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Dissolved gas and ultrasonic frequency dependences of two types of Na emission in sonoluminescence

Na ソノルミネセンスの二つの成分の溶存ガス・周波数依存性

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1. Introduction

In the study of sonoluminescence from alkali-metal salt solution induced by ultrasonic cavitation, we observed a broadening and peak shift of the alkali-metal atom lines which were caused by a high temperature and high pressure within bubbles. Sonoluminescence from NaCl solution exhibited Na emission composed of peaks at 589.0nm and 589.6nm, and a continuum extending from ultraviolet to infrared region. Hayashi and Choi[1] suggested that the Na lines consists of two components, one of which is broadened component which are shifted from original D lines, and the other is unshifted narrow component. We refer these components as Broad and Narrow component. These two components are suggested to originate from different bubble populations from the observation that the timing of light pulses and light emitting distribution were different between the Broad and Narrow components[2]

In order to investigate the origine of these two components, we examined dissolved gas and ultrasonic frequency dependences of Na emission in sonoluminescence.

2. Experimental

NaCl aqueous solution with the concentration of 4M was degassed and saturated with rare gas. The solution, a volume of 350 mL, was contained in a cylindrical glass cell.The temperature of the cell was kept at 15℃ by circulating temperature-controlled water. A sandwich-type transducer with a fundamental frequency of 28 kHz or a piezoceramic transducer with a frequency of 512kHz 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 using a transformer. Emitted light was analyzed using the system of a monochromator and a cooled CCD detector.

We examined the frequency dependence of Na components and a blue satellite peak (BSP) at 558nm in Ar saturated NaCl aqueous solution at an electrical power of 20W. The measured frequencies were 85, 145 and 512 kHz.

The spectrum of Na components was also measured at the electrical power of 25W, and the frequency of 145kHz, while changing the He, Ne, Ar or Kr gas dissolved in the solution.

3. Results and discussion

3. 1 Ultrasonic frequency dependence

Figure 1 shows the ultrasonic frequency dependence of Na emission spectra from Ar-saturated 4-M NaCl aqueous solutions. Spectrum in the upper right corner of Fig.1 shows the BSP at 558nm. All spectra are normalized by their maximum intensities. As the frequency increases, the line width seems to be narrower. This may be caused by the relative change of the intensity of Broad and Narrow components. The intensity of BSP decreased with frequency.

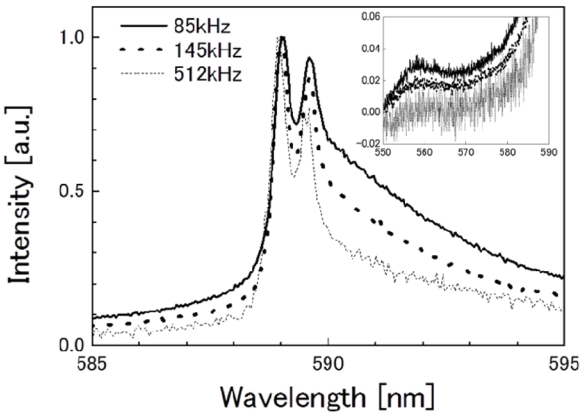

Fig.1. Effect of ultrasonic frequency on Na emission spectra from Ar-saturated 4 M NaCl aqueous solutions at 20W. All spectra are normalized by their maximum intensities. The inset shows blue satellite peaks centered at about 558nm.

We resolved the spectra in Fig.1 into two Broad and two Narrow components using the method by Kazachek et al.[3] Figure 2 compared the relative intensity of Narrow and Broad components at 589.0nm and BSP at 558nm. As the frequency increases, the intensity of Narrow component increases. On the contrary, the intensities of Broad component and BSP decrease.

Lepoint-Mullie et al[4] concluded that the alkali-metal atom emission occurs in the gas phase from the observation that rare-gas dependence of the BSP accorded with the results by gas-phase

fluorescence. They considered that alkali-metal atom and rare gas form Van der Waals molecules and the origin of the BSP is the transition from the higher excited state of the molecules to the ground state, i.e., $B^2\Sigma^+ - X^2\Sigma^+$.

