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Development of Anti-cavitation Hydrophone using a Titanium Front Plate -Effect of the Titanium Front Plate in High Intensity Acoustic Field with Generation of Acoustic Cavitation-

耐キャビテーションハイドロホンの開発
-キャビテーションに対するチタン前面板の効果-

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1. Introduction

Recently, ultrasound diagnostic methods, such as harmonic imaging and ultrasound elastography for elasticity imaging of organs and soft tissues have been used widely. Ultrasound pulses with high intensity are irradiated highly frequently in these diagnostic methods. Furthermore, new ultrasound treatment methods, such as sonoporation for gene transfer, high-intensity focused ultrasound (HIFU) for cancer therapy are developed and used actively. Furthermore, ultrasound cleaners and ultrasonic particle dispersion systems are used in the industrial field. There is a tendency that ultrasound is irradiated at a high frequency. These acoustic field distributions should be measured with a hydrophone[1-2]. However, electrodes or piezoelectric elements of the hydrophones are broken by effect of high sound pressure and acoustic cavitation when acoustic fields of ultrasound apparatus with high intensity ultrasound like ultrasound cleaner or HIFU device were measured by using normal commercial hydrophones. Therefore, it was difficult to measure such high intensity acoustic field by using normal commercial hydrophone.

In this study, an anti-cavitation hydrophone was fabricated by depositing a hydrothermally synthesized lead zirconate titanate (PZT) polycrystalline film[3-4] on the back side of a titanium plate.

2. Fabrication of Hydrophone

A schematic diagram of the hydrophone, which uses a hydrothermally synthesized PZT polycrystalline film on a titanium membrane with a diameter of 3.5 mm,is shown in **Fig. 1**.

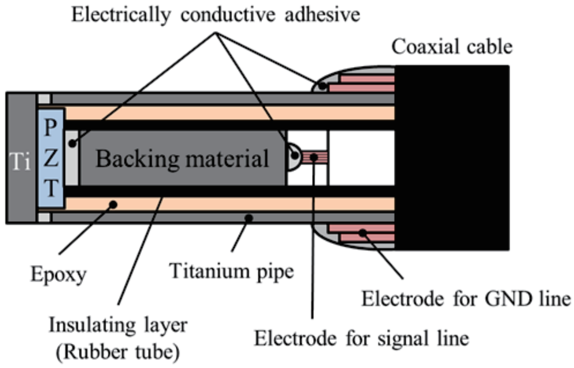

Fig. 1 Structure of our anti-cavitation hydrophone fabricated in this study.

The piezoelectric element consisted of a hydrothermally synthesized PZT polycrystalline film deposited to a thickness of 15 μm on the back of a titanium layer of 50 μm thickness and 3.5 mm diameter. The piezoelectric element was bonded to one end of a titanium rod as backing material, each with a diameter of 2 mm. The titanium rod was then connected to the inner lead wire of the signal line of a coaxial cable. Furthermore, a titanium pipe was connected to the outer conductor as a ground for the coaxial cable. The backing material and titanium pipe were electrically isolated by rubber tubes.

3. Experimental methods

A durability test of our fabricated anti-cavitation hydrophone was performed by exposure to the ultrasound acoustic field with the generation of acoustic cavitation in the water tank of an ultrasound cleaner and to the focused ultrasound field like HIFU. A concave type focused ultrasound system with a diameter of 100 mm was used as an acoustic source for durability test in the

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focused ultrasound field. The resonance frequency of the concave ultrasound transducer is 1.78 MHz. A durability test of our fabricated anti-cavitation hydrophone was also performed by an ultrasound cleaner (Honda Electronics HCL-280A) at 22.5 kHz. The maximum input electric power is 48 W.

Output voltages of hydrophone were measured with our fabricated tough hydrophone at acoustic far-field of 3.5 MHz transmitting ultrasound probe. Output voltages from the hydrophone under test were measured at 3.5 MHz for before and after ultrasound exposure in the focused ultrasound at 1.78 MHz or in the acoustic field of ultrasound cleaner at 22.5 kHz. In addition, we observed the change in appearance such as receiving surface of the hydrophone before and after ultrasound exposure.

