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Effect of thin intervening layer on acoustic impedance measurement of soft tissue using ultrasonic microscope
超音波顕微鏡による軟部組織の音響インピーダンス測定に対する薄層の影響

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1. Introduction

Studies to ultrasonically detect and monitor HIFU-induced heat coagulation are underway. The differences in acoustical properties such as acoustic impedance between coagulated and non-coagulated tissues should be investigated for the purpose because they are the sources to cause ultrasonic changes detectable from outside the body.

Ultrasonic microscopes have been started being used in medical applications such as the pathology diagnosis without dyeing, as well as in nondestructive testing of materials at high accuracy [1]. In these applications, the samples to be observed, such as a cut of frozen or formalin-fixed paraffin-embedded tissue, have rather smooth surfaces. Ultrasonic properties of the tissue may be significantly changed by these fixation processes. This should be avoided in our experiment because we are interested in the changes due to coagulation, which are ultrasonically detectable from outside the body.

A standard way of acoustic impedance measurement using an ultrasonic microscope is to measure the echo amplitude from the boundary between a polystyrene petri dish and the sample tissue on it. In order to make this measurement successful, the smoothness of the tissue sample surface is very important.

For a tissue sample cut with a sharp razor blade, the roughness of the sample surface seemed to have influenced the measurement. Such influences are quantitatively studied and the way to make accurate measurement is researched.

2. Simulation

We used PZFlex, a time-domain finite element method software, for numerical simulation. We set the model having the structure of four layers: water, polystyrene, water, and the sample. The influence of the thin water layer between the polystyrene and the sample was examined by changing thickness of the layer. A pulsed, one wavelength long, plane wave at 80 MHz with a Blackman-Harris envelope was used.

3. Materials and Methods

After ruining the surface of the acrylic plate with the sandpaper (#240), we spread the mold lubricant and molded silicone with a known acoustic impedance on it. This silicone piece was used as the sample.

3.1 Measurement of surface ruggedness

We measured the shape of the surface of the sample with a laser microscope (VK-9700 GenerationII, KEYENCE).

3.2 Acoustic impedance measurement

The sample was attached on a petri dish with a known acoustical property and its acoustic impedance was measured with a pulse excitation type ultrasonic microscope for the biological tissue (HUM-1000, Honda Electronics). An ultrasonic transducer with a center frequency of 80 MHz and a focal length of 3.2mm was used. An area of 2.4×2.4 mm^2 with 300×300 sampling points was mechanically scanned.

Water is applied between the sample and the petri dish for better acoustic coupling. A flat plate with a certain weight was put on the sample to ensure the coupling. It was confirmed that putting any more weight had no influence on the measurement. A silicone piece with known acoustic impedance and a smooth surface enabling complete contact with the petri dish was used as the reference sample for calibration.

4. Results

4.1 Simulation results

Figure 1 shows simulation results for a tissue and silicone samples. The reflected wave amplitude is plotted against the thickness of the water layer between polystyrene and the sample. It was normalized by the amplitude without the layer. When the layer is very thin, the amplitude decreases, and the apparent acoustic impedance is increased for both samples.

4.2 Surface ruggedness image

Figure 2 shows the result from the measurement with the laser microscope. Roughness with a height difference of 5-10 μm is observed.

4.3 Acoustic impedance image

Figure 3 shows the acoustic impedance image of the silicone sample with a roughened surface and the reference silicone with an acoustic impedance of 0.97 Mrayls. The acoustic impedance of the sample varies from 0.9 to 1.5 Mrayls.

Figure 4 shows the histogram of the acoustic

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impedance in a square part in the image in Fig. 3. It distributed from -6% to +15% of 0.97 Mrayls.