The present results indicated the similar frequency dependence between the intensity of BSP and Broad component. Broad component is asymmetrically broadened and red shifted, indicating this component corresponds to the transition of $A^2\Pi^+ - X^2\Sigma^+$. Thus, the Broad component and BSP are caused by the strong interactions with alkali-metal atom and rare gas in the bubble at collapse.

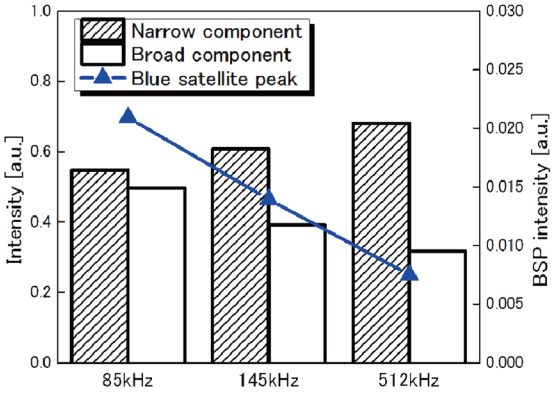

Fig.2. Effect of ultrasonic frequency on the relative intensities of Narrow and Broad components, and BSP from Ar-saturated 4-M NaCl aqueous solutions at 20W.

3. 2 Dissolved gas dependence

Figure 3 shows the spectrum of the Na emission from 4 M NaCl solutions dissolved with He, Ne, Ar or Kr at the power of 25W and the frequency of 145kHz. The line width is broader, and the line shape is more symmetrical, as the atomic number of the dissolved gas decreases.

The spectra in Fig.3 were separated to Broad and Narrow components by simulation, and their intensities and their ratio are plotted in Fig. 4 for various dissolved gas. The intensity of Narrow component relative to Broad one increases when the dissolved gas changes from He to Kr. The thermal conductivity of the rare gas is reduced in the order of He, Ne, Ar, and Kr. Kr has the smallest thermal conductivity, resulting in the highest temperature at bubble collapse because heat within bubble is hard to conduct from the bubble.

Thus, when Kr is dissolved, the temperature within bubble may be higher than He. Therefore, Narrow component originates from bubbles of higher temperature than those for Broad component.

The rare gas dependence of the half width of the Broad components is consistent with the spectroscopic literature values for the gas phase[5]. This suggests that the cause of the Broad component is the collisional interaction of the rare gas and alkali metal atoms in the bubbles.

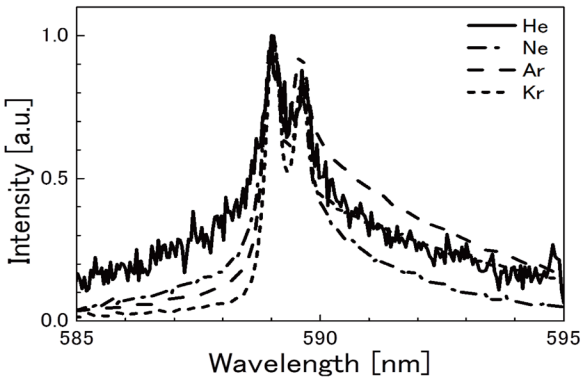

Fig.3. Effect of dissolved gas on Na emission lines in 4 M NaCl solutions at 145kHz.

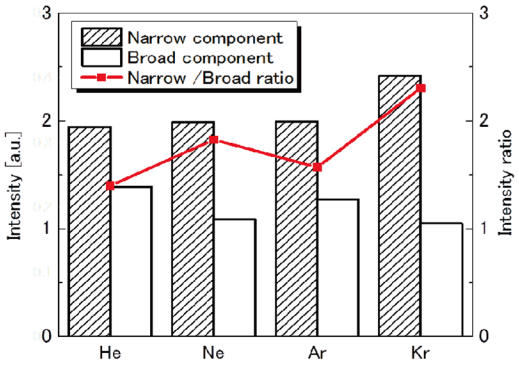

Fig.4. Rare gas dependences of relative intensity of Narrow and Broad components.

4. Conclusion

Sonoluminescence from NaCl solution exhibited two types of Na emission, Broad and Narrow components, and BSP. The Broad component and BSP are originated from strong interactions with alkali-metal atom and rare gas in the bubble, suggesting the formation of van der Walls molecules. Narrow component is associated with higher-temperature conditions within bubble.

References

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