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Multispectral phase-contrast imaging of acoustic impedance by using interference method for puncture needle-type ultrasonography

超音波干渉法による穿刺型超音波顕微鏡用マルチスペクトル位相差画像法

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1. Introduction

To enable tissue diagnosis by endoscopic ultrasonography, we have been developing puncture needle-type ultrasonography.[1–5)] We previously demonstrated an imaging method for determining the phase difference of the acoustic complex impedance.[6)] This imaging method enables observation of a cell without staining as in phase-contrast microscopy. For this imaging method to be used for pathological diagnosis, much more information must be displayed in the image to enable cancer tissue to be distinguished from normal tissue. As is well known, the frequency dependence of the scattering depends on the shape of the scattering body and distribution. In addition, the frequency dependence of the attenuation due to viscosity and elasticity depends on the type of elastic body and the amount of oil contained therein. Our experimental results indicated that signals reflected from the sample surface contain information about the sample in the depth direction. The ability to display the difference in the frequency dependence for an image may provide useful information for pathological diagnosis. We have now demonstrated that multispectral phase-contrast imaging of the acoustic impedance can be used to obtain the difference in frequency dependence of a sample.

2. Principle

2.1 Phase-contrast imaging of acoustic complex impedance[6)]

The phase-contrast imaging procedure is illustrated in **Fig. 1**. The acoustic complex impedances are represented as

$$\dot{Z}_{L1} = |Z_{L1}| e^{j\varphi_{L1}} \quad (1)$$

$$\dot{Z}_{L2} = |Z_{L2}| e^{j\varphi_{L2}} . \quad (2)$$

When a burst signal is transmitted from the PZT, it is reflected at the ends of the rod sensors and the surfaces of the samples. These reflected signals interfere with each other, and the amplitude of the interference signals indicates the magnitude and phase difference of the acoustic complex impedance of the sample. If the difference in the magnitude is small ($|Z_{L1}| \approx |Z_{L2}|$), the contrast of the image indicates mainly the phase difference ($\varphi_{L1} - \varphi_{L2}$) of the acoustic complex impedance.

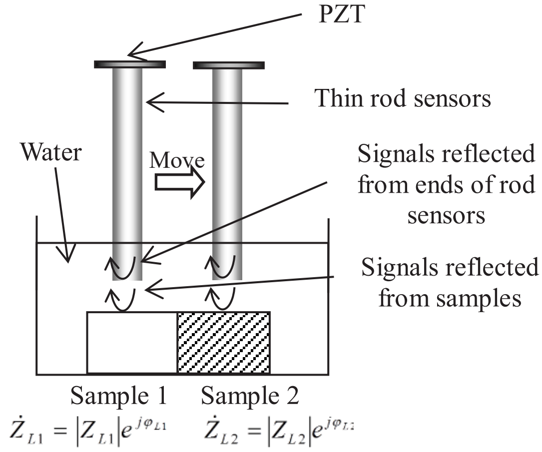

Fig. 1. Phase-contrast imaging procedure.

2.2 Multispectral phase-contrast imaging of acoustic impedance

Figure 2 illustrates the concept of multispectral phase-contrast imaging. The frequency-dependent scattering and attenuation are displayed on one image by measuring three images at different frequencies and

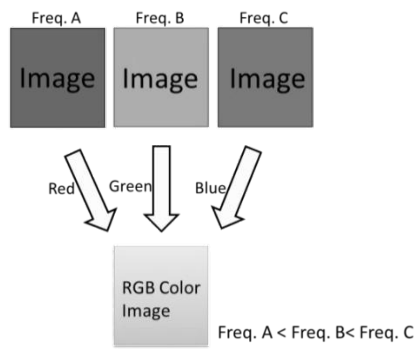

Fig. 2. Concept of multispectral phase-contrast imaging.

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superimposing them with intensity modulation for three colors (red, green, and blue) on one image.

