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Application of Cellular Polypropylene to Ultrasonic Transducers in Water

多孔性ポリプロピレンの水中用超音波トランスデューサへの応用

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1. Introduction

We have researched and developed ultrasonic technology for medical use to allow imaging with ultrasonic about 100 kHz intended to achieve wireless transmission and downsizing of them.

In materials such as piezoelectric ceramics and piezoelectric composite which have been used in traditionally, optimum thickness for responding at 100 kHz in the thickness mode resonance is about 15 mm. However, a new material, charged piezoelectret cellular polypropylene (cellular PP) film which is very thin, has been reported that the film has a piezoelectric response near 100 kHz at the same mode in the thickness [1]. Furthermore, there are some good parameters as shown in Table 1.

So, we consider it may be possible to develop ultrasonic transducers in a thinner size smaller and good receiving characteristics by utilizing cellular PP films.

Up until recently, we have been researching on an underwater **u**ltrasonic **r**eceiving **t**ransducer with a **F**ET **b**uilt-in housing (FBURT) and reported the results previously [2].

In the research, we developed the new transducer, **F**ET-**l**ess underwater **u**ltrasonic **r**eceiving **t**ransducer (FLURT), and evaluated it. And we have discussed 2 topics.

1. Temperature dependence of FLURT on sensitivity.
2. Comparison for output voltage between FBURT and FLURT on the same condition.

Table 1 Material constants of typical piezoelectric materials.

Material	Relative permittivity	Piezoelectric strain constant	Voltage output constant	Young's modulus
	$\varepsilon_{33} / \varepsilon_0$	d_{33}[pC / N]	g_{33} [Vm / N]	E [GPa]
PZT-5	1750	171	0.011	50
PVDF	64	20	0.2	2
Cellular PP	1.2	400 – 1200	60 - 180	0.002

2. Experiments

2.1 Preparation of FLURT

Figure 1 shows a structure of FET-less underwater ultrasonic receiving transducer (FLURT) containing cellular PP piezoelectret film adhered rigidly to internal substrate which has large acoustic impedance in order to resonate in quarter – wave mode. And the diameter of receiving surface is about 15 mm. They are built within SUS housing for corrosion proof and electromagnetic shield.

And, we prepared circuit both inside and outside of housing which has same FET as FBURT. Then, we prepared three types for comparison of output voltage as shown in Table 2.

Table 2 Three types of transducer system.

Type	Transducer	FET
A	FBURT	Built-in
B	FLURT	External
C	FLURT	Less

2.2 Evaluation method.

Figure 2 shows the system of measurement. Sound source is the transducer made by KGK with ϕ32 mm piezoelectric composite whose nominal center frequency is 100 kHz. A driving signal was 123 kHz, 80$V_{p\text{-}p}$ and 13 cycles sinusoidal burst wave generated by Function Generator and RF amplifier.

A size of water tank is 120 × 160 × 300 mm^3. Sound source was placed on the bottom of the tank and toward the water surface. Then FLURT was immersed at the place of 100mm distance from sound source.

An acoustic pressure at the setting place of FLURT was measured by hydrophone, Type 8103 (B&K). So the receiving sensitivity can be expressed as a value of receiving voltage divided by the acoustic pressure.

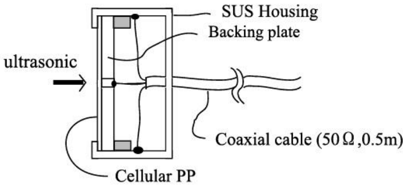

Figure 1 Structure of FLURT.

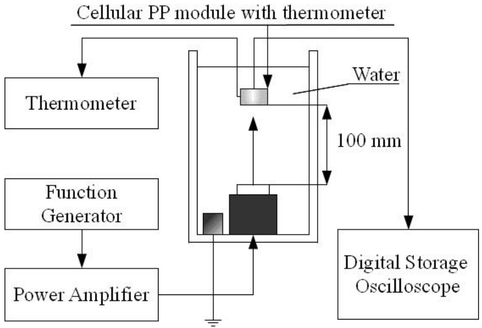

Figure 2 System of measurement.

3. Results and discussions

3.1 Receiving characteristics of FLURT.

Figure 3 shows the output waveform from FLURT measured in water at 25 ℃. In the period of just after pulse falling, there are some small noisy signals originated from travelling ultrasounds along abnormal courses. Amplitude value is 83 $mV_{p\text{-}p}$ in the period of steady-state. The value of sensitivity became about -226 dB re 1V / μ Pa , which is a relatively larger than a MHz-range hydrophone made from PVDF.

3.2 Temperature dependence for the sensitivity of FLURT.

Figure 4 shows the temperature dependence for the sensitivity of FLURT in water. Up to around 40℃, the sensitivity is roughly -226.5 dB re 1 V / μ Pa. However, beyond 40℃, it increases. We are under considering this phenomenon now strictly.

3.3 Comparison of output voltage for three types of transducer system.

We discussed a comparison for output voltage for three types of transducer system. To compare 3 patterns, it is clear that result of type A is the largest for an output voltage because a cable length is the very short. And, the output voltage of type B and type C is 75% of type A.

Table 3 Output voltage of three types.

Type	A	B	C
Output voltage [$mV_{p\text{-}p}$]	111	76.7	83.2

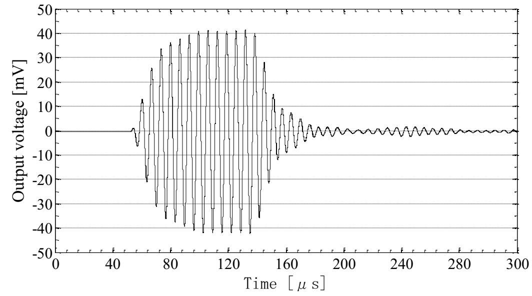

Figure 3 Output waveform from URLF in water at 25 ℃.

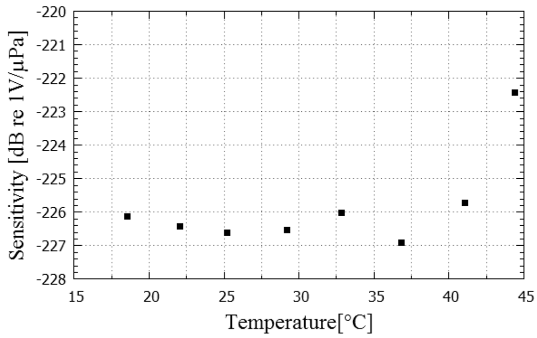

Figure 4 Temperature characteristic in water of sensitivity of FLURT.

4. Conclusion

In this preliminary report, we described the result of some characteristics and some consideration on a new immersion type and newly structured ultrasonic transducers using cellular PP films. The temperature dependence on the sensitivity of FLURT is enough stable up to 40℃, it is considered that this piezoelectret film can be used for the medical application in the view of temperature stability.

We have some plans in the near future to make some phenomena not shown here be clear, to make some circumstance parameter test and to develop new type of both transmitting and receiving ultrasonic transducers for commercial use.

Acknowledgment

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References

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