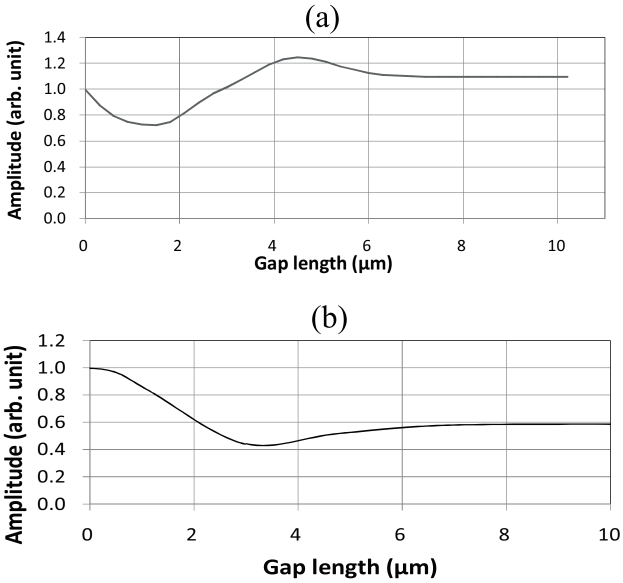

Fig. 1 Simulation of effects of thin water layer
(a)Muscle (b)Silicone

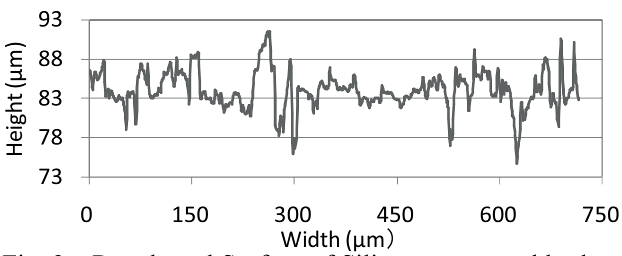

Fig. 2 Roughened Surface of Silicone measured by laser microscope

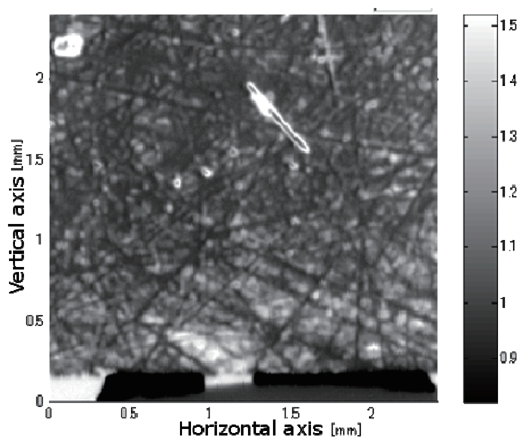

Fig. 3 Acoustic impedance image of roughened silicone (water coupler)

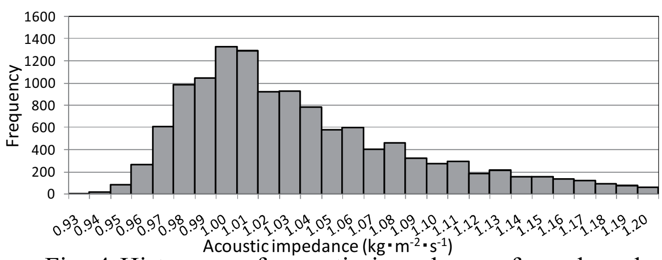

Fig. 4 Histogram of acoustic impedance of roughened silicone (water coupler)

5. Discussion

The simulation result suggests that a very thin water layer with a thickness of about a tenth of the wavelength can influence the acoustic impedance measurement. The error can be about ±12% and 0-70% for a tissue and silicone sample, respectively.

The upward shift of the apparent acoustic impedance shown in the histogram of Fig. 4 is consistent with the simulation result with silicone. The thickness of the water layer estimated from the simulation and the histogram is about 0-2 μm. This is much smaller than the optically observed gap heights in Fig. 2. The gaps might have been compressed in the ultrasonic measurement due to the applied weight.

Because a ruggedness order is 10μm or less, it can be thought as one reason the influence shown by the

6. Conclusion

The numerical simulation result suggests that a very thin water layer with a thickness of about a tenth of the wavelength can cause an error of about 10% in the acoustic impedance measurement of a tissue. The results from the simulation and acoustic impedance measurement were reasonably consistent for a silicone sample with a roughened surface.

References

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