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SIZE, OPTICAL AND STABILITY PROPERTIES OF GOLD NANOPARTICLES SYNTHESIZED BY ELECTRICAL EXPLOSION OF WIRE IN DIFFERENT AQUEOUS MEDIA

L.H. Bac[1,2], J.S. Kim[1] and J.C. Kim[1]

[1]School of Materials Science and Engineering, University of Ulsan, Daehak-ro 102, Nam-gu, Ulsan, 680-749, South Korea
[2]Institute of Engineering Physics, Hanoi University of Science and Technology, Dai Co Viet Road, Hanoi, Vietnam

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Abstract. In this work, we investigated the effects of the ambient liquid medium on the size, optical and stability properties of gold nanoparticles synthesized by electrical explosion of wire. The explosion process was carried out in deionized water, cetyl trimethyl ammonium bromide (CTAB), sodium dodecylbenzenesulfonate (SDBS) and tween 20 (TW20) solutions. Particle size and shape of nanoparticles were observed by transmission electron microscope. Optical absorption spectrum was employed for characterization of optical properties. In TW20 and CTAB solution, particles were in nearly spherical shape. In water and SDBS solution, the particles formed to a chain across particles. The wavelengths of optical absorption peak were 525, 526, 530, 532 nm in SDBS, TW20, CTAB, and water respectively. Stability of gold suspension was estimated by multiple light scattering using Turbiscan lab machine. Gold suspension in TW20 showed the best stability in four samples.

1. INTRODUCTION

Gold nanoparticles suspended in a solution have attracted much attention because they have many applications due to their unique physical and chemical behaviour, which are different from those of bulk materials [1-3]. These properties are much dependent on the particle size, shape and liquid medium. It is known that optical properties of gold nanoparticles strongly depend on the size and shape [4]. The stability of suspension depends not only on size, shape but also on liquid medium. The liquid in which nanoparticles suspend can affect on the surface charge of nanoparticles. Surface charge leads to repulsive forces between nanoparticles and keeps them far from each other, which results in a high stability of suspension [5].

Electrical explosion of wire (EEW) in gas have been applied to synthesize many kinds of nanomaterials including metal and compounds [6-8]. More recently, this method has been developed to synthesize metal nanoparticles in a solution [9-11]. Compared with the EEW in gas, EEW in liquid has been less investigated. It has become one of promising method for synthesis metal nanoparticles because of its simplicity, effectiveness and low cost. Synthesis of nanoparticles in liquid needs no vacuum system. In addition, nanoparticles can synthesize in water without impurities or in any arbitrary solution.

Properties of nanoparticles synthesized by EEW depend on many conditions of electrical explosion process, which include wire properties such as wire dimension (diameter and length) and wire material,

