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The Effects of Gas Sparging and Reflector on Sonochemical Oxidation in 300 kHz Sonoreactors

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1. Introduction

Acoustic cavitation can induce significant sonochemical and sonophysical effects and many sonochemists have optimized these effects for various ultrasonic processes including material synthesis, pollutants removals, washing/cleaning, and energy generation. Recently some researchers have investigated the effect of geometric factors such as liquid height/volume, stability of liquid body, and reflector and it was revealed that even very small change in geometric factors can cause significant impact on sonochemical and sonophyscial reactions.[1-5)]

The purpose of this study is to understand the effects of liquid height/volume, gas sparging, and reflectors on sonochemical oxidation reactions in 300 kHz sonoreactors. The sonochemical oxdiation was quantified using the KI dosimetry and the cavitation active zone was visualized using the luminol method (sonochemilumenescence, SCL).

2. Materials and methods

Figure 1 shows the sonoreactor system used in this study. The transducer module was placed at the bottom of the reactor and the module includes four 300 kHz transducers. The liquid height based on the wavelength (λ) of the applied frequency increased from 5 λ (25 mm, 4.5 L) to 30 λ (150 mm, 8.9 L) and the wavelength was obtained using the following equation:

$$\text{Wavelength}\ (\lambda) = \frac{c}{f}\ , \qquad (1)$$

where c is the speed of sound in water (1500 m/s) and f is the applied frequency.[2)] The electrical input power, which was measured using a power meter (HPM-300A, ADpower), was 260 W for all cases. The calorimetric energy was obtained using the following equation:

$$P_{cal} = \frac{dT}{dt} C_P M\ , \qquad (2)$$

where P_{cal} is the calorimetric energy, dT/dt is the rate of increase of the liquid temperature, C_p is the specific heat capacity of the liquid (4.2 H/(g·K) for water), and M is the mass of the liquid. [2)]

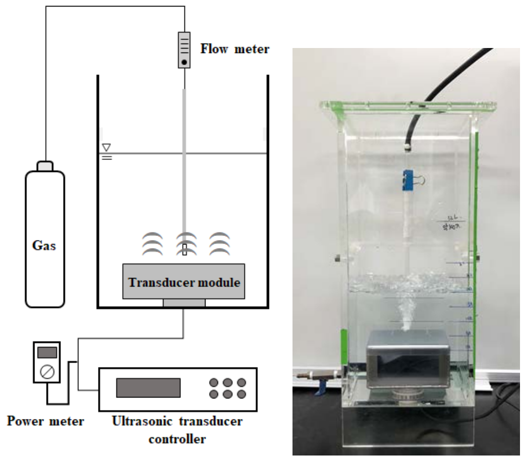

Fig. 1 The sonoreactor system used in this study.

The glass sparger was placed 1 cm above the transducer module to supply gas molecules continuously. The flow rate was 0 to 6 L/min. The dissolved oxygen (DO) concentration was measured using a DO meter (ProODO, YSI).

To quantify sonochemical reactions the KI method (KI conc.: 1 g/L) was used and the cavitation-active zone was visualized using the luminol method (luminol conc.: 0.1 g/L, NaOH conc.: 1 g/L). [2)]

3. Results

Figure 2 shows the mass of I_3^- formed for various liquid height and air flow rate conditions. Because the liquid volume changed from 4.5 to 8.9 L, the mass of I_3^- was introduced to appropriately compare the degree of sonochemical reactions. For no air sparing condition, the highest value was obtained at 5 and 10 λ and then the mass of I_3^- decreased significantly as the liquid height increased. It was reported that the highest sonochemical values in terms of the mass of sonochemical reactions' product could be obtained from 5 to 10 λ for various frequency conditions. [2)] The images of SCL for 5 to 30 λ were shown in **Figure 3**.

