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Geometric effects on sonochemical oxidation activity in 20kHz sonicator systems

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1.Introduction

Ultrasound technology can used to degrade pollutants through sonochemical effects, including pyrolysis and radical reactions[1)]. The impact of various parameters, including vessel size, liquid volume, probe immersion depth, input power, probe horizontal position, and gas injection, on sonochemical oxidation activity was examined under various geometric conditions using sonicator systems[1-7)]. It was found that optimization of the geometric parameters could result in a significant enhancement of sonochemical activity.

In the case of circular vessels using 20 kHz probe-type sonicator, which is commonly employed in laboratories[1,2)], it was found that the sonochemical activity increased significantly when the probe was positioned in closer relation to the vessel's bottom. Furthermore, it was found that the expanded sonochemical active zone, induced by ultrasonic reflection from the bottom and reactor walls.

As a follow-up study to our previous study for understanding the various sonochemical applications of the 20 kHz-probe system, in this study, the cavitational oxidation activity under vessel shape and thickness was investigated.

2. Material and methods

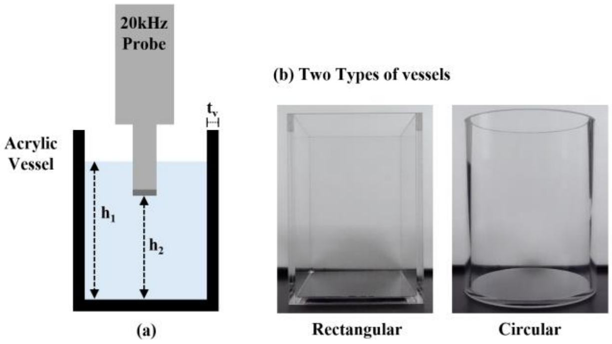

Fig. 1 (a) Schematic of the experimental setup; (b) Two Types of vessels (Rectangular, Circular).

A 20-kHz probe-type sonicator (VCX-750, Sonics & Materials Inc., USA), equipped with a threaded-end type probe and a replaceable tip of 13 mm diameter, made of a titanium alloy, was used in this study. The probe was submerged in an acrylic vessel made of two types: rectangular and circular, as shown in Fig. 1. The height of the liquid in the vessel was 12 cm, determined based on the probe immersion depth (h_1). The distance from the probe tip end to the vessel bottom surface, varied from 1 cm to 7 cm (h_2), and the thickness of the vessel is 5 mm and 10 mm (t_v). The input power of the probe was 50 % displayed as the power level of the device.

The sonochemical oxidation reactions of each condition were quantified using KI solution (1 g/L KI), and the irradiation time was 10 min. The mass of I_3^- ions was measured using a UV-vis spectrophotometer (Vibra S60, Biochrom Ltd., UK). The sonochemical active zone was visualized using a luminol solution (0.1 g/L luminol and 1 g/L NaOH). SCL (Sonochemiluminescence) images were obtained using an exposure-controlled digital camera (α58, Sony Corp., JPN) in a completely dark room and the exposure time was set to 10 s.

3. Results and discussion

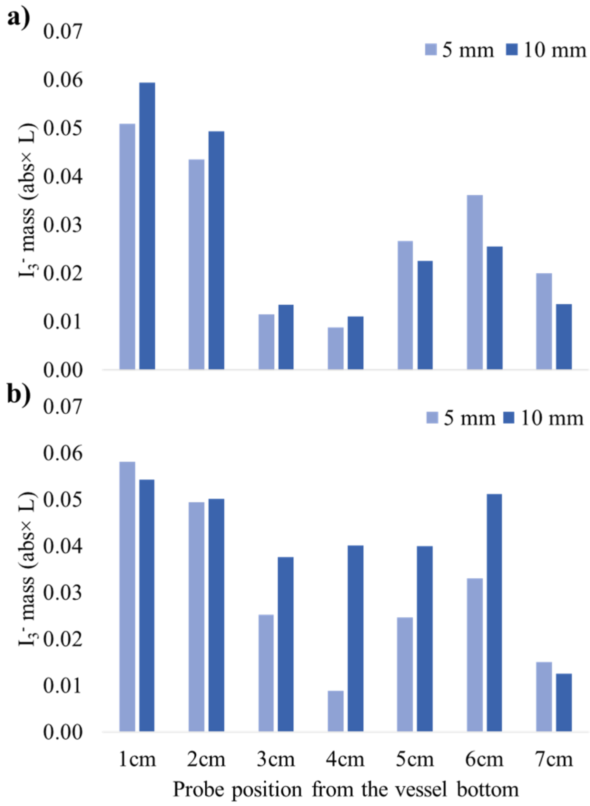

Fig. 2 I_3^- concentration at each probe at different probe positions (1-7 cm) in two different-thickness vessels: a) circular, b) rectangular.

