2P3-4

Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

Design of an Ultrasonic Fingerprint Sensor made of 1-3 Piezocomposites by the Finite Element Method

Haejune Park and Yongrae Roh[†]
(Kyungpook National University, Korea)

1. Introduction

Over the past two decades, many researchers have studied how to capture an electronic image of a human fingerprint. Among these, capacitive fingerprint sensors are the ones most widely used in consumer electronics. The sensor consists of an array of capacitors. When a finger is placed on top of the sensor, skin creates a change in the capacitances. By measuring the difference between the capacitors contacting ridges and valleys in the fingerprint, a fingerprint pattern can be resolved [1]. However, capacitive fingerprint sensors are extremely sensitive to contamination and moisture on the finger. Ultrasonic fingerprint sensors offer a potential solution to this problem because the fingerprint's valleys and ridges are easily distinguished due to the great difference in their acoustic impedance [2, 3].

In this paper, a detailed study on the operation of the ultrasound fingerprint sensor was carried out by analyzing the amplitude and arrival time of the wave reflected by the fingerprint patterns. The fingerprint sensor was designed using a 1-3 piezocomposite material to take advantage of its low acoustic impedance and high electro-mechanical coupling factor.

2. Pulse-echo Analysis with 2D FEA Models

2D finite element (FE) models of the ultrasonic fingerprint sensors are shown in **Fig. 1**. Two models were analyzed, 100 μm thick PDMS layer without an acoustic wall and 200 μm thick PDMS layer with an acoustic wall. Each piezoceramic rod represents a channel and acoustic waves travel uniformly through these channels. These waves reach the boundary between the fingerprint and the PDMS, and the waves are reflected at the boundary. The fingerprint consists of ridges and valleys where the ridges are presented by pig fat blocks while the valleys are presented by vacuum blocks. The waves reflected at different channels have different properties because of the acoustic impedance difference between the valleys and ridges. The acoustic walls are made of silicon and work as wave isolators to diminish the interference between the channels. Each channel detects the reflected wave, thereby the valleys and ridges are distinguished by the amplitude and peak time of output voltages.

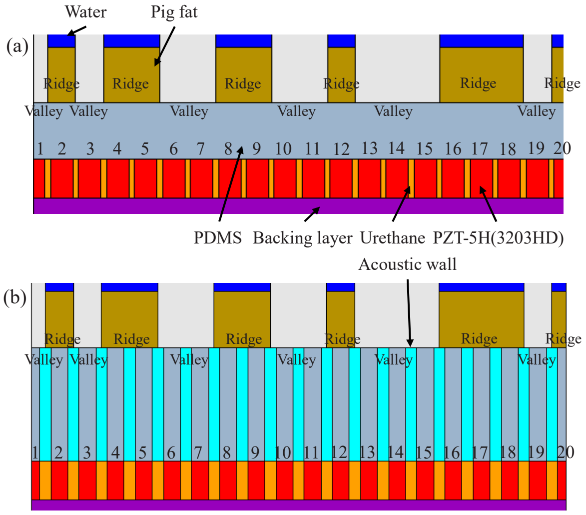
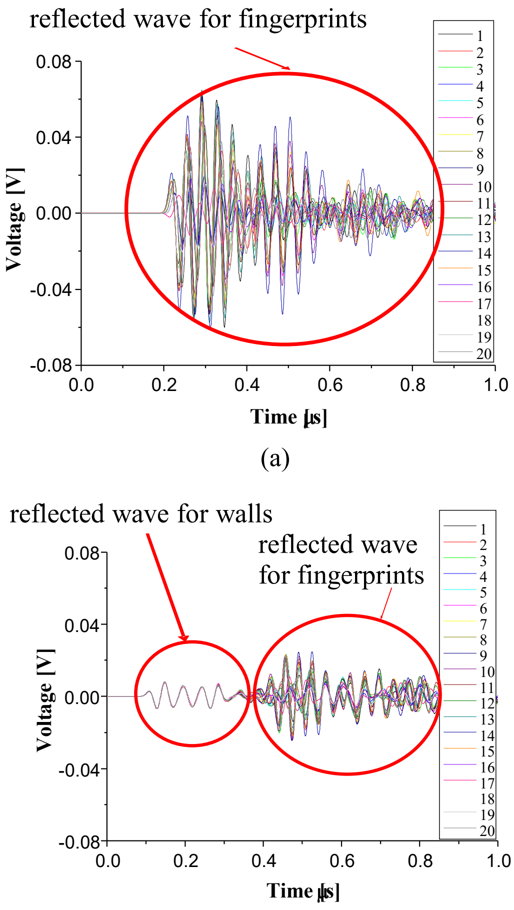


Fig. 1. 2D FEA models of the fingerprint sensor: (a) without acoustic walls, (b) with acoustic walls.

