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High-speed observation of cavitating bubble diameter in surface active SDS solutions

高速度カメラ観測による音響キャビテーション気泡径の界面活性剤SDS効果

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1. Introduction

Previous studies on the size of acoustic cavitation bubble adsorbed by surfactant molecules have been made by using techniques of acoustic emission and sonoluminescence. It have been reported that the adsorption causes the charge of bubbles and prevents from bubble coalescence, which stimulates bubble growth by increasing the effect of rectified diffusion [1]. In this study, we measured the size of the cavitation bubbles in sodium dodecyl sulfate (SDS) solutions by directly observing shadowgraph movies. We investigated the distribution of maximum diameters of cavitation bubbles with various concentrations of SDS. We have already studied the effect of ultrasound frequency on bubble dynamics in surfactant solutions. This study showed that an average of bubble size decreased and a quantity of large bubbles was reduced with the increase in frequency. These results were caused by the hindrance of bubble coalescence. In this paper, we report the effect of SDS concentration on bubble size and also the direct comparison of expansion and contraction of bubble adsorbed by SDS with those in pure water.

2. Experimental

A sample cell used was rectangular glass cell (55×55×70mm). A 28 kHz bolt-clamped Langevin transducer was bonded to the bottom of the cell. A signal from function generator was amplified by a power amplifier, and applied to the transducer through a matching circuit. Deionized water and SDS solutions with concentrations of 0.1, 1, 5 and 10mM were used as a sample. Shadowgraph movies of cavitating bubbles were captured using a high-speed video camera (SHIMADZU, HPV-2, a maximum speed of 1,000,000 fps) and a stroboscopic light was synchronizing with the camera. The camera was equipped with two zoom lens (maximum magnification of 15 times), and the minimum view size was 1.22 × 1.46 mm. The maximum bubble diameters were measured on images by analysis software of ImagePro. In the present experimental condition, the resolution of observation of bubble size was limited to 4.71μm.

3. Results and discussion

3.1 Time evolution of cavitation bubble

Figure 1 shows the typical time evolution of bubble expansion and contraction in deionized water and in 1 mM SDS solution at a frequency of 125 kHz. The change in bubble diameter in SDS solution seems to form a slightly-distorted sine curve, and that in deionized water to form a greatly-distorted curve. This indicates that bubble vibrates spherically in SDS solution and aspherically in deionized water. High-speed movies confirmed this inference. Hence, it is suggested that bubbles tend not to fragment and to make stable vibration when adsorped with SDS molecules.

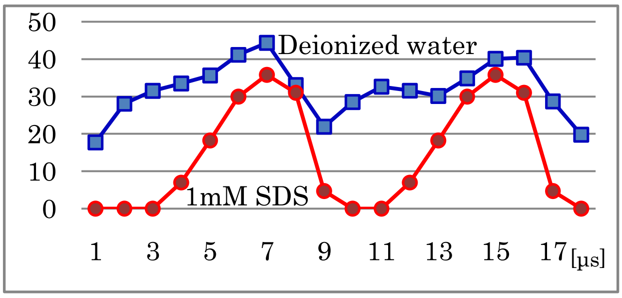

Fig. 1 The evolution of bubble diameter observed in deionized water (upper) and 1mM SDS solution (lower) at 125 kHz.

