1st International Conference on Sensing Technology
November 21-23, 2005 Palmerston North, New Zealand

Material discrimination and detection of thickness and hardness by touch sensor based on piezoelectric ceramics

Akira Kimoto and Katsunori Shida
Faculty of Science and Engineering,
Saga University, Honjyo 1, Saga Japan
kimotoa@cc.saga-u.ac.jp

Abstract

In this paper, material discrimination and detection of thickness and hardness are presented by using a new touch sensor. In the proposed sensor, ultrasonic and electrical properties are measured by same sensor. In the experiment, four kinds of materials such as aluminium, polymer gel, silicone rubber and acrylic resin were prepared. Three kinds of hardness in polymer gel and silicone rubber were also prepared. In addition, three kinds of thickness such as 1cm, 2cm and 4cm in each material were used. Discrimination of their materials and detection of the thickness and hardness were demonstrated by measurements of capacitance and propagation time at two kinds of contact conditions. As a result, it was suggested that discrimination of four kinds of materials and detection of the three kinds of the hardness of silicone and polymer gel and the thickness between 1cm and 4cm were possible by using the proposed touch sensor.

Keywords: Piezoelectric ceramics, Electrical property, Ultrasonic property, Hardness, Thickness

1 Introduction

Many tactile sensors have been researched for material discrimination, recognition of the shape and detection of the hardness and so on [1]-[5]. The aim of this research is to establish the tactile sensor for material discrimination, hardness detection and recognition of shape, simultaneously. In our research, the touch sensor based on a pair of piezoelectric ceramics was proposed [6]. The proposed sensor measures the ultrasonic property by a pair of piezoelectric ceramics, and also measures the electrical property by using the surface electrode of each piezoelectric ceramic. Therefore, ultrasonic and electrical properties are simultaneously measured by the proposed sensor. Actually, it was found that the detection of the thickness and the material discrimination of the object were possible by measuring the ultrasonic and electrical properties. In this paper, the material discrimination of the object and the detection of the thickness and hardness are demonstrated by measuring ultrasonic and electrical properties at two kinds of contact conditions.

2 Measurement method by proposed touch sensor

Figure 1 shows the measurement method of the proposed touch sensor. In figure 1(a), the ultrasonic property is obtained by using a pair of piezoelectric ceramics. They are respectively used as transmitter and receiver. In figure 1(b), the electrical property is obtained by using a pair of electrodes on the surface of each piezoelectric ceramic. Therefore, measurements of the ultrasonic and electrical properties are possible by a pair of piezoelectric ceramics. Moreover, it is possible to obtain several information of the object such as the quality of material and the thickness by using their measurement values. In addition, the hardness of material is detected by measuring both ultrasonic and electrical properties at two kinds of contact conditions.

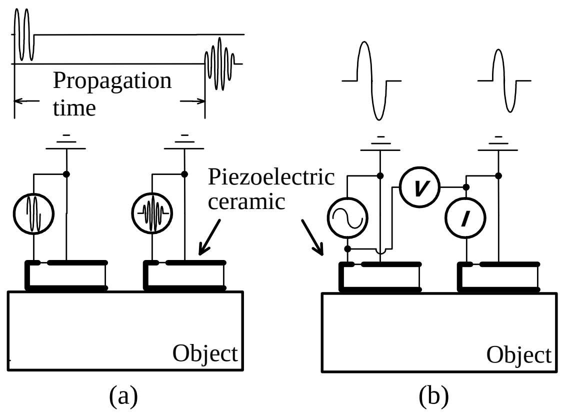


Figure 1: Measurement method of proposed touch sensor. (a) Measurement of ultrasonic property. (b)Measurement of electrical property.

3 Experimental method

Figure 2 shows the schematic diagram of measurement system by the proposed sensor. The proposed sensor is constructed by a pair of rectangle piezoelectric ceramics (1×0.5×0.1 cm) arranged to acrylic plate (4 × 3 × 0.5 cm) with 1cm distance between centres of the piezoelectric ceramic. Each

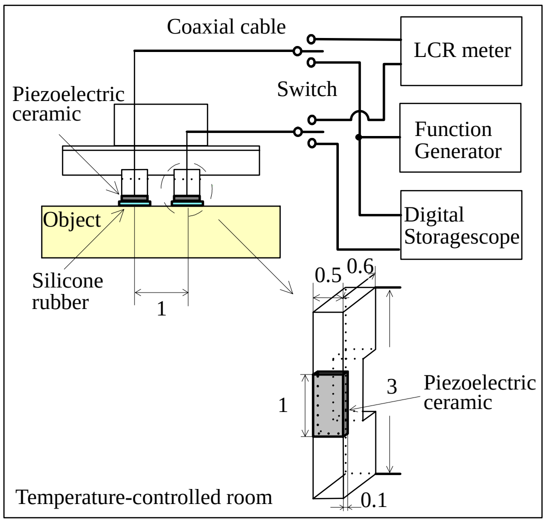


Figure2: Schematic diagram of measurement system using proposed touch senor.

