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Effect of vessel and liquid height on reaction rate in sonochemical reactor with indirect irradiation

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1. Introduction

Sonochemical reactors are devices that utilize ultrasonic cavitation for chemical reactions. There are two types of sonochemical reactors: one directly irradiates ultrasound to a sample, and the other indirectly irradiates ultrasound by putting the sample in a vessel. The sonochemical reactors with indirect irradiation are used in material synthesis because they are unlikely to cause contaminations in the sample. However, few studies have been reported that increase the reaction rate by propagating high ultrasonic power to the sample. Behavior of sonochemical reactions at high ultrasonic power is also unclear.

In this study, effects of vessel diameter and liquid height on the reaction rate in the sonochemical reactor with indirect irradiation were investigated while increasing electric power to the transducer.

2. Experiment

Fig. 1 shows the outline of experimental apparatus. A piezoceramic device with 50 mm in diameter was used as the transducer. The distance between the transducer and the vessel was 2.8 mm. The water tank outside the vessel was filled with degassed water at 298 K and 4 mg·L^{-1} of dissolved oxygen. The vessel was made of glass and was 0.8 mm in thickness at the bottom. The inside diameter of the vessel was changed from 10 mm to 56 mm. As the sample, potassium iodide (KI) solution with 0.1 mol/L was used[1]. The liquid height in the vessel was changed from 7 mm to 40 mm. Ultrasound at 500 kHz was irradiated indirectly to the sample in the vessel for 60 seconds. The ultrasonic power in the sample was measured by calorimetry[2]. The concentration of I_3^- ion produced by sonochemical reaction was measured using an ultraviolet visible spectrometer.

To visualize sonochemical reaction field, a mixed solution of luminol with 0.01 wt% and sodium carbonate with 0.5 wt% was used as the sample and sonochemical luminescence was photographed with a digital camera.

3. Results and discussion

Fig. 2 shows the effect of the electric power

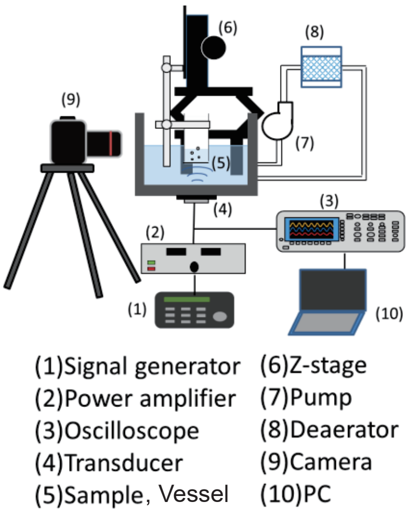

Fig. 1 Outline of experimental apparatus

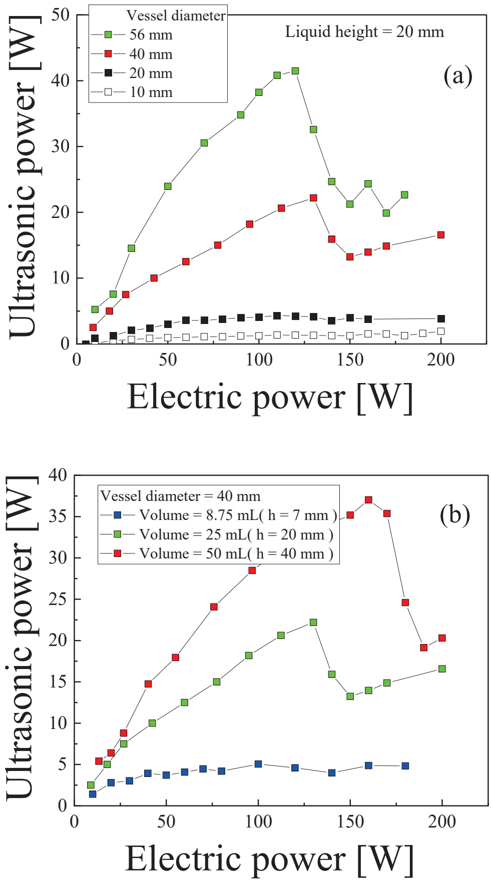

Fig. 2 Effect of the electric power applied to the transducer on the ultrasonic power for different vessel diameter (a) and liquid height (b)

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applied to the transducer on the ultrasonic power. For different vessel diameters in Fig.2 (a), the ultrasonic power increased with increasing vessel diameter at fixed electric power. This means that ultrasound propagates more efficiently to samples in larger vessels. When the vessel diameter was 40 mm and 56 mm, the ultrasonic power first increased as the electric power increased, reached a maximum value, and then decreased. This decrease in the ultrasonic power was also observed at 40 mm of liquid height in Fig.2(b). However, there was no decrease in ultrasonic power when the vessel diameter was 10 mm or the liquid height was 7 mm. Ultrasonic power increased with increasing liquid height.

