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Comparison of Sonochemical and Sonophysical Effects in 20 kHz Horn-type Sonoreactors

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1. Introduction

Ultrasound technology has been widel used in various field. Ultrasound irradiation induces cavitation phenomena and violent sonochemical and sonophysical effects and these effects enable to design effective chemical engineering and environmental engineering processes.[1)]

One of the most commonly used ultrasonic in lab-scale experiments apparatus is a probe-type sonicator, which generates very powerful low-frequency ultrasound from a small tip. Generally the probe-type sonicator is placed in a small vessel and relatively homogeneous ultrasonic effects in the vessel can be expected.

Recently the importance of geometric factors on ultrasonic reactions has been reported and optimziation of probe-type sonicator in terms of geometric factors has been rarely reported.[1-5)] In this study the effect of probe-type sonicator position in the vessel was investigated for various liquid volumes. The KI method and luminol method were used to quantify the degree of sonochemical reactions. In addition, the aluminum foil method and glass beads method was used to analyze sonophysical effects.

2. Materials and methods

The 20 kHz probe-type sonicator (VCX-750, Sonics & materials, Inc.) equipped with a solid probe (13 mm) was place in various vessels including 100, 250, 500, and 1,000 mL vessels. The probe was placed at three positions including 1 cm above from the bottom (designated as “B”), at mid position (designated as “M”), and 1 cm below the water surface (designated as “T”) as shown in **Figure 1**. The input power was 25, 50, and 75 % and the calorimetric energy was obtained using the following equation:

$$P_{cal} = \frac{dT}{dt} C_P M \quad , \qquad (1)$$

where P_{cal} is the calorimetric energy, dT/dt is the rate of increase of the liquid or soil temperature, C_p is the specific heat capacity of the liquid or soil (4.2 J/(g·K) for water and M is the mass of the liquid.[1)]

Fig. 1 The positions of the sonicator’s probe used in this study.

To quantify sonochemical reactions the KI method (KI conc.: 10 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).[1)] Sonophysical effects were analyzed using the aluminum foil method and the glass beads methods: An aluminum foil was placed in the vessel and the degree of damage by ultrasound irradiation was analyzed; the painted glass beads were placed at the bottom of the vessel and the degree of peeling by ultrasound irradiation was analyzed.

3. Results

Figure 2 shows the variation of I_3^- concentration and mass for various liquid volumes and probe positions. Because the liquid volume changed from 100 to 600 mL in different vessels, the mass of I_3^- was introduced to appropriately compare the degree of sonochemical reactions. Under the same input electrical energy (50 %) the mass of I_3^- increased as the liquid volume increased. Interestingly, the mass of I_3^- for the irradiation from the bottom (“B”) was much higher than other positions (“M” and “T”). This indicates that more violent sonochemical reactions occurred when the probe was place at the bottom and the characteristics of cavitation active zone could change significantly.

In order to investigate why violent sonochemical reactions occurred when the probe was place adjacent to the bottom of the vessel, sonochemiluminescence (SCL) images were obtained as shown in **Figure 3**. The location and the size of cavitation-active zone, where bright light was detected, changed significantly depending on

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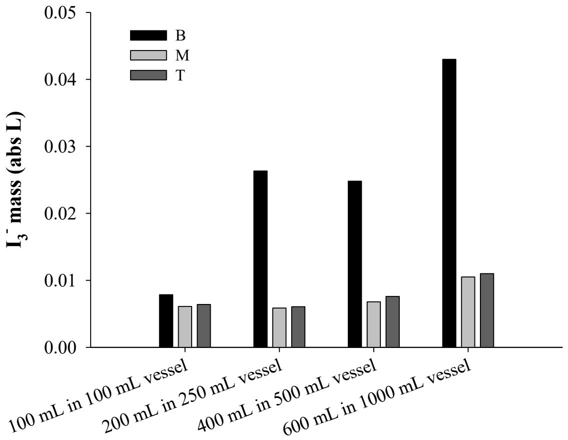
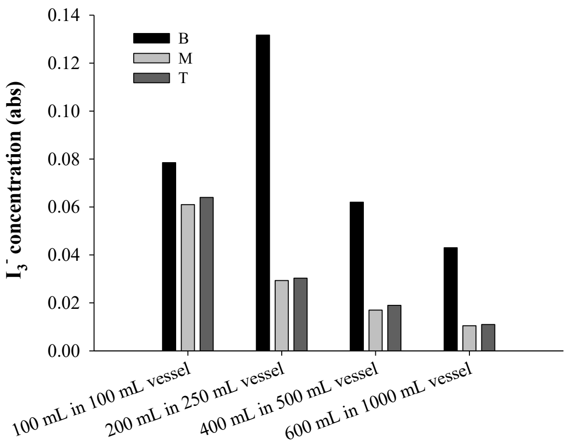
the position of the probe in the vessel. As expected, the cavitation-active zone for the bottom irradiation ("B") was much wider and brighter than other conditions' zones. In the ultrasound irradiation for all probe positions bright zone was observed under the probe tip. On the other hand, very bright zone surrounding the probe column was also detected for the "B" condition. It might be due to the reflection of ultrasound from the bottom.

