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High-speed observation of acoustic bubbles in highly-viscous liquids
高粘性液体中における音響キャビテーション気泡運動の高速度観察

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1. Introduction

Intense ultrasound irradiated in liquid creates bubbles which grow up from gas nuclei dissolved in liquid. These acoustic bubbles expand and contract with synchronizing the cycle of acoustic pressure. Sonoluminescence is emitted at the timing of bubble collapse. Na atom emission can be observed from NaCl aqueous solutions, and the optical pulse measured is single-peaked pulse. In NaCl ethylene-glycol solutions, on the other hand, the shape of Na emission pulse was multiple-peaked [1]. We pointed out that the multiple-peak pulses are associated with bubble dynamics peculiar to viscous liquids such as ethylene glycol. In this paper, we have observed characteristic behavior of bubble dynamics using high-speed photography in liquids with various viscosity including ethylene glycol and glycerin. We also observed sonoluminescence from these liquids.

2. Experimental

We used ethylene glycol, glycerin and aqueous solutions of glycerin with concentrations of 80% and 69% as samples. They were carefully degassed while stirring and saturated with Ar gas under 1 atm. The sample cell was 300 mL rectangular glass flask with 70 x 70 mm in widths and 90 mm in height. A sandwich transducer was bonded to the bottom of the cell. Frequency used was 50 kHz and applied voltages were 90 and 180 Vpp. An experimental system used is shown in Fig.1.

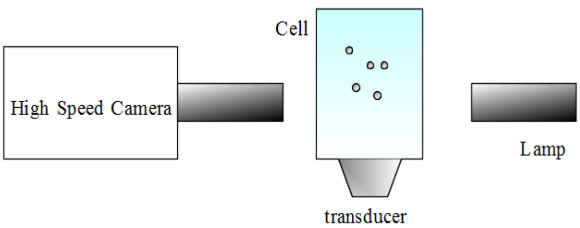


Fig.1 Experimental apparatus for measurements of bubble shadowgraphs.

Shadowgraph of acoustic bubbles was observed using a high-speed camera (Shimadzu, HPV-2) with a maximum frame speed of 1 million and a 250 W light source equipped with a glass fiber.

3. Results and discussion

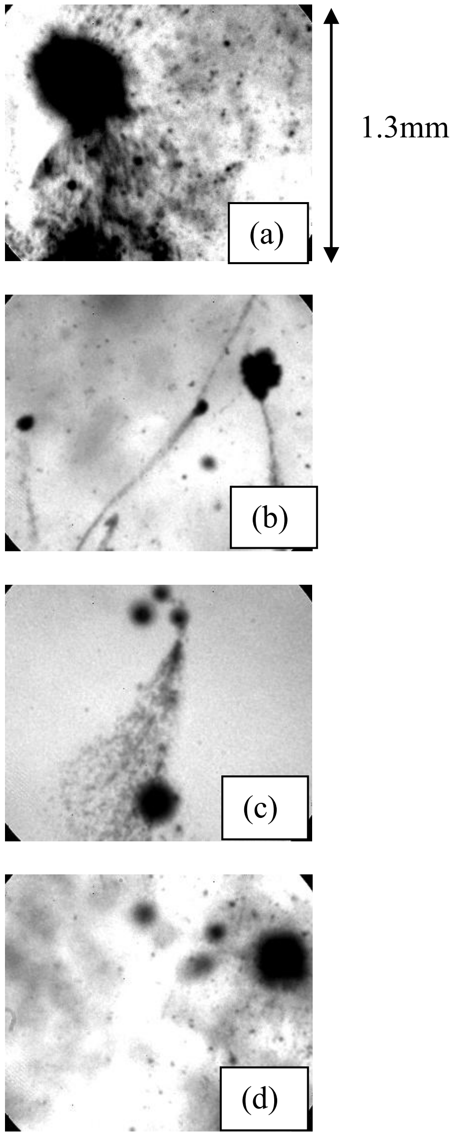


Fig.2 High-speed images of acoustic bubbles in ethylene glycol(a), glycerin 100%(b), glycerin 80% solution(c), and glycerin 67% solution(d) at the frame rate of 8000 fps.

Figure 2 (a)-(d) show high-speed images of acoustic bubbles taken at the speed of 8000fps in ethylene glycol (a), glycerin (b), 80 % glycerin solution (c), and 67 % glycerin solution (d) at 90 Vpp. We can frequently observe bubbles that are 300 - 400 μm in diameter as indicated in Fig. 2 (a). They emitted many daughter bubbles. In fig. 2 (b) a large bubble with diameter of 200 μm seems to be aggregate of several small bubbles. This bubble also emitted tiny daughter bubbles.

Figure 2 (c) shows typical acoustic bubbles in glycerin 80 % solution. We can observe bubbles with diameter of about 300 μm, also emitting many daughter bubbles. A quantity of daughter bubbles is larger than that in 100 % glycerin. Figure 2 (d) indicates acoustic bubbles in 67 % glycerin solution. The viscosity of this solution is nearly equal to that of ethylene glycol. We can observe bubbles with the diameter of 300 μm. The bubble dynamics is similar to that observed in ethylene glycol solution, although the occurrence of these bubbles is much less frequent. The salient feature common to these viscous liquids is occurrence of large bubbles which emitting many tiny daughter bubbles. This dynamics has not been observed in pure water. The large bubbles are generated via bubble coalescence and are hard to breakup because viscosity tends to stabilize the shape anisotropy of large bubbles.

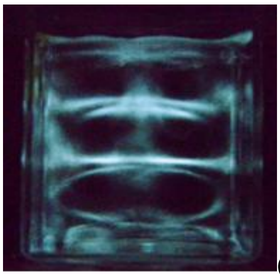
Sonoluminescence (SL) was observed from glycerin and 80 % glycerin solution. Figure 3 shows photographs of SL taken with a Nikon D7000 camera. The ISO was 25,600 and the expose time was 1 min. Figures 3 (a) and (b) show SL for glycerin at applied voltage of 180 V and 90 V, respectively. Figures 3 (c) and (d) represent SL for 80 % glycerin solution at applied voltage of 180 V and 90 V, respectively. All SL images show continuum emission. The SL intensity from all the emission sites was estimated from the images using "Image J" software. The intensity values from bright pixels having 256 gradation sequence were integrated. Table.1 lists the total intensity of the emission calculated in this way. The intensity in 80% glycerin solution is considerably larger than that in 100 % glycerin. Young [2,3] reported concentration dependence of SL in glycerin solutions, and showed that SL is strongest at 80 % solutions. The present results agree with his results. The number of bubbles is much larger in 80 % glycerin solution than in 100 % glycerin. Detailed analysis of bubble dynamics in relation to SL is now in progress.

Table.1 SL intensity from glycerin solutions.

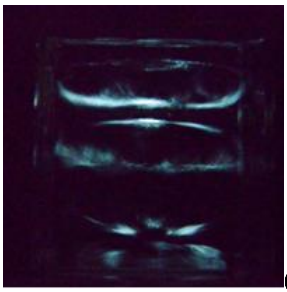
Conc./ Voltage	SL intensity(a.u.)
(a) 100% / 180V	4867
(b) 100% / 90V	1032
(c) 80% / 180V	15740
(d) 80% / 90V	6625

(a) Glycerin, 180 V

(b) Glycerin, 90 V



(c) 80 % glycerin, 180 V



(d) 80 % glycerin, 90 V

Fig.3 Sonoluminescence from glycerin and 80 % glycerin solution

4. Reference

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[3] P.I.Golubnichii et al, Sov.Phys.Acoust. (1970)16, 115-117