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Sonoluminescence from viscous liquids using horn-type transducer

ホーン型振動子を用いた粘性液体からのソノルミネセンス

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1. Introduction

Multi bubble sonoluminescence (SL) from horn-type transducer that locally irradiates strong acoustic pressure is greatly different from that of the steady wave type oscillator. B. Dubus et.al reported[1] that characteristic bubble behavior is subjected to decay of sound velocity. Besides it is well-known that SL from liquid including alkali metal includes alkali-metal atom emission along with continuum emission [2]. However, there are still many problems such as emission site of alkali metal and bubble behavior.

The purpose of this work is to investigate the dependence of viscosity of sample liquid on SL and bubble dynamics under high-acoustic pressure. For this purpose, we observed SL and bubble behavior in water, ethylene glycol, glycerin solution using 24kHz horn-type transducer.

2. Experrimental system

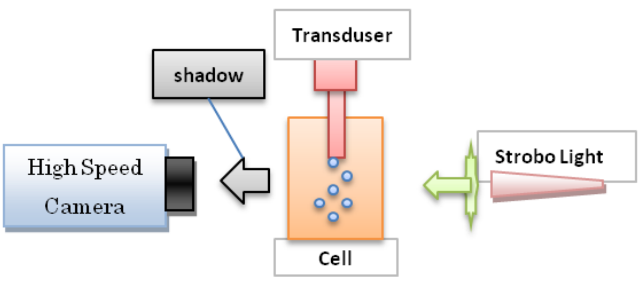

Fig.1 System of shadowgraphy of cavitating bubble using a horn type transducer.

A typical experimental apparatus is shown in Fig. 1. The ultrasonic frequency of horn type transducer (Hielscher, UP400S 400W) is 24 kHz. NaCl-ethylene glycol solutions and NaCl aqueous solutions were degassed and saturated with Ar for a few hours as a sample of experiment of 3.1. As a sample of experiment of 3.2, Ar-saturated ethylene glycol solutions and glycerin solutions are used. Shadowgraph of cavitating bubbles was taken using a high-speed camera (Shimadzu, HPV-2) and a flash light.

3. Results and discussion

3.1 Sonoluminescence of Na emission

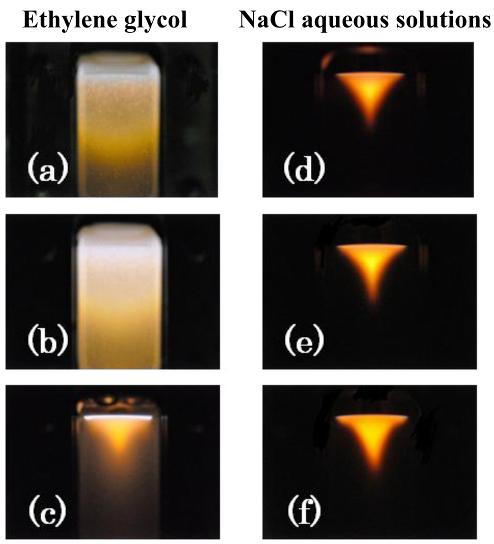

Fig.2 Sonoluminescence of Na emission from Ar-saturated NaCl-ethylene glycol solutions (a)-(c) and NaCl aqueous solutions (d)-(f) using a 24kHz horn. Photographs were obtained at the horn amplitude of 20%, 40%, and 100% from top to bottom.

Ultrasonic power dependence of sonoluminescence is shown in Fig. 2 from 1 M-NaCl solutions in ethylene glycol (a)-(c), and 1 M-NaCl aqueous solutions (d)-(f). Ultrasonic amplitude used was 20%:(a),(d), 40%:(d),(e), and 100%:(c),(f). Spatial separation of continuum emission (white area) and Na atom emission (orange area) was confirmed in ethylene glycol solutions, whereas only continuum emission was observed in NaCl aqueous solutions. Spatial distribution of emission was very different between both solutions. In NaCl aqueous solutions, the distribution shows a wedge shape, which is well known phenomenon. Bubble layer is not uniform under the horn surface because acoustic pressure is largest at the center of horn surface. This generates higher bubble density at the center and lower bubble density at the circumference of the horn surface. The higher bubble density provides the lowering of sound velocity which resulted in convergent distribution of bubble. In ethylene glycol solutions, the emission distribution exhibits a hemisphere shape especially at lower pressure as shown in Fig.2 (a) and (b). These contasting shapes are associated with bubble motions in both solutions.

