Journal of Sensor Science and Technology
Vol. 26, No. 1 (2017) pp. 24-27
http://dx.doi.org/10.5369/JSST.2017.26.1.24
pISSN 1225-5475/eISSN 2093-7563

Development of Capacitive-type Pressure Mapping Sensor using Printing Technology

Young-Tae Lee[+]

Abstract

In this study, I developed a simple and low cost process—printing a silver, carbon, dielectric, adhesive layer on PET films using screen printing technology and bonding the two films face-to-face—to fabricate a low price capacitive pressure-mapping sensor. Both electrodes forming the pressure measuring capacitor are arranged between the two PET films similar to a sandwich. Therefore, the sensor has the advantage of minimizing the influence of external noise. In this study, a 10×10 capacitance-type pressure-mapping sensor was fabricated and its characteristics were analyzed

Keywords: Pressure-mapping sensor, Capacitive type, Screen-printing, Carbon ink, PET film

1. INTRODUCTION

Pressure mapping sensors [1-5] are being widely used. These sensors are installed on chairs [2], beds, shoes, etc., to measure pressure distribution, and then, signal processing is used for employing this in practical applications such as attitude control and product development. Further, the pressure-mapping sensor can be applied in the field of medicine to measure the pressure distribution of teeth or muscles, in wearable devices to measure posture movement, and in sensing parts of robots such as their hands or feet. The fields in which the pressure-mapping sensor is applicable are relatively broad. Thus, its market can dramatically expand if we increase the reliability of its performance. Currently, the pressure-mapping sensor is too expensive for use in various areas owing to its short supply; this is because there are very few global and domestic manufacturers.

In this study, I developed a capacitive-type pressure-mapping sensor by forming the electrode and adhesives on plastic films using only the screen-printing process, and then finishing the process by bonding the two films. This reduced the cost significantly. By completing 3 to 4 layers of screen printing on low-priced plastic films such as polyethylene terephthalate (PET) and bonding the two films afterwards, the quantity of the pressure-mapping sensor material was reduced and the process costs lowered. However, the setup was relatively good for measuring the pressure distribution. This pressure-mapping sensor is suitable for automated mass production, and this is expected to lower costs dramatically compared to the existing manufacturing approaches.

Department of Electronic Engineering Education, Andong National Unversity, 1375 Gyeongdong-ro, Andong, Gyeongsangbuk-do 760-749, Korea
[+]Corresponding author: ytlee@anu.ac.kr
(Received: Jan. 23, 2017, Revised: Jan. 27,2017, Accepted: Jan. 31, 2017)

2. CAPACITIVE-TYPE PRESSURE-MAPPING SENSOR

2.1 Measuring Principle

The capacitive-type pressure-mapping sensor is fabricated on a structure by forming multiple pressure sensors on the same surface, which are capacitor-type arraying electrodes on both sides of a dielectric film.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \tag{1}$$

As can be seen in (1), the capacitance value of a capacitor is directly proportional to the area of the electrodes and inversely proportional to the distance between them. In the case of the capacitive-type pressure-mapping sensor, the distance d between the electrodes decreases when pressure is applied, and therefore, capacitance increases proportionally. Because the sensitivity of the sensor is directly affected by the change in the distance between the electrodes due to the applied pressure, this should be carefully considered during the design of the sensor. Further, as the influence of stray capacitance cannot be ignored in the case of the capacitive-type sensor, we need to design the sensor such that the capacitance is minimized. Figure 1 shows the structure of the

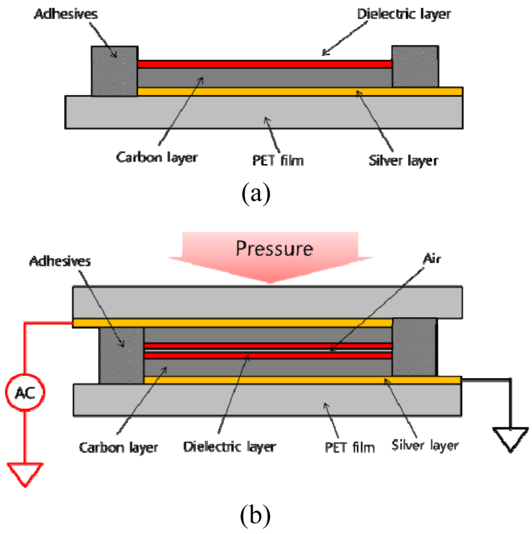

Fig. 1. Pressure mapping sensor.