4. Experimental results

The relationships between sonication time of focused ultrasound field and voltage ratio of the output signal from the hydrophone is shown in **Fig. 2**.

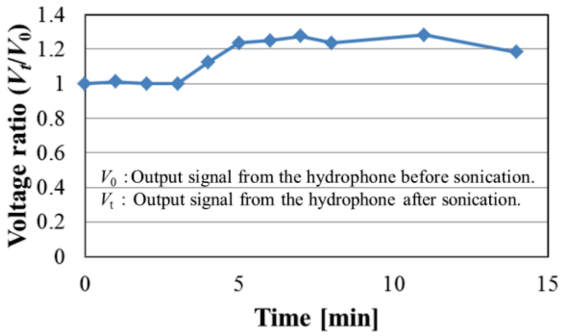

Fig. 2 Relationships between sonication time of focused ultrasound field and voltage ratio of the output signal from the hydrophone.

The output signal from the fabricated hydrophone did not decrease after 14 min. The hydrophone was found to have a durability of about 14 min. The titanium front plate and the hydrophone was not damaged at all even at after ultrasound exposure.

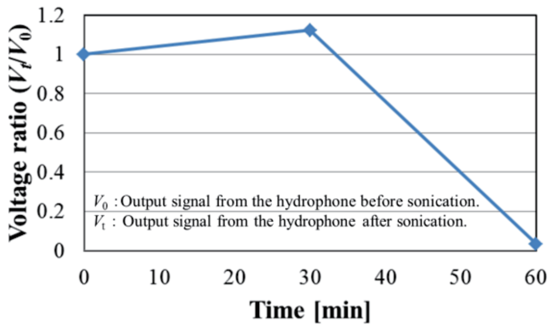

Fig. 3 Relationships between sonication time of ultrasound cleaner and voltage ratio of the output signal from the hydrophone.

On the other hand, the experimental result performed in the sound field with generation of the acoustic cavitation in the water tank of ultrasound cleaner is shown in **Fig. 3**.

In this case, a small hole could be observed in the titanium front plate after 30 min of exposure to ultrasound field of the ultrasound cleaner, titanium front plate was peeled off from the tip of hydrophone after 60 min of exposure. The photographs of the titanium front plate of the fabricated hydrophone before and after exposure to ultrasound field of the ultrasound cleaner are shown in **Fig. 4**.

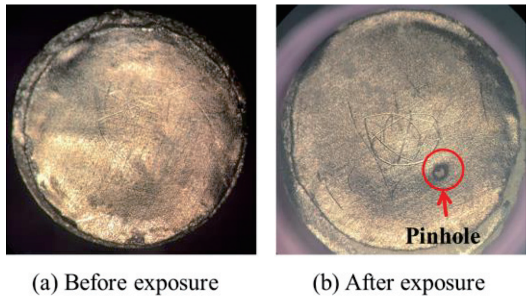

Fig. 4 Photographs of electrode of the commercial hydrophone before and after of exposure to ultrasound in the ultrasound cleaner.

5. Conclusions

We estimated the durability of the anti-cavitation hydrophone with a hydrothermally synthesized PZT polycrystalline film deposited on the back of a titanium front plate. As results, in the case of measurement by setting the hydrophone at the focal point of the focused ultrasound field (Input Power 100 W), the hydrophone showed high robustness. In this case, the hydrophone did not damaged at all. However, in the sound field with generation of the acoustic cavitation in the water tank of ultrasound cleaner (Input Power 48 W), small hole was observed in the titanium front plate after 30 min of exposure and titanium front plate was peeled off after 60 min exposure.

We considered as reason for above results that, Mechanical Index becomes very high in the ultrasonic cleaning device that operates at comparatively low frequency. In the future, it is considered to be a necessary to the improvement of structure.

Acknowledgment

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