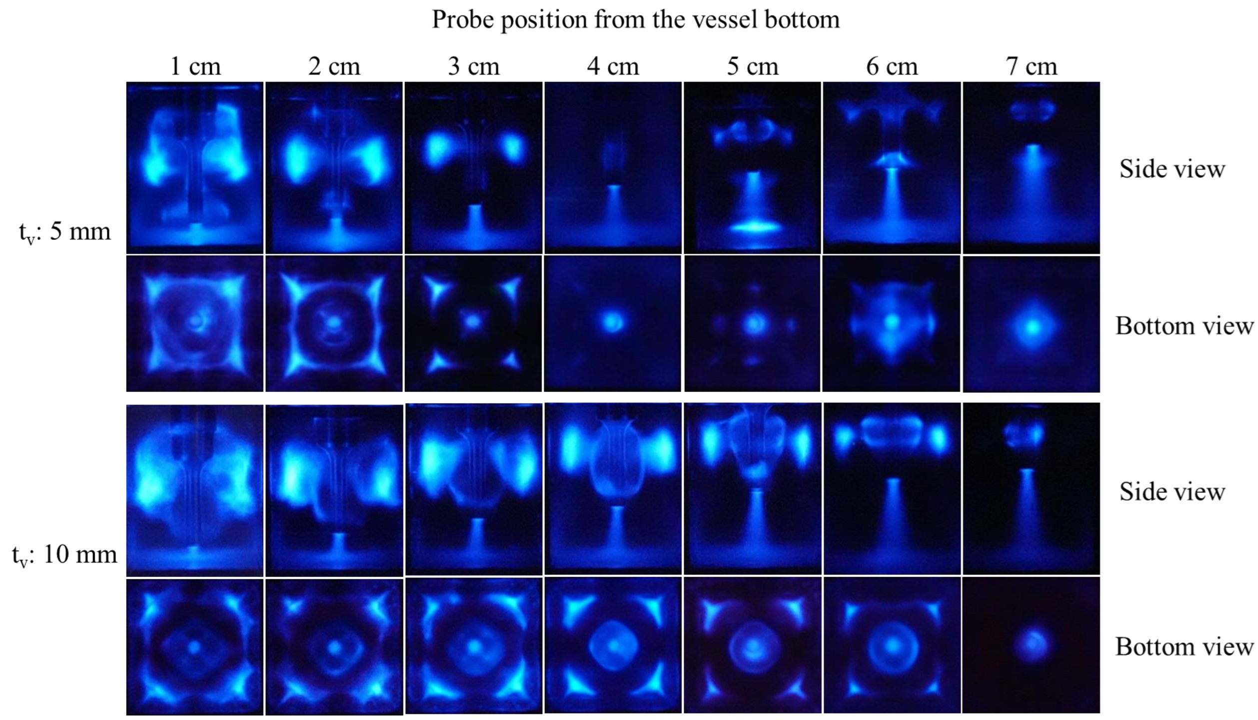

Fig. 3 Bottom-view and Side-view SCL images at different probe positions (1-7 cm) in two different **r**ectangular vessels (the thickness of the reactor wall (t_v): 5 and 10 mm).

The effect of the probe position from the reactor bottom on the sonochemical oxidation activity was investigated in vessels with different shape and thickness using KI dosimetry. As shown in Fig. 2., the position of the probe tip from the bottom was experimented in the range of 1-7 cm in 1 cm steps. Fig. 2 (a) shows the results for circular vessels, where the position of the probe tip showed high sonochemical activity at 1, 2 cm and low sonochemical activity at 3, 4 cm. Fig. 2 (b) shows the results for a rectangular vessel (thickness was 5 mm), where the position of the probe tip showed high sonochemical activity at 1 and 2 cm and low sonochemical activity at 4 cm. The circular and rectangular (t_v: 5 mm) vessels exhibited similarities in their observed trends. On the other hand, in the rectangular vessel, when the thickness was 10 mm, the position of the probe tip from the bottom showed high sonochemical activity at 1, 2, and 6 cm, and low sonochemical activity at 7 cm.

SCL images were obtained to understand the changes in the sonochemical active zone as the probe position and rectangular vessel thickness changed. The ultrasound active zone was observed at positions close to the bottom, yielding a pattern consistent with that observed in previous studies[1,2]. The activation area decreased as the probe position moved away from the floor. A bottom view of the SCL images at different geometric positions was taken to better understand the changes in the active cavitation area. Compared to the circular vessel, the active area was different when viewing the SCL of the rectangular vessels. In the circular vessel, it was observed concentric circular active zone, whereas in the rectangular vessels, the active zone formed mainly at the corners of the reactor. The larger active zones were found in the thicker wall thickness, which is due to stronger reflections from the walls and bottom, amplifying the sonochemical activity.

Acknowledgment
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