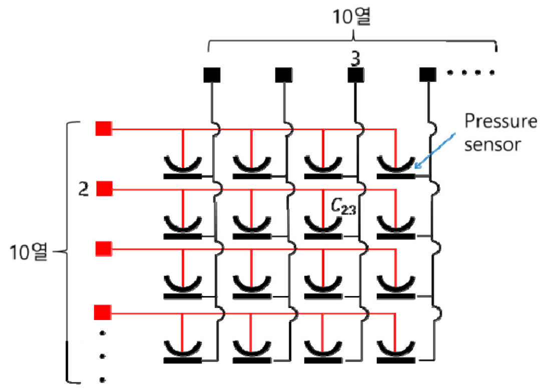

Fig. 2. Circuit of the pressure-mapping sensor.

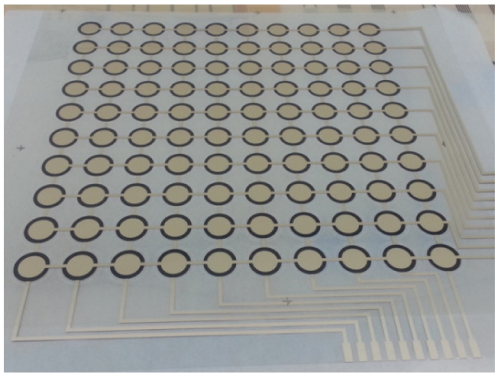

Fig. 3. A 10×10 pressure-mapping sensor.

electrodes and the pressure-mapping sensor.

The electrodes in Fig. 1(a) were printed using a three-layer structure on a PET film. They were formed by printing a circular electrode with silver, carbon, and dielectric ink, in this order. The electrodes are 16 mm in diameter and about 100 μm thick. To bond the two electrodes facing each other, a 4-mm-wide adhesive layer with a 24 mm external diameter was printed. Fig. 1(b) shows the structure of the pressure-mapping sensor completed by bonding the two electrodes. The capacitor structure of the capacitive-type pressure-mapping sensor in Fig. 1(b) shows the characteristic existence of an air layer. This is because the dielectric is divided into two layers. Because the air layer plays the role of another dielectric, the change in the distance between the electrodes increases when pressure is applied, and as a result, we can realize the effect of increasing sensitivity. To minimize the influence of stray capacitance on the pressure-mapping sensor, both the electrodes of the sensor are formed in between the PET film.

2.2 Structure of the Pressure-Mapping Sensor

In this paper, I fabricated a 10×10 pressure-mapping sensor by arranging 100 pressure sensors to measure the pressure distribution.

The pressure-mapping sensor consists of 100 capacitive-type pressure sensors arranged by a 10×10 parallel circuit on a plastic film. For example, in Fig. 2, if pressure is applied to sensor C_{23}, the capacitance between the electrode No. 2 (in length) and No. 3 (in width) changes. Thus, we can map the pressure distribution at a certain spot. Figure 3 shows the fabricated pressure-mapping sensor.

The overall size of the sensor is 310×310 mm^2 and the size and shape can be freely designed according to its intended use. The fabricated pressure-mapping sensor can be used for various purposes, because it has a very simple fabrication process that involves forming electrodes and adhesive layers using the printing process and then bonding the two films. The design of density is free and there are several ways to arrange the pressure sensor.

2.3 Measuring Method

I fabricated a simple measuring circuit to analyze the properties of the pressure-mapping sensor. A signal processing circuit measures pressure by choosing vertical columns in order with switch and applies a 10 kHz square wave input signal to the chosen columns. The capacitance change in each pressure sensor is printed out by voltage. The ADC uses 8-bit and prints out a digital signal of 256 levels.

3. RESULTS AND DISCUSSIONS

3.1 Results

To analyze the characteristics of the developed pressure-mapping sensor, I used software that illustrates graphs of 10×10 form data printed out with the digital value of 256 levels. I measured the capacitance change of each pressure sensor when a person sat on a chair with a 10×10 pressure-mapping sensor installed on the chair. The person sat with his legs in the direction of the arrow, as shown in Fig. 4. The change in the pressure is shown in Fig. 5.

