3Pb5-3

Evaluation of Flexible Ultrasonic Array Based on Sol-Gel Composite Spraying Technique

Masayuki Tanabe[1†], Kosuke Sato[2], Toru Uda[2], and Makiko Kobayashi[1]
([1]Kumamoto Univ; [2]NOK)

1. Introduction

Sol-gel composite spray technique is a method of fabricating flexible, thin, broadband piezoelectric sensor[1-5]. This technique is based on spraying a liquid mixture of PZT powder and PZT solution, which results in a porous PZT thin film. A large number of porosities in the piezoelectric layer provides strong bending resistance and a broad frequency bandwidth. By utilizing these properties, flexible and thin medical ultrasound sensors with high axial resolution can be developed.

Most of the previous studie were aimed at nondestructive testing, and the array structure design and biocompatibility required for medical sensors have not been sufficiently investigated. To use this PZT film as medical ultrasonic sensors, not only the PZT film but also wiring and waterproofing are required. These material selection and structural design should be considered in terms of flexibility, biocompatibility, and mass production.

In this study, a prototype of a new medical imaging ultrasound array sensor is fabricated by optimizing the electrodes and waterproofing process for medical applications of piezoelectric materials using the sol-gel composite spray technique, and fundamental evaluation experiments are conducted.

2. Method

The PZT layer was generated by spraying a mixture of sol-gel powder and solution on the stainless-steel thin plate, followed by sintering at 650 °C for 5 minutes, and repeating these steps. The thickness of the produced PZT layer was approximately 100 µm, and the d33 measured after polarization was roughly 40 pC/N. The top electrode was pattern-printed with conductive paste. The element width was 0.5 mm, kerf was 0.5 mm, length was 3 mm, and the number of elements was 64 channels. Rubber with a high attenuation coefficient was placed on the back of the PZT-sprayed stainless steel plate as a backing material.

Next, flexible printed circuit (FPC) cables were connected on each of the 64 upper electrodes. Both sides of the sensor were then molded with biocompatible rubber. This rubber was acoustically optimized as a matching layer. The fabricated sensor is shown in **Fig. 1**. All the materials used for the sensor are flexible, allowing it to be attached along the curved surface of the body surface, as shown in **Fig. 2**.

A customized ultrasound system was used for imaging experiments. Traditional focusing beamforming was applied with an aperture length of 8 channels for transmitting and receiving.

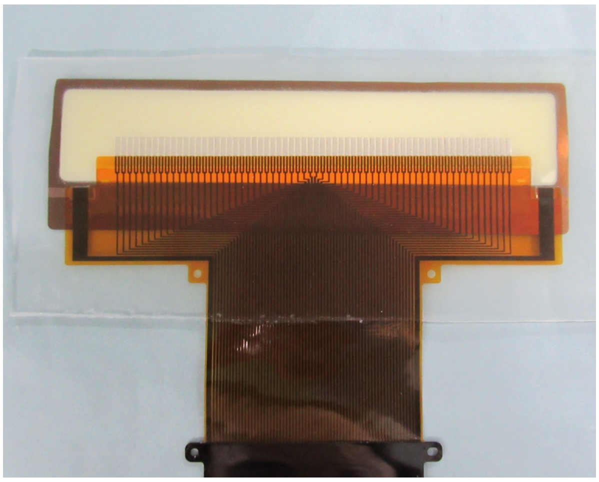

Fig. 1. Prototype of flexible ultrasonic array sensor.

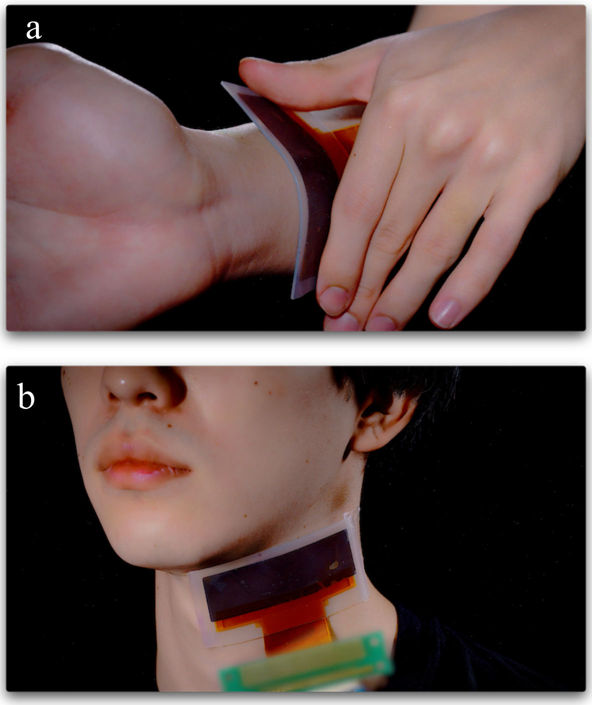

Fig. 2. Photos of prototype sensor in use.

mtanabe@cs.kumamoto-u.ac.jp

3. Results

Fundamental performance evaluation was conducted in a water tank using one element of the prototype sensor, and echoes with a center frequency of 4 MHz and a bandwidth of 4 MHz were obtained.

