1J1-4

Effects of electric fields on sonoluminescence intensity and bubble dynamics

ソノルミネセンス強度と気泡運動への電場の影響

Hyang-Bok Lee[1†] and Pak-Kon Choi[2] ([1]Dept. of Mathematical and Physical Sciences, Japan Women's Univ.; [2] Dept. of Physics, Meiji Univ.)

李香福 [1†], 崔博坤 [2] ([1] 日女大理, [2] 明大理工)

1. Introduction

Microbubbles suspended in water are considered to be negatively charged at the liquid–bubble interface [1,2]. However, the electrical charge at the liquid–bubble interface of acoustic cavitation bubble has not been studied.

The interface conditions of cavitation bubble are different from normal microbubble. Inside of cavitaition bubble becomes a high–temperature and high–pressure states and those conditions lead to chemical reactions producing molecules such as OH and HNO_2 and also emit light, called sonoluminescence (SL), at bubble collapse. Those products inside bubble diffuse out into bulk water through the liquid–bubble interface [3-5].

We investigated the existence of charge at an interface of bubble exhibiting single-bubble sonoluminescence (SBSL) in water. We applied DC voltage to the bubble trapped in a standing wave under primary Bjerknes force, and determined whether the bubble was charged or not from the observation of bubble translation under electric fields. If SL bubble is electrically charged, the bubble will move to an equilibrium position balancing primary Bjerknes force and electrostatic force.

Our previous study showed that a SBSL bubble in water is positively charge. Further the amount of bubble translation under electric fields was dependent on a duration time of sonoluminescence [6]. This result suggested that the products generated inside bubble affected the charge of SBSL bubble.

If the interface of SBSL bubble is electrically charged, it is expected that external electic fields influence to the bubble expansion and contractioin. We measured the effect of electric fields on bubble expansion and contraction by using a light scattering technique. The light scattering measurements showed that the bubble size and SL intensity increased when negative voltage was applied to the hot electrode. Appling positive voltage resulted in the decrease in the bubble size and SL intensity. Those results also support that SL bubble is positively charged.

leeh@fc.jwu.ac.jp

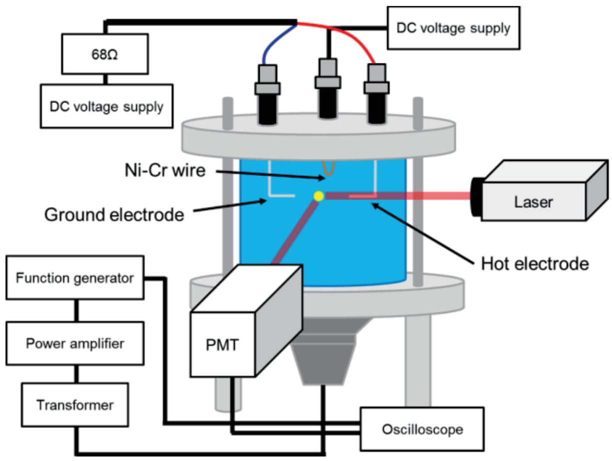

Fig. 1 Experimental system for SBSL.

2. Experimental

Figure 1 shows an experimental system for SBSL. The ultrasound frequency used was 28.5 kHz. The sample liquid was deionized water, which was degassed until the dissolved oxygen was less than 1 mg/L, and the electric conductivity was 1 μS/cm. The sample liquid was contained in a cylindrical cell (a depth is 64 mm and height is 66 mm) made of quartz glass. The temperature of the cell was kept at 13℃ by circulating temperature-controlled water through a silicone tube that surrounded the cell.

For applying electric fields, we used platinum needles with diameter of 0.5 mm as electrodes. The electrode tips were faced with each other. The distance between electrodes was 12 mm and the bubble was located in the middle of the electrodes. We applied direct-current (DC) voltage in the range from − 60 V to + 60 V to electrodes.

