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Nano particle Dispersionizer by using Ultrasonic Cavitation and Streaming

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1. Introduction

In order to materialize the superior properties of nano materials, an essential technique that disperses nano particles evenly and stably is required[1]. Ultrasonic dispersion techniques have been suggested for nano particles, and the dispersion without any surfactants is expected by using the techniques[2]. In this study, an ultrasonic dispersion system is newly suggested as followings:

In order to form high-intensity ultrasonic field in the center of the cylinder, the piezoelectric transducers are arrayed inside the cylinder so that the shockwaves over the frequency of 1MHz can be generated by ultrasound. To make eddy current caused by ultrasonic streaming which is radiated from the piezoelectric transducers in nano suspensions, those transducers are tilted by the regular degree from inner surface of the cylinder. In this study, the newly suggested ultrasonic dispersion system is fabricated and the effect of dispersion with the system is examined.

2. Construction of dispersionizer

Figure 1 shows the concept of the ultrasonic dispersion system suggested in this study. Identical six piezoelectric vibrators are arrayed on the inner wall of the aluminum cylinder as shown in Fig. 1(a). To generate shear stress of the fluid caused by ultrasonic streaming effect in acoustic medium which is inside the cylinder, surface of the piezoelectric vibrators are tilted by regular degree. To prevent the extraneous substance from being mixed up into the suspension, a glass container with 0.7 mm thickness is placed in the center of the aluminum cylinder. Water is filled between the glass container and the aluminum cylinder so that the water could perform not only as cooling water but also as an acoustic material that makes ultrasound from the transducers to transmit into the glass container. To keep a constant temperature, the cooling water is circulated by a water pump. The eddy current caused by the ultrasonic streaming in the suspension causes the splitting effect from shear stress of the fluid of the suspension, and the clusters of nano particles are divided into several pieces[3].
To make a high intensity ultrasonic field in the container of the suspension located in the center of the cylinder, the piezoelectric vibrators are arrayed on the inner wall of the cylinder toward the center. The ultrasonic shock wave due to the high intensity ultrasound causes the erosion dispersion, and then the agglomerated nano particles can be dispersed by single particles.

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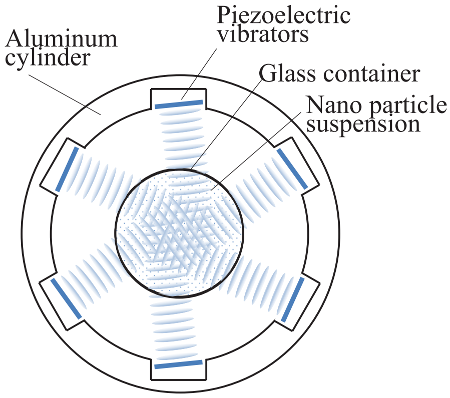
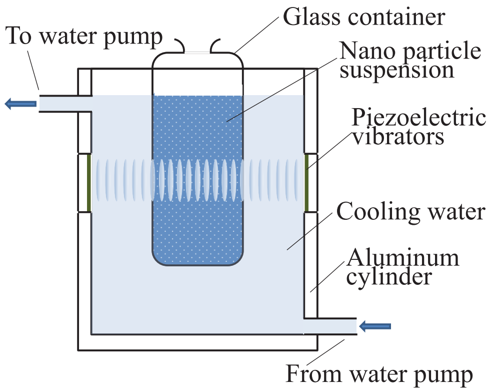


(a)



(b)

Fig. 1 Schematic of suggested ultrasonic dispersionizer. (a) Top view and (b) side view.

