Proceedings of Symposium on Ultrasonic Electronics, Vol. 31 (2010) pp. 13-14
6-8 December, 2010

Analysis with equivalent circuit for characteristics of hydrophone with hydrothermally synthesized PZT film and Ti front layer

等価回路を用いた水熱合成 PZT 膜と Ti 前面板を有する堅牢ハイドロホンの特性解析

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1. Introduction

Recently, we developed the original hydrophone with hydrothermal PZT film deposited on a reverse surface of a Ti front layer as protection layer in order to realize a hydrophone which can measure the high intensity ultrasound with cavitaion near focal point of HIFU or in an ultrasound cleaner[1,2]. However, it was pointed out the problem about fidelity of waveform, because we could not observed the output waveform of the hydrophone without nonlinear distortion in spite of measurement in high intensity ultrasound field. We considered the cause of above problem by numerical simulation with MASON's equivalent circuit[3] as PZT film and 1 dimensional transmission model for Ti front layer. Furthermore, we proposed a provision for above problem.

2. Anti cavitation hydrophone

Schematic structure of our hydrophone is shown in **Fig.1**. Hydrothermal PZT film was deposited on a reverse surface of Ti front layer with thickness of 50 μm and diameter of 3.6 mm at a head of the hydrophone. Frequency characteristics of receiving sensitivity of the hydrophone calibrated in NMIJ, AIST is shown in **Fig.2**. The hydrophone could measure ultrasound at focal area of HIFU (Chongqing Haifu Technology Co.,Ltd, Type. H16 L110) and in an ultrasound cleaner (BRANSON INC. 3210J-DTH) without broken.

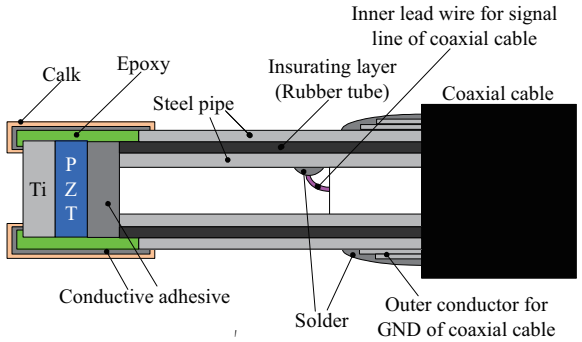

Fig. 1 Our hydrophone for high power ultrasound using PZT film on Ti film with diameter of 3.6 mm

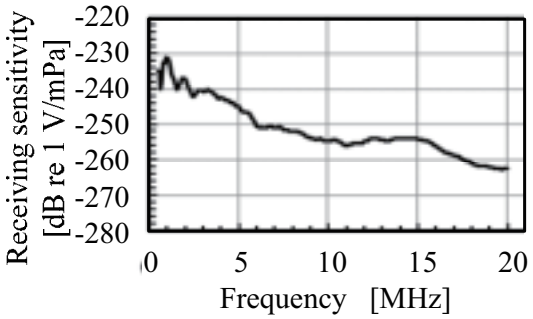

Fig. 2 Frequency characteristics of receiving sensitivity of our hydrophone for high power ultrasound

However, it was pointed out the problem about fidelity of received waveform, because we could not observe the output waveform of the hydrophone without nonlinear distortion in spite of measurement in such high intensity ultrasound field. An output waveform from our hydrophone at focal point of HIFU is shown in **Fig. 3**. We think that the nonlinear distortion in the waveform could not be observed because the sensitivity becomes lower in higher frequency range as shown in Fig.2

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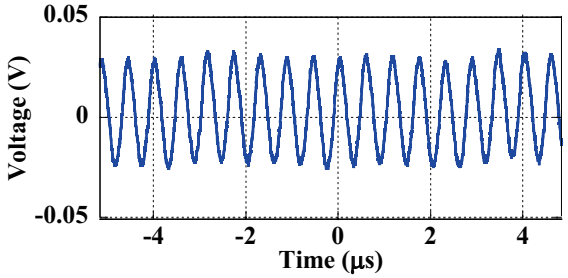

Fig. 3 Received ultrasound waveform at focal point of HIFU by using our hydrophone for high power ultrasound.

3. Consideration by numerical simulation with equivalent circuit

We calculated the frequency characteristics of receiving sensitivity of the hydrophone by using Sittig's transfer function[4], the MASON's equivalent circuit for PZT film and one dimensional transmission line model for Ti front layer. Calculated relationship between specific acoustic impedance Z_B of backing material of PZT film and frequency characteristics of receiving sensitivity by using this model is shown in **Fig.4**. Calculated result with backing material like epoxy resin having specific acoustic impedance Z_B of 3 Mrayl is more similar to the measures result in Fig. 2 than calculated result with air backing. We intended that a backing of PZT film was air, however we think that the actual backing of the PZT film was conductive epoxy resin which was used to adhere the PZT film and metal pipe for signal line.

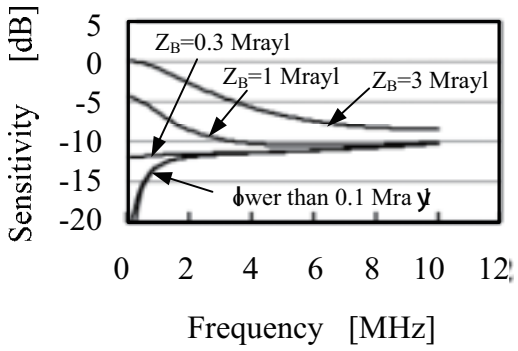

Fig. 4 Calculated relationship between specific acoustic impedance Z_B of backing material and frequency characteristics of receiving sensitivity of our hydrophone

The calculated relationship between thickness of Ti front layer and frequency characteristics of receiving sensitivity was shown in **Fig. 5**. It was found from the calculated results that the thinner Ti film is employed as front layer in the hydrophone, the sensitivity decrease more slowly in high frequency range. We can expect that the hydrophone with thinner Ti front layer has higher fidelity of received waveform with nonlinear distortion and nonlinear harmonic components.

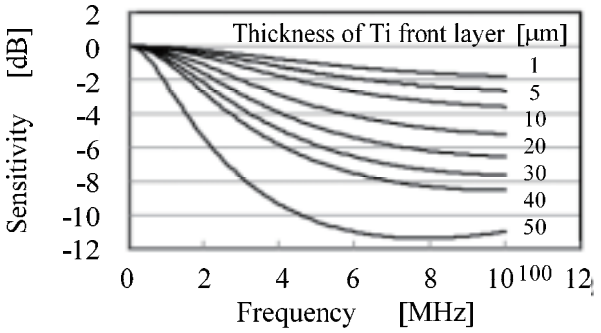

Fig. 5 Calculated relationship between thickness of Ti film front layer and frequency characteristics of receiving sensitivity of our hydrophone

4. Conclusion

It can be thought that output signal from our hydrophone was sinusoidal waveform without nonlinear distortion in spite of the hydrophone at focal point of HIFU, because of lower sensitivity of the hydrophone in higher frequency range. It was found by numerical analysis about characteristics of hydrophone that we should use Ti film with thickness thinner than 5 μm instead of current 50 μm Ti film. We are developing new hydrophone with 5 μm Ti film.

References

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