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Study on Heavy Matching Layer Transducer Towards Producing Second Harmonic.

第二高調波信号生成のためのヘビーマッチングレイヤートランスデューサ

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1. Introduction

Cavitation is the formation of vapor cavities in a liquid that are the consequence of rarefactional pressure acting upon the liquid. Cavitation bubbles can enhance thermal, mechanical, and even chemical effects of ultrasound. They are typically used to expedite the treatment time of the thermal therapy using high intensity focused ultrasound (HIFU) [2-3]. They are also practiced in lithotripsy and histotripsy[3].

The peak negative pressure that is the primary factor to induce cavitation bubbles are reduced due to the nonlinear propagation followed by the focal phase shift. Superimposing the second harmonic to fundamental proves more efficient in generating and controlling cavitation bubbles compared to single frequency waves[1-3]. However, the conventional air-backed transducer design is not suitable to generate the second harmonic. In this study, we are introducing a transducer with a heavy matching layer as an approach to overcome this problem.

2. Methods

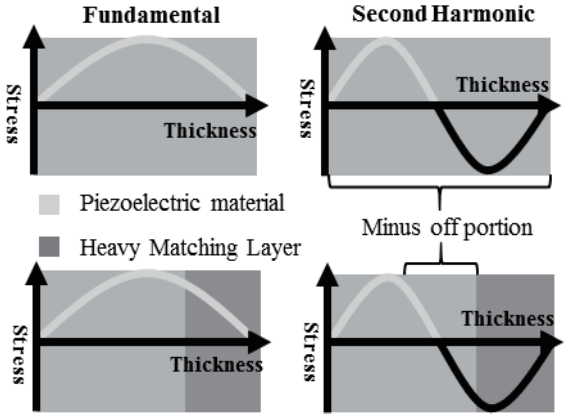

Fig. 1. Effect of heavy matching layer on fundamental and second harmonic.

Fig. 1 demonstrate that a conventional air back transducer fails to produce the second harmonic because the compression and expansion stresses occur simultaneously inside piezoelectric material. Meanwhile by adopting heavy matching layer, the second harmonic can coexist with the fundamental although a portion of the second harmonic will be cancelled off. Simulation and experiment are conducted in order to verify this concept.

A) Simulation

The transducer in the proposed design as shown in **Fig. 2** was numerically analyzed using a finite element code, PZFlex. The numerical model was designed based on one piezoceramic pillar of PZT5H surrounded by soft polymer material with mirror boundary condition on all the four lateral sides. This way, a transducer with infinitely large lateral size can be simulated in a very short computation time. Furthermore, a high impedance matching layer with an acoustic impedance value close to piezocomposite was used as interface between piezocomposite and intervening water.

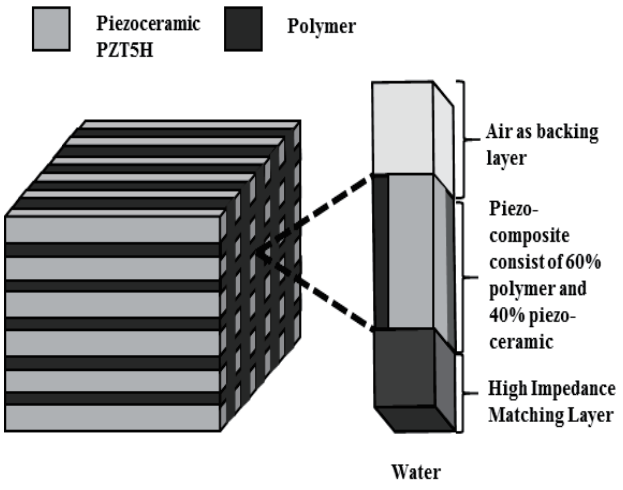

Fig. 2. Numerical model design.

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B) Experiment

A prototype transducer with 7 elements (Japan Probe) was fabricated based on one of the designs adhering to aforementioned concept are shown in **Fig. 3** below.

Fig. 3. Heavy matching layer prototype transducer.

Fig. 4 show the experiment setup that was practiced in order to investigate the efficiency of the transducer. This experiment was conducted by measuring the changes of value in weight when driving the transducer with continuous sine waves. It was measured in the range of frequency from 0.6 to 2.2 MHz. The drive voltage was varied to check the linearity between the square of voltage and the acoustic power.

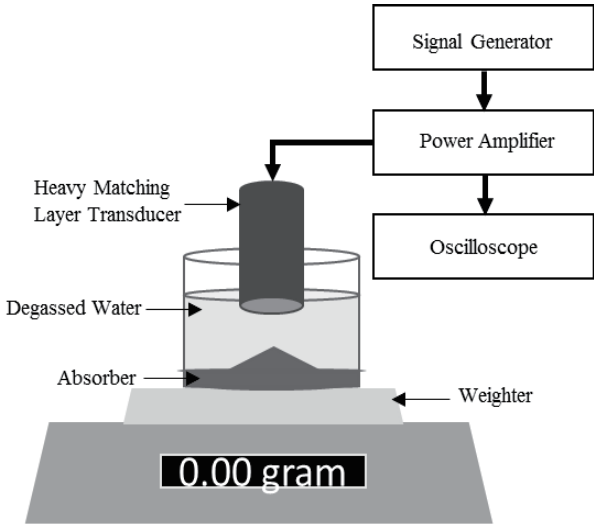

Fig. 4. Schematic of experiment setup.

3. Results and Discussion

The simulation and experimental results shown in **Fig. 5** indicate that the transducer with a heavy impedance matching layer was proved to be able to produce both the fundamental and second harmonic at high efficiency. They also indicate the validity of the aforementioned concept.

Fig. 5 also illustrate that the fundamental and second harmonic that generate from simulation was around 0.98 and 1.98 MHz while from measurement result was around 1.1 and 2.1 MHz. The difference between the simulation and measurement results may be due to the potential difference in thickness or properties of the material used in the simulation and measurement. Besides, the effect of the cable might be a factor that contribute to the difference, as it is not being considered in the simulation result.

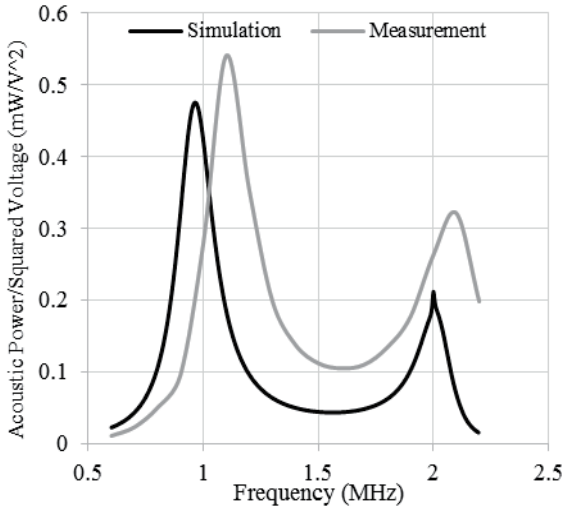

Fig. 5. Comparison between simulation result and measurement result.

4. Conclusion

Implementing a heavy acoustic impedance matching layer with an appropriate thickness on piezocomposite was demonstrated to be able to produce both the fundamental and second harmonic at high efficiency, while the conventional air back transducer cannot. The overall agreement between the simulation and measurement results verified the validity of this approach.

References

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