Corresponding author: J.C. Kim, e-mail: jckimpml@ulsan.ac.kr

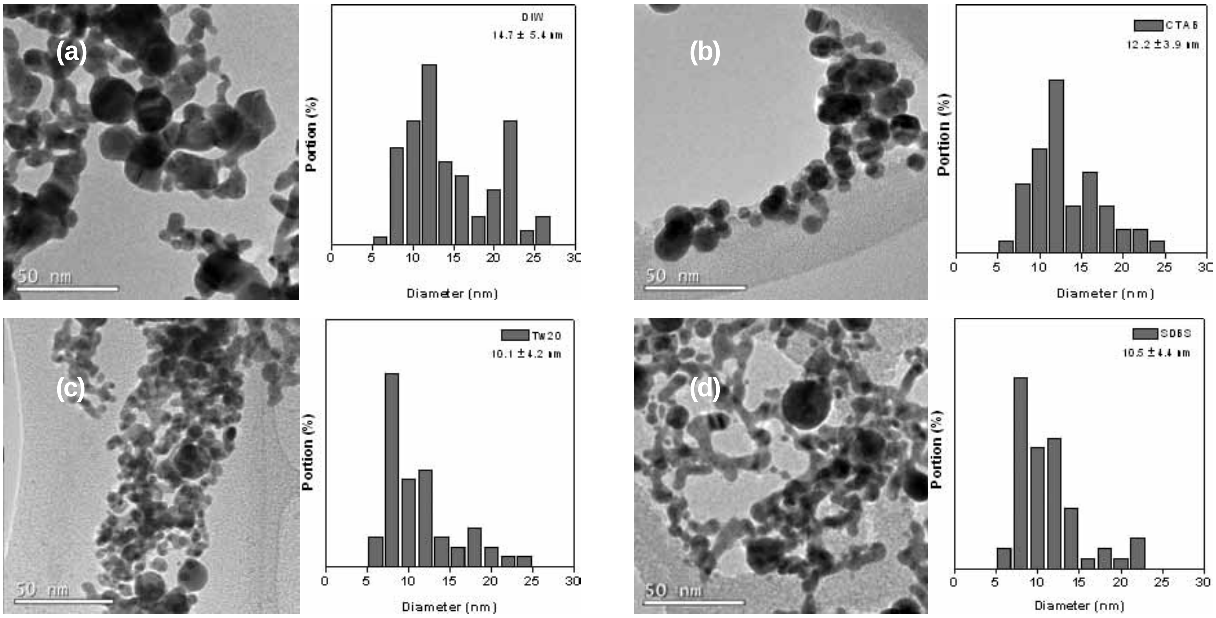

Fig. 1. TEM micrographs and size distributions of the gold nanoparticles synthesized by EEW in different media: (a) DIW, (b) CTAB, (c) TW20, and (d) SDBS.

capacitor-charged voltage, characteristics of the electrical circuit, and ambient medium. Among these, ambient liquid medium is an important parameter, which much affects on the properties of nanoparticles. In the present study, we report the effects of explosion medium on the size, optical and stability properties of gold nanoparticles synthesized by electrical explosion of wire. A change of the ambient medium in explosion process presents a simple and flexible technique to modify the properties of nanoparticles.

2. EXPERTIMENTAL

Gold wire with a diameter of 0.2 mm was exploded in liquid to produce gold nanoparticles. CTAB, SDBS, and TW20 surfactants were dissolved in deionized water with concentration of 0.01 M and they were used as the explosion medium for preparation of gold nanopowder. The detail of explosion process was reported elsewhere [12]. Typical experimental conditions are summarized in Table 1.

After explosion, the suspension was collected for analysis. The morphology and the size of the prepared gold nanoparticles were observed by transmission electron microscopy (TEM). A drop of gold suspension was dropped on a carbon coated copper grid, dried at room temperature and then subjected to electron-microscopic chamber for observation. The absorption spectrum gold colloid was investigated by UV-vis method in the wavelength range of 300-800 nm. The dispersion stability was estimated using a Turbiscan Lab (Formulaction Co., France) based on multiple light scattering method; it detects concentration variation in the colloid by scanning the whole height of the sample in transmission and backscattering.

3. RESULTS AND DISCUSSION

Fig. 1 shows the TEM images of gold nanoparticles obtained in different ambient environments. The micrograph demonstrates that the gold nanoparticles depended on the ambient environment. The particles changed both particle size and size distribution.

Fig. 1a shows a TEM image and particle size distribution of gold synthesized in deionized water. As shown in the image, the nanoparticles were nearly spherical in shape but the nanoparticles seemed to connect and form a network. The mean

Table 1. Experimental conditions to prepared gold nanoparticles.

Capacitance	30 μF
Charging voltage	3.0 kV
Material wire	Au (Φ 0.2 mm × 27 mm)
Ambient liquid	DIW, CTAB, SDBS, TW20
Liquid content	500 mL
Number of explosion	25 times

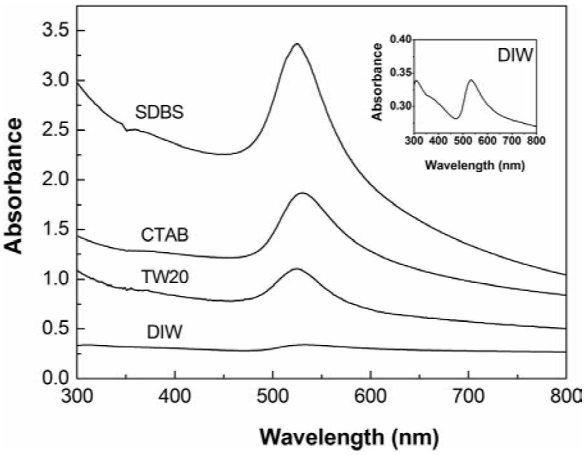

Fig. 2. Optical absorption spectra of the gold nanoparticles synthesized by EEW in different media.

