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Focused ultrasonic effect on nano particle size distribution in water

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1. Introduction

The residual particles with nano size have been reported even in the pure water such as distilled water. Even though many researches about the particles are being studied, the reasons and treatments for them have not been clarified yet[1,2)]. In the application fields of the synthesized nano particles, the residual particle distribution of water contributes to problems in evaluating the dispersion state of the nano particles. There is a hypothesis that the water pH and the storage container of water affect the residual particle distribution in the literature (W. Brain et. al.)[3]. However the basis of the hypothesis has been undefined.

Meanwhile, the change of water pH associated with the collapse of ultrasonic cavitation has been noted in many literatures[4,5)]. In the literature, the water pH can be reduced to 4.0 by the ultrasonic cavitation. Therefore, in this study, to change the water pH without adding acid for the purity of the water, a focused ultrasound was radiated into the pure water, and the effect of water pH on the residual particle distribution in the water was investigated.

2. Experimental setup

To produce a focused ultrasound field, an experimental system was fabricated using a cylindrical piezoelectric transducer as shown in Fig. 1. A glass tube at center of the cylindrical transducer was used because the ultrasonic field can be focused at non-contact way. The cylindrical vibrator has an inner radius of 38.5 mm, an outer radius of 46.5 mm, and height of 19.2 mm. The vibration mode of the vibrator is approximately the mode of thickness between the inner surface and the outer surface because the polarization direction is the radial direction. A tungsten tube filled with cooling water was inserted between the transducer and the glass tube because the ultrasonic field from the transducer can be transferred to the glass tube by the cooling water. To prevent heating the piezo-electric transducer, the cooling water was circulated by a water pump. The thicknesses of the glass tube and tungsten tube are 0.3, and 0.5 mm, respectively. They are chosen thin enough not to be effective for the ultrasound. Deionized water (DI water) and distilled water were circulated through a plastic tube connecting the glass tube to a water pump. The piezoelectric transducer has a resonant frequency of 480 kHz, and it was driven by the frequency. The DI water was generated with a Barnstead Nanopure system (Model D1794).

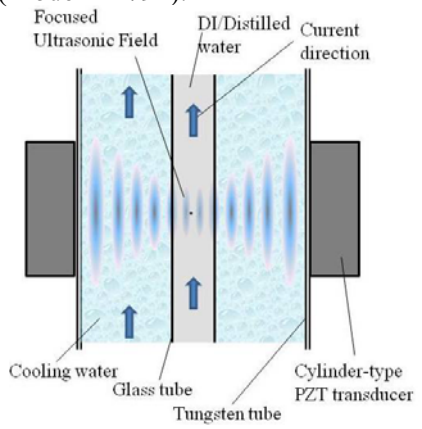

Fig. 1 Schematic of ultrasonic cavitation generating system.

The purified water and cooling water were circulated at flow rates of 3.0 and 1.5 mL/s, respectively. The piezoelectric transducer was driven by power amplifier with 120 W. The ultrasound wave from the transducer was focused on the center of the glass tube filled with the purified water. The particle size distributions of the residual particles in the water were measured with the particle counters CPC 5.403 (GRIMM Aerosol Technik) and the aerosol generator and disperser (TSI, Inc.). Prior to the experiment, the all containers and equipments such as water pump, plastic tubes, glass tube, and beakers were rinsed carefully. We confirmed that the impurity of them didn't have any dominant effects on the distribution of the residual particles in the waters.

3. Results and discussion

To investigate the effect of the ultrasound, the particle size distributions of distilled water were

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measured using different exposure times of ultrasound, as shown in Fig. 2. In this figure, the *y*-axis denotes the number of particles per unit volume. The results of Fig. 2(a) reveal that the residual nanoparticles have distributions even in the distilled water. Prior to the ultrasound irradiation in the distilled water, a peak was observed in the range of 10~20 nm, which moved to the range of 20~30 nm after the focused ultrasound was irradiated. The peak of particle number was increased as the exposure time of ultrasound increase. To analyze the effect of ultrasonic irradiation on the particle distribution, each result after the ultrasonic irradiation was subtracted by the one before the ultrasound as shown in Fig. 2(b). This result shows that the peak of the particle number is in the range of 40 nm when the ultrasonic exposure time is shorter than 30 min. However, in the case of 60 min exposure time, the peak is appeared at 25 nm of particle size. The results of the deionized water are shown in Fig. 3. The residual particles in the DI water are distributed in the smaller particle size range than those of the distilled water before the ultrasonic irradiation. As similar to the results of the distilled water, the peak of the particle number moved to around 20 nm, and the particle numbers were increased over the whole range after the focused ultrasound was irradiated. The increment of the particle number due to the ultrasound shows in Fig. 3(b). It can be considered that the ultrasound irradiation generated the nitric acid and then it changed the water pH[5]. According to the literature[3], adding nitric acid to the distilled water increases the number of residual particle in the water, and it agrees with the results in this study. Unfortunately, the reason of the peak changes after the ultrasound irradiation has not been clarified.

4. Conclusion

The effects of a focused ultrasound field on the residual particle distribution in the DI/distilled water were investigated. The particle size distributions were measured for various exposure time of ultrasound radiation. The number of residual particles were increased as the exposure time of the ultrasound increased because of the change of water pH.

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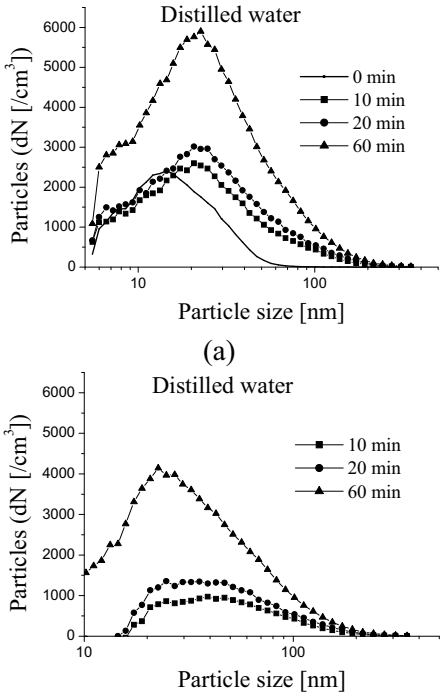

Fig. 2 Particle distribution change with ultrasonic exposure time in distilled water (a); Effect of ultrasound on residual particles in distilled water (b)

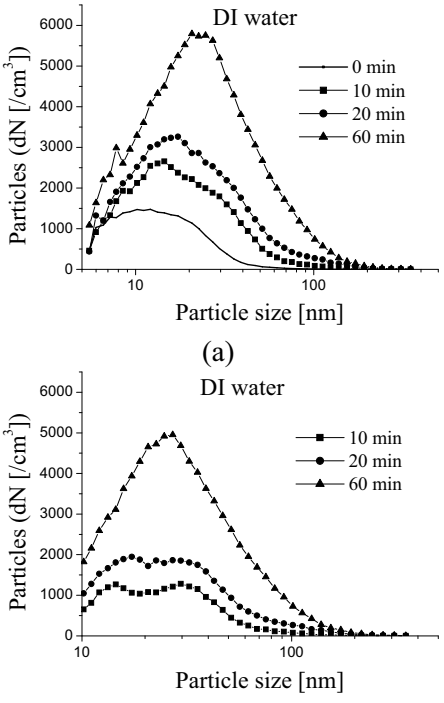

Fig. 3 Particle distribution change with ultrasonic exposure time in DI water (a); Effect of ultrasound on residual particles in DI water (b)