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Size distribution of nano particles in the droplets ultrasonic atomized from Al_2O_3 suspension

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1. Introduction

The agglomeration problem of nano particles is greatly interested since the nano particles have the inhomogeneous distribution or lose their intrinsic properties due to the agglomeration[1)]. Although the techniques of dispersing agglomeration of nano particles have been frequently reported, there are quite a few limitations for practical use[2)]. Generally, a particle size distribution depending on the dispersion exists even in the dispersed suspension. Ultrasonic atomizing effect can be considered as one method that separates to one only under certain size in suspension including the nano particles of various sizes or its agglomeration. It is known that ultrasonic atomization is generated by amplitude divergence of capillary waves formed by ultrasound on the boundary surface in liquid. At this point, the scattered droplets' diameters are controlled to the range less than several μm[3)]. Furthermore, the diameter of the scattering droplets can be determined by surface tension of the suspension. When the nano particle suspension is atomized, the particles in the droplets can be restricted to less than certain size by the surface tension of suspension. In this study, a recollection method for only particles below a certain size by using ultrasonic atomization is suggested. Alumina(Al_2O_3) nano particles are separately recollected from the suspension with an ultrasonic atomizer, and particle distribution is observed to confirm the effectiveness of the suggested method.

2. Construction of recollection system

Figure 1 shows the construction of recollection system for nano particle by using ultrasonic atomization. Ultrasound radiated from the ultrasonic transducer generates capillary waves on the surface of nano particle suspension, and the droplets of the suspension are scattered into the air by amplitude divergence. The scattered droplets including nano particles moved to the condensation pipe by the air pump. A steel cooling filter is installed in the pipe for condensation of the droplets. The droplets passing through the filter lose their kinetic energy and thermal energy because of collision with the filter, and they then are easily condensed. To take condensed suspension, a valve was installed in lower part of the pipe. Only the particles under the condition that ascensional force caused by wind velocity is bigger than the gravity are able to move into the pipe and collected after being condensed. Six identical piezoelectric vibrators with 20 mm diameter in the ultrasonic atomizer were arrayed in a circular acrylic plate with 200 mm diameter. Admittance characteristics of the piezoelectric vibrators used in the ultrasonic atomizer were measured. The resonant characteristics of the vibrators are similar to each other and the resonant frequencies were over from 1.61 MHz to 1.63 MHz. On the other hand, the droplet diameter d is related to the surface tension of suspension as follows[4)]:

$$d = \frac{\left(\frac{2}{3}\right)^{1/3} c_1 + \left(\frac{1}{18}\right)^{1/3} \left(9c_2 + \sqrt{(9c_2)^2 - 12c_1^3}\right)^{2/3}}{\left(9c_2 + \sqrt{(9c_2)^2 - 12c_1^3}\right)^{1/3}} \qquad (1)$$

Here, c_1 and c_2 are $4\pi^2 a^2/2.89$, and $\pi\sigma/f_0^2\rho$, respectively. ρ and f_0 are the density of suspension and the resonant frequency, respectively. Therefore, the droplet size can be determined by the surface tension of suspension in the given conditions. As a result, the size of recollected nano particles can be restricted by changing the surface tension because the size of particles in the droplets is proportional to the droplet size.

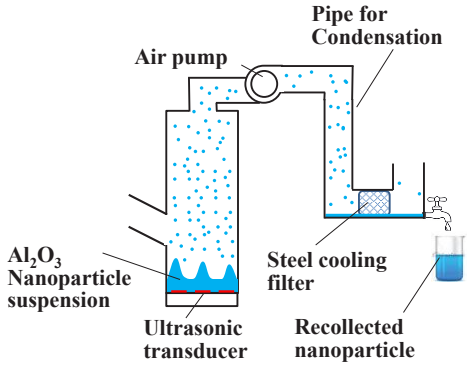

Fig. 1 Recollection system for nano particles.

