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Viscosity dependences of multibubble sonoluminescence in aqueous solutions of glycerol

グリセリン水溶液中におけるマルチバブルソノルミネセンスの粘性依存性

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1. Introduction

Sonoluminescence (SL) in viscous liquid has been interested. In water-glycerol mixtures, Young [1] showed that SL intensity exhibits a maximum at a concentration of 80 % glycerol. Choi et al. [2] reported that multiple-peak SL pulses were observed in NaCl-ethylene glycol solution, which pulses were resulted from bubble dynamics peculiar to viscous liquid. Bubble dynamics in a viscous liquid is still unresolved and an extensive study is necessary. We aim to clarify the mechanism of the viscosity dependence of SL intensity and pulses, correlating with bubble dynamics.

2. Experimental

We used aqueous solutions of glycerol with various concentrations saturated with krypton. Also used was 1M NaCl aqueous solution of 80 % glycerol. The sample cell was a rectangular glass container with a volume of 300 mL. The sample temperature was controlled using a water jacket at 15℃. A sandwich transducer was bonded to the bottom of the cell. Frequency used was 28 kHz, 50 kHz and 150 kHz, and the input electric power was 10W, 20W, 30W, 40W and 50W. SL spatial distribution was captured with a digital camera (Canon EOS 6D) with a sensitivity of ISO 16,000 and an exposure time of 15 s. SL pulse was detected using a cooled photomultiplier (Hamamatsu, H7422-01) with a rise time of 750 ps and a digital oscilloscope (Agilent, DSO5052A) with a 500MHz bandwidth and a sampling speed of 4 G Sa/s. A single SL pulse curve was well fitted by a Gaussian. The statistical analysis of each pulse-width measurement was carried out using a set of one hundred items of data. Shadowgraph movies of cavitating bubbles were taken using a high-speed video camera (Shimadzu, HPV-2) with a maximum frame rate of 1,000,000 fps.

3. Results and discussion

3.1 Viscosity dependences of SL intensity

Figure 1 shows viscosity dependences of SL intensity for various concentrations of glycerol and five different powers at 50 kHz (Fig. 1(a)) and 150 kHz (Fig. 1(b)). We obtained the intensity by integrating a brightness of each pixel of photographs using Image J software. The SL intensity at 50 kHz increased with increasing glycerol concentration, which result is similar to that by Young. While at 150 kHz, SL intensity decreased with increasing the glycerol concentration. At high frequency, a bubble expansion is more suppressed by viscosity, leading to lower SL intensity at higher viscosity. SL intensity increased as the power increases except the case of pure water in which bubbles form clusters at high powers [3]. The clusters do not exhibit SL because they undergo transient oscillation where temperature inside bubbles is not high enough to generate SL.

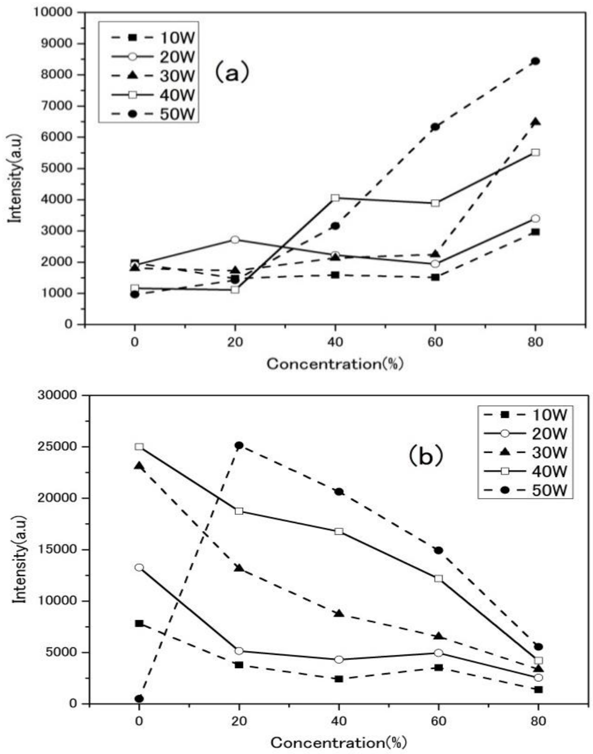

Fig.1 Viscosity dependences of SL intensity at 50 kHz (a), 150 kHz (b) in aqueous solutions of glycerol for various input powers.