In Fig. 5, the parts of the chair that the hips and legs lay on show larger capacitance value (pressure value). Thus, we can check the position and posture of the sitting person with the output value. As in Fig. 4, the front edge of the chair on which the right leg is placed is higher than the center where stronger pressure is to be applied. This is seen from the measured results in Fig. 5. The output value of each sensor of the pressure-mapping sensor shows relatively high sensitivity from 0.79 nF minimum to 1.46 nF maximum. The pressure-mapping sensor developed in this study is capable of measuring the relative strength of the applied pressure distribution. Hence, various measurements such as the source shape, weight, and balance direction of the measurement are possible.

Fig. 6 shows the measured results of pressure distribution and direction of the measurement source arranged on the pressure-mapping sensor. The output value of the capacitance of the pressure sensor is showed by an 8-bit digital value. We can find the change of pressure distribution due to the position and direction of the measurement source. The exact position, pressure distribution (weight, posture), and direction of the measurement source can be found. Because of the measurement, the developed

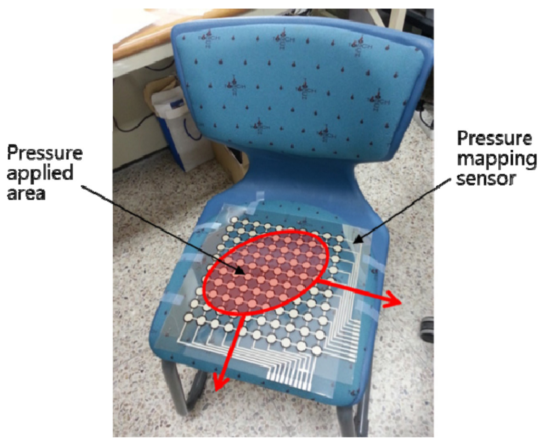

Fig. 4. Pressure-mapping sensor installed chair.

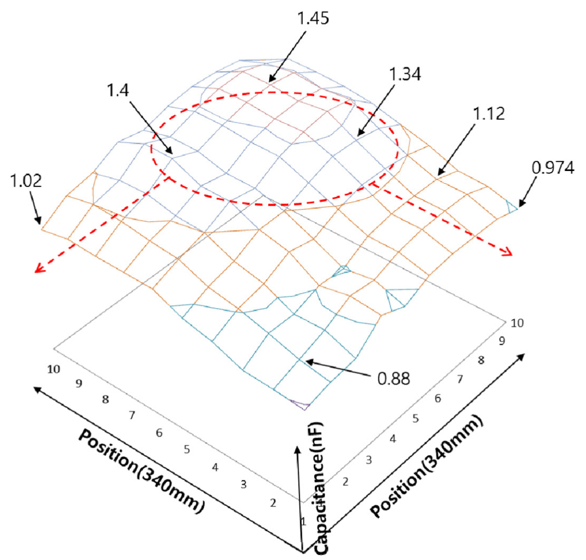

Fig. 5. Output characteristics of the 10×10 pressure-mapping sensor.

