Multi-layered Transducers Using Polyurea Film

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1 Introduction
We have been investigating ultrasonic transducers using polyurea (PU) piezoelectric material, which is fabricated throughout vapor deposition process[1][2]. To increase the sensitivity of the transducer, multi-layered structures using polyurea film are considered in this report.

2 Fabrication of the multi-layered transducer using polyurea film

2.1 Fabrication process of polyurea film
A special twin chamber shown in Fig. 1 is used for depositing PU film and aluminum (Al) electrodes. The chamber enables us to fabricate transducers without breaking vacuum throughout the whole process. The PU film is deposited with an addition polymerization process described by the following reaction equation.

\[
\text{MDI} + \text{ODA} \rightarrow \text{Polyurea} + \text{H}_{2}\text{N} \rightarrow \text{H}
\]

(1)

In order to obtain high piezoelectricity, 4,4’-diphenyl methane diisocyanate (MDI) and 4,4’-diamino diphenyl ether (ODA) should be balanced in quantity, and are evaporated at temperatures of 62°C and 122°C[3][4]. After the deposition process, an electric field of 80 V/µm is applied at 180°C for 10 minutes to polarize the PU film.

2.2 Configuration of the multi-layered transducer
Fig. 2 shows the configuration of a single layer transducer. PU (thickness: 1.5 µm) and Al electrodes are deposited on a polyimide film (thickness: 25 µm). The bottom electrode (thickness: 0.125 µm) and PU film are layered alternately for 2, 3, and 4 layered transducers (Fig. 3). This can be achieved by moving a substrate between the two chambers using handler belts. Only the thickness of the top electrode was 5 µm.

3 Evaluation of the multi-layered transducers

3.1 Capacitance measurement
Fig. 4 shows the results of the measured capacitances for the number of layers. The theoretical values of capacitances using the dielectric constant of PU (= 4.4) are indicated by a solid line. We can see that the capacitances increase as the number of layers increased.
transmitted from this side. The reflected pulse was received by the same transducer and observed using an oscilloscope, moving the glass slide along x axis from 0 to 13 mm by 0.1-mm step.

Fig. 5 Experimental setup for the pulse/echo experiment.

Fig. 6 indicates the amplitudes of the reflected waves in time domain for 1, 2, 3, and 4 layered transducers. The maximum amplitudes corresponding to the resulted waveforms are plotted in Fig. 7. From the results, we see that the amplitudes increase as the number of layers.

Fig. 6 Results of the reflected waveforms.

Using the waveforms, we calculated the spectrum densities by means of the Welch’s method[5](Fig. 8). The spectrum peaks are consists of the several frequencies: the fundamental resonant frequency of the transducer is around 20 MHz, the frequency of system noise distributes around 10 MHz, and the frequency because of the reflection in the connected electrical cable is observed around 50 MHz. We can see the amplitudes at fundamental frequencies increase as the number of the layers become large.

4 Conclusion
We made 2, 3, and 4 layered transducers using polyurea film. We found that the capacitances increased as the number of layers increased. The results of the pulse/echo experiment show that the maximum amplitudes and the spectrum densities also increase because of the multilayer lamination. As a future work, the numerical analysis for the multi-layered transducer will be considered to evaluate its effectiveness.

References