3.2 Observation of cavitating bubbles using high speed camera.

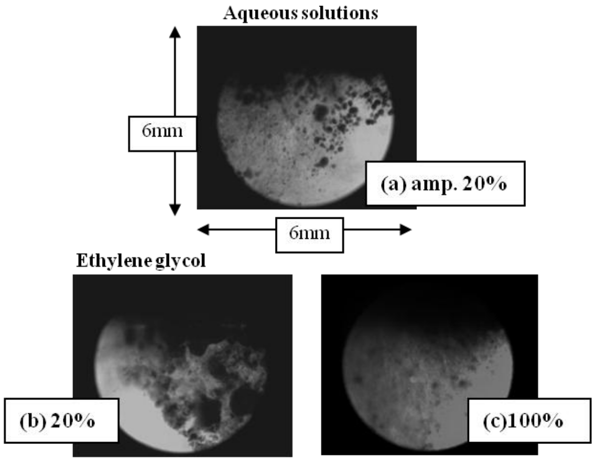

Fig. 3 High speed movies of cavitating bubbles (a) in water , and (b), (c) in ethylene glycol solution using a 24kHz horn.

We observed dynamics of cavitating bubbles at the speed of 32,000 fps. Figure 3 shows images from high speed movies in water at pressure amplitude of 20 % (a), and in ethylene glycol at amplitude of 20 % (b) and of 100 % (c). Bubble motion in water converges at a point. Figure 3 (b) showed a peculiar bubble movement in ethylene glycol, where large bubbles stayed just under the horn. In water acoustic streaming emanates from a large acoustic pressure just under the horn. Generated bubbles, therefore, move along the course of the acoustic streaming. On the other hand, the bubbles in Fig.3.(b) are large and stay under the horn. Sound waves attenuate owing to the large viscosity, leading to less acoustic streaming.

3.3 Dependence of viscosity

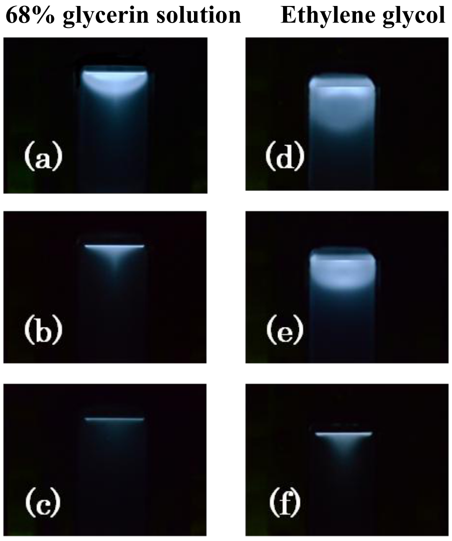

Fig. 4 Sonoluminescence of continuous emission from Ar-saturated glycerin solutions (a)-(c) and ethylene glycol solutions (d)-(f) using a 24kHz horn transducer. Photograph ware obtained at the amplitude of 20%, 40% ,and 100% from top to bottom.

Sonoluminescence of continuum emission as a function of ultrasonic pressure amplitude using a 24kHz horn is shown in Fig. 4. Figure 4 (a)-(c) are photographs in 68% glycerin solution, viscosity of which is similar to ethylene glycol, and (d)-(f) are those in ethylene glycol. Each ultrasonic amplitude is 20%:(a) and (d), 40%:(b) and (e), and 100%:(c) and (f). In both solutions, the emission region is hemispherical shape at lower pressure amplitude. On the other hand, the emission region becomes to be wedge shape with increasing pressure amplitude. The emission region with hemisphere shape is corresponding to large bubbles as observed in Fig. 3 (b).

References

[1] B. Dubus et al. : "On the physical origin of conical bubble structure under an ultrasonic horn " Ultrasonics Sonochemistry 17 (2010) 810–818

[2] P.-K. Choi, S. Abe, and Y. Hayashi, J. Phys. Chem. B, 112, 918(2008)