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Fabrication of Two-Dimensional Sparse Array Probe Based on Sol-gel Composite Spray Technique

ゾルゲル複合スプレー技術を用いた 2 次元スパースアレイプローブの作製

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1. Introduction

Medical ultrasound imaging has become widespread and is being used in many medical fields. In recent years, there has been a steady increase in the number of users as many manufacturers have launched less expensive portable ultrasound systems, such as Vscan (GE Healthcare Ltd.), iViz Air (FUJIFILM Medical Co., Ltd.), and viewphii US (Socionext Inc.). In addition, several wearable devices that employ ultrasound have been introduced, such as DFree (TripleW Japan Inc.).

Among the components of an ultrasound system, one of the most costly parts is the probe. A probe consists of piezoelectric materials, a matching layer, and a backing material. The piezoelectric materials currently available on the market are mainly made of bulk PZT, but the microfabrication of bulk PZT is expensive to manufacture, and its high rigidity results in fragility.

Recently, inexpensive and flexible ultrasonic sensors [1–4] have been developed for applications in wearable devices. Among them, sol-gel composite spraying sensors [5-7] have suitable properties for wearable devices, such as low fabrication cost and flexibility. In this study, an eight-channel two-dimensional sparse array probe was fabricated using this method, and echo experiments were conducted to evaluate its basic performance.

2. Method

2.1 Probe fabrication

Sol-gel composites are prepared by mixing PZT powder and PZT sol-gel solution. The mixed solution is sprayed onto a stainless-steel substrate of 50 mm in length, 40 mm in width, and 0.1 mm in thickness. Eight circular elements are made by spraying through a metal mask with eight holes of 10 mm in diameter. After spraying, drying (150 °C) and heat treatment (650 °C) are repeated for 5 minutes each to produce the circular piezoelectric sensors with a thickness of 100 μm. This process is followed by polarization treatment with positive polarity corona discharge at 40 kV at room temperature. The circular upper electrode is then made with silver paste and dried at 100 °C for 2 hours. The wires are glued to eight electrodes and a stainless-steel substrate. Finally, parylene is deposited on the surface of the probe to make it waterproof. A photograph of the fabricated probe before the electrode was created is shown in **Fig. 1**. The d_{33} of the fabricated element was 40-60 pC/N.

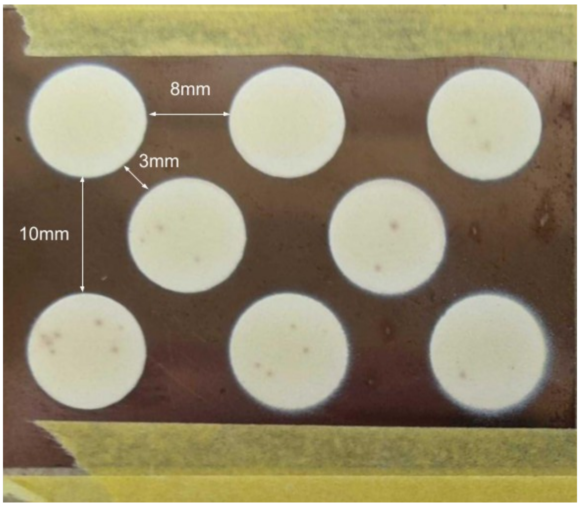

Fig. 1. Photo of fabricated 8ch transducer.

2.2 Experimental setup

In order to evaluate the fundamental performance of the fabricated probe, a pulse-echo experiment was conducted. An aluminum block as the target and the probe were submerged in a water tank, and the distance between each other was set to approximately 25 mm. One of the eight elements was connected to a pulser/receiver (DPR300, JSR Inc.) and a pulse voltage was applied. The echoes reflected back to the target were received by the same electrode as the transmitting electrode, and the signal waveform was acquired. The settings of the pulsar/receiver used in this experiment are shown in **Table I**.

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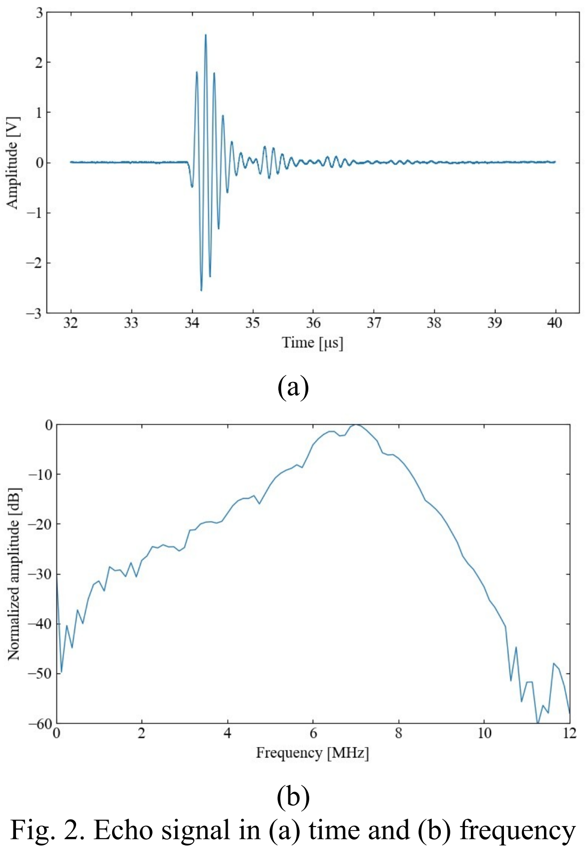
TableI: Setting of Pulser/Receiver.

Tx	Pulse Amplitude	3.5
	Pulser Energy	HIGH 3
	Damping	2
	PRF rate	16
Rx	Gain [dB]	7
	High-Pass Filter [MHz]	1.0
	Low-Pass Filter [MHz]	35.0

3. Results

An example of the obtained signals is shown in **Fig. 2**. The amplitude of the obtained signal waveform is 5.1 V_{pp}. The center frequency is 6.85 MHz and the frequency bandwidth of −6 dB is 2.00 MHz (5.85–7.85 MHz). For the other seven elements, pulses were sent and received in the same way, and almost the same waveform as in Fig. 2 was obtained.



(a)

(b)

Fig. 2. Echo signal in (a) time and (b) frequency domains.

4. Discussion

The signal waveform obtained from this experiment had a long tailing. This is probably due to the substrate ringing. In order to reduce the ringing of the substrate, we plan to improve the probe by adding a backing material to the back of the sensor.

In the experiment we conducted, the same element was used for both transmission and reception to acquire echoes, making it possible to view the movement of organs in M-mode. Since this probe has multiple elements, it is expected to be able to find the target area more quickly. Furthermore, it is possible to acquire M-mode images while switching between multiple elements to observe the movement of a single organ in more detail.

A completely different imaging method, 3D volume imaging by using all eight elements, is also a future challenge.

References

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