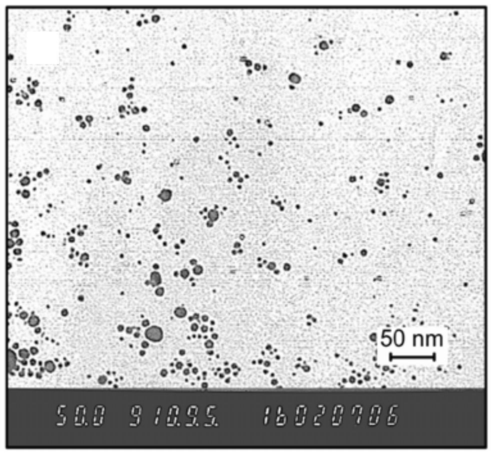
Fig. 1. (a) Schematic of the spark discharge system (SDS), voltage and current created during etching of the gold electrodes (b) in ethanol and (c) in water.

D. Instrument for gold nanoparticles characterization

The microstructures of gold nanoparticles were investigated using Transmission Electron Microscopy (TEM, HITACHI H-800). The crystal structure of gold nanoparticles was determined by means of X-ray Diffraction (XRD, RINT2000). The Zeta potential measurement (Malvern NanoZS90) of charged gold nanoparticles in ethanol / water was calculated by measuring the velocity of a particle in a unit electric force field.

III. RESULTS

A TEM image clearly shows that gold nanoparticle dispersions have a mean particle size of 5 nm in ethanol (Fig. 2a) and 31 nm in water (Fig. 2b). These are well dispersed on the copper grid support without any signs of aggregation. The particle size distribution summarized from TEM image is shown in Fig. 2c. The formation of gold particles was also verified by the XRD pattern, as shown in Fig. 2d. The colloidal gold sediments deposited on the quartz were prepared for XRD characterization. They showed narrow peaks assigned to the (111), (200), (220), (311), and (222) planes of a face-centered cubic (FCC) lattice of gold.



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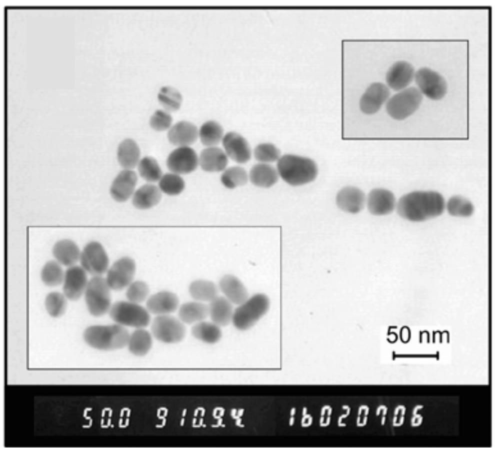

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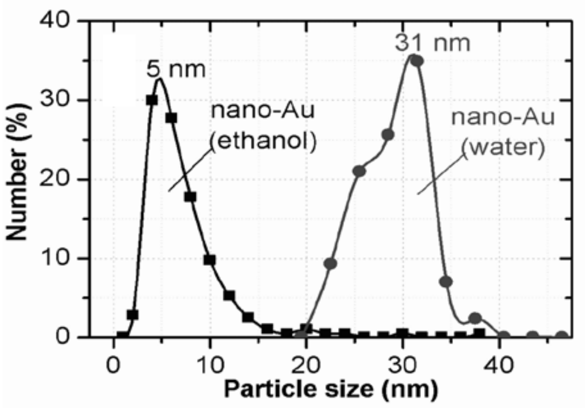

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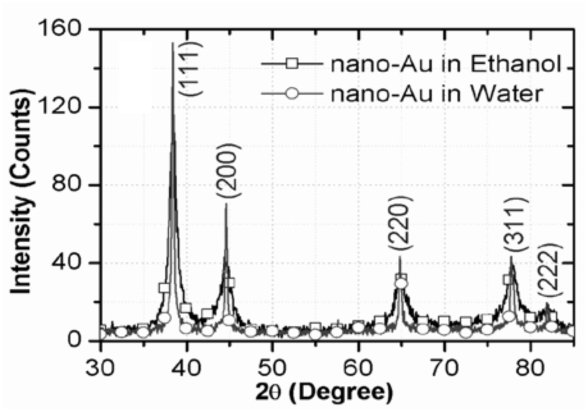

(d)

Fig. 2. TEM image of gold nanoparticles (a) in ethanol (b) in water, (c) particle size distribution calculated based on TEM image, (d) XRD pattern of gold nanoparticles deposited on a quartz surface.

Fig. 3a presents Zeta potential distributions of gold colloid with a negative charge greater than -50 mV in ethanol and -30 mV in water, which is sufficient to keep the particles from interacting with each other and therefore maintain a stable particle size of the sample.

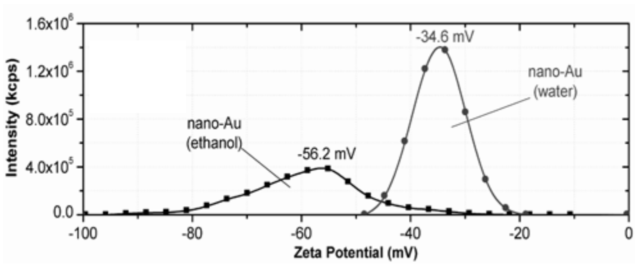

Fig. 3. Distribution of Zeta potential of gold nanoparticles

The experimental result showed that the mean particle size of gold colloid is 5 nm in ethanol and 31 nm in water. Furthermore, the Zeta potential is -56.2 mV and -34.6 mV respectively. It is found that colloidal gold fabricated in ethanol has smaller particle sizes and higher stability of suspension than that in water. It is further observed that the gold nanoparticles in water tend to form oval shape, while those in ethanol are closer to sphere. At this moment the fundamental reason for these differences are not known and merits further investigation.

IV. Conclusion

In this paper a novel method of spark discharge system (SDS) for producing gold nanoparticles in different medium (ethanol / water) without additives is proposed. The most significant contribution of this SDS research is the capability to directly fabricate gold nanoparticles with different particle sizes and shapes in different media. Moreover, the gold nanoparticles produced through SDS are well-dispersed and form a stable suspension for an extended period of time.

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