EVALUATION OF THE NUMBER OF CAVITATION BUBBLES AT VARIOUS CONTENTS OF DISSOLVED AIR

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Abstract

Evaluation of the number of cavitation bubbles in an ultrasonic standing wave field at various contents of dissolved air is studied experimentally with light scattering. When a thin light sheet finer than half of wavelength of sound is introduced into the cavitation bubbles at an antinode of sound pressure, the scattered light intensity oscillates. The peak-to-peak light intensity corresponds to the number of the bubbles which contribute to the sonochemical reaction because the radius for oscillating bubbles at pressure antinode is restrictive in a certain range due to the shape instability and the action of Bjerknes force that expels from antinode bubbles larger than the resonant size. It is shown that, as the air content varies, the tendency in the peak-to-peak intensity is in good agreement with the tendency for the yield in the sonochemical reaction of the liberation of iodine from a KI solution under the irradiation of ultrasound.

Introduction

When a liquid is irradiated by intense ultrasound, more contents of dissolved gas in liquid have a greater probability to produce cavitation bubbles and some studies on the influence of the content of dissolved gas on the sonochemistry or sonoluminescence have been performed [1-3]. The authors clarified that the effect of ambient-pressure reduction on the intensity of sonochemiluminescence caused at supersaturation of solution [3]. Dissolved gas content is an important parameter to study the cavitation mechanism in a sonochemical field.

In this paper, the number of cavitation bubbles that repeat expansion and contraction in the ultrasonic standing-wave field is investigated through the intensity measurements of scattered light from bubbles changing the content of dissolved air. Next, the experiment for the yield in the sonochemical reaction of the liberation of iodine from a KI aqueous solution under the irradiation of ultrasound is implemented to compare with the results by the light scattering.

Experiment

Experiment of light scattering by cavitation bubbles

A cw sinusoidal signal of 142 kHz generated by a function generator was amplified with a 55-dB power amplifier. The electric output was fed to a 45 mm diameter Langevin-type transducer. The transducer was fixed to a stainless steel plate. A rectangular glass cell of 50 x 50 x 145 mm^3 internal dimensions was set above the transducer. The thickness of the glass cell was 5 mm. Distilled water in the cell was 250 cm^3 and the temperature was 20 ^oC. Air content of the distilled water was adjusted by bubbling air. The content of dissolved oxygen (DO) in the distilled water was measured with a DO meter and served as an index of the amount of dissolved air. Laser-sheet light was introduced into cavitation bubbles generated at an antinode of a sound pressure in the cell, and the intensity of scattered light from the bubbles were measured, where the illuminated area was tetragonal and half of one anti-nodal plane which one side was set closely to the sound beam axis. Large bubbles originated from the coalescence of tiny bubbles are expelled from the antinode due to the action of Bjerknes force [4], and they are out of observation. Therefore, it is possible to detect the intensity of scattered light from only tiny bubbles by the present method. The intensity of scattered light from bubbles was measured with a photomultiplier tube through a converging lens and a slit. The waveform of scattered light, which is composed of superposition of scattered light intensity according to the scattering cross section of each bubble repeating expansion and contraction due to the acoustic cycle, is recorded with a digital oscilloscope controlled by a computer. Each data obtained was the one averaged over 32 times. In the present experimental condition, an ultrasonic power input to the cell was determined calorimetrically and the value is 11 W.

Experiment of sonochemical reaction

Next, the experiment for the yield in the sonochemical reaction of the liberation of iodine from a KI aqueous solution under the irradiation of ultrasound is implemented to compare with the results by the light scattering. Ultrasonic irradiation into an aqueous KI solution produces oxidation of I^- ions to give I_2 and I_2 reacts with I^- to form I_3^- ions in the presence of excess I^- ions [5]. In the present experiment an absorbance measurement with a spectrophotometer was performed within the range from 300 to 500 nm including the absorbance of I_3^- at 352 nm. 0.1 M-250 cm^3 KI aqueous solutions with different DO content was prepared and sonicated by 3 minutes. Just after 5 minutes from the end of the irradiation, the absorbance of the solution was measured on each case.