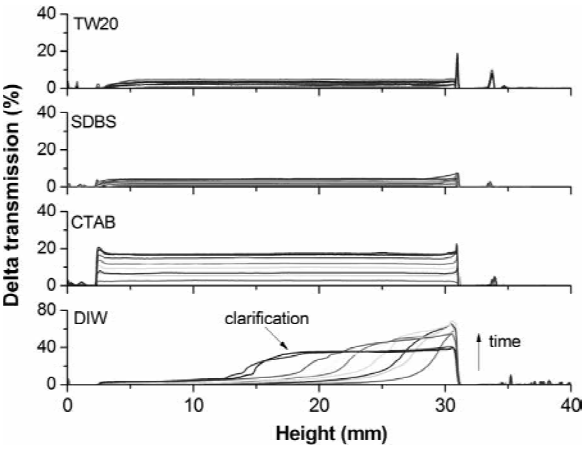

Fig. 3. Transmission profile of gold nanoparticles suspended in different aqueous media.

diameter was about 15 nm and the standard deviation was 5 nm. Fig. 1b demonstrates the gold nanoparticles obtained in cationic surfactant (CTAB). The particles in this surfactant had higher sphericity than in DIW. Not like in DIW, the nanoparticles prepared in CTAB separated without connection. The size distribution in Fig. 1b indicates that gold nanoparticles in CTAB had a narrower distribution and smaller size. The mean diameter size decreased to ~12 nm with standard deviation of 4 nm. Fig. 1c shows the electron micrograph of gold nanoparticles prepared in TW20. Similar to the case of CTAB surfactant, the nanoparticle size decreased and shape was nearly spherical. Compared with CTAB solution, the nanoparticles were smaller with a mean size of 10 nm and standard deviation of 4 nm. Fig. 1d shows TEM image and size distribution of gold nanoparticles in SDBS surfactant. The nanoparticles in SDBS were in cross-linking and formed the chain-like structures. The mean particle size was 10 nm and standard deviation was 4 nm.

Optical properties of gold nanoparticles were studied by UV-vis measurements of gold colloids. According to the Mie theory, metal nanoparticles with spherical shape had a light absorption due to scattering of light by small particles. The optical absorption spectra of gold nanoparticles in the range of 300 - 800 nm were shown in Fig. 2. It is clearly seen that the optical properties depend much on the synthesized liquid. All the gold nanoparticles in different liquid exhibited one intense peak at about 530 nm, which assigned to the surface plasmon resonance of gold nanoparticles [13]. The maximum of optical absorption showed a red shift in the gold nanoparticles in water. The smallest wavelength of band in case of TW20 was 525 nm corresponding to the smallest diameter size. Bandwidth of optical extinction is related to the size distribution and the agglomeration of nanoparticles [14]. In the case of gold nanoparticles in water, the bandwidth of optical extinction was broadest (Table 2). As seen in TEM, its size distribution was the widest in 4 samples, therefore it caused the optical extinction widen. The maximum of extinction and bandwidth of gold nanoparticles in CTAB were smaller than those in water. The particle size of gold in CTAB was 12 nm, it was smaller than size in water and the size distribution was narrower. The smaller size and narrower distribution of nanoparticles in CTAB determined the blue shift and narrower bandwidth. The similar behavior can be seen in the absorption

Table 2. Optical properties, size and zeta-potential of gold nanoparticles in different media.

Sample	Plasmon absorption wavelength (nm)	FWHM	Mean particle size (nm)	Zeta-potential (mV) As-synthesis	Zeta-potential (mV) 5 months
SDBS	526	58.83	10.5 ± 4.4	-39.23	-36.24
TW20	525	54.19	10.1 ± 4.2	-29.16	-29.03
CTAB	530	65.17	12.2 ± 3.9	49.48	45.07
DIW	532	79.48	14.7 ± 5.4	-9.21	-

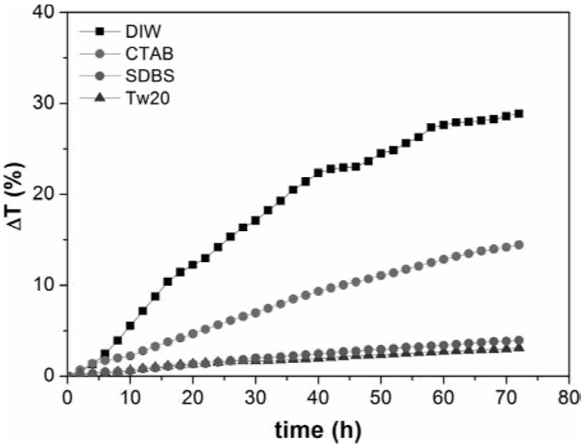

Fig. 4. Variation of the transmission signal of the gold nanoparticles suspended in different aqueous media.

spectra of gold nanoparticles prepared in TW20 and SDBS.

