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Visualization of Temperature Elevation due to Focused Ultrasound Generated by Tone Bursts Wave

Moojoon Kim[1†], Jihee Jung[1], Jungsoon Kim[2], and Kanglyeol Ha[1]
([1]Dept. of Physics, Pukyong National Univ., ; [2]Dept. of Media Engineering, Tongmyong Univ., Korea)

1. Introduction

Study on temperature elevation due to a focused ultrasound in a dissipative medium has been carried out by many researchers[1,2)]. It is because the analysis of the temperature distribution caused by ultrasound in a dissipative medium such as human tissue can provide very important information in the medical field[3)]. In the previous research, we reported a visualization method using thermochromic film for temperature distribution due to the focused ultrasound in a phantom made of agar[4)]. To control the temperature elevation effect by the focused ultrasound, tone burst wave is generally used as the input signal of the transducer. The experimental analysis on the temperature elevation generated by the tone burst of ultrasound has not been studied sufficiently, whereas it has been studied theoretically by many researchers[5)].

In this study, the temperature elevation depending on the duty cycle of the tone burst ultrasound in a phantom is investigated with the visualization method. The problems of the opacity and the characteristic mismatch, which occur when agar is used for the phantom material, are solved by using gelatin whose acoustic characteristics are similar to a biological medium.

2. Experiment

The gelatin was coagulated in an acryl box of 115×180×75 mm^3 to make the dissipative medium, and a focused ultrasonic transducer was contacted with the medium from a lateral side of the acryl box. The concentration of the gelatin used in this experiment was 10 %, and the physical properties of the gelatin are listed in Table I. The size of the thermochromic film was 105 × 148 mm^2, and the film was located in the center of the dissipative medium along the acoustic axis of the transducer in order to show the temperature change by the ultrasound. It is considered that the film does not affect the transmission of the ultrasound wave because the thickness of the film was 78 m, and it is sufficiently thin compared to the wave length of the ultrasound of 1.7 mm. The thermochromic film produces red-yellow in the temperature range between 10 ^{o}C and 28 ^{o}C. The red-yellow turns to brown when the temperature is lower than 10 ^{o}C, and yellow when it is higher than 28 ^{o}C. The experimental setup is shown in Fig. 1. Tone burst wave with 920 kHz carrier frequency was generated by a function generator, and was amplified by a amplifier to drive the focused ultrasonic transducer. The discolored area on the thermochromic film due to the temperature elevation was recorded by a camera when the duty cycle of the burst wave changed.

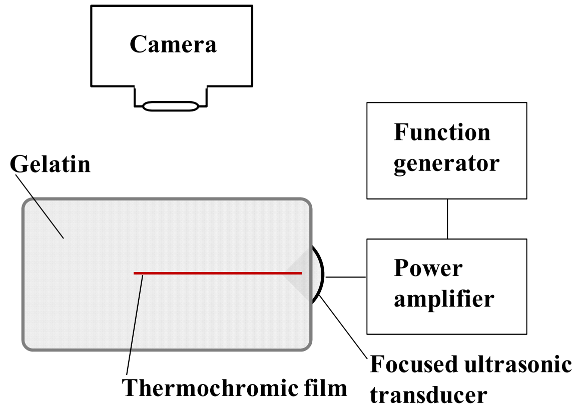

Fig. 1 Experimental setup.

Table I. Characteristics of gelatin

Sound velocity*	152247.5 cm/s
Attenuation coefficient*	0.1990 dB/cm/MHz
Density*	1.052 g/cm^3
Heat capacity[6)]	3.973 J/cm^3 ^{o}C
Thermal conductivity[7)]	12.2×10^{-4} W/cm ^{o}C
*measured	

3. Results and discussion

Figure 2 shows the discolored areas due to the temperature elevation on the film in different duty cycles of the burst wave. As shown in this figure, the discolored area changed differently depending on the duty cycle of the burst wave from the function generator

kimmj@pknu.ac.kr.

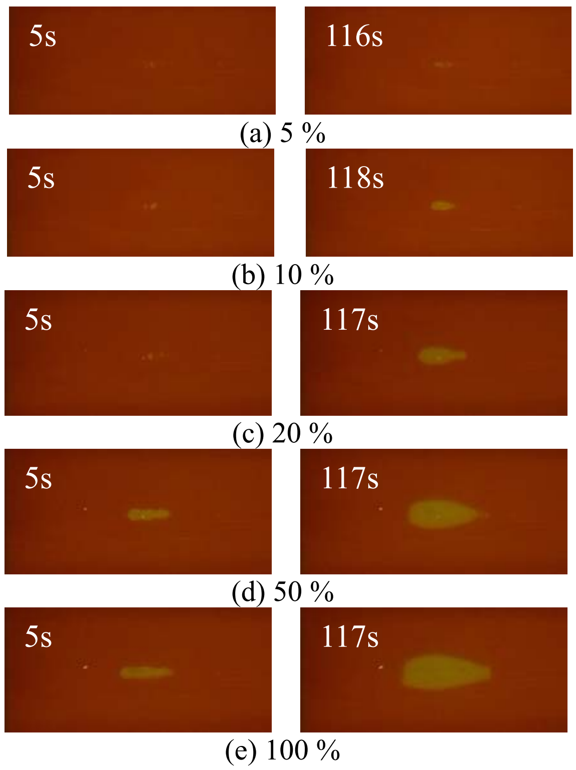

Fig. 2 Dispersion results by focused ultrasound for different exposure time.

To examine the change of high temperature area on the focal point depending on the duty cycle, the recorded discolored images were processed with the image processing technique. The change of the area of the domain that rose up by 6 ^{o}C or more from the room temperature is shown in Fig. 3. It can be seen that the high temperature area after 5 second exposure time increases as the duty cycle of the burst wave increases. The high temperature area increased substancially to more than 0.37 cm^2 from 50% and more, whereas the initial high temperature area was less than 0.05 cm^2 until 20% of the duty cycle. If the high temperature area is observed for 2 minutes exposure time, it can be seen that the high temperature area can maintained less than 0.5 cm^2 using less than 20% of the duty cycle. From these results, it is confirmed that the temperature can be raised in a limited target area in the dissipative medium by controlling duty cycle of a burst wave.

4. Summary

To investigate temperature elevation generated by tone burst ultrasound inside a dissipative acoustic medium experimentally, we adopted a thermochromic film. For the dissipative acoustic medium, gelatin layer was chosen in this study.

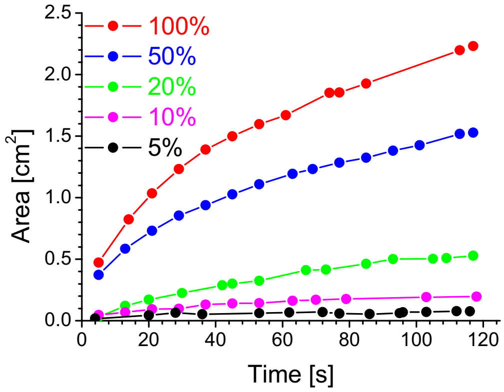

Fig. 3 Change of high temperature area depending on the duty cycle of burst ultrasound.

The temperature change due to the ultrasound was measured depending on the duty cycle of the tone burst ultrasound. The discolored area on the film due to the ultrasound was investigated when the duty cycle was from 5% to 100%. As the result, the high temperature area can be restricted within aimed area in the dissipative medium by controlling the duty cycle of the burst wave.

Acknowledgment

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