

OH Emission and Bubble instability in single-bubble sonoluminescence

ソノルミネセンスにおける OH 発光と気泡の不安定性

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1. Introduction

The emission from the excited state of OH radicals has been observed in single-bubble sonoluminescence (SBSL).^{1,2)} This emission was observed at low acoustic pressures where the intensity of continuum emission is very small. It was predicted that the OH line is emitted from a lower temperature bubble.^{3,4)}

Further studies are required to clarify the mechanism of the OH emission from a single bubble. We present the experimental results exploring the correlation of OH emission with bubble instability.

We examined the dependence of the dissolved Ar pressure on the OH line spectra in SBSL. We observed the bubble trajectory using a high-speed shadowgraphy.

2. Experimental

Figure 1 shows the experimental setup for observing SBSL spectrum and bubble dynamics. We used two kinds of sample. First, deionized water was degassed down to 19% of the saturated value. For preparing Ar containing water, deionized water was degassed down to 3% and Ar gas was dissolved under 7, 15, 30, 45, or 60 kPa.

The sample was contained in a cylindrical quartz glass cell. The temperature of the cell was kept at 13°C by circulating cooled water around the cell using a tube.

A sandwich transducer with a fundamental frequency of 28 kHz was glued by epoxy-resin adhesive to the bottom of the cell. A continuous signal from a function generator was amplified using a power amplifier and impedance-matched

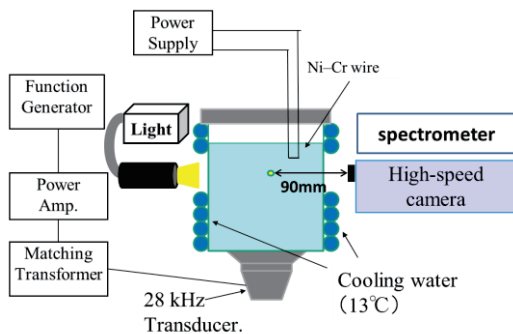


Fig.1. Experimental setup for observing SBSL spectrum and the bubble shadowgraphy.

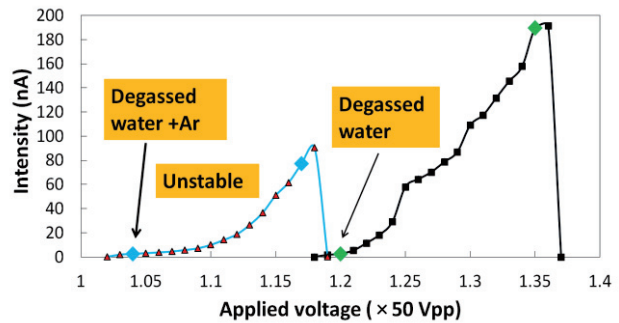


Fig.2. SBSL intensity vs. applied voltage

using a transformer. The ultrasonic frequency is 28.6 kHz. The speed of a high-speed camera was 30,000 fps, and this is nearly the same as the ultrasonic frequency.

Figure 2 shows the SBSL intensity as a function of applied voltage for degassed water (closed squares) and Ar containing water (triangles). The OH emission was only observed at low applied voltages, indicated by the arrow for Ar containing water.

3. Results and discussion

3.1 Ar pressure dependence of the spectrum

Figure 3 shows the Ar pressure dependence of the OH lines spectra from degassed water and water containing Ar from 7 to 60 kPa. We could not measure the OH lines for degassed water. The three peaks observed can be attributed to the vibronic transitions of about 290 nm (A→X, 1 to 0), 310 nm

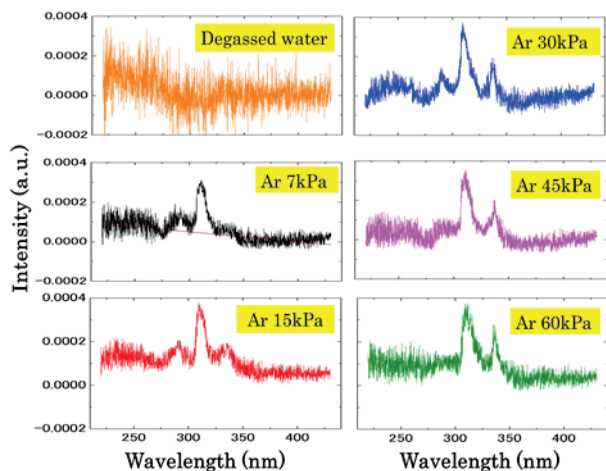


Fig.3. SBSL spectra from degassed water and Ar containing water.