B-mode imaging was first performed using the ultrasound phantom (US-2, Kyoto Kagaku, Japan). In the phantom, 0.1 mm diameter string targets are placed laterally at 10 mm intervals at a depth of 10 mm. The obtained B-mode image is shown in **Fig. 3**. It can be seen that each string B-mode image is broadened in the lateral direction but very thin in the axial direction.

Imaging was actually performed *in vivo* as well. The B-mode image obtained with the sensor attached to the forearm with the sensor bent is shown in **Fig. 4**. In this situation, the ultrasound beam was not generated as expected, and the echo image should be distorted because imaging was performed with the probe bent. In the future, beamforming should be performed to account for the deformation of the probe, and the B-mode image should be corrected[6].

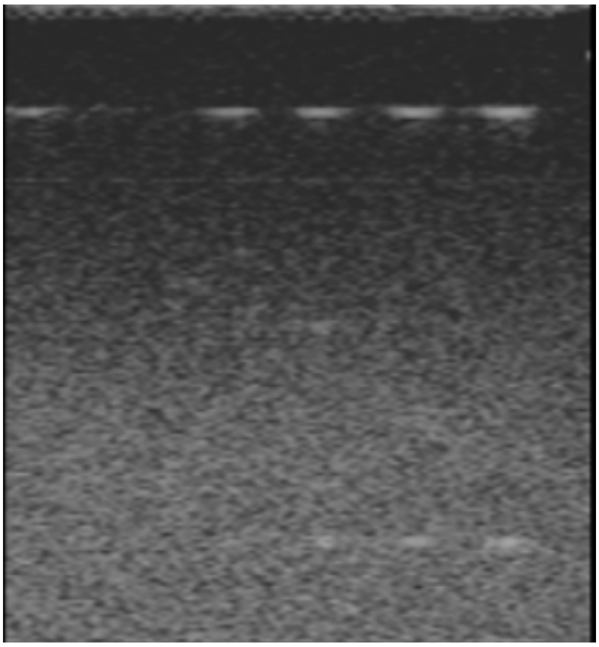

Fig. 3. B-mode image of string targets.

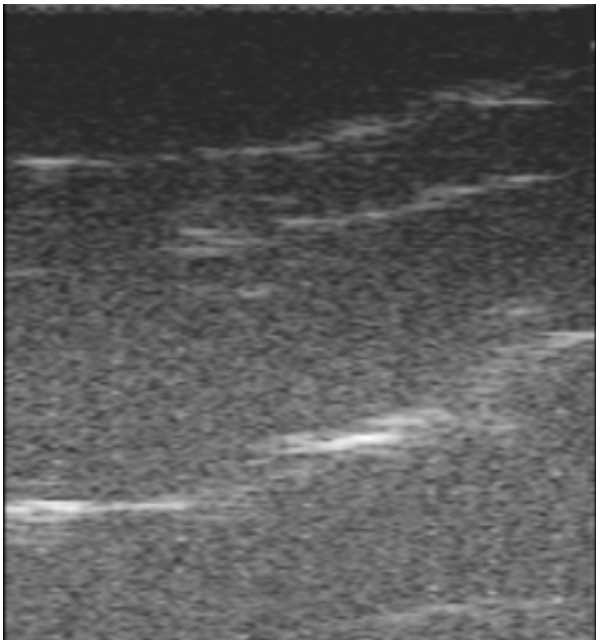

Fig. 4. B-mode image of forearm.

4. Conclusion

The prototype of flexible ultrasonic array sensor based on sol-gel composite spraying technique was fabricated and its fundamental evaluation was conducted. As a result, very sharp B-mode image was obtained in the axial direction. The lateral spread remains a possibility due to the performance of the control machine as well as the characteristics of the probe. Further detailed evaluation, analysis, and sensitivity improvement of the sensor will be conducted in the future.

References

1. K. Kimoto, M. Matsumoto, T. Kaneko and M. Kobayashi: Jpn. J. Appl. Phys. **55** (2016) 07KB04.
2. M. Kobayashi and M. Matsumoto: Jpn. J. Appl. Phys. **55** (2016) 07KD05.
3. H. Kouyama, T. Kibe, S. Fujimoto, T. Namihira and M. Kobayashi: Jpn. J. Appl. Phys. **55** (2016) 07KD12.
4. Tomoya Yamamoto and Makiko Kobayashi: Jpn. J. Appl. Phys. **57** (2018) 07LB16.
5. T. Hara, M. Furukawa, S. Nozawa, K. Nakatsuma and M. Kobayashi: Jpn. J. Appl. Phys. **59** (2020) SKKC10.
6. M. Sada and M. Tanabe: Jpn. J. Appl. Phys. **59** (2020) SKKE25.