# 2P4-5

## Proposal of an ultrasonic generator for generating sterilization radicals

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## 1. Introduction

The sterilization treatment technology utilizing radicals generated by high-intensity ultrasound in water has been extensively researched(1-2). However, for the efficient implementation of this technology, the generation of a substantial amount of radicals is imperative. This necessitates achieving high efficiency in ultrasonic transducers. Typically, bolt-clamped type ultrasonic transducers are employed for ultrasonic sterilization due to their durability and ability to attain significant vibration displacement(3). In the fundamental mode of the bolt-clamped type ultrasonic transducer, the installation of a fixed flange at the longitudinal vibration node is challenging. Consequently, the radiation surface, which represents a vibrational antinode exhibiting the largest vibration displacement, is often utilized as the fixed plane. In this case, there is a problem of having to endure a reduction in efficiency. This study addresses the aforementioned issues by proposing a novel structure for an ultrasonic transducer. The aim is to facilitate the formation of ultrasonic cavitation by improving transducer efficiency through modifications in the mechanical conditions of the radiating surface and reevaluating its characteristics. By adopting this innovative approach, the practical application of high-intensity ultrasound sterilization technology can be significantly enhanced.

## 2. Construction of transducer

The experimental setup featured the structure of a bolt-clamped type ultrasonic transducer, as shown in Fig. 1. For the experiment, a commercially available Langevin-type ultrasonic transducer, resonating at 40 kHz and typically utilized in ultrasonic cleaners, was employed. The circular radiation surface boasted a diameter of 45 mm, to which a circular stainless-steel plate measuring 70.5 mm in diameter was affixed. Additionally, rubber O-rings were fixed on both sides of the plate's edge to provide both waterproofing and reliable support for the transducer. A round tube made of PVC with an outer diameter of 85mm and an inner diameter of 56mm, along with its socket, was utilized as the housing to enable underwater use.

## 3. Experimental method

To assess the extent of ultrasonic cavitation induced by the transducer, as depicted in Fig. 2(a), a fabricated vessel measuring 200 mm in both width and length, crafted from 10 mm thick acrylic material, was employed. The positioning of the ultrasonic transducer within the vessel was achieved through the drilling of a central hole with a diameter of 83 mm on the bottom surface of the vessel. For comparison, as shown in Fig. 2(b), a stainless-steel vessel with a width and length of 140 mm was attached to the radiation surface of the transducer in the same structure as a conventional ultrasonic cleaner. The luminol solution was concocted with a ratio of 0.1 g of luminol powder and 0.5 g of sodium carbonate per 1 L of distilled water. The luminol solution was poured into each container, ensuring a depth of 500 mm. By actuating the ultrasonic transducer, positioned at the bottom surface of the vessel, each light emission phenomenon was captured using a DSLR camera. The photography settings included an aperture of F3.5, an ISO value of 1600, and a shutter operated in Bulb mode for durations of 1 minute and 2 minutes, respectively.

## 4. Results and discussion

Figure 3(a) shows the measurement results of the input admittance depending on the presence or absence of an acoustic load of water for the transducer shown on the left of Fig. 2. In this result, to investigate the change in the characteristics of the bolt-clamped type ultrasonic transducer due to the change in boundary conditions. From this result, it can be seen that the electroacoustic efficiency(3) of the transducer based on the water load is about 81%. For comparison, Fig. 3(b) shows the input admittance measurement result for the transducer on the right side of Fig. 2 where the stainless water tank is fixed on the radiation surface. In this result, the admittance characteristic is deteriorated by the metal tank fixed on the radiation surface, and the electroacoustic efficiency is about 54%. This is thought to be the result of some of the ultrasonic energy being used for bending and vibration of the water tank. In order to confirm the degree of occurrence of cavitation by ultrasound, a photograph of Sonoluminescence using the experimental device shown in Fig. 2 is shown in Fig. 4. The pictures were taken with shutter speeds of 1 minute and 2 minutes, and the results of using the ultrasonic generator proposed in this study (Fig. 2(a)) is shown in Fig. 4(b) and (d), and the results of using the structure similar to the conventional ultrasonic cleaner (Fig. 2(b)) are shown in Fig. 4(a) and (c). In order to quantitatively compare the luminescence intensity of sonoluminescence, the results of Fig. 4 were image-processed and shown in Fig. 5. From this result, it

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can be seen that the pixel value representing brightness increases as the shutter speed slows down both in the case of using the proposed device and in the case of using the structure of the conventional ultrasonic cleaner. In addition, the peak value of pixel value was found to be similar regardless of the type of ultrasonic generator. However, Fig. 5(b) and (d), which are the results using the proposed device, show that the sonoluminescence generation area is wider than the results using the conventional method. This means that ultrasonic cavitation occurs in a wider range, and it can be confirmed that it is advantageous as a radical generator.