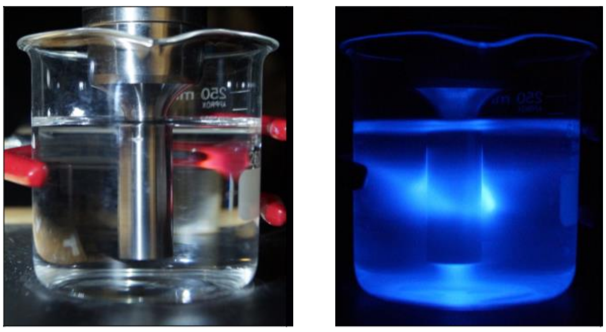


(a) The concentration of I_3^- for various conditions

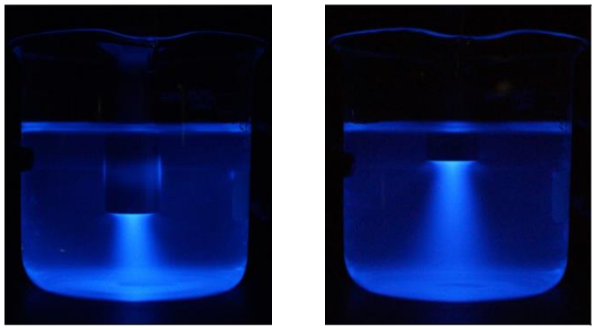


(b) The mass of I_3^- for various conditions

Fig. 2 The variation of I_3^- concentration and mass for various liquid volume and probe position conditions.

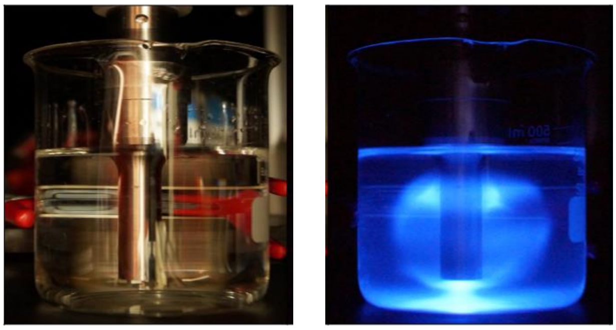


(a) Real image (b) SCL image for "B"

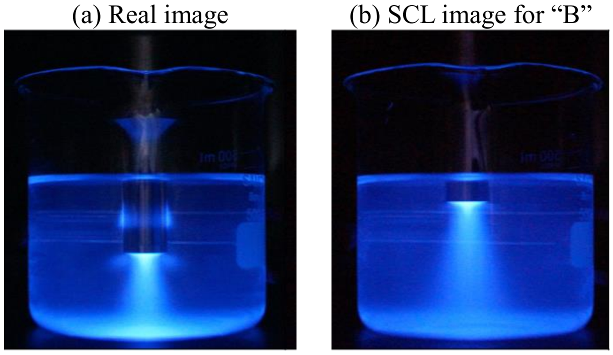


(c) SCL image for "M" (d) SCL image for "T"

Fig. 3 The SCL images for 200 mL in the 250 mL vessel.



(a) Real image (b) SCL image for "B"



(c) SCL image for "M" (d) SCL image for "T"

Fig. 4 The SCL images for 400 mL in the 500 mL vessel.

Acknowledgment

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References

1. Y. Son: Chem. Eng. J. **328** (2017) 654.
2. Y. Asakura, T. Nishida, T. Matsuoka, and S. Koda: Ultrason. Sonochem. **15** (2008) 244.
3. N. S. M. Yusof, B. Badgi, Y. Alghamdi, M. Aksu, J. Madhavan, and M. Ashokkumar: Ultrason. Sonochem. **29** (2016) 568.
4. K. Tran, Y. Asakura, and S. Koda: Jpn. J. Appl. Phys. **51** (2012) 07GD06.
5. B. Sajjadi, A. A. A. Raman, and S. Ibrahim: Ultrason. Sonochem. **24** (2015) 193.