3. Fabrication and evaluation

The ultrasonic dispersion system was fabricated using an aluminum cylinder with 100 mm outer diameter, 76 mm inner diameter, and 100 mm depth. Six piezoelectric vibrators which have the diameter of 20mm, the thickness of 1.24 mm, and the resonant frequencies of 1.6 MHz, were arrayed with the regular interval on the inner wall of the cylinder. A glass container was fixed in the center of the cylinder, and the capacity and the thickness are 100ml and 0.7 mm respectively was fixed in the center of the cylinder. In order to examine the dispersion efficiency of the fabricated system, TiO_2 suspension of 0.01 wt.% and vanadium dioxide (VO_2) suspension of 1.0 wt.% were made and dispersed for 30 minutes with the suggested dispersionizer. **Figure 2** shows the precipitation states in the vials of the TiO_2 suspensions with time elapse after dispersion. For comparison, the TiO_2 suspension dispersed with a conventional bath type ultrasonic dispersionizer is shown in the leftmost of Fig. 2. Sample suspensions dispersed with suggested method were collected from the upper part, the middle part, and the lower part of the glass container to examine the dispersion degree depending on the depth of the container. The state of the suspension right after the dispersion is shown in Fig. 2(a), and it shows turbid state by the floating particles. In the result after 48 hours from the dispersion as shown in Fig. 2(b), the suspension dispersed with the conventional dispersionizer is not dispersed enough, so the agglomerated particles are precipitated, whereas the suspensions dispersed with the suggested method are turbid because the particles by the dispersion become light enough to float. Even though it passed 72 hours from the dispersion, the result in Fig. 2(c) is similar to that of Fig. 2(b). Therefore, it can confirm the dispersion effect of suggested method in this study. It seems that there is no difference in dispersion depending on the position of ultrasonic transducers so that there is no significant difference in the dispersion effect according to the depth of the suspension. As mentioned above, it is because the suspension in the container was dispersed homogeneously by stirring effect caused by the ultrasonic streaming. Figure 3 shows the dispersion results of VO_2 suspension, which is greatly interested as a functional material in the industrial fields. Since the VO_2 has a phase transition very close to room temperature, its electrical resistivity, opacity, etc, can change up several orders. Due to these properties, it has been widely used in surface coating, sensors, and imaging. Potential applications include use in memory devices. In this figure, the suspension dispersed with the conventional method is placed on the right side, and the suspensions which are collected from the upper part, the middle part, and the lower part of the glass container after dispersion with the suggested method are filled in vials. In this case, the solvent of suspension is ethanol. Similarly to the result shown in Fig. 2, while all of the vials show turbid state at right after the dispersion as shown in **Fig. 3(a)**, the precipitation of agglomerated particles due to insufficient dispersion are observed in the suspension dispersed with conventional method, which is the result after 24 hours from dispersion as shown in Fig. 3(b). Although the opacity of the suspension dispersed with the suggested method slightly decreased because of the precipitation, there is no significant difference in opacity compared with the state right after dispersion. It confirmed that the precipitation was inactively progressed even in the state of 48 hours after from the dispersion as shown in Fig. 3(c). There is also no meaningful difference in dispersion effect depending on depth of the suspension in the container.

4. Summary

In this study, an ultrasonic dispersion system with a new manner was suggested, which is able to cause simultaneously the erosion dispersion and the division dispersion. To investigate the efficiency of the fabricated system, the TiO_2 and VO_2 suspensions were dispersed with that system. As the result, it was confirmed that the suggested system is an effective method to disperse nano particle suspension. It can be expected that the suggested method can provide possibility of massive capacity dispersion as well as keeping a high degree of purity due to the non-contact way.

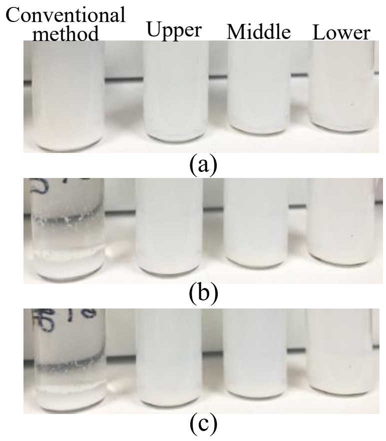


Fig. 2 Aging effect of dispersed TiO_2 suspension.
(a) Right after dispersion, (b) 48 hours after dispersion, and (c) 72 hours after dispersion

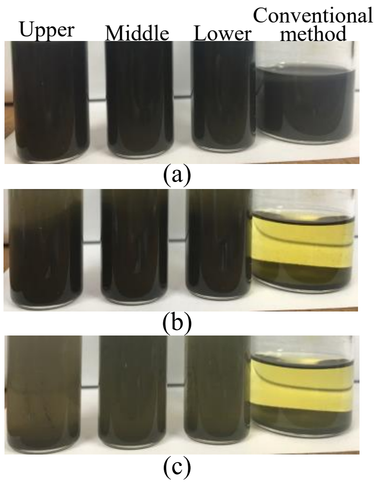


Fig. 3 Aging effect of dispersed VO_2 suspension.
(a) Right after dispersion, (b) 24 hours after dispersion, and (c) 48 hours after dispersion

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References

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