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Development of Sensing Capsule with Impedance Transforming Window for Puncture Needle-Type Ultrasonography
穿刺型超音波顕微鏡用インピーダンス変換機能付計測カプセル

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1. Introduction

Since the acoustic characteristics of living organisms are known to vary according to their organic composition, minute structural differences, and other factors,[1)] an acoustic microscope has been applied to biological tissue characterization. Many imaging methods for acoustic characteristics such as the measurement of the speed of sound or acoustic impedance have been developed for acoustic microscopes. They are useful for intraoperative pathological examination because staining that is required in the optical method is not required. In particular, since acoustic impedance can be used to visualize a surface without slicing a biological tissue, it may be applied to endoscopic ultrasonography.[2)] However, no suggestions for the sensing device and scanning mechanism for endoscopic ultrasonography have been made.

For endoscopic ultrasonograpy to facilitate tissue diagnosis, we are developing the puncture needle-type ultrasonography. Previously, we demonstrated that the scanning method and the imaging method for determining the acoustic impedance difference for puncture needle-type ultrasonography using a thin rod.[3-4)] In this method, a thin rod sensor was placed to face the tissue through the acoustic coupler. The reflection signal from the tissue was small because the acoustic impedance of the tissue was almost same as that of the acoustic coupler. Then, to make imaging the impedance difference more effective, the top cover was needed to have a function of impedance transformation. In this paper, we examined the effect of use a quarter-wavelength film and a half-wavelength film for the top cover of the capsule protecting the thin rod sensor on the acoustic difference image.

2. Principle

Figure 1 shows the schematic of the equipment for the puncture needle-type ultrasonography. The measurement principle of the method was previously reported.[3)]

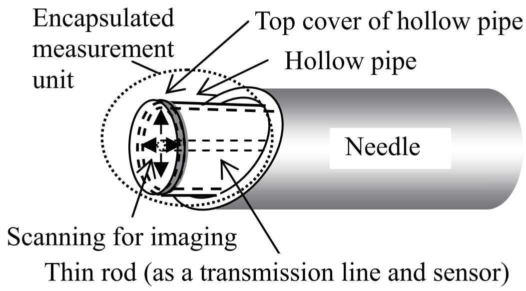

Fig. 1. Basic concept for puncture needle-type ultrasonography.

The measurement unit is encapsulated, as shown in Fig. 1. The thin rod sensor faced the tissue through the top cover and acoustic coupler. The reflection signal from the tissue is small because the acoustic impedance of the tissue is almost the same as that of the acoustic coupler.

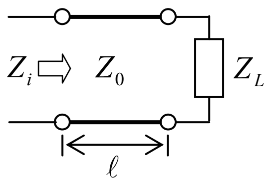

Fig. 2. Series-impedance transformer.

The series section of a transmission line of characteristic impedance Z_0 and length ℓ, as shown Fig. 2, that transforms an impedance Z_L to Z_i, as follow equation,

$$Z_i = Z_0 \frac{Z_L \cos\beta\ell + jZ_0 \sin\beta\ell}{Z_0 \cos\beta\ell + jZ_L \sin\beta\ell}. \quad (1)$$

When $\ell = \lambda/4$ and $\beta\ell = \pi/2$, the above equation reduces to

$$Z_i = \frac{Z_0^2}{Z_L}. \quad (2)$$

In addition, when $\ell = \lambda/2$ and $\beta\ell = \pi$, the

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equation (1) reduces to

$$Z_i = Z_L \,. \tag{3}$$

In this case, the impedance isn't transformed.

3. Experiment and results

Figure 3 shows the schematic diagram of the measurement. In this experiment, a fused quartz rod with a diameter of 1mm and length of 84 mm was connected to a transducer with a center frequency of 4.7 MHz for the experiment of quarter-wavelength film 9.0 MHz for the experiment of half-wavelength film, respectively. The tip of the fused quartz rod was a concave spherical surface with a diameter of 2 mm, whose focal length is approximately 0.3 mm from end of the rod. An electrical burst wave having an amplitude of 10 V, a center frequency of 4.4 MHz for the experiment of quarter-wavelength film 8.8 MHz for the experiment of half-wavelength film, respectively, and pulse width of 30 cycles was applied. The PVDF (polyvinylidene fluoride) film with a thickness of 128 µm was used as transformer film.