Results and Discussions

Figure 1 shows an example of measured waveform of intensity of scattered light from cavitation bubbles at 8.86 mg/L in DO content where the liquid is air-saturated. We can confirm the intensity oscillating with the same period as that of the applied ultrasound (7 μs). Since peak-to-peak light intensity of such waveform corresponds to the number of active cavitation bubbles, to clarify the relationship between the peak-to-peak intensity and sonochemical reaction yield is attempted for various DO contents in the next, where the peak-to-peak light intensity is defined as the difference between the maximum and minimum of the light intensity.

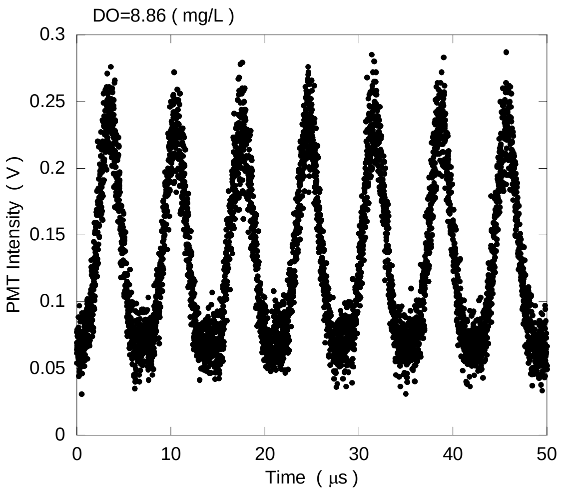

Figure 1: An example of measured waveform of scattered light from cavitation bubbles.

Figure 2 shows the comparison in DO-content dependence between the peak-to-peak scattered light intensity and the peak value of I_3^- absorbance. In the figure filled circles are for the averaged peak-to-peak intensity of scattered light over 3-minutes measurement under irradiation of ultrasound, where the intensity is plotted as the value at the intermediate DO content determined from DO content measured before and after the irradiation. Open circles are for the peak value of absorbance at different DO content, where the intermediate DO content was used to plot the data similarly to the case of scattered light-intensity measurement. It was shown that cavitation threshold for DO content existed at both cases of scattered light intensity and the absorbance. In a range of 4 to 5 mg/L in DO content the absorbance was not detected while the scattered light intensity was done due to the higher sensitivity of this method. There was a good agreement in the tendency that the appearance of dip at around 7 mg/L in DO content was observed in both cases and also the light intensity and the absorbance were saturated at the highest DO content respectively. Accordingly, peak-to-peak scattered light intensity from cavitation bubbles corresponds to the number of active cavitation bubbles effective for sonochemical reaction. Thus, through the above study of scattered light from cavitation bubbles comparing with the sonochemical reaction yield, we conclude that the present method of light scattering has a proof of good cavitation-bubble detector for sonochemistry. Future study will deal with a clarification of a mechanism for the dip appeared in both cases of scattered light intensity and the absorbance.

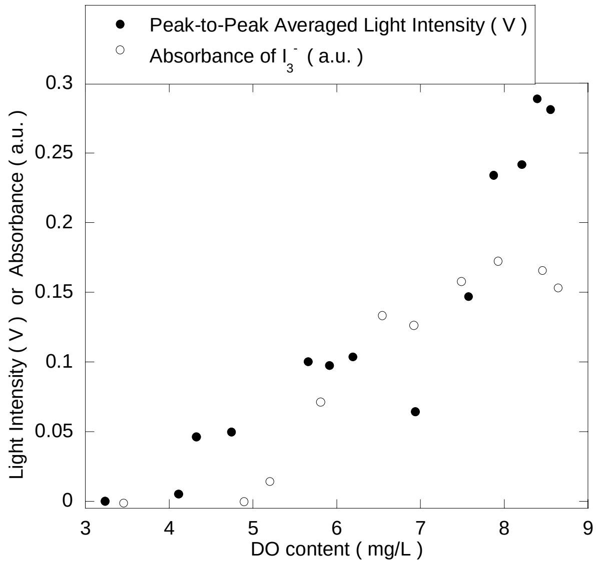

Figure 2: Comparison in DO-content dependence between the peak-to-peak scattered light intensity and the peak value of I_3^- absorbance.

Acknowledgements

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