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Tissue mimicking phantom for visualization of thermal distribution caused by ultrasound

Jungsoon Kim[1†], Yejoon Park[2], Moojoon Kim[2], and Kanglyeol Ha[3] ([1]Tongmyong Univ. , Pukyong National Univ., Korea)

1. Introduction

In the case of ultrasound treatment using high power, the temperature distribution must be measured for safety in medical applications[1]. Tissue mimicking phantom is an important tool for performance testing and calibration of medical ultrasound devices[2]. The phantom should present the basic acoustic properties of human tissue such as sound speed, density, and attenuation coefficient. Especially, thermal distribution depended on the attenuation coefficient is a significant factor to develop the medical ultrasonic systems. However, the commercialized phantom with thermal reaction is irreversible and it cannot express the thermal distribution. Therefore, a development of proper phantom for the purpose in various applications is strongly required. Previously, our group has suggested the visualization method for thermal distribution in a tissue mimicking phantom using a thermochromic particle[3]. The aim of this work is to develop a phantom with the proper acoustic properties for visualization of thermal distribution.

2. Experiment

To adjust the acoustic properties in tissue mimicking phantom, sugar was added to a basic solvent to obtain variation in acoustic impedance, and attenuation coefficient. The basic soltvent was made of 500 ml water with agar powder 4 g. The agar gel with sugar was filled in the container of $110 \times 68 \times 53$ mm^3, and was congelated by staying at room temperature for 5 hours. We investigated the change of the acoustic characteristics of the phantom according to the concentration of sugar. The experimental set up for the sound speed and the attenuation coefficient is shown in Fig. 1. In this figure, the ultrasonic transducer with diameter of 20.8 mm was fabricated by PZT ceramic, and the resonant frequency of the transducer was 1.02 MHz. The alumimun block with cylindrical hole was used as a support for the phantom. A burst pluse with 10 V_{pp} of electric signal was applied to the transducer for the sound speed. The sound speed was measured by pulse-echo method. Meanwhile, for the attenuation coefficient, the input signal was used burst pulse with 30 V_{pp}. The attenuation coefficient was obtained by equation (1).

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kimmj@pknu.ac.kr

$$\alpha[\text{dB/cm}] = \frac{20\log\left(\frac{A}{A_0}\right)}{\Delta x} \qquad (1)$$

In the equation, the amplitudes A and A_0 were measured by pulse-echo method. The Δx is the thickness of a phantom, A and A_0 are the amplitudes of the 1st and the 2nd reflection waves from the surface of the phantom, respectively.

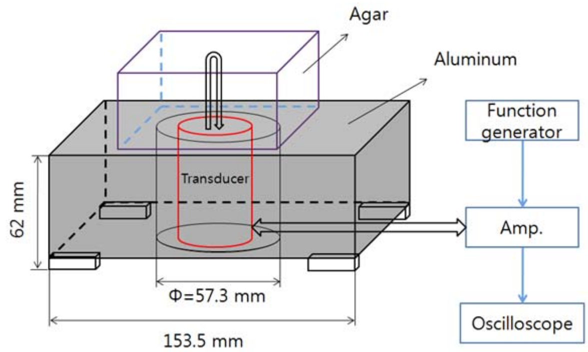
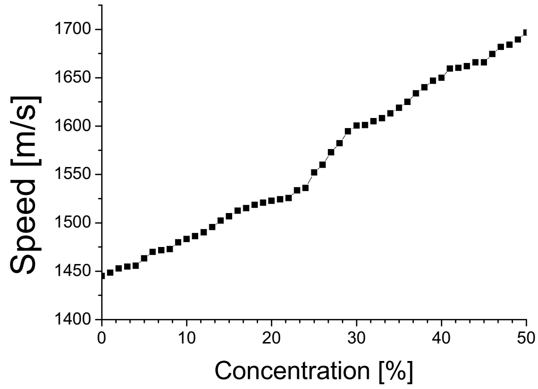


