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Fabrication of Hydrophone using Titanium Membrane Acoustic Receiving Surface and Hydrothermally Synthesized PZT film for High Intensity Ultrasound

受音面にチタン箔を使用した強力超音波測定用
水熱合成 PZT ハイドロホンの開発

Kazuho Yoshimura[1†], Norimichi Kawashima[1], Takeyoshi Uchida[2], Tsuneo Kikuchi[2], Minoru Kurosawa[3], and Shinichi Takeuchi[1] ([1]Toin Univ. of Yokohama; [2]NMIJ･AIST; [3]Tokyo Inst. of Tech)
吉村一穂 [1‡], 川島徳道 [1], 内田武吉 [2], 菊池恒男 [2], 黒澤実 [3], 竹内真一 [1] ([1] 桐蔭横浜大院・工; [2]NMIJ・AIST, [3] 東工大院・総合理工)

1. Introduction

The acoustic field distribution (sound presuure distribution) should be measured with a hydrophone to confirm the safety of medical ultrasound.[1-2)] Hydrothermally synthesized PZT poly-crystalline film can be deposited on a tiny or complex-shaped titanium substrate. Furthermore, it is thought that ultrasound probes with ultrawide frequency characteristics of their receiving sensitivity can be fabricated with the hydrothermally synthesized PZT poly-crystalline film.[3-4)] We fabricated the miniature needle-type hydrophones with a small aperture by deposition of a hydrothermally synthesized poly-crystalline PZT film on thin titanium wires and measured their performance.[5-6)] However our conventional needle-type hydrophones can not be used to measure high power ultrasound. We fabricated new hydrophones using titanium membrane acoustic receiving surface and hydrothermally synthesized PZT film for measurement of high intensity ultrasound.[7)]

2. Fabrication of hydrophone using titanium membrane acoustic receiving surface and hydrothermally synthesized PZT film

We deposited PZT film (thickness of 16 μm) on the disk shaped titanium membrane with diameter of 3.6 mm and thickness of 50 μm. Then, we could obtain the disk type unimorph piezoelectric element. We bonded piezoelectric element to the steel pipe of signal line by electrically conductive adhesive. We inserted the steel pipe used as signal line into a steel pipe used as GND line. The structure of our new hydrophone is shown in **Fig. 1**. Acoustic receiving surface is titanium membrane in type-1. Titanium is tough material. So, it can be expected to measure high power ultrasound without break down. Also, we fabricated another type hydrophone with different structure as shown in **Fig. 2** for reference. Acoustic receiving surface is electrically conductive adhesive layer in type-2.

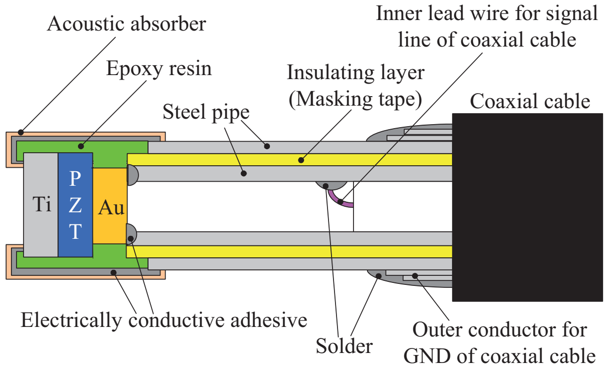

Fig. 1 Schematic diagram of miniature membrane-type hydrophone using hydrothermally synthesized PZT film on titanium membrane with diameter of 3.6 mm (type-1: acoustic receiving surface is titanium membrane)

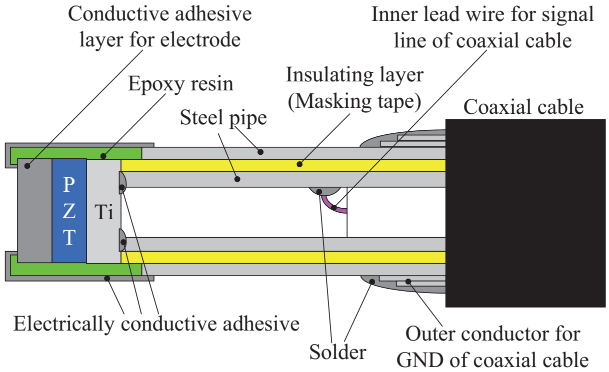

Fig. 2 Schematic diagram of miniature membrane-type hydrophone using hydrothermally synthesized PZT film on titanium membrane with diameter of 3.6 mm (type-2: acoustic receiving surface is electrically conductive adhesive layer for electrode)