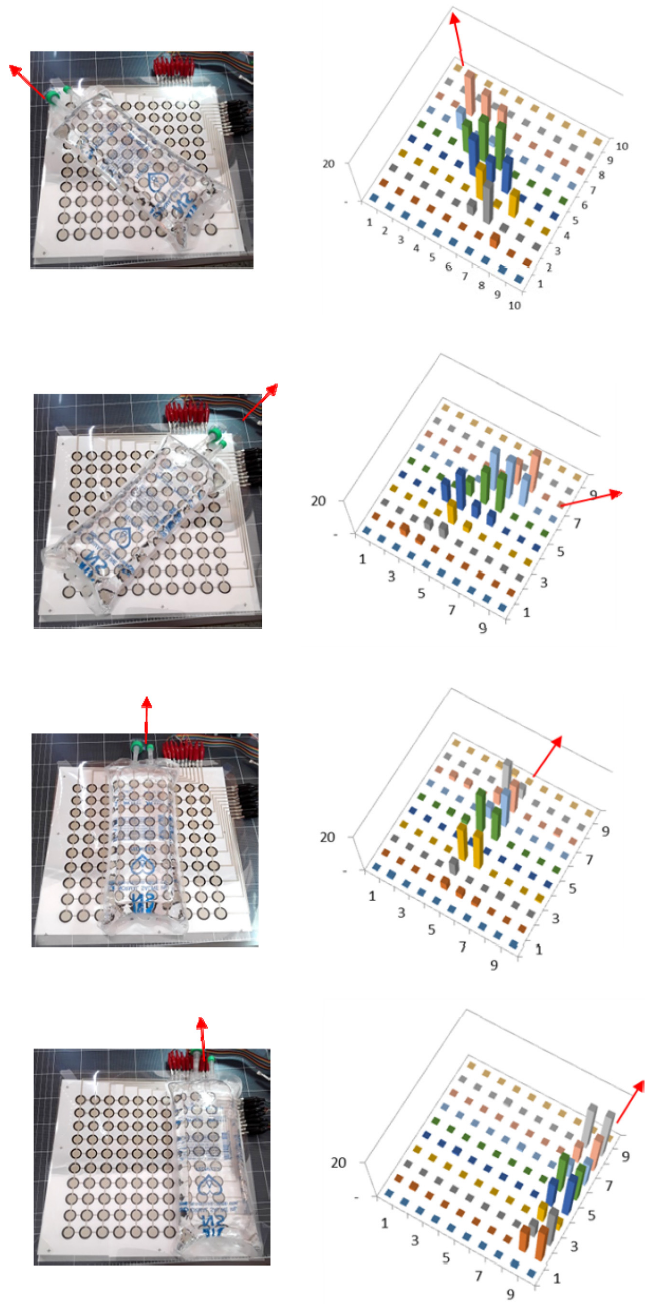

Fig. 6. Output characteristics of pressure distribution and direction.

pressure-mapping sensor is suitable for measuring the shape, posture, and direction of the source by measuring relative pressure rather than absolute pressure.

3.2 Discussions

The film-type pressure sensor or pressure-mapping sensor has the disadvantage of lack of diversity and high price. By developing a low-cost pressure-mapping sensor in diverse sizes and shapes, the demand in relevant or new fields of application will increase.

The capacitive-type pressure-mapping sensor developed in this study can be fabricated in many different shapes and sizes. This is because the electrodes of the pressure sensor can be fabricated with printing techniques. Further, the PET film used for substrate makes it simple to fabricate the sensor in any shape through the cutting process such that it can be developed for multiple applications such as for installations in beds, chairs, shoes, and medical equipment. The pressure-mapping sensor developed in this study is completed by forming electrodes and adhesive parts by printing four layers on the PET film and then bonding the two films. The process is very simple and a low-price general-purpose ink is used for printing. Thus, it is possible to develop a low-cost pressure-mapping sensor. Pertaining to manufacture, the initial cost of the facilities is very low and high technology is not required. This is because it can be produced simply with printing and bonding processes. Outsourcing manufacturing is possible because the domestic printing infrastructure is good. A characteristic of the capacitive-type pressure-mapping sensor developed in this study is that it minimizes the influence of stray capacitance as the pressure sensor of the capacitor structure (electrode/dielectric/electrode layer) is fabricated between two PET films. Further, its structural characteristic is to increase the sensitivity, i.e., the change of capacitance following the application of pressure, by dividing the dielectric film into two layers and forming an air layer between them.

4. CONCLUSIONS

In this paper, a capacitive-type pressure-mapping sensor was developed by bonding two PET films, on which two face-to-face electrodes were fabricated by printing process (silver/carbon/dielectric layer). A signal processing circuit with charge amplifiers was used to get the signals from the developed pressure-mapping sensor. The developed pressure-mapping sensor minimized the influence of stray capacitance because its electrodes are formed from PET films. Further, it increased the sensitivity by forming an air layer between the two divided layers of the dielectric. The developed pressure-mapping sensor was installed in a chair for analyzing its characteristics and the measurement result of pressure distribution shows that its pressure-mapping performance is excellent. Thus, we can expect its commercialized production and application for various purposes.

ACKNOWLEDGMENT

This work was supported by a grant from 2015 Research Funds of Andong National University.

REFERENCES

[1] https://www.tekscan.com/

[2] M. Ferguson-Pell and M. D. Cardi, "Prototype development and comparative Evaluation of wheelchair pressure mapping system," *Assistive Technology*, pp. 78-91, Vol. 5, 1993.

[3] C.M.A. Ashruf, "Thin flexible pressure sensors," *Sensor Review*, pp. 322-327, Vol. 22 (4), 2002.

[4] M. Hunston, "Innovative thin-film pressure mapping sensors," Sensor Review, pp. 319-321, Vol. 22 (4), 2002.

[5] Z. Del Prete, L. Monteleone, and Steindler, "A novel pressure array sensor based on contact resistance variation: Metrological properties", *Review of Scientific Instruments*, Published Online, Vol. 72 (2), 2001.