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Effect of Ultrasound on Agglomeration and Redistribution of Microbubbles
マイクロバブルの凝集と再分散におよぼす超音波の影響

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1. Introduction

Recently, microbubbles with a diameter less than 50 μm in a liquid has been used practically in the field such as aquaculture, waste water treatment and medical treatment.

The terminal rise velocity of air microbubble in pure water is around 1.0 – 6.0 mm/s. In addtion, it is generally reported that microbubbles stably disperse in static liquid due to electrical repulsion[1]. It is advantageous to utilize the microbubble for gas – liquid contact operation, because the residence time in a liquid is long, and specific gas – liquid interfacial area is large. Therefore, it is useful to apply the microbubble to the chemical process. However, it is difficult to control the dynamic behavior of microbubbles in a liquid.

Some interesting behaviors have been observed in our previous study. When the ultrasound is irradiated into the microbubble suspension that looks milky white, the suspension rapidly becomes clear. After the irradiation is stopped, the view of suspension changes again to milky white. However, the mechanism of this behavior has not been investigated in detail. In this study, the behavior of microbubbles in an ultrasonic field was investigated by visualization.

2. Experiment

Fig. 1 shows the experimental setup of observing the removal of microbubbles using indirect ultrasonic irradiation. The ultrasonic frequency, *f*, was 2.4 MHz (HM – 303N, Honda Electronics). The bubble column was made from transparent glass, and the inner diameter and height were 0.07 m and 0.4 m. The effect of ultrasonic irradiation on the temporal change of the boundary between milky white layer and transparent layer inside the bubble column was observed using the video camera (GZ – MG575, Victor).

Before ultrasound was irradiated, the solution with air microbubbles prepared using microbubble generator (OM4 – GP – 040, Aura Tec) was put into the column. Ion exchanged water was used as a liquid phase.

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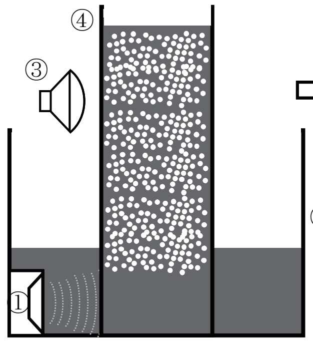

Fig. 1 The experimental setup of removal of microbubbles using indirect ultrasonic irradiation.

Fig. 2 shows the experimental setup of observing the microscopic behavior of microbubbles under indirect ultrasonic irradiation. The ultrasonic frequency was 2.4 MHz (HM – 303N, Honda Electronics) or 28 kHz (SC – 300D, SMT). The observation slit column with a width of 8 × 30 mm and a length of 250 mm was made from transparent acrylic resin.

Before ultrasound was irradiated, the solution with air microbubbles prepared using microbubble generator (OM4 – GP – 040, Aura Tec) was put into the observation column. Ion exchanged water was used as a liquid phase.

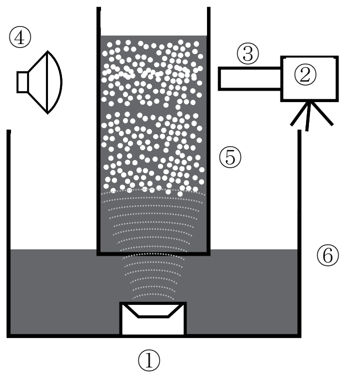

Fig. 2 The experimental setup of microscopic behavior of microbubbles.

3. Results and discussions

The mean bubble size using this study was around 25 μm, and size distribution was narrow. From the results of microscopic visualization, it was observed that the size of microbubble was in the range from 20 μm to 40 μm. By the comparison of results of laser diffraction method and visualization method, the bubble diameter was almost same.

Fig. 3 shows the effect of ultrasonic irradiation condition on temporal change of the distance between bottom of the column and boundary position. Ultrasonic irradiation conditions were defined as follows.

Condition 1: Without US irradiation
Condition 2: Steady US irradiation
Condition 3: Unsteady US irradiation
(30 s US Off, 2 s US On, 30 s US Off, 2 s US On)

The solution with the microbubble in the bubble column retained milky white solution without ultrasonic irradiation, because the residence time of microbubble was very long. On the other hand, after ultrasonic irradiation, milky white liquid became transparent liquid rapidly. It was found that rise velocity of the bubble increased with ultrasonic irradiation. On the other hand, in the condition 2, the rise velocity of boundary layer under ultrasound stop was small. And, the rise velocity in ultrasonic irradiation was increased again. Therefore, this behavior of microbubble was able to be reversibly controlled by the ultrasonic power.

