2P4-14

Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 289-290
20-22 November, 2013

Geometric effects on sonochemical reactions

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1. Introduction

Many researchers have reported the significant effects of acoustic cavitation in various chemical and environmental engineering processes such as synthesis, cleaning, extraction, water treatment, and disinfection. However it seems that the application of ultrasound technology in industrial large-scale processes needs further research as Dr. Pandit's group, one of pioneering research group in the optimization and design of sonoreactors, recently reported. It is mainly because most previous works were conducted in laboratory scale sonoreactors, which were very small compared to industrial scale chemical reactors.[1-2)]

Recently some researchers have focused on the geometric effects on cavitational reactions and found sonochemical reactions could be noticeably enhanced by slightly changing the geometry of sonoreactors. Thus it can bridge the gap between labaratory small-scale sonoreactors and industrial large-scale sonoreactor to understand the geometric characteristics of sonoreactors.[1,3-4)]

The purpose of this study was to understand the geometric effects on sonochemical reactions in single and dual irradiation sonoreactors as one of the basic steps to develop ultrasound technology for industrial use. The formation of cavitation active zone in sonoreactors were compared using sonochemiluminescence (SCL) method and sonochemical reactions were quantified and analyzed using iodide method in both irradiation systems.

2. Experimental Methods

Figure 1 shows a schematic of the experimental setup. The sonoreactor consisted of an acrylic bath and ultrasound transducer module on each side. The distance between two transducer modules was changed and as a result of this the liquid volume was changed under the same input power condition. The opposite transducer module acted as a reflector in the case of single irradiation. The applied frequency was 334 kHz and the input powers for single and dual irradiation were 240 and 480W, respectively. The applied distances and power densities were summarized in Table I.

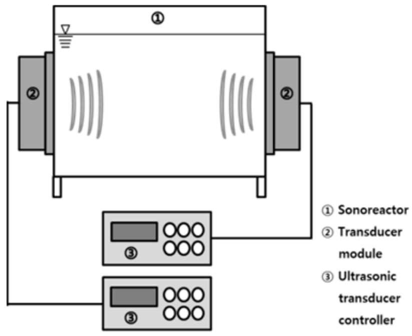

Fig 1. A schematic diagram of the experimental set-up.

Table I. Liquid volume and power density at each distance condition in single and dual irrdiation systems.

Experimental conditions		Distance between two modules				
		50	100	150	200	250
Power density (W/L)	Single	169	93	65	50	41
	Dual	338	186	130	99	81

To quantify the sonochemical reactions for each condition, the iodide method using KI solution (10 g/L) was used and the concentration of triiodide ion was analyzed using a UV-vis spectrophotometer (SPECORD 40, Anayticjena) at 350 nm. The result of each different liquid volume condition was compared using the cavitation yield, which means the amount of sonochemical reaction product per unit input power and unit irradiation time, as follows:

$$\text{Cavitation yield} = \frac{C V_L}{P_E T_I} \qquad (1)$$

where C is the triiodide ion concentration, V_L is the liquid volume, P_E is the input power, and T_I is the irradiation time.[1)]

To visualize and compare the formation of cavitation active zone of each condition SCL method was used using luminol solution (0.1 g/L

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luminol and 1 g/L NaOH) and an exposure-controlled digital camera in a completely dark room.[1)]

3. Results

Figure 2 shows the variation of the cavitation yields for single and dual irradiation condition in five distance conditions. The cavitation yields in dual irradiation were much higher than those in single irradiation for all distance conditions. Enhanced effects were calculated using Eq (2) as follows:

$$\text{Enhanced effect}_{\text{Cavitation yield}} = \frac{Y_{\text{dual irradiation}}}{Y_{\text{single irradiation}}} \qquad (2)$$

where $Y_{\text{single irradiation}}$ and $Y_{\text{dual irradiation}}$ are the cavitation yield at single and dual irradiation, respectively. The enhanced effects were 2.72, 4.35, 4.66, 4.31, and 3.88 for five distance conditions, respectively. It was found that the enhancement in dual irradiation was due to the expansion of cavitation active zone as shown in Figure 3.

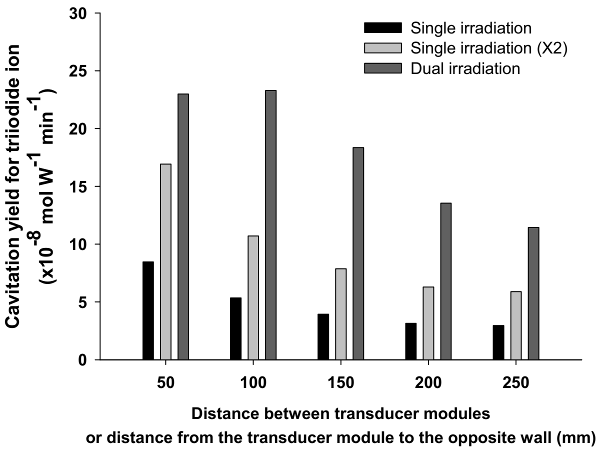
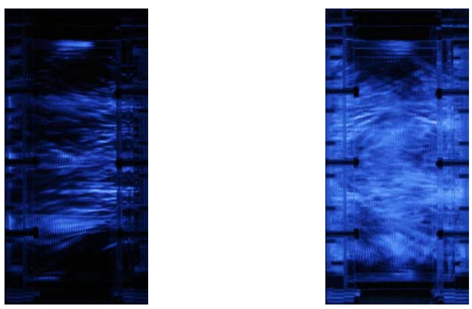


Fig 2. The variation of cavitation yields for single and dual irradiation in five distance conditions.



Single irradiation Dual irradiation

Fig 3. SCL images at 100 cm condition for single and dual irradiation.

Acknowledgment

This work was supported by Research Fund, Kumoh National Institute of Technology.

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