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Generation of Gold Nanoparticles by RF Plasmas in Aqueous Solution
液中高周波プラズマを用いた金ナノ粒子の生成

Shoma Mizukuni[1], Sinobu Mukasa[1], Hiromichi Toyota[1], Shinfuku Nomura[1], Ayato Kawasima[2], Tsunehiro Maehara[1]

水國将馬 [1]，向笠忍 [1]，豊田洋通 [1]，野村信福 [1]，川嶋文人 [2]，前原常弘 [1]

[1] *Graduate School of Science and Engineering, Ehime University, Bunkyo 3, Matsuyama, 790-8577, Japan.*

[2] *Faculty of Agriculture, Ehime University, 3-5-7 Tarumi, Matsuyama 790-8566, Japan.*

[1] 愛媛大学理工学研究科　〒790-8577　松山市文京町 3

[2] 愛媛大学農学部　〒790-8566　松山市樽味 3-5-7

E-mail: maehara@phys.sci.ehime-u.ac.jp

A process for generation of nanoparticles by RF of 13.56 MHz plasma in aqueous solution is proposed. Gold nanoparticles were produced at atmospheric pressure through erosion of a gold electrode exposed to plasma. Characterization of the produced nanoparticles was carried out by Transmission Electron Microscope (TEM).

1. Introduction

Recently the generation of functional nanostructures has attracted much attention. In many cases, plasmas in liquid were employed for the genelation of nanoparticles. For examples, gold nanoparticles were generated in solution plasma process (SPP) [1]. In SPP, erosion of electrodes was also reported [2], and Au/Pt nanocomposites were formed [3]. In our research group, synthesis of tungsten oxide, silver, and gold nanoparticles by RF plasma in water was reported [4].

On the other hand, RF power was applied to water using an electrode and RF plasma was generated and maintained in water over a wide range of water conductivities (0.2–7000 mSm^{-1}) [5]. Ions in water are expected to affect the generation of functional nanostructures. Here, we study gold nanoparticles produced at atmospheric pressure through erosion of a gold electrode exposed to plasma in aqueous solution.

2. Experimental apparatus

RF plasma in water was generated between two electrodes in a vessel (Fig. 1). A Pyrex glass container (80 mm ID, 90 mm height) was used for the vessel. 300 mL solution was stored in the container. Water flowing in a plastic tube was used to prevent the increase in temperature caused by the supply of RF power. Water temperature was maintained in the range of 25–40 ºC. The upper electrode was at the ground potential and did not come in contact with the plasma. The lower electrode was made of gold; its diameter was 1.0 mm. It was covered with a ceramic pipe (2 mm OD, 1 mm ID). The electrodes were connected to a resonator by copper leads, and RF power was supplied to the resonator through a tuner from a power supply (Thamway, T161-6013H). For absorbance spectra measurements, USB 2000 spectrometer (Ocean Optics) was used.

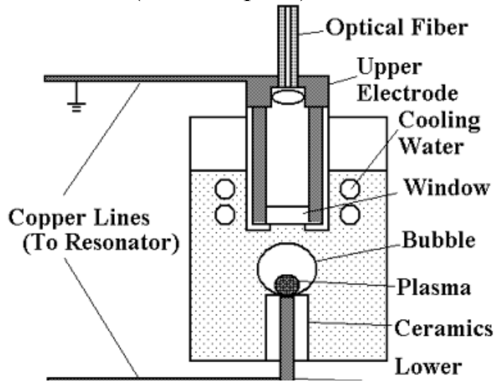

Fig. 1 Schematic view of experimental apparatus.

3. Experimental Results

Plasma was generated as follows: After the tuner was adjusted to reduce the reflected power at a low power (30 W), RF power was increased until breakdown. Input power for breakdown was 100–300 W. Before breakdown, RF power was absorbed by water in the ceramic tube so that some bubbles appeared. After breakdown, we maintained the successive RF plasma by applying a low RF power (140 W). Although the bubbles were initially generated due to Joule heating, they were generated by the plasmas after breakdown.