3. Particle size depending on surface tension

In order to separate and recollect the nano particle from the suspension by ultrasonic atomizing, Al_2O_3 suspension of 0.1 wt.% was made, using Al_2O_3 powder with the average diameter of 300 nm. To separate the nano particles effectively,

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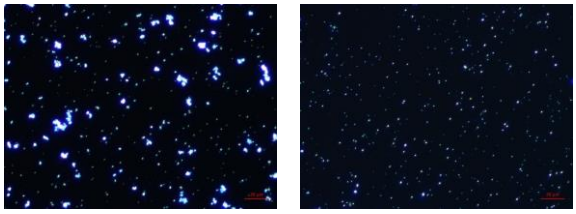
the suspension was dispersed with ultrasonic cleaner for 30 minutes. To confirm the effectivity of recollection system, Al_2O_3 suspension based on distilled water was used in the recollection system and the particle distribution was observed with an optical microscope (ZEISS, Axio Lab.A1), as shown in Fig. 2.



(a) (b)

Fig. 2 Change of particle distribution in the alumina suspension by ultrasonic atomization. (a) Original suspension, and (b) recollected suspension.

A drop of suspension was dried on the slide glass and then the particle distributions in the suspension were observed by using the optical microscope. In these figures, the scale bar refers to 20 μm. Figure 2(a) shows the particle distribution of the suspension before ultrasonic atomization, there were found the clusters of 10 μm by agglomerating of the nano particles. The clusters over certain size in the original suspension were removed in the recollected suspension of Fig. 2(b). As mentioned above, the sizes of the nano particles in the suspension are expected to be smaller than those of nano particles in Fig. 3 because the particles can be agglomerated during the drying procedure on the slide glass. The surface tension of suspension was changed with different concentration of ethanol. Change of the surface tension depending on ethanol concentration was measured, as shown in Fig. 3. From the results shown in Fig. 3, the surface tension of the suspension exponentially decreases as the concentration of ethanol increases. In order to examine the particle distribution in collected suspension depending on surface tension, the particle distributions were observed for different surface tensions of the suspension. The particle sizes in Fig. 4(b) ~ (d) are smaller than the ones in Fig. 4(a) because of the decrease of surface tension due to the added ethanol. Especially, the sizes of particles in the Fig. 4(d) are remarkably small as compared with the sizes of other particles in Figs. 4(b) and (c). It is because the surface tension with the ethanol concentration of 25% is by far smaller than that with the 5% and the 10% of ethanol concentration, as shown in Fig. 3. From these results, it can be confirmed that the size of recollected nano particles can be restricted by controlling surface tension of suspension.

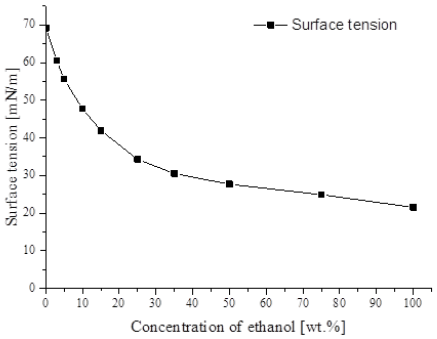
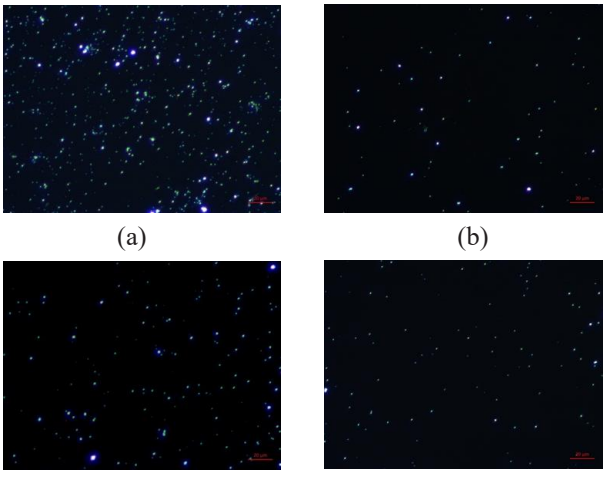


Fig. 3 Surface tension of suspension depending on concentration of ethanol.



(a) (b)

(c) (d)

Fig. 4 Size distribution of collected particles depending on surface tension. (a) 69.2 mN/m, (b) 55.6 mN/m, (c) 47.8 mN/m, and (d) 34.3 mN/m.

4. Summary

Nano particles were separately recollected by using the suggested method with the suspension made of alumina powder of the center diameter of 300 nm and the particle distributions in recollected suspension were observed with an optical microscope. From the observed results for different surface tensions of the suspension, it was confirmed that the sizes of the particle in recollected suspension become small by decreasing surface tension.

Acknowledgement

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