piezoelectric ceramic was fixed in the center of acrylic resin (0.5 × 3 × 0.6 cm). The piezoelectric ceramic with the resonance frequency of 2MHz was used. Silicone rubber with 0.5mm thickness was pasted to the surface of each piezoelectric ceramic for stability of contact condition between the sensor and the object. Capacitance as electrical property and propagation time as ultrasonic property were measured by the proposed sensor placed on the object at two kinds of contact conditions. Two kinds of contact conditions are respectively the contact at the weight of the sensor (30g) as the contact condition 1 and that placed the load of 80g on the sensor as the contact condition 2. Propagation time as the ultrasonic property was obtained from time interval between transmitted wave and reflected wave by the trigger level given to each wave. In this time, the trigger levels of transmitted and reflected waves were 1 V and 2mV, respectively. In this system, the received wave over 4μs from transmitted wave was detected as the reflected wave because the detection of the reflected wave within 4μs was difficult. As the transmitted wave, burst wave of three sinusoidal waves with 10 V voltage and 2MHz frequency at the time interval of 10 ms was generated by the function generator. Capacitance as the electrical property was measured by LCR meter at 1 V voltage and 5 kHz frequency. Capacitance and propagation time were measured by changing the connection of the coaxial cable. They were also measured at 25^{o}C temperature controlled box.

As the experiment, acrylic resin, silicone rubber, aluminium and polymer gel with three kinds of thickness 1cm, 2cm and 4cm were prepared. Three kinds of hardness in silicone and polymer gel were respectively prepared. The size of each sample material was also 5cm×5cm. Three kinds of hardness in silicone rubber were made from silicone oil (SE1821LTV:Dow Corning Toray) and soft oil

Table 1: Ingredients of silicone rubber

	Silicone rubber (Hardness)		(Softness)
	A	B	C
Silicone	0.875	0.5	0.125
Soft oil	0.125	0.5	0.875

Table 2: ratio of acrylamide to distilled water

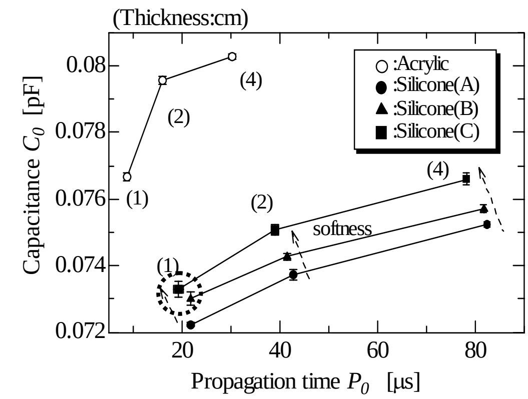
	(Hardness)	Polymer gel	(Softness)
	A	B	C
Acrylamide	8	16	24

(%)

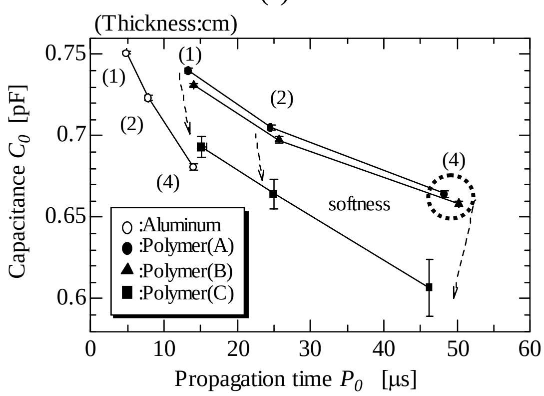
(SH200) to adjust the hardness. Table 1 shows the ratio of silicone oil to soft oil. Three kinds of hardness in polymer gel were also composed by the ratio of acrylamide to distilled water. Table 2 shows the ratio of them. Polymer gel was made from Ammonium peroxodisulfate(0.1%), TEMED(0.1%) and bis(0.1%) in addition to the ingredient of table 2.