3.2 Bubble dynamics

For highly viscous solution and only at 28kHz and 50 kHz, we frequently observed bubble images that shows large bubbles of 100-300 μm in diameter as shown in Fig 2. The large bubbles are generated via the coalescence of 8-10 bubbles and keep stable because viscosity tends to stabilize the shape anisotropy of large bubbles. Beside this large cluster bubbles, a number of tiny bubbles were observed, the size of which is smaller than those in pure water. .

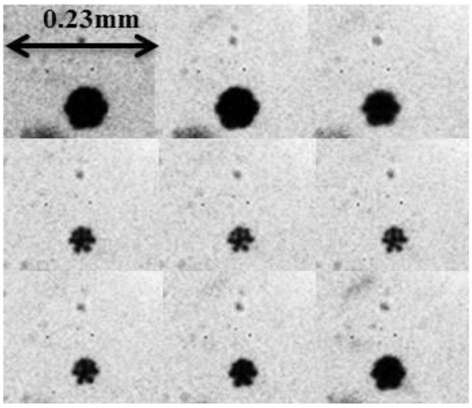

Fig.2 High speed images of bubble dynamics taken at the speed of 500kfps at 50 kHz in 80% glycerol solutions.

3.3 Viscosity dependence of SL pulse width

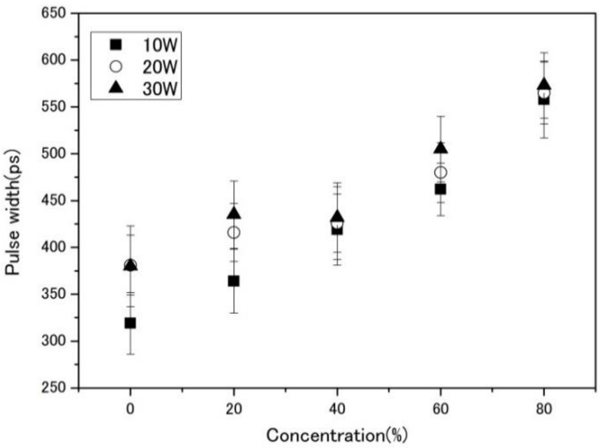

Fig.3 SL pulse width observed with different glycerol concentrations at 50 kHz.

Figure 3 shows the full-width at half-maximum of SL pulse observed with different glycerol concentrations and at powers of 10, 20, and 30 W. The values were corrected for using an instrumental width obtained with femto second laser. The pulse width in water is about 350 ps in average which is in agreement with the value in SBSL. Compared to pure water, the pulse width becomes larger with increasing the concentration. The increase in the SL pulse width may be associated with a viscous slowing of the bubble wall in the very last stages of the initial collapse. If the compressive heating is still strong enough to result in plasma formation, the lowered wall velocity might allow the plasma to remain intact and hot for a longer period of time than in pure water [4].

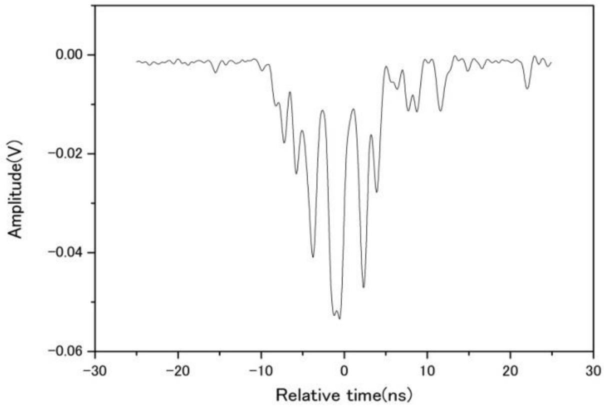

Fig.4 The multiple-peak pulse from NaCl glycerol solutions saturated with krypton at 28 kHz.

Figure 4 represents an expanded view of the multiple-peak pulse observed from NaCl solution of 80% glycerol at 28 kHz. This type of pulse is resulted from Na emission, not from continuum emission. At higher frequencies the multiple-peak pulses are less observed. This tendency is similar to the appearance of the large bubbles shown in Fig. 2. This suggests that the multiple-peak pulses are caused by the superposition of SL from the tiny bubbles consisting of the large cluster bubble.

4. Conclusion

SL intensity varied with the concentration of glycerol, the frequency and power. Compared to pure water, the bubbles in glycerol mixtures produce longer SL pulses. Increase in the SL pulse width is associated with a viscous slowing of the bubble oscillation. The multiple-peak pulses observed at low frequency are caused by the large cluster bubbles which radiates Na emission.

References

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