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Vibration characteristic analysis according to thickness of support layer of diaphragm type PZT resonator

ダイアフラム型 PZT 共振器の
支持層の厚みに応じた振動特性分析

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1. Introduction

For high performance of medical ultrasound imaging, improvement of diagnostic depth and spatial resolution are essential themes. The former can be solved by decreasing the attenuation using low frequency band and increasing the reception sensitivity. The latter requires wide band measurement. Therefore, both themes are in a trade-off relationship, and many researches on realization of compatibility have been made.

So far, PMUT has focused on research for applications that use continuous wave transmission and reception, such as fingerprint detection. We are aiming at imaging application of PMUT. Considering the resolution that can be applied to an acoustic microscope, the diameter of PMUT needs to be 100 µm or less. In that case, the thickness relative to the size increases, and the thickness vibration coexists with the membrane vibration. As a result, it is clear from our studies that a very wide band characteristic can be obtained.[1-3)]

Since the thickness of the support layer on which PZT is placed can be expected to control the coexistence ratio of membrane vibration and thickness vibration, this study analyzes the effect of the thickness of the support layer on the receiving characteristics of PMUT. Two materials, Si and stainless steel, are used as the material for the support layer. The thickness of the PZT layer is fixed at the standard value of 2.0 µm. While Si has the advantage of being capable of MEMS processing, our study has confirmed that stainless steel improves reception sensitivity and bandwidth.[4)] We examine the suitability of the received waveform which is a characteristic directly related to image quality for both materials by changing the thickness of the support layer.

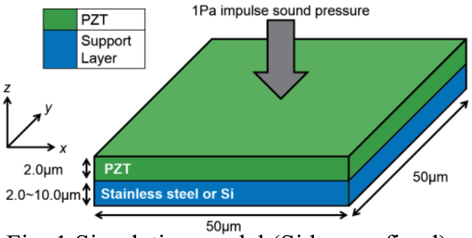

Fig. 1 Simulation model (Sides are fixed).

2. Simulation method

The FEM (finite element method) simulator PZFlex is used to evaluate piezoelectric characteristics. In the diaphragm type PZT resonator, the size and the film thickness exist as variables. In this evaluation, we consider the optimization of the film thickness by setting the size to 50 µm square. Impulse sound pressure of 1 Pa is applied to the center of the upper surface, and the thickness of the PZT film and the stainless steel plate are changed on the order of microns to obtain time history data such as received voltage and displacement. By performing discrete Fourier transform on these as necessary, the film thickness and frequency characteristics of reception sensitivity and bandwidth are investigated. **Figure 1** shows the simulation model.

3. Result

Figures 2 and **3** show the reception waveform for several support layer thicknesses. The received waveform when the back of the 2.0 µm thickness support layer is fixed so as not to move is also shown. Under this condition, it is expected that no membrane vibration occurs and only the thickness vibration of the thin film PZT occurs. From those, the amplitude and the pulse width in the thickness of each support layer are summarized in **Fig. 4** and **Fig. 5**. The pulse width is defined by the -3dB level. The ratio of sidelobe amplitude to mainlobe amplitude amplitude is shown in **Fig. 6** as well. Each star marks show that data of the back face fixed model. Finally, **Figures 7** and **8** show

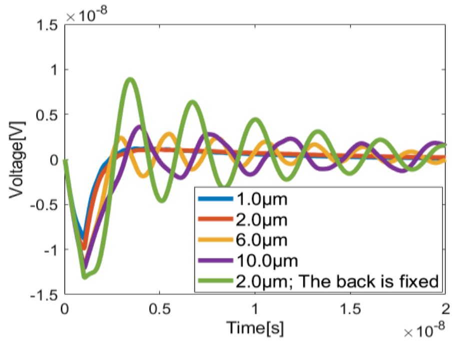

Fig. 2 Received waveform with Si support layer.

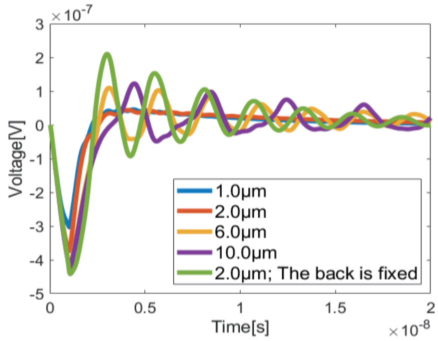

Fig. 3 Received waveform with stainless steel support layer.