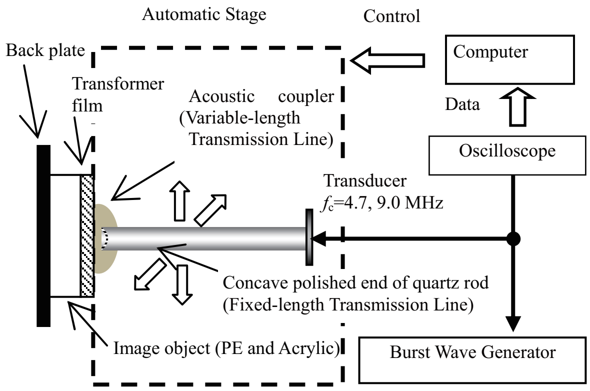

Fig. 3. Schematic diagram of measurement.

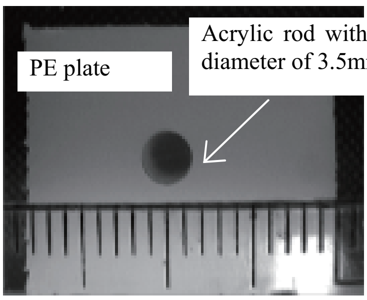

Fig. 4. Measured object.

The imaging object (PE plate and acrylic rod with a diameter of 3.5 mm embedded therein) shown in Fig. 5 was used in this measurement. Figure 5 shows the maximum amplitude of interference signal mapped as a function of X-Y position. These results show that the transformer film acts desirable function.

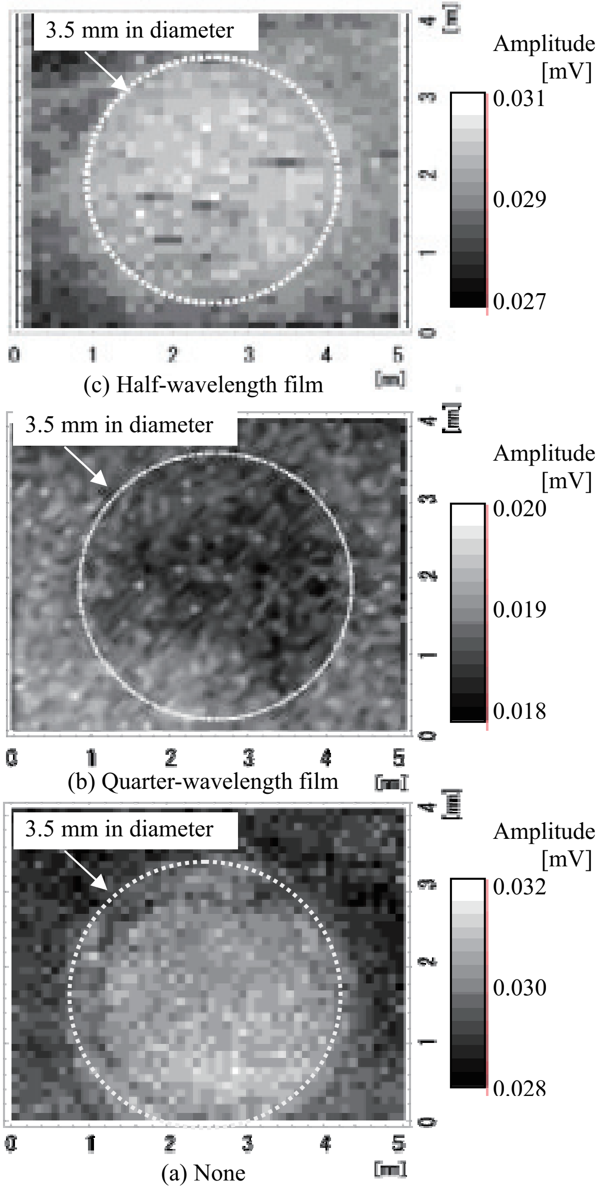

Fig. 5. Experimental results.

4. Conclusion

In order to develop a sensing capsule with an impedance transforming window for the puncture needle-type ultrasonography, we confirmed experimentally that the series-impedance transforming window can be used for the top cover.

References

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