In our preliminary tests air sparging (3 to 12

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L/min) was very effective to enhance sonochemical oxidation reactions in the same sonoreactors for 36 kHz. However significant enhancement by the air sparging was observed only at 20 λ for 300 kHz as shown in Figure 2. It might be explained by the following reasons: 1) The air sparging can induce violent mixing and supply oxygen molecules continuously, which are one of the sources of oxidizing radicals such as hydroxyl radicals; 2) The sound field or cavitation-active zone can be transformed severely by the air sparging and less sonochemical oxidation reactions occur under non-favorable condition for cavitation events; 3) The instability of the liquid body can increase because very unstable liquid surface and standing wave field can be formed when the air sparging is applied for higher liquid heights such as 30 λ. The first factor can enhance sonochemical oxidation while second and third factors may be disputable.

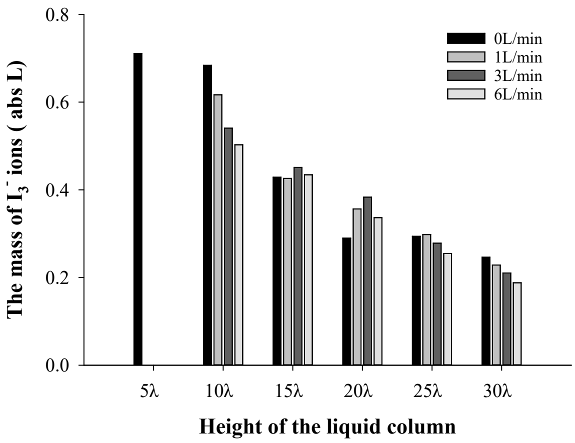
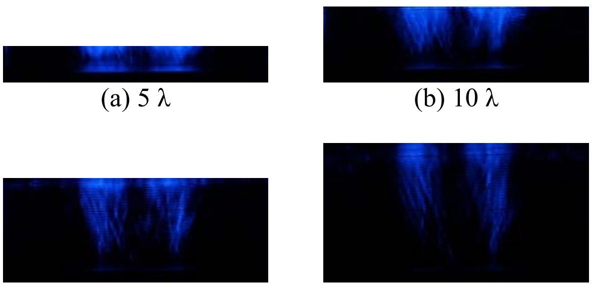


Fig. 2 The mass of I_3^- ions for various liquid height and air flow rate conditions (No air sparing was applied for 5 λ due to the narrow depth).



(a) 5 λ (b) 10 λ

(c) 15 λ (d) 20 λ

(e) 25 λ (f) 30 λ

Fig. 3 SCL images for various liquid height conditions (No gas sparging and reflector was applied.).

Figure 4 shows the mass of I_3^- ions for various gas sparging and reflector conditions at the liquid height of 20 λ where the enhancement by air sparging was observed. Interestingly, the sparging of Ar and O_2 was not effective and the parafilm reflector resulted in relatively high sonochemical activity comparing to other reflector conditions.

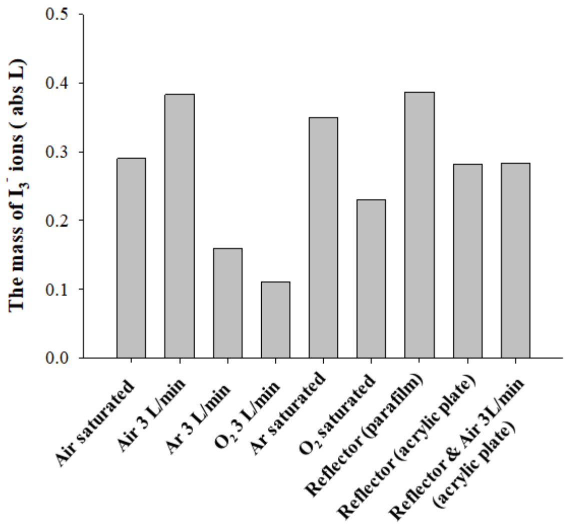


Fig. 4 The mass of I_3^- ions for various gas and reflector conditions.

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