3. Calibration of receiving sensitivity

Receiving sensitivity of the fabricated hydrophone was calibrated in the Acoustic and Ultrasonics Section of the National Institute of

Advanced Industrial Science and Technology.[8) There are shown in **Fig. 3**. Peak was observed at the 0.7 MHz in the frequency characteristics of receiving sensitivity of type-1 hydrophone. That was observed at the 0.9 MHz in the case of type-2 hydrophone.

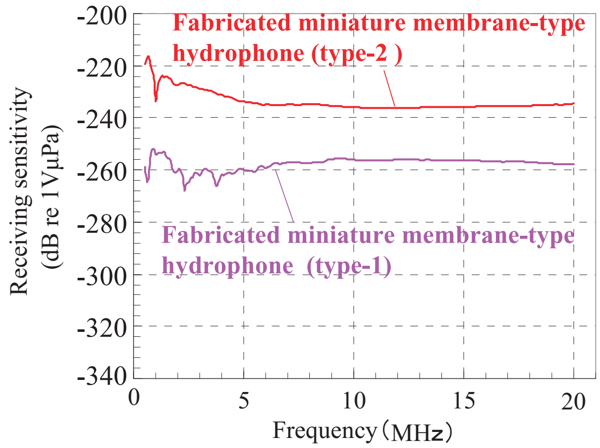

Fig. 3 Frequency characteristics of receiving sensitivity of our fabricated miniature membrane-type hydrophones type-1 and type-2

We calculated resonant frequency in radius mode to research the cause of peaks. The resonant frequency in radius mode can be calculated with **eq. (1)**.[9) Material properties of hydrothermally synthesized PZT poly-crystalline film are shown in **Table Ⅰ**.[10) It was found by using eq. (1) and material properties in Table Ⅰ that relationship between diameter of unimorph type piezoelectric element in membrane-type hydrophone and calculated resonant frequency in radius mode is shown in **Fig. 4**. Resonant frequency is in inverse proportion to diameter of unimorph piezoelectric element. It was proved that resonant frequency of our hydrophone in radius mode was calculated 0.62 MHz.

$$f_r = \frac{\eta_1}{\pi D}\sqrt{\frac{C_{11}}{\rho\left(1+\sigma^E\right)\left(1-\sigma^E\right)}} \qquad (1)$$

η : Normalized frequency D : Diameter of piezoelectric element C : Stiffness ρ : Density σ : Poisson ratio

Table Ⅰ. Material properties of hydrothermally synthesized PZT poly-crystalline film

η: Normalized frequency	2.08
C: Young's modulus (10^{10} N/m^2)	4.4
ρ: Density (10^3 kg/m^3)	4.3
σ: Poisson ratio	0.32

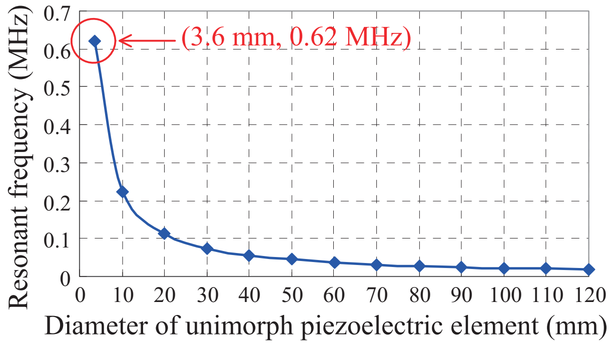

Fig. 4 Relationship between diameter of unimorph type piezoelectric element in membrane-type hydrophone and calculated resonant frequency in radius mode

4. Conclusion and future works

Undesired peaks were observed about 1 MHz in the frequency characteristics of receiving sensitivity of our miniature membrane-type hydrophone. We think this peak frequency should be shifted away 1.0 MHz. Because our final purpose is the measurement of high intensity focused ultrasound (HIFU) using about 1.0 MHz frequency. Now, we are developing the new hydrophone with diameter of 30 mm. We expect that the peak can be shifted from 1.0 MHz to 0.075 MHz. And, we will measure for HIFU by our fabricated hydrophone.

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