3. Experiment

Figure 3 shows a schematic diagram of the experimental setup. In this experiment, a fused quartz rod with a diameter of 0.83 mm and length of 62 mm was connected to a transducer with a center frequency of 44.9 MHz. The tip of the rod had a concave spherical surface with a focal length approximately 0.5 mm from the end of the rod. Three electrical burst waves having an amplitude of 10 Vpp, frequencies of 40.0 MHz, 44.9 MHz, and 50.0 MHz, and a pulse width of 20 cycles were applied. The sample (PE plate with embedded 3.5-mm-diameter acrylic rod) was used as the object to be imaged.

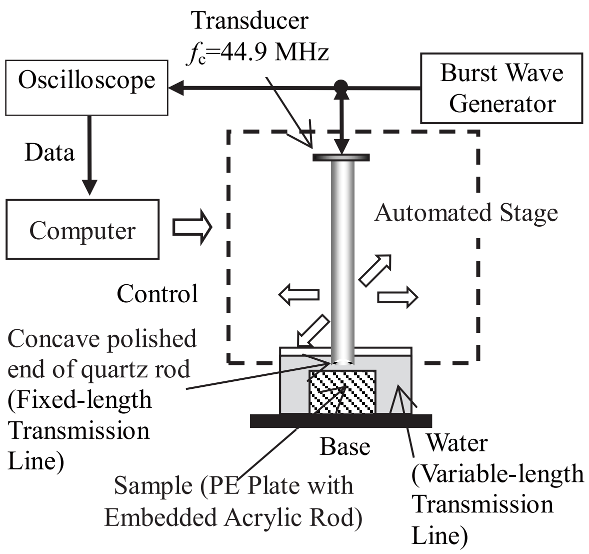


Fig. 3. Schematic diagram of experiment.

4. Results and discussion

Figure 4 shows a photograph of the sample. **Figures 5 (a)–(c)** show the phase-contrast images measured at the three burst wave frequencies. **Fig. 5(d)** shows the superimposed image. The sample was tilted slightly, so a stripe pattern was obtained.

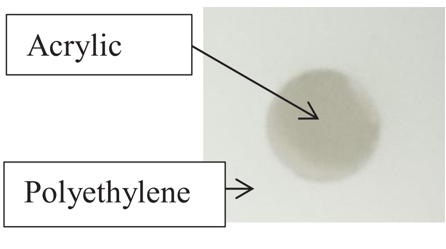
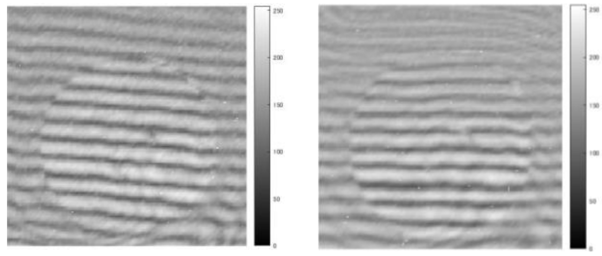
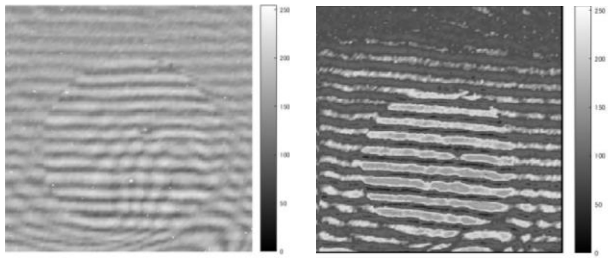


Fig. 4. Photograph of sample.

In Fig. 5 (d), the polyethylene region of the image is displayed darker than the acrylic region. The red was displayed darker in the grayscale superimposed image. This indicates that the polyethylene region of the sample reflected the lower frequency component of the acoustic wave, which means that the sample had frequency dependence.



(a) Red image (40.0 MHz) (b) Green image (44.9 MHz)



(c) Blue image (50.0 MHz) (d) Superimposed image

Fig. 5. Phase-contrast images of sample.

5. Conclusion

We have demonstrated that multispectral phase-contrast imaging of acoustic impedance can be used to obtain the difference in frequency dependence of a sample.

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