4 Experimental result

In figure 3(a)(b), measurement results of capacitance



(a)



(b)

Figure 3: Experimental results. (a)Relationship between capacitance and propagation time in the case of silicone rubber and acrylic resin. (b)Relationship between capacitance and propagation time in the case of alminium and acrylic resin.

and propagation time at contact condition 1 were shown. Vertical axis shows capacitance value (C_0) and horizontal axis is propagation time (P_0). From results, the change of capacitance is different to that of propagation time in material and thickness, respectively. Material discrimination and detection of the thickness and hardness are difficult by using either capacitance or propagation time. However, it is found that material discrimination and the detection of the thickness and hardness are possible from measurements of capacitance and propagation time, although the accuracy of detection of thickness and hardness in silicone rubber or polymer gel is insufficient, especially at the circle of dotted line.

In figure 4(a)(b), the changed values of capacitance and propagation time measured at two kinds of contact conditions in acrylic resin and silicone rubber are respectively shown. Vertical axis of figure 4(a) shows the ratio of capacitance(C_0) measured at the condition 1 to that (C_{80}) at the condition 2. Vertical axis of figure 4 (b) shows the difference between propagation time (P_0) measured at the condition 1 and that (P_{80}) at the condition 2. As a result, it is found that the hardness are detected from the change value of capacitance or propagation time measured at two kinds of contact conditions although it is difficult to detect difference of hardness between acrylic and silicone rubber(A) in this system.

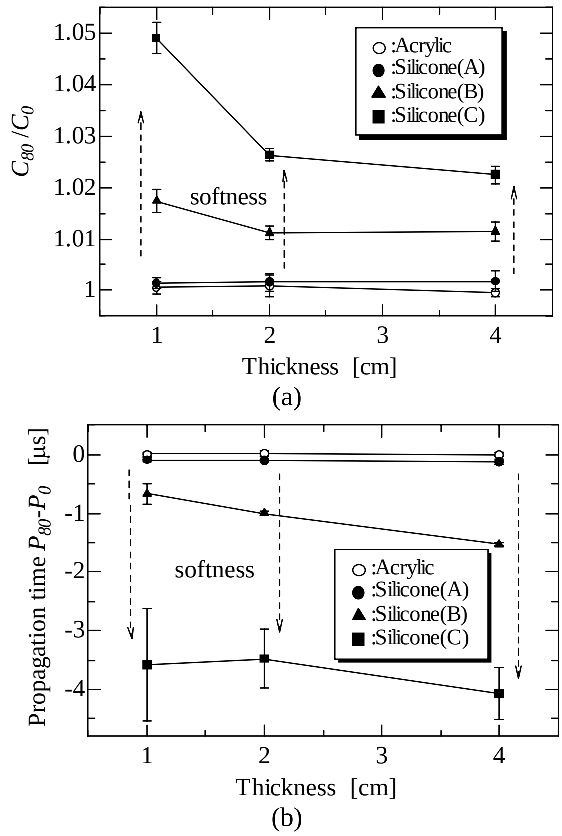


Figure 4: Changed values of capacitance and propagation time between two kinds of contact conditions in case of materials of acrylic resin and silicone rubber. (a)Measurement result of capacitance. (b)Measurement result of propagation time.

In figure 5(a)(b), the changed values of capacitance and propagation time measured at two kinds of contact conditions in aluminium and polymer gel are respectively shown. Vertical axis of figure 5(a) shows the ratio of capacitance(C_0) measured at the condition 1 to that (C_{80}) at the condition 2. Vertical axis of figure 5 (b) is the difference between propagation time (P_0) measured at the condition 1 and that (P_{80}) at the condition 2. As a result, it is found that hardness are detected from the change value of capacitance or propagation time measured at two kinds of contact conditions although it is difficult to detect difference of hardness between aluminium and polymer gel(A) around 1cm thickness.