Figure 2 shows TEM images of gold particles. RF plasma in pure water with polyvinylpyrrolidone (PVP) as a dispersing agent generated a few nanometer particles like Fig. 2 (a). No spherical and polygonal shapes are observed. In NaCl solution (≈0.1 wt %; 194 mSm^{-1}), many types of polygonal particles are observed (Fig. 2 (b)). These facts suggest that dissolved NaCl can affect the generation of gold nanoparticles.

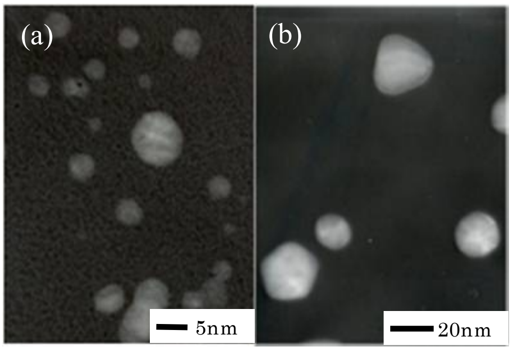

Fig. 2 TEM images of particles generated by RF plasma in (a) pure water with PVP, and (b) NaCl solution.

Absorbance spectra of gold nanoparticles in aqueous solutions have a single peak. Figure 3 shows relationship of electrical conductivity and peak of absorbance spectra. While wavelength at the peak increases with increase in water conductivity, it gradually decreases 20 mSm^{-1} over (Fig. 3 (a)). In Fig. 3 (b), absorbance at the peak increases a little by dissolved a smidgen of NaCl. It decreases with increase in water conductivity over 1 mSm^{-1}.

4. Summary

A process for generation of nanoparticles using RF plasma in aqueous solution is proposed. Gold nanoparticles were produced at atmospheric pressure through erosion of a gold electrode exposed to plasma. Characterization of the produced nanoparticles was carried out by TEM. TEM images and absorbance spectra show that dissolved NaCl can affect the generation of gold nanoparticles.

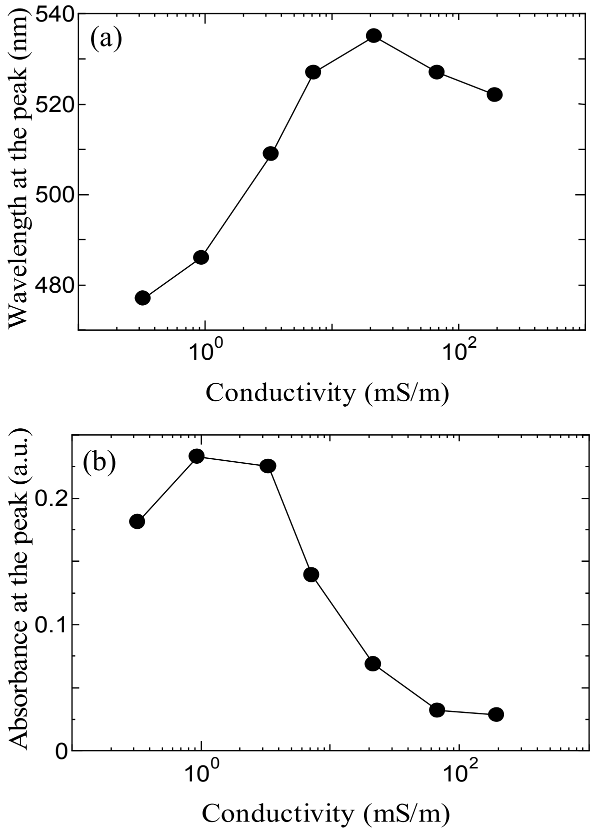

Fig. 3 Relationship of electrical conductivity and peak of absorbance spectra. (a) wavelength (b) absorbance

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