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Piezoelectric Characteristic Analysis of Ultrasonic Transmission and Reception Using Diaphragm Type PZT Transducer

ダイアフラム型 PZT 振動子による超音波送受信の
圧電特性解析

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1. Introduction

In this study, we evalute the characteristic of vibrator which can transmit and receive at 20MHz band ultrasound. For such the band, it is nessessary to use a MEMS[1] processing. The MEMS processing is appropreate for generating a diaphragm-type[2] vibrator becauce its thickness is much thinner than a bulk-type one. The parameters determining the mechanical resonance frequency of diaphragm made of a piezoelectric layer and a Si layer are the size and the thickness of each layer. The main parameter is the size. The MEMS can generally make a thin film of a few micronmeters When the thickness is 2.0μm, the mechanical resonance frequency of the diaphragm with a size of 50μm is 20MHz. This study is to evalute the diaphragm-type vibrator whose PZT layer has a thickness of 2.0μm and a size of 50μm. This model has been found to have wide frequency band of receiving. It is nesscessary to transmite the sufficient sound pressure in the receivable frequency band.

2. Analysis method

This study consists of two simulations using the PZFlex that is a one of the ultrasonic propagation simulators with the finite element method (FEM).

A. Evaluation of the characteristics of the resonance frequency and the determination of the analysis model

When the size is 50μm and the thickness is 2.0μm of the PZT layer, we determine the thickness of the Si layer that the mechanical resonance frequency is 20MHz. In the first simulation, 1Pa impulse sound pressure is applied to the center of diaphragm (see **Fig. 1**). The waveform of the displacement of the center point of the diaphragm is obtained as a result. The frequency characteristic of the displacement is obtained through the FFT analysis of the waveform. The mechanical resonance frequency is the frequency having maximum amplitude. We carry out the same evaluation while changing the thickness of the Si layer by 0.5μm from 4.0μm to 6.5μm. **Figure 2** (a) shows the mechanical resonance frequency characteristics for the thickness of the Si layer. Figure 2(b) shows that the

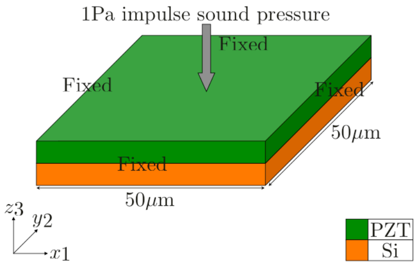

Fig. 1 Analysis model for evaluation of mechanical resonance frequency.

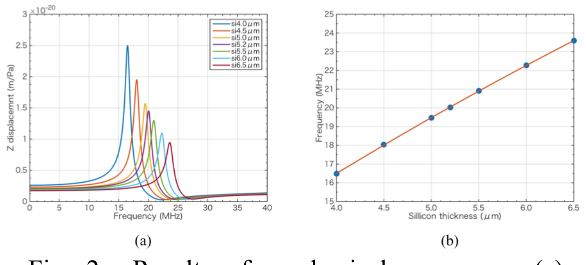

Fig. 2 Results of mechanical resonance: (a) Frequency characteristics of displacement of center point; (b) mechanical resonance frequency.

mechanical resonance frequency is 20MHz when the Si layer is 5.2μm. The thickness of the Si layer is set to 5.2μm in the following simulation.

B. Evaluation of the transmission frequency characteristic and vibration mode

Figure 3 shows the frequency characteristic of receiving. This model can be received wideband. It is necessary to transmit these frequency bands.[3]

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In the second simulation, a continuous sine wave with amplitude of 1V is applied while changing the frequency by 5MHz from 5MHz to 60MHz. The displacement and the sound pressure are observed. The displacement is observed at the center point of the diaphragm. The sound pressure is observed in water 1mm away from the center point of diaphragm (see **Fig. 4**(a)). The vibration mode is observed also. Figure 4(b) shows the electrical circuit used in the simulation.

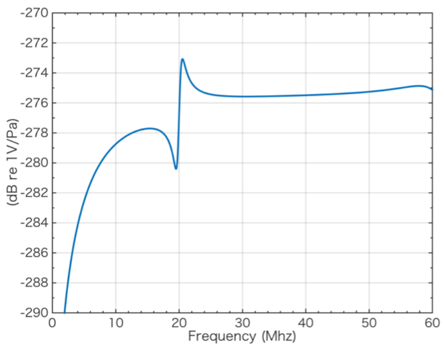

Fig. 3 Frequency characteristic of receiving.

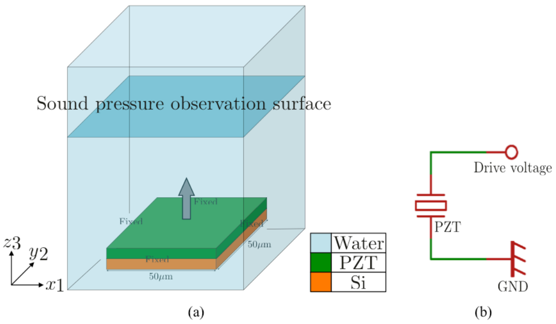

Fig. 4 Simulation for transmission: (a) analysis model for evaluation; (b) electrical circuit for transmission.

3. Result

Figure 6 shows the frequency characterristics of the displacement. **Figure 7** shows the state of vibration. **Figure 8** shows the frequency characteristics of the sound pressure. The mechanical vibration of the diaphram has a very narrow band. It is possible to transmit high sound pressure at the other mechanical frequency. This model vibrates in the hig-order mode at 60MHz band.

4. Conclusion

In this study, we evaluate the transmission characteristic of the vibrator which can transmit and receive at 20MHz band. This model can transmit with wide receiving band. The diaphragm-type is low receiving sensitivity. The transmission at high sound pressure leads to improve receiving sensitivity. It is necessary to evaluate the phase of the sound pressure because of higher-order mode.

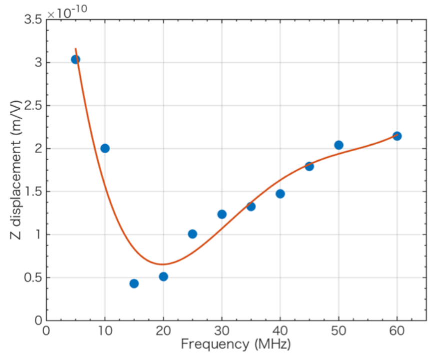

Fig. 6 Frequency characteristics of displacement at center point of diaphragm.

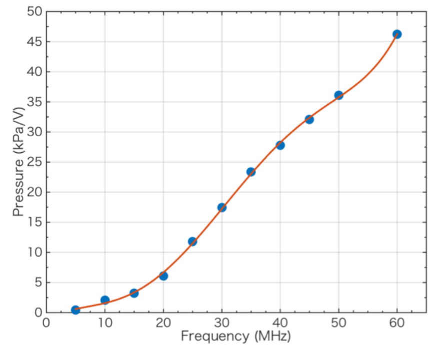

Fig. 8 Frequency characteristics of sound pressure.

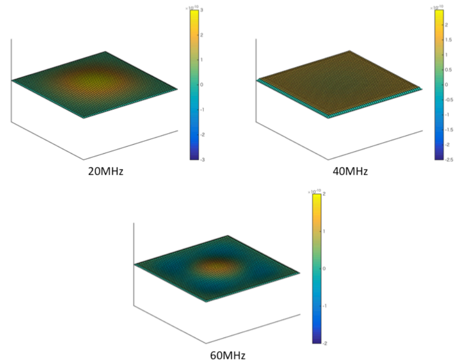

Fig. 7 Sate of vibration.

References

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