Results of the analysis using the 2D FE models of fingerprint sensors are shown in **Fig. 2**. The reflected waves for fingerprints only are shown in Fig. 2(a) whereas those for both fingerprints and walls are shown in Fig. 2(b) corresponding to Fig. 1(a) and 1(b), respectively. Fig. 2(a) shows higher amplitude than Fig. 2(b) because the PDMS in Fig. 2(a) is thinner than that in Fig. 2(b). Fig. 2(b) shows distinctive reflected waves for fingerprints and walls. If the reflected wave for walls is removed, remaining waves will depict valleys and ridges more distinctively than Fig. 2(a).

Sensor sensitivity is defined as the ratio of maximum output voltage per input voltage to the sensor. The model without walls has the sensitivity of -35.7 dB at ridges and -23.8 dB at valleys. The model with walls has the sensitivity of -42.3 dB at ridges and -24.8 dB at valleys. In addition to the sensitivity, peak time values were also checked. The model without walls has 0.299 μs at ridges and 0.263 μs at valleys whereas the model with walls has 0.473 μs at ridges and 0.461 μs at valleys. Hence the valleys and ridges could be distinguished through checking either the amplitude or the peak time of the reflective waves.

[†] yryong@knu.ac.kr



(a)

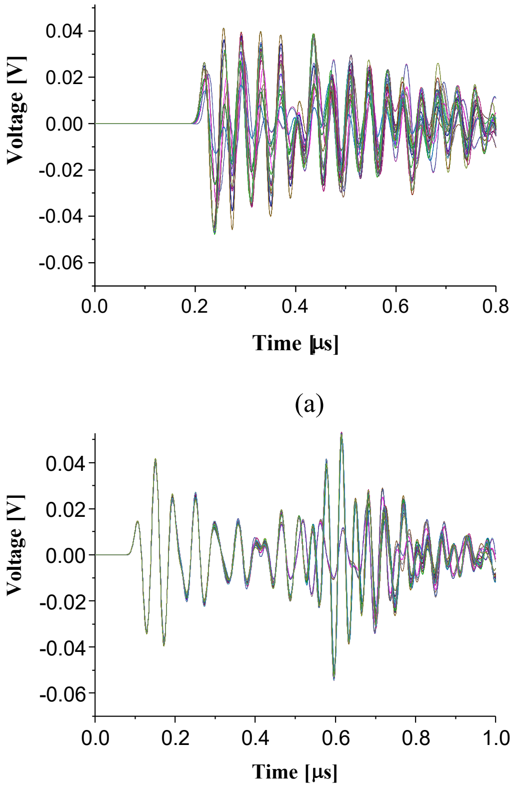
(b)

Fig. 2. The results of 2D FEA models of the fingerprint sensor: (a) without acoustic walls (b) with acoustic walls.

3. Pulse-echo Analysis with 3D FEA Models

3D FE fingerprint sensor models were analyzed for the same configuration as in 2D models. The total number of channels was 64 with square planar (8x8) configuration. Ridges were built along the diagonal line. The results from the 3D FE model of the sensor are shown in **Fig. 3**.

The model without walls has the sensitivity of -28.7 dB at ridges and -31.7 dB at valleys. The model with walls has the sensitivity of -28.1 dB at ridges and -25.4 dB at valleys. As before, the peak time of the reflected wave was also checked to distinguish the valleys from the ridges. The model without walls has the peak time of 0.267 μs at ridges and 0.259 μs at valleys whereas the model with walls has 0.519 μs at ridges and 0.509 μs at valleys. Overall, these results coincide with those of the analysis with 2D FE models. The model with the walls distinguished better than the model without the walls. The amplitude change in the model with walls could distinguish but that without the walls could not distinguish the ridge and valleys. However, the peak time change could distinguish in both of the two models.



(a)

(b)

Fig. 3. The results of 3D FEA models of the fingerprint sensor: (a) without acoustic walls (b) with acoustic walls.

4. Conclusions

In this research, the design and analysis of ultrasonic sensors was carried out with a 1-3 piezocomposite material to distinguish valleys and ridges in human fingerprints. The distinctive amplitudes were possible only when the FEA models of the sensor had acoustic walls. On the other hand, the peak time measurement could distinguish the ridges and valleys regardless whether the sensor had acoustic walls or not.

Acknowledgment

This research was supported by the Next-generation Medical Device Development Program for Newly-Created Market of the National Research Foundation (NRF) funded by the Korean government, MSIP(No. 2016M3D5A1937126).

References

1. S. M. Jung: Int. J. Biosci. Biotechnol. **5** (2013) 1.
2. Y. Lu, H. Tang, S. Fung, Q. Wang, J. M. Tsai, M. Daneman, B. E. Boser, and D. A. Horsley: Appl. Phys. Lett. **106** (2015) 263503.
3. K. Nam, Y. Park, B. Ha, D. Shim, and I. Song: J. Korean Phys. Soc. **47** (2005) 309 [in Korean].