Fig. 3 shows transmission profiles of gold nanoparticles suspended in water, CTAB, SDBS, and TW20 in 3 days. The transmitted light flux in % related to the density of suspension in the liquid. The initial transmission scan showed 0% as a baseline. The variation of the dispersed nanoparticles between the top and the bottom of the sample bottle varies the transmission signal. Fig. 3a shows the transmission scan of the gold nanoparticles in water. It can be seen clearly that the transmission signal decreased at the top of the sample due to a decrease of suspension concentration. The phase thickness of the right peak gradually increased following the time. In 3 days, the phase thickness was about 50% height of the sample. The appearance of the transmission curves in CTAB, SDBS and TW20 was similar. Each curve was flat on the main part of sample without clarification. However, the transmission decreasing with time was different due to the settling rate. The evolution of the transmission light versus time was shown in Fig. 4. The transmission variation in CTAB, SDBS, and TW20 had the same behavior but the rate of the transmission variation was different. The slope of gold nanoparticles in TW20 was smallest in all samples, this means that the sedimentation rate of this sample was lowest. In other words, this sample is most stable in four samples. The slope of transmission variation of gold nanoparticles in TW20 was little higher than that in SDBS but much smaller than that in CTAB. The transmission variation of gold nanoparticles in water had different behavior; it increased significantly in first 40 hrs and afterward went up more slightly. These experimental data are in good agreement with the data of TEM and zeta-potential (Table 2). The big particle size, low zeta-potential of gold nanoparticles in water caused this sample unstable. The higher zeta-potential value is a key parameter to maintain the stability of suspension because it will make a repulsive force and keep the gold nanoparticles away from each other, which results in a high stability of suspension. In this research, the surfactants exhibited to enhance the zeta-potential in comparison with pure water; therefore, the gold nanoparticles in surfactant solution have much better stability. Zeta-potential values of Au suspension in surfactant media remained high value even after 5 months (Table 2). Compared to the zeta-potential values of as-synthesis samples, the zeta potential of the 5-month samples reduced slightly. Zeta-potential of suspension in DIW after 5 months was unable to measure because all gold nanoparticles settled. Fig. 5 shows the sedimentation behaviors of the gold suspension with times. The color of the Au suspensions in the TW20, SDBS and CTAB was not changed after 5 months, but it was changed immediately in the DIW. These results were well matched with Zeta-potential values as shown in Table 2. Combination of sedimentation pictures and zeta-potential of Au suspensions indicates that the gold suspension is instable in DIW and can be stable for more than 5 months in surfactant solutions.

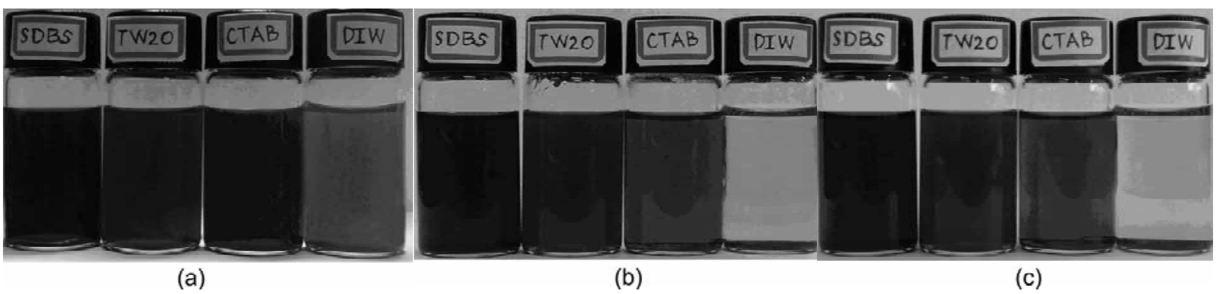

Fig. 5. Sediment pictures of gold suspension: (a) as-synthesis, after (b) 10 days and (c) 5 months.

4. CONCLUSIONS

In this work, effects of the liquid media in the EEW method on the size, optical and stability properties were investigated. DIW, CTAB, TW20, and SDBS media were used for synthesis of gold nanoparticles. Optical absorption spectroscopy, TEM and multiple light scattering were used to characterize the synthesized nanoparticles. In DIW, gold nanoparticles had largest size distribution and biggest size. In surfactant solutions, the gold nanoparticles were smaller and had the smallest size in TW20. Stability of suspension significantly depended on the liquid media. In DIW, suspension was unstable and precipitated completely after 10 days. In surfactant solutions, suspension had a good stability with small sediment and maintained stable for more than 5 months. The suspension obtained in TW20 shown the best stability.

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