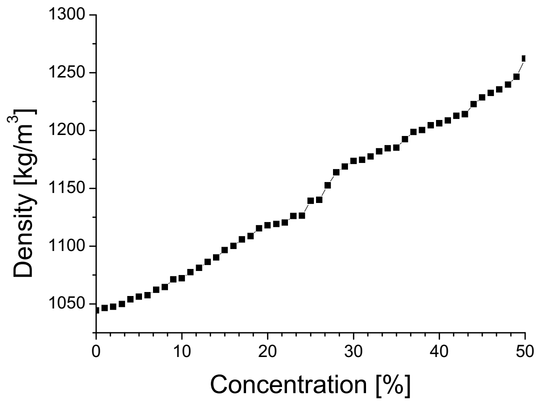
Fig. 1 Experimental set up for acoustic properties measureing

3. Results and discussion

The results of the sound speed and density according to the sugar concentration are shown in Fig. 2. The sound speed of the phantom linearly increased over the range of 1450~1700 m/s when the sugar concentration was changed from 0 % to 50 % as shown in Fig. 2(a). Comparing to the sound speed of human organics, this result was enough to cover the variation range of human body (1400 ~1600 m/s)[4,5]. The density showed the variation of 1050 ~ 1250 kg/m^3 as shown in Fig. 2(b). Figure 3 shows the change of attenuation coefficient according to the sugar concentration. Even though there is a dramatic fluctuation in the result, the attenuation coefficient has a tendency of being proportional to the sugar concentration. In general, the attenuation coefficient of human body has the value of the range 0.4~2.0 dB/cm[4,5].



(a)



(b)

Fig. 2 Sound speed (a) and density (b) according to the sugar concentration

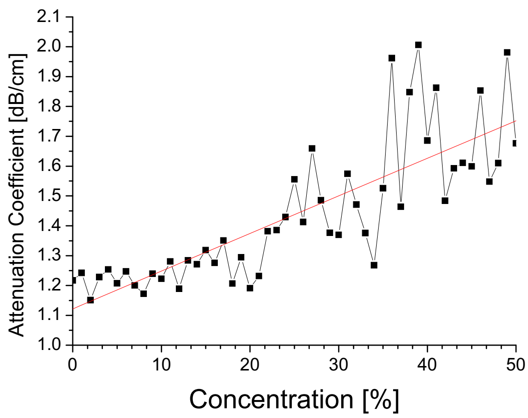


Fig. 3 Attenuation coefficient of phantom by concentration of sugar

Our result shows that the attenuation coefficient of the phantom can be adjusted by the sugar concentration. Figure 4 shows a visualization example of thermal distribution of the phantom caused by focused ultrasound field. In this figure, the degree of bright corresponds to the temperature difference as shown in index of the figure. On the basis of the result, it was found that the focal point in the phantom was heated to about 70 degree.

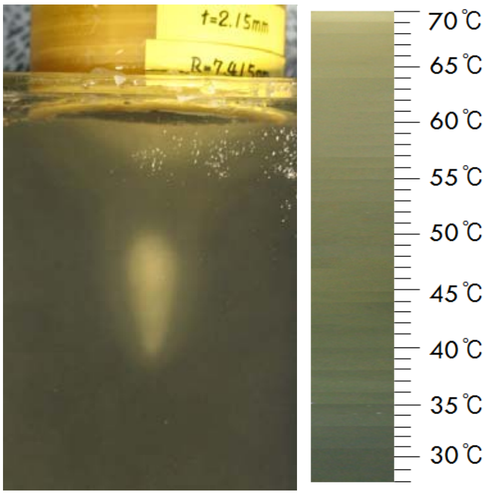


Fig. 4 Visualization example of thermal distribution of the phantom[3]

4. Discussion and conclusion

A Tissue mimicking phantom made of agar for visualization of thermal distribution was suggested. To adjust the properties of the phantom to those of the human organics, the sugar concentration of the agar was controlled. As the results, the sound speed, density, and attenuation coefficient could be obtained similar to those of human body.

Acknowledgment

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