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Visualization of thermal distribution caused by focused ultrasonic field in an agar phantom

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1. Introduction

Recently, since the use of the ultrasonic wave increases in the medical field, there has been increasing interest in thermal distribution of the organic material. The ultrasonic wave has been used not only in medical diagnostic system but also in medical treatment one. High Intensity Focused Ultrasound (HIFU) is used to treat cancer tumours without requiring surgery[1]. To evaluate a HIFU transducer, the temperature distribution on the tissue from the focused ultrasonoic field should be investigated. However, it is not easy to measure the thermal distribution on the real tissue as well as on phantom of tissue *in vivo*. Well-known method for temperature visualization is Schlieren method in fluids[2]. However, the convection in the water prevents to evaluate the heating effect by the HIFU even though the water has similar characteristics to human tissue.

In this study, a cholesteric liquid crystals is used to visualize the thermal distribution in the phantom for human tissue[3]. They are quite sensitive to the temperature and they show variety of colors within a range of order 1°C with response time of order 0.1 second. The liquid crystals are suited to know temperatures on a solid wall, while there is a difficulty in measuring temperatures in bulk material. The microcapsules filled with liquid crystal (Produced on commercial base) are suspended in the water with agar powder. Gel state of the agar has been used as a phantom of human tissue because its acoustic characteristic is very similar to that of human tissue. A focusing ultrasonic transducer is fabricated, and an agar layer with thermochromic particles is molded. Using the transducer and the agar layer, the temperature distribution of the phantom was measured.

2. Experimental procedure

To make the focused ultrasound field in the phantom, a concave type transducer was fabricated as shown in Fig. 1. The focal length and resonant frequency of this transducer were measured 26.0 mm and 2.08 MHz, respectively. Figure 2 shows the experimental setup for the investigation of the temperature distribution in the phantom when the ultrasound wave from the transducer was radiated to the phantom. To transform the temperature into the brightness of gray, thermochromic micro capsules of 1~5μm particle size (Nano I&C, Korea) were mixed with agar suspend of 0.67 %. The solvent of the agar suspend was the water of 80 °C. The thermochromic particle has critical temperature in which the color would be changed. In this experiment, two kinds of the thermochromic particles, which the critical temperatures are 31℃, and 45 °C, respectively, were used. 1 % and 0.67 % thermochromic particles were mixed with the agar suspend. A gel layer of agar with the thermochromic particles was molded by cooling the solution. A pure agar layer was covered on the suspended agar layer to observe the color change as shown in Fig. 2.

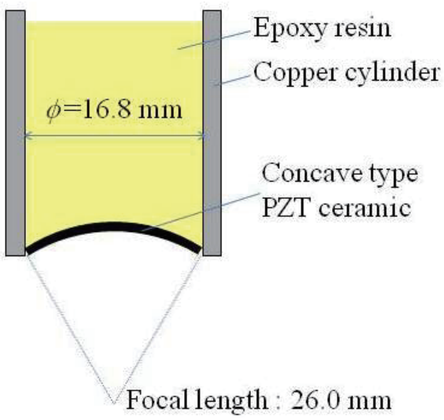

Fig. 1 Construction of a focusing ultrasonic transducer

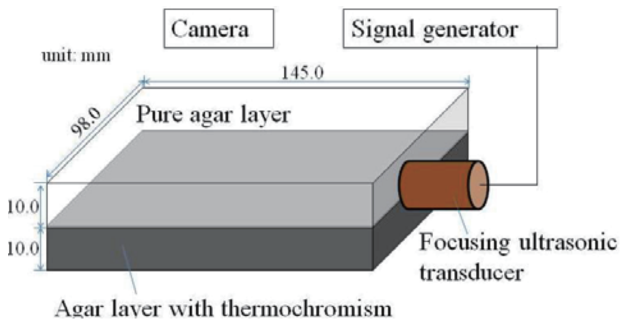

Fig. 2 Schematics of experimental setup

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A camera captures the temperature distribution of the phantom when the ultrasonic field is focused by the transducer.

3. Results and discussion

The acoustic characteristics of the phantom was measured and listed with those of water and human tissue in Table I. From this table, it is confirmed that the phantom is reasonable to be used as a substitution of human tissue.

Table I Acoustic characteristics of materials

	Density[kg/m^3]	Sound speed[m/s]
phantom	1000	1625
human tissue[4] (muscle)	1050	1547
water	998	1481

To investigate the radiation characteristic of the ultrasonic transducer, the acoustic field was measured by Schlieren method as shown in Fig. 3(a). The result is compared to the calculated one (Fig. 3(b)). These result shows that the ultrasonic field is focused at 24 mm from the transducer. Figure 4 shows the pattern caused temperature distribution of the phantom. The difference of the brightness corresponds to the temperature difference as shown in index of the figure. In this figure, high temperature region in the phantom appears in vicinity of the focal point of Fig. 3. The bright region of left side is caused by the heat from surface of the transducer. From this result, the focal point in the phantom was heated to about 40 °C.

4. Conclusion

To investigate the temperature distribution of the phantom by the focused ultrasound, we newly suggested the visualization method of the temperature. Ultrasonic field was focused by a concave type transducer in an agar layer mixed with thermochromic particles and the pattern change according to the temperature was observed. This method could be used not only in designing but also in inspection of the safety of HIFU.

Acknowledgment
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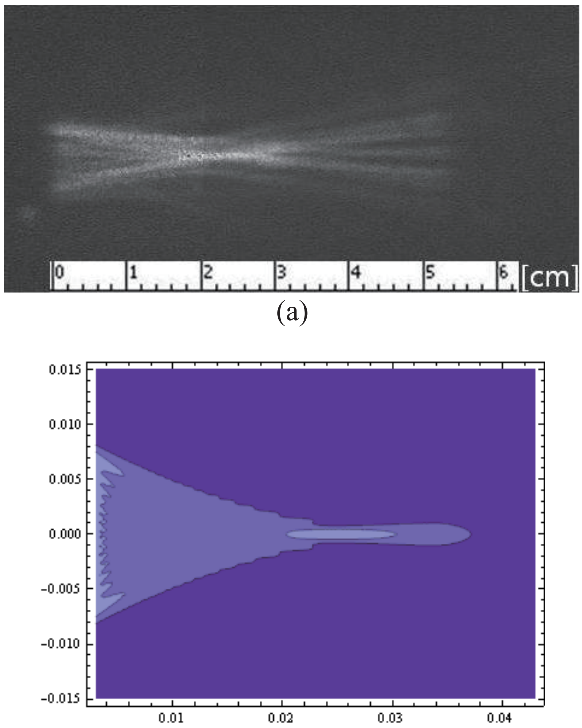

(a) (b)

Fig. 3 Acoustic field of the focusing ultrasonic transducer
(a) Calculated result (b) Measured result

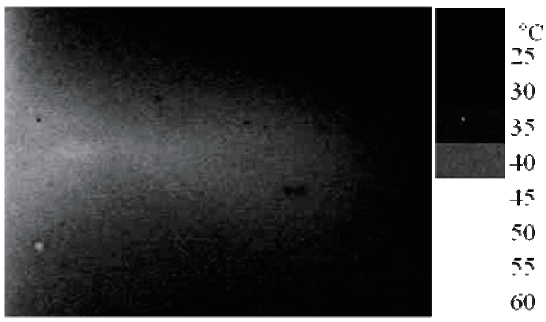

Fig. 4 Thermal distribution on the agar phantom by the focused ultrasonic field

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