## 5. Summary

This research paper focuses on developing a radical generator utilizing high-intensity ultrasound and emphasizes the crucial need to enhance the efficiency of the ultrasonic transducer. In this study, a method is proposed to improve the electroacoustic conversion efficiency by modifying the mechanical conditions of the radiating surface of the bolt-clamped type ultrasonic transducer. Through experimentation and analysis, the effectiveness of the proposed method was evaluated by measuring the degree of ultrasonic cavitation using sonoluminescence. The results demonstrated that the proposed method significantly increased the occurrence of ultrasonic cavitation over a wider area compared to conventional methods. This outcome highlights the potential of the novel approach in achieving a more efficient radical generation process using high-intensity ultrasound, opening new avenues for practical applications in various fields.

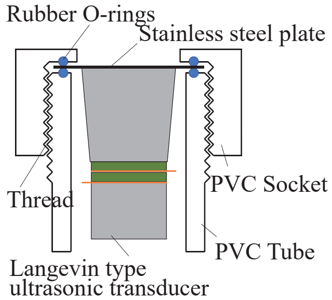


Fig. 1 Construction of simply supported ultrasonic transducer.

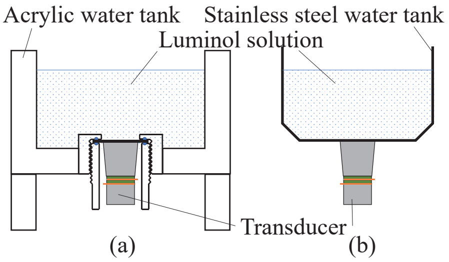
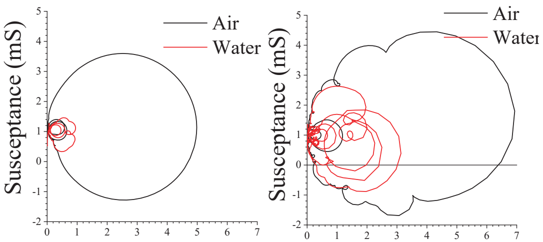


Fig. 2 Experimental setup for measuring sonoluminescence. (a) Proposed structure (b) Ultrasonic cleaner structure.



(a) (b)

Fig. 3 Changes in admittance locus with and without acoustic load of water.
(a) Suggested transducer (b) Transducer for ultrasonic cleaner.

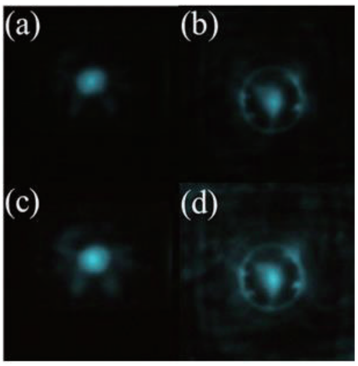


Fig. 4 Sonoluminescence images under following conditions.
(a) Shutter speed 1 min., ultrasonic cleaner
(b) Shutter speed 1 min., proposed device
(c) Shutter speed 2 min., ultrasonic cleaner
(d) Shutter speed 2 min., proposed device

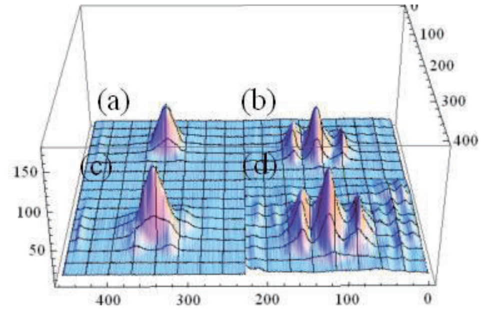


Fig. 5 Image processing result of luminescence intensity of sonoluminescence. Each result corresponds to the result in Fig. 5.

## Acknowledgment

This work was supported by Pukyong National University of Korea.

## References

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