(A→X, 0 to 0), and 340 nm (A→X, 0 to 1). Interestingly, the relative intensity of these three peaks varies by changing Ar pressure. Figure 4 shows the variation of the ratio of these three peaks. The peak intensity is normalized by the value of 310 nm. With increasing Ar pressure, the 290 nm peak relative to the 310 nm peak decreased, and the 340 nm peak increased.

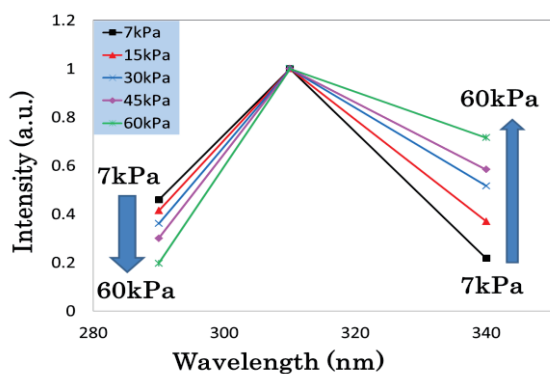


Fig.4. Dependence of the peak ratio of vibronic transitions on Ar pressure.

3. 2 Bubble dynamics

Figure 5 shows a typical example of the bubble fragmentation in water containing 30kPa Ar. The bubble moves around while fragmenting a daughter bubble and soon coalesces. This fragmentation makes the bubble unstable.

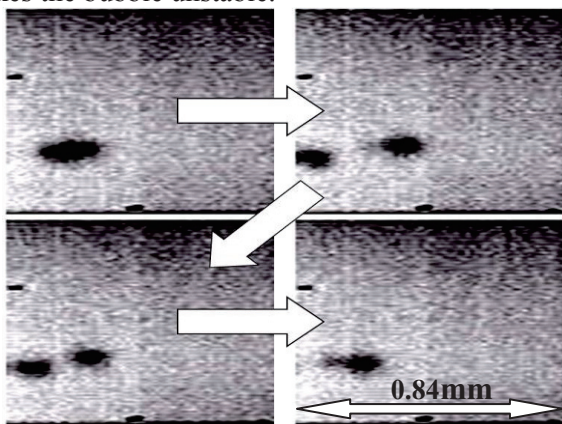


Fig.5. Bubble fragmentation and coalescence in water containing 30 kPa Ar .

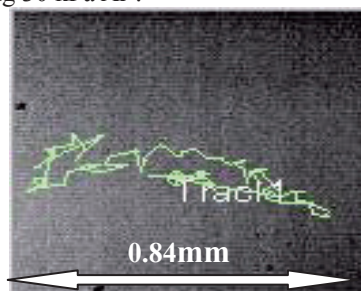


Fig.6. Bubble trajectory in water containing 30 kPa Ar

The bubble movement in the movie can be tracked using a software and the bubble path length was measured during 16.7 ms (500 frames). Figure 6 shows the bubble trajectory in water containing 30 kPa Ar, represented by a green line.

Figure 7 compares the bubble path length and the peak intensity at 310 nm as a function of the Ar pressure. The bubble path length increases with the increase in Ar pressure. The peak intensity at 310 nm also increases up to 30 kPa and shows saturation.

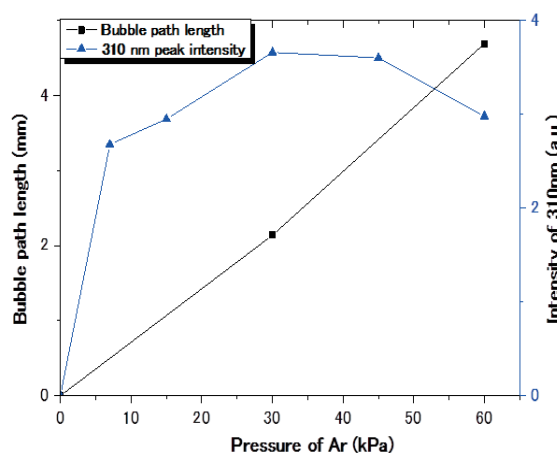


Fig.7. Dependence of the intensity at 310 nm (triangles) and the bubble path length (squares) on the Ar pressure

4. Conclusion

Three spectral lines of OH emission were observed from Ar containing water in SBSL. A high-speed observation of the bubble showed that the OH emission originates unstable bubble that repeats fragmentation and coalescence. With increasing Ar pressure, the relative intensities of three OH vibronic transitions changed. There are two possible reasons. Bubble core temperature may decrease with increasing Ar pressure owing to the translational motion. Another reason is the effect of formation of ArOH exciplex. If ArOH van der Waals molecules are formed in the bubble at collapse, the potential energy of OH excited state may shift and this provides the change in relative peak intensities according to the Franck-Condon principle.

References

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