Fig. 3 shows the effect of the electric power on the reaction rate per unit volume. As the electric power became higher, the reaction rate increased to a maximum and then decreased. This decrease phenomenon is called quenching of the sonochemical reaction[3] and was observed for the first time in the sonochemical reactor with indirect irradiation. When the liquid height was 20 mm and the vessel diameter was 40 mm and 56 mm in Fig. 3(a), quenching of the sonochemical reaction was occurred in two stages: a gradual decrease in the reaction rate at first and then the rapid decrease at 130 W. On the other hand, when the vessel diameters were small (20 mm and 10 mm) or the liquid height was low (7 mm), a gradual decrease in the reaction rate was observed, but no rapid decrease of reaction rate was observed.

Fig. 4 shows photographs of sonochemical luminescence when the vessel diameter is 40 mm and liquid height is 20 mm. These photographs correspond to the data in the red circles in Fig.3(a). Sonochemical luminescence also becomes stronger at 90W of the electric power, slightly weaker at 120 W, and extremely weak at 130 W. We observed that the liquid surface in the vessel while increasing electric power to the transducer and found the liquid surface significantly moved at 130 W. These results suggests that the rapid quenching of sonochemical reaction is caused by the large movement of the liquid surface, which prevents the formation of standing waves.

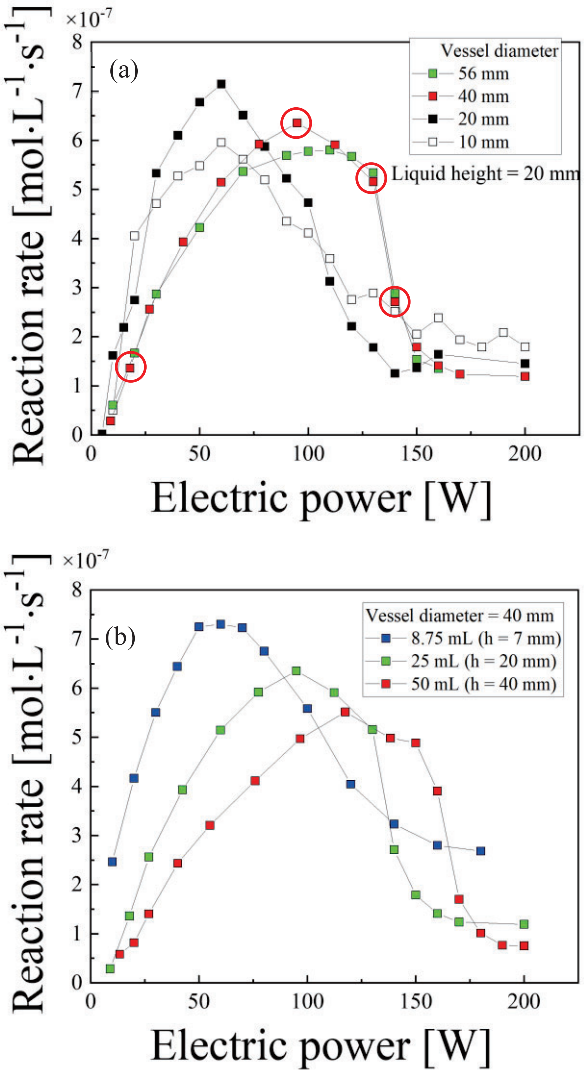

Fig. 3 Effect of the electric power applied to the transducer on the reaction rate for different vessel diameter (a) and liquid height (b)

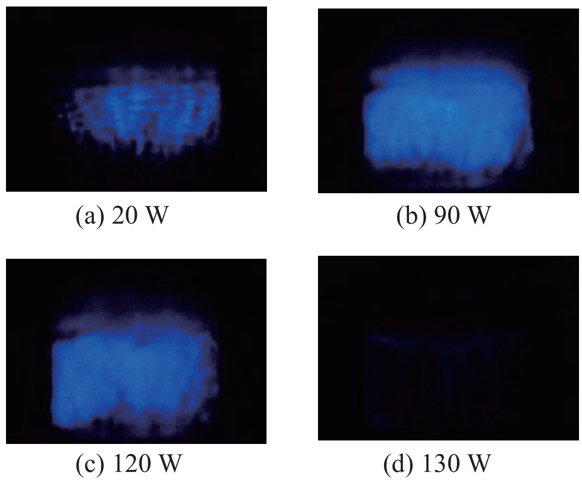

Fig. 4 Photographs of sonochemical luminescence for different electric power (vessel diameter = 40 mm, liquid height = 20 mm)

Acknowledgment

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References

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