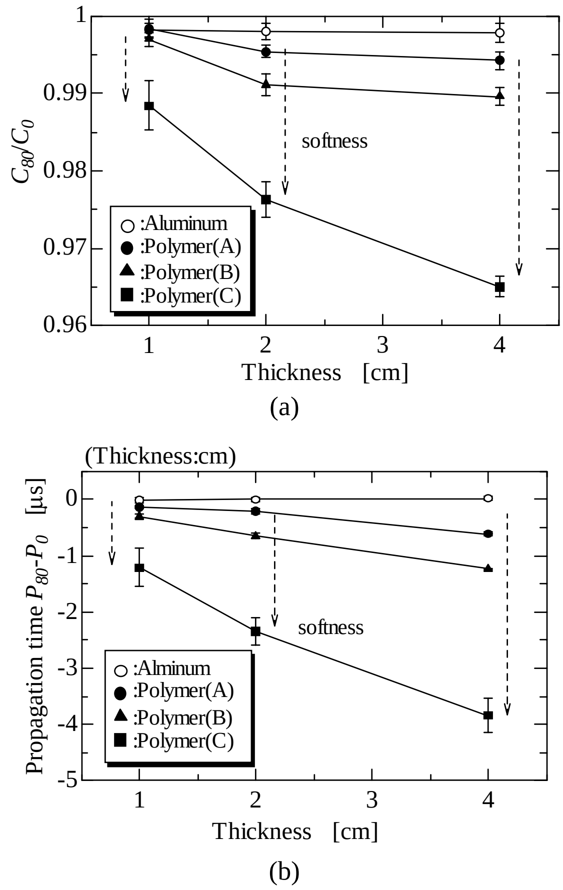


Figure 5: Changed values of capacitance and propagation time between two kinds of contact conditions in case of materials of aluminium and polymer gel. (a)Measurement result of capacitance. (b)Measurement result of propagation time.

5 Discussion

It was suggested that material discrimination and detection of thickness and hardness were possible by capacitance and propagation time measured at two kinds of contact conditions. In this system, the measurement accuracy was insufficient, especially, in case that sample material was soft. This was mainly caused by instability of contact condition between the sensor and the material. Therefore, the higher measurement accuracy would be obtained by improvement of the sensor structure or the measurement system such as how to give the load to the sensor and the adjustment of the hardness or viscosity of the silicone rubber pasted on the surface of piezoelectric ceramic.

As the method of material discrimination and detection of thickness and hardness in this system, firstly, capacitance and propagation time are measured at condition 1. From these data, material discrimination and detection of thickness are presented. Next, capacitance and propagation time are measured at the contact condition 2. From the changed values between measured values at the contact condition 1 and 2, the hardness of the material is detected. In this time, the measurement values of capacitance and propagation time at the contact condition 1 varied in the different hardness of silicone rubber or polymer gel, respectively. This was caused by the influence of the weight of the sensor. As a result, the accuracy of detection of thickness or material discrimination was insufficient. Therefore, material discrimination and detection of thickness and hardness will be improved by measuring at the contact condition which capacitance and propagation time in different hardness of the silicone rubber or polymer gel are respectively obtained as constant values.

In this experiment, capacitance and propagation time were measured by contacting the sensor without the load and with the load of 80g to the material. If the relationship between the pressure of the sensor and capacitance and propagation time is analysed by simulation, the capability of detection of the hardness will be improved.

6 Conclusion

In this paper, material discrimination and detection of the thickness and hardness were demonstrated by the proposed touch sensor. In the proposed sensor, electrical and ultrasonic properties are measured at same sensor. As the experiment, four kinds of materials such as acrylic resin, silicone rubber, aluminum and polymer gel with three kinds of thickness such as 1cm, 2cm and 4cm were prepared. In addition, three kinds of hardness in silicone rubber and polymer gel were respectively prepared. Capacitance and propagation time were measured by the proposed sensor at two kinds of contact conditions. As a result, the possibility of material discrimination and detection of the thickness and hardness were shown by the proposed sensor, although measurement accuracy was insufficient.

7 References

[1] Dario P., Rossi D.D.,“Tactile sensors and the gripping challenge”, IEEE SPECTRUM, August pp.46-52 (1985)

[2] Shinoda H., Oasa H., “Wireless Tactile Sensing Element Using Stress-Sensitive Resonator”, IEEE/ASME Trans. on Mechatronics, Vol.5, No.3, pp.258-265 (2000)

[3] Shimojo M., Namiki A., Ishikawa M., Makino R., Mabuchi K.,“A tactile sensor sheet using pressure conductive rubber with electrical-wires stitched method”, IEEE Trans. Sensor Journal, Vol.4 No.5, pp.589-596 (2004)

[4] Murali G., Rajanna K.,“Tactile sensor based on piezoelectric resonance”, IEEE Trans. Sensor Journal, Vol.4 No.5, pp.691-697(2004)

[5] Shikida M., Shimizu T., Sato K., Itogawa K., “Active tactile sensor for detecting contact force and hardness of an object”, Sensor and Actuators A, 103, pp.213-218 (2003)

[6] Kimoto A., Shida K.,“Material discrimination by means of multifunctional touch-sensor based on piezoelectric ceramics”, IEEJ-E,Vol.124, No.9 pp.311-315 (2004) (in Japanese)