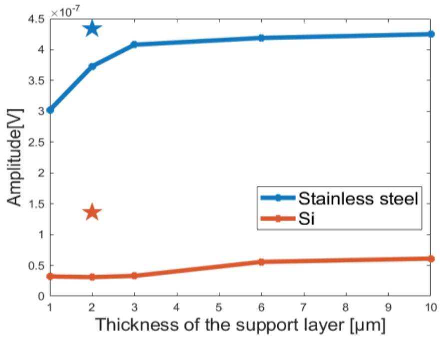

Fig. 4 Amplitude corresponding to thickness of support layer.

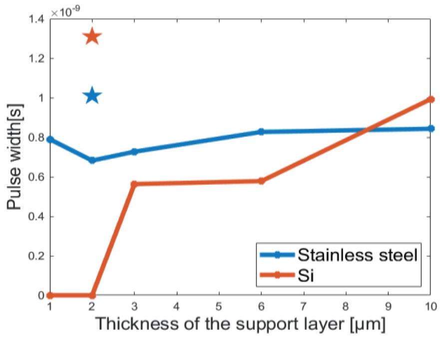

Fig. 5 Pulse width corresponding to thickness of support layer.

the frequency characteristics of amplitude and phase that based on **Fig. 2**.

As can be seen from these figures, regardless of the material of the support layer, the received voltage is slightly improved as the thickness of the support layer increases, but the pulse width is not narrowed and ringing occurs. In particular, when only the thickness vibration is obtained by fixing the back surface, disturbance of the waveform becomes conspicuous. It can be considered that mixing of membrane vibrations improves frequency phase characteristics and can prevent ringing of received waveforms. On the other hand, it is generally known that membrane vibration easily occurs when the thickness of the support layer is reduced, and the waveform is disturbed by the narrow band characteristic of the membrane vibration. The thickness of the support layer was found to be important in terms of controlling the superposition of the thickness vibration and the membrane vibration.

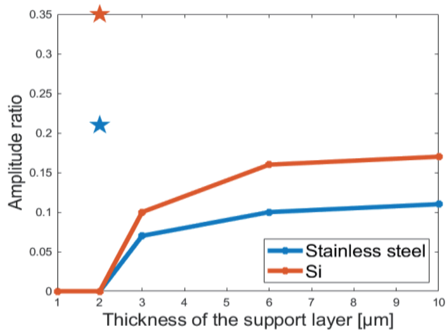

Fig. 6 Amplitude ratio between main lobe and first side lobe.

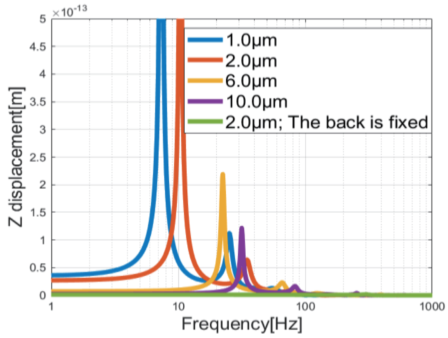

Fig. 7 Frequency characteristics of amplitude in z-axis direction of Si layer

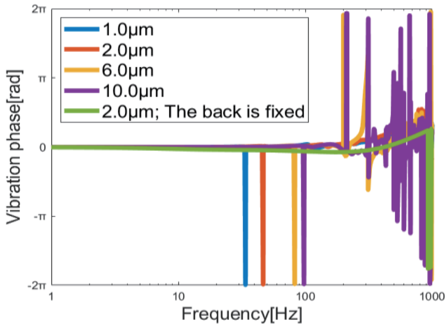

Fig. 8 Frequency characteristics of phase in z-axis direction of Si layer

4. Conclusion

From the above results, it was suggested that the material of the support layer, which has high bulk modulus for wideband characteristics of thickness vibration and low bending modulus for phase characteristics, is suitable. Ease of bending of the material also contributes to improvement of transmitted sound pressure. As a future task, we will continue these investigations and strive to determine the appropriate material and thickness.

5. References

1) Y. Ishiguro, J. Zhu, N. Tagawa, T. Okubo, and K. Okubo: Jpn. J. Appl. Phys., **56** (2017) 07JD11.
2) Y. Ishiguro, N. Tagawa, and T. Okubo: *Proc. Symp. Ultrasonic Electronics*, **38** (2017) 3P3-3.
3) Y. Ishiguro, N. Tagawa, and T. Okubo: *Ultrasonic Technology*, **29** (2017) No. 6, 78-83.
4) M. Suzuki, N. Tagawa, M. Yoshizawa, and T. Irie: *Proc. Symp. Ultrasonic Electronics*, **39** (2018) 1P5-8.