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On the influence of bulk nanobubble concentration on the intensity of sonoluminescence
ナノバブル濃度が音響発光強度に与える影響

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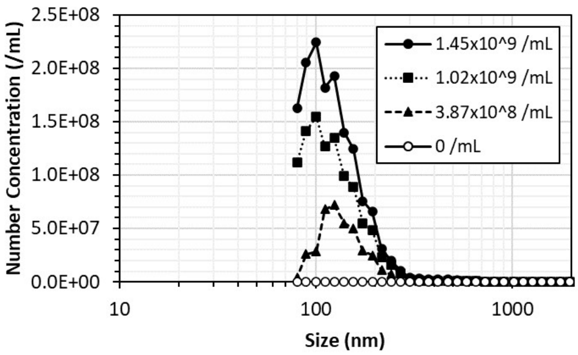
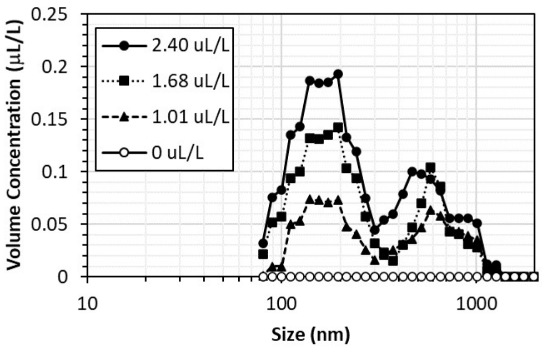
1. Introduction

Long-lived floating bulk nanobubbles (ultrafine bubbles having the size of smaller than 1 μm) in liquid have recently been studied [1, 2]. In order to clarify the existence of gaseous nanobubbles, it is necessary to distinguish them from solid or liquid particles [3]. Recently, Hata et al. observed sonoluminescence (SL) from water containing argon nanobubbles to find that sonoluminescence occurred evidently in the presence of nanobubbles compared with that in the absence. [4]. SL is defined as light emission from a cavitating liquid exposed to intense ultrasound.[5] Tuziuti et al. measured the intensity of SL for various acoustic amplitude in both of the presence and the absence of air nanobubbles to show that at excessively high amplitude where a decrease in the SL intensity was often observed, the SL intensity in the presence of nanobubbles could be higher than that in the absence. [6, 7]. These results infer that SL is a measure to evaluate the exsistence of nanobubbles in a liquid.

Little is known on the intensity of SL when the concentration of nanobubbles is varied, so far. The present study deals with measurements of the intensity of SL at different concentrations of nanobubbles and evaluates an increment of the intensity by nanobubbles compared with that in the absence.



(a)



(b)

Fig. 1 Size distribution of nanobubbles at different concentration. Upper and lower figures {(a) and (b)} are plotted as the number and volume representation, respectively.

2. Experiment

Nanobubbles in pure water (Millipore Essential Elix 5) were prepared using a bubble generator apparatus (YBM Faby-10) based on the impact of bubble cavitation and the shear force imparted by vortex flow, as described in a previous publication [8]. The concentration of nanobubbles was adjusted with mixing of nanobubble water and air-saturated pure water for dilution at different ratio. The air saturation was established by bubbling air at 23 ˚C in a thermostatic chamber (TAITEC BR-40LF). Sizing nanobubbles was performed with a size distribution measurement apparatus (Shimadzu SALD-7500X10). The principle of size measurements using this apparatus has been described elsewhere [9].

The intensity of SL from the water in the presence and absence of nanobubbles during exposure to 54 kHz continuous-wave sinusoidal ultrasound using the amplified signal from a function-generator (FG) was measured with the output voltage from a photomultiplier (PMT) tube for various acoustic amplitudes as described elsewhere [7].

3. Results and Discussion

Fig. 1 shows size distribution of nanobubbles at different concentration plotted as the number and volume representation, respectively. It is confirmed that in both representation each of the distribution

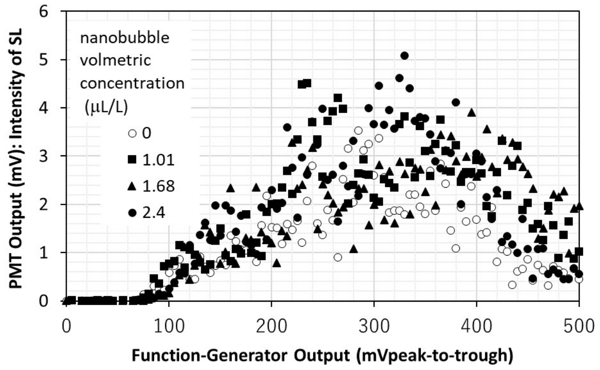


Fig. 2 Intensity of sonoluminescence from water containing nanobubbles at different concentration as a function of function-generator output voltage.

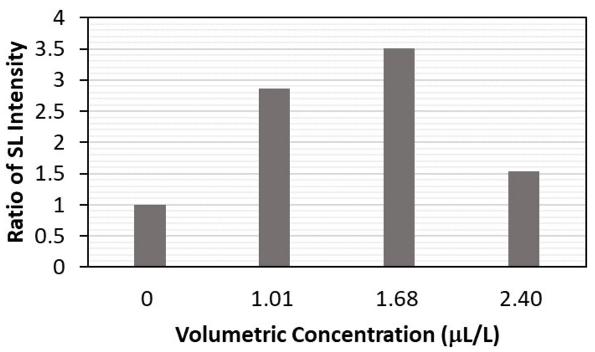


Fig. 3 Average ratio of intensity of sonoluminescence over the range from 400 to 500 mVpeak-to-trough in function-generator output voltage compared with the intensity in the absence of nanobubbles for different volumetric concentrations of nanobubbles.

including the distributions at the intermediate diluted concentrations has the values mainly in the range of 100-200 nm, which agrees with that in the literature [10].

Fig. 2 shows the intensity of sonoluminescence from water containing nanobubbles at different concentration as a function of function-generator (FG) output voltage which is used here as an index of sound pressure amplitude. As the FG output increases, each of the intensity of SL increases to show the maximum. After that, the intensity of SL decreases at further FG output. Such decrease in SL intensity at excess amplitude is often observed [11]. It seems that there are differences in the intensity between the absence and the presence of nanobubbles, although the data are rather scattered. In order to find the difference, the ratio of the intensity of SL in the presence of nanobubbles against that in the absence at each of the FG output is calculated and the average over the range of relatively high amplitude (400-500 mVpeak-to-trough in FG output) is obtained for different concentration of nanobubbles.

Fig.3 shows the average ratio of intensity of sonoluminescence over the range from 400 to 500 mVpeak-to-trough in function-generator output voltage for different volumetric concentrations of nanobubbles compared with the intensity in the absence of nanobubbles. Each of the ratio is normalized by that in the absence of nanobubbles. It is found that the ratio is higher than 1 at each of the concentrations in the presence of nanobubbles. This probably means that high amplitude given is over the Blake threshold and accordingly nanobubbles could expand to some extent leading to SL. It is found that the ratio becomes lowest at the high concentration (2.40 μL/L). This may be due to shielding of bubbles that means ineffective propagation of a sound in the inside of clustered bubbles leading to suppression of luminescence [12, 13].

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