Design of Multi Bubble Sonoluminescence Reactor for Low Frequency Pressure Radiation

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1. Introduction

Sonoluminescence phenomenon has been intensively studied due to its extraordinary capability to produce very high temperature and pressure within micro bubbles exposed by the pressure radiation [1,2]. In general, it has been widely used for the chemical treatment including dissociation of the toxics and synthesis of functional materials such as nano catalysis. As for the nuclear applications, some of researchers tried to realization of the bubble fusion and change of the decay constant. Unfortunately applications to the nuclear industry are very skeptically accepted in the academic society. In spite of all such skepticism, the studies on sonoluminescence still have the room to be explored. In the present study, we investigated the relation among the reactor size, power and frequency of the pressure radiation. Main motivation of the present study came from some mismatch in the degradation rate of TCE in the multibubble sonoluminescence reactors (MBSL reactor) between Lee et al (2011) [3] and Oh and Lee (2010) [4]. Both studies utilized horn type ultrasound source with the frequency of 20 kHz. However, the shape and volume of the reactors were different form each other. In the present study, we simply measured the light emission from the luminol solution in the reactors to evaluate the effectiveness of the MBSL. As noted in the study of Lee et al, the hot spot of MBSL dissociate water molecules into OH radicals [5,6] which dissociate luminol in the solution to emit radiation. Therefore, the intensity and distribution of the radiation of luminol dissociation in the reactor are key index of the population of hot spots.

Results and discussions are made by comparing the light emission intensity with different operating powers.

2. Experimental Apparatus and Methods

2.1 Experimental Apparatus

As shown in Fig. 1, the experimental apparatus for multibubble sonoluminescence consists of a cylindrical glass cell into the 10mm diameter titanium horn (Misonix S-4000, USA) is inserted. The horn type ultrasound system was operating at 20 kHz, and its maximum power is 600W. A soft adaptor was used to connect the titanium horn and the cylindrical cells. In the adaptor, two O-rings were used to seal between the horn and the cell, and an extra O-ring was used to maintain certain pressure.

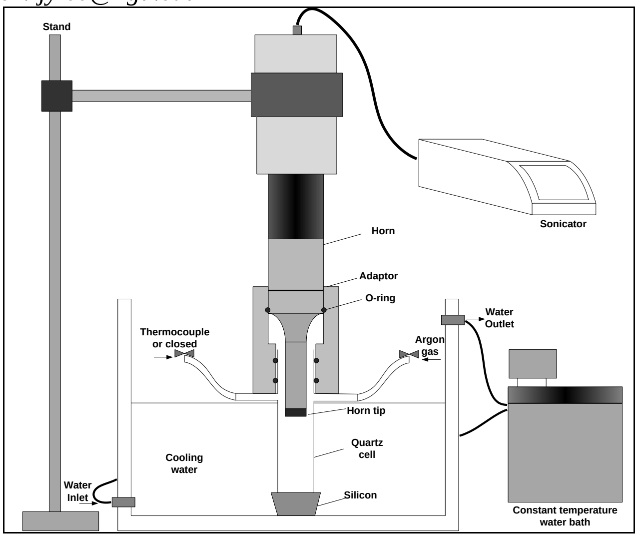

Fig. 1. Schematic of the experimental apparatus

The T-type quartz is connected by urethane tube for a thermocouple and inlet of argon gas. The luminol solution in the test cell was kept at constant pressure (1.25 bar) with argon gas. The cell was placed in an acrylic transparent cooling bath, and constant temperature water bath keeps the temperature of the solution inside the cell around 10 ℃. The luminol solution is mixed with 1L of distilled water and 0.1 mM of luminol. In order to take the picture of the light emission while MBSL occurs, Nikon D80 DSLR camera with a prime lens (NIKKOR 50mm 1:1.2) was used. The MBSL condition was adjusted by trial and error at a proper ultrasound intensity, liquid temperature and distance between the horn tip and the bottom of the cell.

2.2 Reactors

In order to investigate the effect of the reactor shape on MBSL, we prepared two different shapes of reactor; cylinder type and bottle type as shown in Fig. 2. The cylinder type was used by Lee at al. and the bottle type was used in the work of Oh and Lee. In the study, we investigate the cylindrical type intensively in order to quantify the effect of the reactor height and the ultrasound wave length. It has been known that the populations of the micro bubbles in the pressure radiation are subjected by the Bijerken force which strongly depends on the wave length. Therefore, we set the test variable as the height of the cylinder (3.6cm, 4cm, 4.5cm, and 5cm). As for the bottle type of the reactor with 6cm in diameter and 10cm in height used by Oh and Lee are tested to see how much different from the present cylindrical reactor and partially to explain why the degradation rate of TCE in the bottle type reactor were similar to the value of normal sonification.