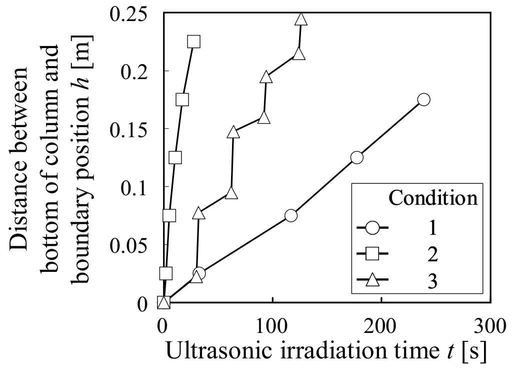

Fig. 3 Effect of ultrasonic irradiation condition on temporal change of distance between bottom of column and boundary position.

Fig. 4 shows the representative snapshot of the behavior of the microbubble under ultrasonic irradiation. Before ultrasonic irradiation, microbubbles stably dispersed in the liquid by the electrical repulsion. After ultrasonic irradiation, microbubbles were agglomerated, and the rise velocity of bubble was increased. After ultrasonic irradiation was stopped, the bubble dispersed again.

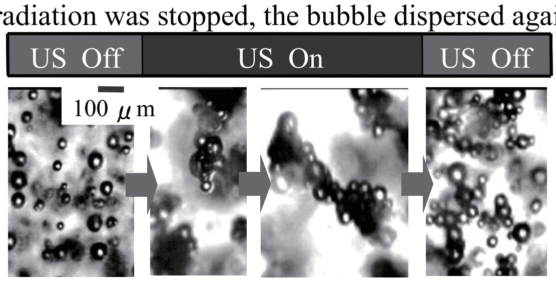

Fig. 4 Microscopic behavior of the microbubbles in an ultrasonic field.

Fig. 5 shows the effects of ultrasonic frequency on microscopic dynamic behavior of microbubbles in an ultrasonic field. Ultrasonic frequency was found to influence size and shape of agglomerated bubbles.

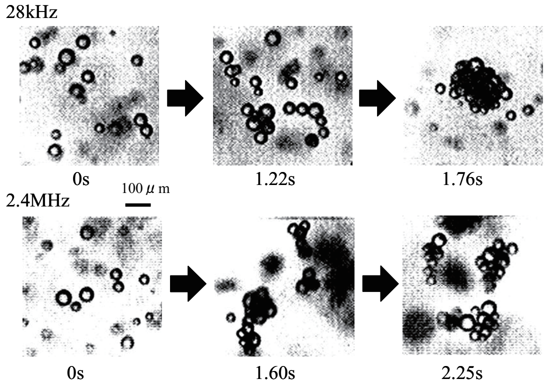

Fig. 5 Effect of frequency on microscopic behavior of microbubbles in an ultrasonic field.

Fig. 6 shows the image of effect of frequency on the size of agglomerated microbubbles in an ultrasonic field. The microbubbles were considered to be agglomerated around antinode at 28 kHz, and around node at 2.4 MHz by the Bjerknes force. The wavelength of ultrasound was considered to affect the size and shape of agglomerated bubbles.

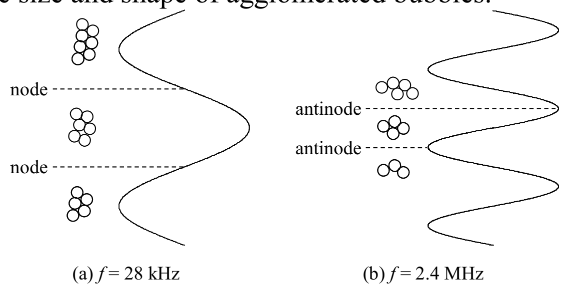

Fig. 6 Image of effect of frequency on the size of agglomerated microbubbles in an ultrasonic field.

4. Conclusions

When the ultrasound is irradiated into the microbubble solution, microbubbles approach and are agglomerated. Ultrasonic frequency and potential of surface of the microbubble influence this agglomeration mechanism.

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References

1. M. Takahashi: J. Phys. Chem. B. **109** (2005) 21858