The expansion and contraction of SBSL bubble can be examined by light scattering intensity measurement. As shown in Fig.1, a laser (Thorlabs CPS 635F) was irradiated to the SBSL bubble, and the light scattered from the bubble was received by a photomultiplier (Hamamatsu Photonics H7422-01) and observed with an oscilloscope

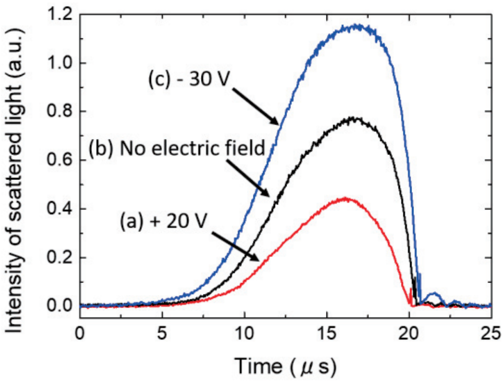

Fig. 2 Intensity of scattered light under electric fields.

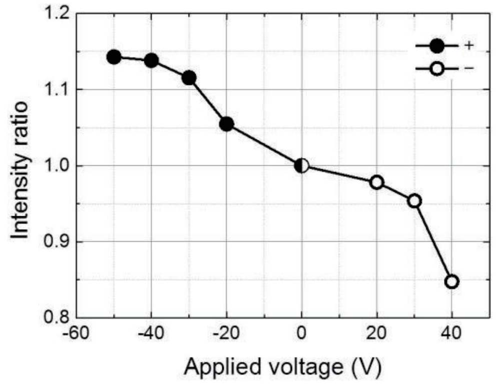

Fig. 3 Dependence of SBSL intensity on applied voltage to the electrodes.

(Agilent DSO5052 A, 4G Sa / s). The scattered light signal was averaged 256 times. We also measured the intensity of SBSL with the photomultiplier.

3. Results and discussion

We measured the effect of electric fields on bubble expansion and contraction by using a light scattering technique. Since the scattered light intensity is proportional to the cross section of bubble, the change in the bubble diameter can be obtained by measuring the scattered light intensity.

Figure 2 shows the result of measuring the light intensity scattered from the SBSL bubble under electric fields. In Fig. 2, (b) is a scattered light signal in the absence of electric fields. Expansion, contraction, and rebound motion of SBSL bubble are recognized. Also SL pulses were observed around 20 μs. (a) shows the case when +20 V was applied to the hot electrode. The maximum intensity of scattered light decreased and the timing of SL shifted earlier. Furthermore, when −30 V was applied (c), the maximum intensity of scattered light increased and the timing of SL was delayed. These results are explained as follows.

The distance between the bubble and the electrode is sufficiently large compared to the bubble diameter. If the maximum radius of bubble is assumed to be 50 μm, the potential difference between the bubble center and the bubble wall is only 1.5%. Thus the electric fields in the range of bubble size are nearly uniform. The positively charged bubble is subjected to repulsive force under positive voltage, then the bubble growth is suppressed and the bubble diameter is reduced. Conversely, under negative voltage, the bubble growth was promoted, so that the bubble diameter increased.

In addition, we observed the change in SL intensity under electric fields. **Figure 3** shows the SBSL intensity as a function of applied voltage to the hot electrode. The SBSL intensity was measured with the photomultiplier during 10 seconds and was averaged. The SBSL intensity normalized to the value in the absence of electric fields. The SBSL intensity decreased under positive voltage and increased under negative voltage. The SBSL intensity was changed about 15 % when −50 V or +40 V was applied to the hot electrode.

We consider that the variation of the SBSL intensity under electric fields is due to the change in minimum bubble diameter. As the maximum diameter of bubble increases, the bubble collapse occurs more violently, leading to the increase in SL intensity. The present results of the change in the SBSL bubble diameter under electric fields strongly supports that SBSL bubble is positively charged. Additional research is needed to clarify the charging mechanism of SBSL bubble.

Acknowledgment
This work was supported by JSPS Grant Number 19K15452.

References

1. B.E. Conway: J. Solution Chem. **7** (1978) 721.
2. M. Takahashi: J. Chem. Phys. B. **109** (2005) 21858.
3. B. P. Barber, R. A. Hiller, R. Lofstedt, S. Putterman, and K. R. Weninger: Phys. Rep. **281** (1997) 65.
4. D. Lohse, and S. Hilgenfeldt: J. Chem. Phys. **107** (1997) 6986.
5. K. Yasui, T. Tuziuti, Y. Iida, and H. Mitome: J. Chem. Phys. **119** (2003) 346.
6. H.-B. Lee and P.-K. Choi: Proc. Symp. Ultrason. Electron. **39** (2018) 3P4-3.