High Speed Synthesis of Nanoparticles by Liquid Flow-type Microwave Plasma

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Introduction: Recently, liquid-plasma interaction has been given much attentions and its applications to various materials processing have been reported. In parallel with the application study of plasma-processed liquid, study of the plasma processing equipment of the liquid is also important from the viewpoint of their industrial applications. So far, we have developed an in-line microwave plasma system which realizes reduced pressure environment and easier plasma production by utilizing Venturi effect by water flow in a narrow liquid path. As one of applications, the in-line microwave plasma source is applied to the nanoparticle production and basic properties of nanoparticles are investigated.

Equipment Setup: Figure 1 shows schematic of the experimental device. $AgNO_3$ dissolved in distilled water (10~100 mMol/L) is introduced to the plasma processing device through a water pump. Plasma processing device has a coaxial waveguide, where outer conductor (diameter: 38.8 mm) is separated into upper and lower parts by a narrow discharge gap. The waveguide is surrounded by a quartz tube and liquid flows through a pathway between the quartz tube and the coaxial waveguide. Plasma is produced in the discharge gap by pulsed 2.45 GHz microwave power (pulse frequency: 10 kHz, duty ratio: 50%, average power: 1.5 kW) and $AgNO_3$ solution is processed. The processed solution is returned to the water reservoir again. Nanoparticles are investigated by scanning electron microscope (SEM).

Nanoparticles Synthesis: The color change of plasma treated $AgNO_3$ solution in water reservoir is shown in Figure 2. Before the treatment, the solution is transparent (fig. 2(a)) but after the treatment of only 25 s, the solution color completely changes into dark one (fig. 2(b)), showing very rapid liquid treatment. Figure 3 shows SEM image of nanoparticles collected from solution treated by the plasma for 22 s. Nanoparticles is of 100~650 nm in diameters are observed with an average size of 250 nm.

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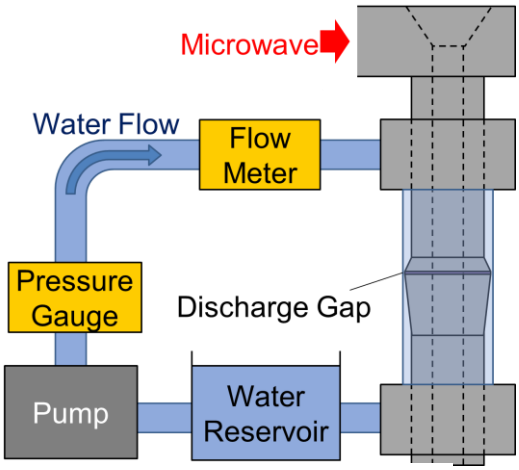

Fig.1 Experimental device

Fig. 2 Color of solution (a) before and (b) after treatment of 25 s.

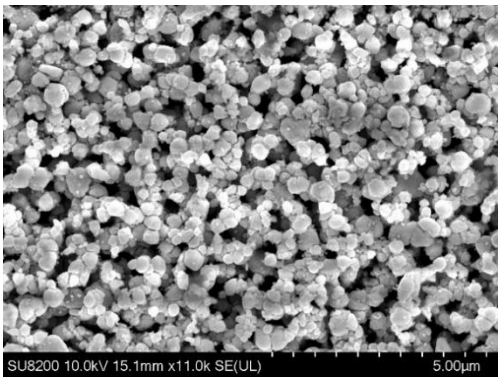

Fig. 3 SEM image of Ag nanoparticles after plasma treatment for 22 s.