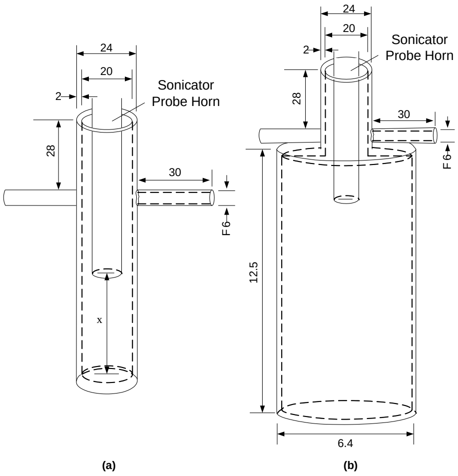

Fig. 2. Size of the MBSL Reactor Chamber.

The design basis of the cylindrical reactor is made by the determination of reactor height; the half of the wave length λ/2 = 3.62cm. In this condition it may be assumed that maximum power delivery of the ultrasound is made to the liquid in the assumption that the horn type transducer is similar to the Langevin or plane type transducer.

3. Results

Experiments have been made by changing the height of cylinder and power applied to the ultrasound horn. As shown in Fig. 3, the intensity of the light decreases as the height increases from 3.6cm to 5cm. Furthermore, the pattern of the light emission varies from bulk to local as the height increases. It clearly shows that the half of the wave length effectively deliver the power of the ultrasound to the MBSL bubbles.

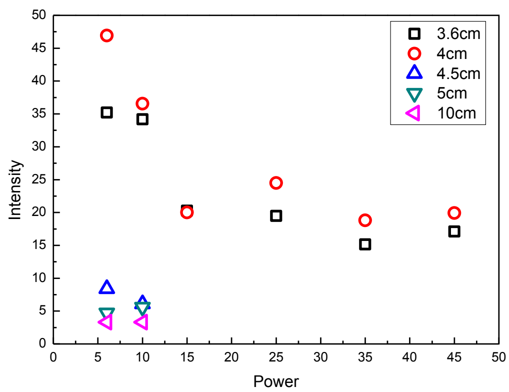

Fig. 3. The intensity of light emitted by image processing

As shown in Fig. 4, as the power applied increases, the MBSL patterns shift from bulk to the local near the horn tip

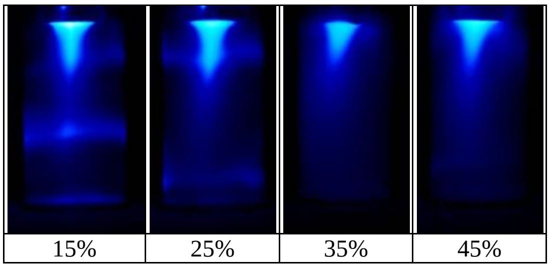

Fig. 4. The pattern variation in increase of input power

However, in case of the bottle type reactor, in any case the MBSL occurs locally near the horn tip which partially explains the reason why it is similar to the normal sonification.

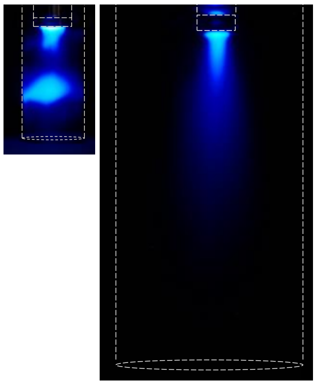

Fig. 5. Diffence of light pattern between cylinder type and bottle type as shown in Fig. 2 in same power (6%)

4. Conclusions

The MBSL patterns in the reactor using 20 kHz ultrasound source are indirectly observed by measuring the light emission in the luminol solution. It was found that the cylindrical reactor with the height of the half of the ultrasound wave length is the most effective in the delivery for the MBSL power because of the bulk population of MBSL bubble. However, in the case of high power or the bottle type reactor, the MBSL occurs near the horn tip so it might be the main cause why such reaction is often regarded as the simple sonification.

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