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Thickness design for output pressure of polyurea high frequency ultrasonic array transducer

ポリ尿素高周波超音波アレイトランスデューサの高出力化に対応した膜厚設計の検討

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1. Introduction

Our research group has studied for ultrasonic transducer made with aromatic polyurea piezoelectric material[1)2)3)]. Polyurea is an oraganic piezoelectric material which can be evaporated on to arbitrary shaped base structure. The authors have proposed an array ultrasonic transducer fabricated by using photolithography technique[4)]. However, the fabricated ultrasonic transducer did not have enough efficiency from the viewpoint of k_{eff}. On the other hand, the authers have performed a design of multilayered polyurea ultrasonic transducers to improve the amplitude of the output sound pressure[5)6)] by the equivalent circuit analysis for multilayered transducers[7)8)]. In this reoprt, we investigate thickness designs for small area pulyurea ultrasonic transducer elements which are suitable for the array strucuture.

2. Structure of the array transducer.

In this report, unit element transdcers of the array structure fabricated in the ref. 4 are discussed. Figure 1 shows the cross-sectional structure of the array transducer. A bottom aluminum electrode (d_{Albot}), a membrane of polyurea piezoelectric material (d_{PU}), and upper aluminum electrodes (d_{Altop}) are fabricated onto a polyimide base layer (d_{PI}). A thickness vibrator is available where the top electrodes overlap the bottom electrode. In the ref. 3, the thicknesses of the individual layers were as follows; d_{Albot} =0.125 μm , d_{PU}=3.5 μm, d_{Altop}=3.3 μm, and $d_{PI} = 25\ \mu$m. Table I shows the electromechanical coupling factors at resonanse frequencies below 100 MHz calculated by the Mason's equivalent circuit model for that case. These values are lower than that of the single transducers (0.25) which fabricated in ref. 3.

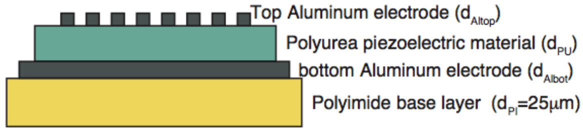

Fig. 1 Structure of the array transducer in this study.

Table I Electromechanical coupling factors for the array transducer calculated in ref. 4.

f_s [MHz]	k_{eff}
38.9	0.079
69.3	0.059
99.4	0.070

3. Thickness design for the element ultrasonic transducer for the array structure.

In the ref. 4, the designs of thicknesses for the array transducer were same as the single ultrasonic transducer of which the area (=6 mm^2) is larger than the array transducer. Thus the electromechanical coupling factors of the former designed array transducer were decreased for an element transducer of the array structure which has very small area (=0.09 mm^2 for 8-array transducer). In this report, thicknesses designs of element ultrasonic transducer for the 8-array structure are examind through equivalent circuit calculations. Frequency characteristics of the element transducer are calculated with varying the thicknesses of polyurea, and resonance frequencies are extracted for below 100 MHz to find the thickness design that gives higher electromechanichal coupling factor k_{eff}. The thickness of polyimide base layer is fixed at 25 μm. Thicknesses of top aluminum electrode, polyurea layer, and bottom aluminum electrode are varied. Combinations of the thicknesses that give maximum k_{eff} at resonance frequencis are selected. Table II shows the results of the thickness design. As the thickness of the base polyimide layer is fixed, basically three resonance frequencies are

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observed around 40 MHz, 70 MHz, and 100 MHz. Table II shows the thickness design which the electromechanical coupling factor of the three frequencies are maximum. The thickness of each layer are as follows; d_{Albot} =1.5 μm , d_{PU}=1.9 μm, d_{Altop}=5 μm, and d_{PI} = 25 μm. For this case, k_{eff} at 71.7 MHz is increased to 0.082. However the design which gives high effeciency for all resonance freqency was not obtained.

Table II Electromechanical coupling factors for the array transducer calculated in this study.

f_s [MHz]	k_{eff}
38.9	0.078
71.7	0.082
103.8	0.068

Accordingly, thickness designes for individual resonance frequencies are performed. Frequency range for the design was set to between 10 and 110 MHz. The frequency range was divided into several number of frequency bands that have a few tens MHz bandwidth. For each divided frequency band, thickness designs for resonance frequencies were performed. Table III shows the result of the thickness design. For the individual resonance frequencies, electromechanical coupling factors of around 0.11 are obtained.

Table III Designed transducer thicknesses for the 8-array structure.

d_{PU} [μm]	d_{Altop} [μm]	d_{Albot} [μm]	f_s [MHz]	k_{eff}
10.0	6.7	5.0	32.6	0.12
10.0	6.7	5.0	47.8	0.10
6.1	4.8	7.7	55.3	0.11
4.4	6.4	5.4	61.7	0.11
10.0	6.7	5.0	74.9	0.08
2.6	4.1	6.3	92.4	0.11

Figures 2 and 3 show the frequency characteristics of the output sound pressure for the designed element transducers of 32.6 MHz (Fig. 2) and 92.4 MHz (Fig. 3) respectively. As shown in the figures, output sound pressures have the maximum value around the designed frequencies.

4. Conclusion

In this reoprt, thickness design of the polyurea ultrasonic transducer for the array structure have been studied. By using the equivalent circuit analysis, thicknesses of the element transducers were designed from the viewpoint of the electromechanical coupling factor. As the result, high output sound pressures were obtained for individual design frequencies. To fabricate and to evaluate the array transducers based on this report is left for further study.

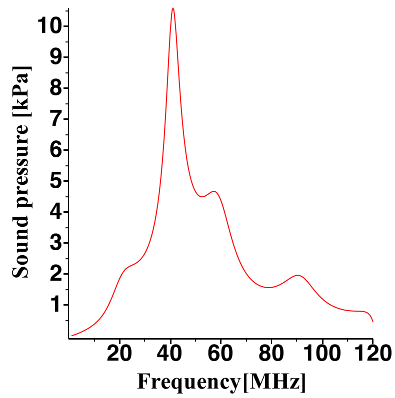

Fig. 2 Output sound pressure for 32.6 MHz resonance transducer.

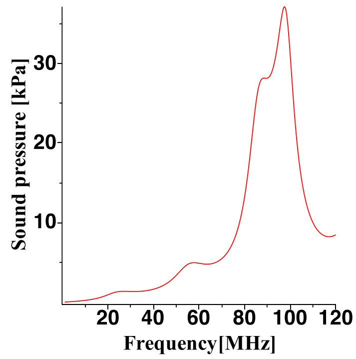

Fig. 3 Output sound pressure for 92.4 MHz resonance transducer.

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