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Evaluation of Reception Characteristics of Diaphragm Type PZT Resonator with Stainless Steel Plate as Vibration Support

ステンレス鋼板を振動板として用いる
ダイアフラム型 PZT 共振器の受信特性評価

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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. In this study, we are trying to solve the problem by coexistence of membrane vibration and thickness vibration.

Based on the previous study ,[1-3) we have a plan to measure the reception characteristics in PZT/stainless steel model. experimentally This model is fmanufactued as a piezoelectric Micromachined Ultrasonic Transducer (pMUT, see **Fig. 1**). Prior to the experiment, in this study, we use FEM simulation to compare the reception sensitivity, bandwidth, etc., between the stainless steel model and the conventional silicon model.

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

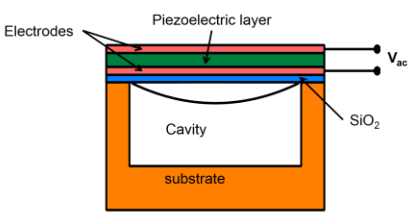

Fig. 1 Outline drawing of pMUT

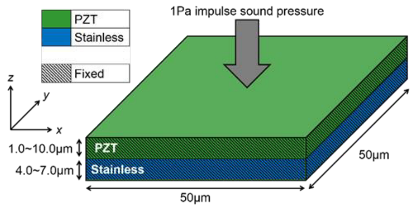

Fig. 2 PZT / stainless steel model

Fourier transformation on these, we investigate the film thickness characteristics and frequency characteristics of the reception sensitivity and bandwidth. **Figure 2** shows the simulation model.

3. Result

3.1 Receiving sensitivity and bandwidth

Figure 3 shows the procedure for deriving the maximum reception sensitivity and the -3 dB bandwidth from the received voltage data obtained by the above simulation method.

Figure 4 shows the maximum reception sensitivity and the -3 dB bandwidth as the film thickness characteristics of the PZT layer. As can be seen from **Fig. 4**, if the thickness of the PZT layer is increased by keeping the thickness of the stainless steel layer constant, the maximum reception sensitivity also increases. At the same time, the -3 dB bandwidth sharply expanded at a certain PZT film

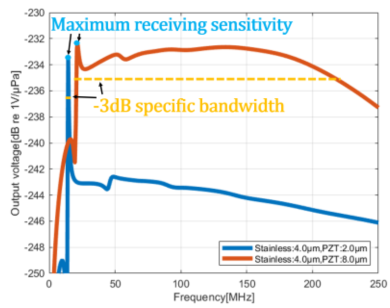

Fig. 3 Frequency characteristics determined from received voltage

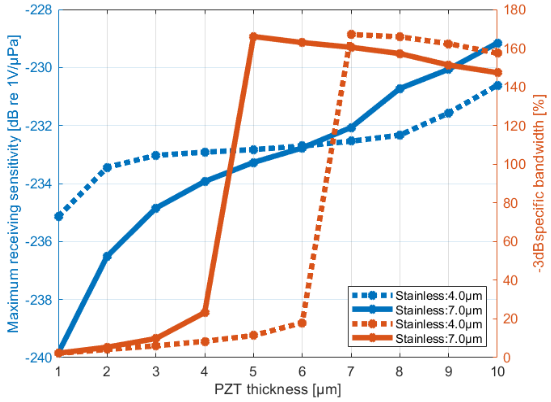

Fig. 4 Film thickness characteristics of PZT layer: maximum receiving sensitivity and -3 dB bandwidth

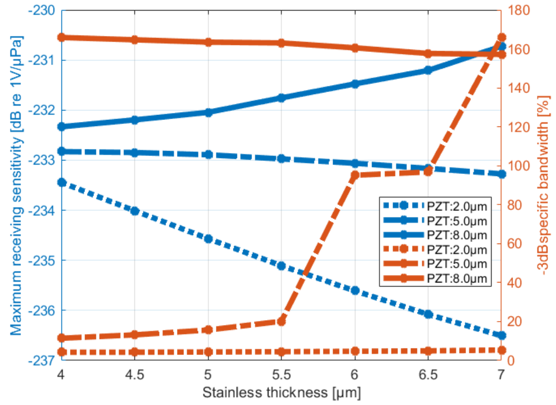

Fig. 5 Film thickness characteristics of stainless layer: maximum receiving sensitivity and -3 dB bandwidth

thickness. The thickness of the corresponding PZT layer tends to become thinner as the thickness of the stainless steel layer increases. This is the characteristic seen also in the PZT/Si model, which shows that this PZT/stainless steel also has the same characteristics.

From **Fig. 5**, if the thickness of the stainless steel layer is increased by keeping the thickness of the PZT layer constant, it can be seen that the tendency of the maximum reception sensitivity is divided into two depending on the thickness of the PZT layer. For the -3 dB bandwidth, the influence of the film thickness of the PZT layer is larger than the film thickness of the stainless layer, but looking at the film thickness of the PZT layer of 5.0 μm, the stainless layer also has a certain influence.

3.2 Comparative evaluation

We compare the PZT/stainless steel model and the PZT/Si model. It is obvious from **Fig. 6** that the maximum reception sensitivity is significantly higher in the PZT/stainless steel model. For the -3 dB bandwidth, it can be seen that the film thickness for widening the bandwidth is different, but it has similar characteristics.

Since stainless steel is more flexible than silicon, the film thickness balance between the PZT layer and the stainless steel layer becomes more important. In addition, as shown in **Fig. 4** and **6**, it is considered that membrane vibration is suppressed by appropriately controlling each film thickness, contributing to wider band.

For example, when the thickness of the PZT layer is 8.0 μm, comparing the PZT/Si model and the PZT/stainless steel model, the -3 dB bandwidth is almost the same, but in the PZT/stainless steel model the maximum reception sensitivity is 35 dB larger than the PZT/Si model, by which we can advocate the usefulness of the PZT/stainless steel model. That is, if the film thicknesses of the model is the same in the so-called thick film region, the PZT/stainless steel model is considered to have better characteristics.

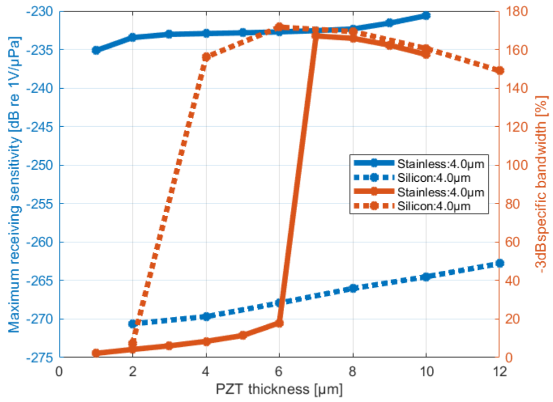

Fig. 6 Comparing the PZT / Si model and the PZT/stainless steel model

Research on a method of directly forming a piezoelectric film on a metal substrate called the AD (Aerosol Deposition) method has been also conducted for thick film production.[4,5]

4. Conclusion

By changing the substrate from silicon to stainless steel, the maximum reception sensitivity was greatly improved while maintaining the reception broadband characteristics. In the future, it is important to clarify factors that greatly improved the maximum reception sensitivity.

5. References

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