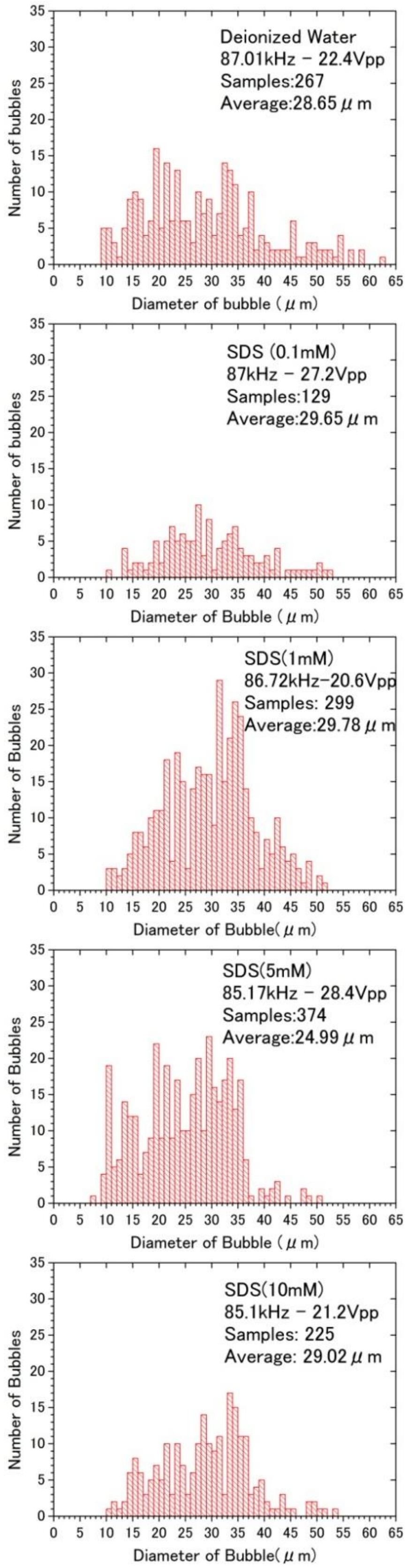

Fig. 2 Histogram of maximum diameter of cavitation bubbles in deionized water (top) and SDS solutions with concentration of 0.1,1,5 and 10mM at 87 kHz.

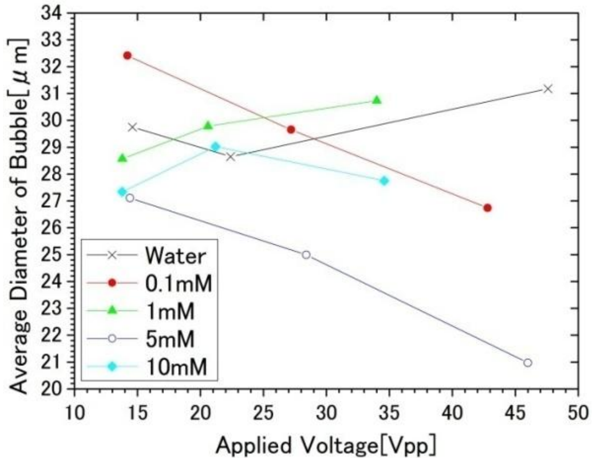

Fig. 3 Power dependence of average of maximum bubble diameter in SDS solutions (0.1,1,5,10mM) and deionized water at 87 kHz.

3.2 Effect of SDS concentration on bubble diameter

Figure 2 shows the histogram of the maximum diameter of bubbles in 0.1, 1, 5 and 10 mM SDS solutions and deionized water at frequency of 87 kHz. The maximum diameter was estimated from video images, and a number of samples was in the range of 129-374 at each concentration. **Figure 3** shows the dependence of the average of the maximum diameters presented in Fig.2 on the applied voltage. From Fig.2 we can recognize that the data with large diameter are lost in the histogram as SDS concentration increases. The effect is remarkable at 5 mM SDS concentration. This is due to the hindrance of coalescence between bubbles. If SDS molecules adsorb bubble surface, the bubble is negatively charged. Then electrostatic repulsion works between bubbles when they approach each other under the second Bjerkness force, which suppresses the coalescence. The histogram at the 10 mM SDS concentration indicates that excess quantity of SDS decreases the effect of hindrance of bubble coalescence. In our system the effect is most pronounced at 5 mM concentration. A similar concentration dependence was also reported by Iida et. al. [2]

References

[1] M.Ashokkumar et al.,Ultrason.Sonochem., 14,470-475,(2007).

[2] Y.Iida et al., Ultrason.Sonochem.,17,473-479,(2010).