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A new touch sensor for material discrimination and detection of thickness and hardness

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Abstract

This paper reports the development of a new touch sensor for material discrimination and detection of thickness and hardness. Ultrasonic and electrical properties of objects are simultaneously measured by the proposed sensor using a pair of piezoelectric ceramic transducers. The properties are also measured under two contact conditions (i.e., two different sensor weights). The material is discriminated and the thickness and hardness are detected from the measured values. In the experiment, four kinds of materials – aluminium, polymer gel, silicone rubber, and acrylic resin – were prepared. Three thicknesses – 1 cm, 2 cm, and 4 cm – were prepared for each material. Additionally, four grades of hardness of polymer gel and silicone rubber were used. Discrimination of the materials including the detection of thickness and hardness was demonstrated by the measured values of capacitance and propagation time under the two contact conditions. The results indicate that the proposed touch sensor could discriminate four kinds of materials and detect thicknesses between 1 cm and 4 cm, and hardness in silicone and polymer gel.

Keywords: Piezoelectric ceramic; Electrical property; Ultrasonic property; Touch sensor

1. Introduction

Tactile, or touch sensors are very important in various industrial fields, especially in robotic arms. Several tactile sensors have been investigated for material discrimination, shape recognition, detection of hardness, and so on. There are tactile sensors based on the pressure of conductive rubber [1,2], a strain gage [3], an acoustic sensor [4], the principle of the piezoelectric resonance [5], and a capacitor [6]. Many other researchers have investigated tactile sensors using piezoelectric transducers and strain gages [7], pneumatic actuation [8], and optical fibers [9]. Fingertip type tactile sensors have been implemented by strain gage and polyvinylidene fluoride (PVDF) film for material discrimination [10], PVDF and a pressure variable resistor [11], a multi-modal tactile sensor based on polymer materials and metal thin film sensors [12], and by a high-speed vision sensor for robotic grasping [13]. Our research has aimed to develop a tactile sensor for material discrimination, detection of thickness and hardness, and for shape recognition; just as fingers do for humans. To achieve this, we propose a touch sensor based on piezoelectric ceramic transducers. The proposed sensor measures the ultrasonic property by the contact between the sensor and the object and measures the electrical property using piezoelectric ceramic surface electrodes. Therefore, ultrasonic and electrical properties are simultaneously measured by the proposed sensor. In this study, the discrimination of four kinds of materials – aluminium, polymer gel in conductive material, acrylic, and silicone rubber in an insulator – and the detection of thicknesses between 1 cm and 4 cm in each material and the hardness of polymer gel and silicone rubber were accomplished by measuring propagation time as the ultrasonic property and capacitance as the electrical property under two contact conditions.

2. Method

Fig. 1 shows the measurement method of the proposed touch sensor. In Fig. 1, the ultrasonic property is obtained using the pair of piezoelectric ceramic transducers when the switches S1 and S2 are connected to the A terminals. The transducers are used as transmitter and receiver, respectively. The electrical property is obtained from voltage and current measured by the front

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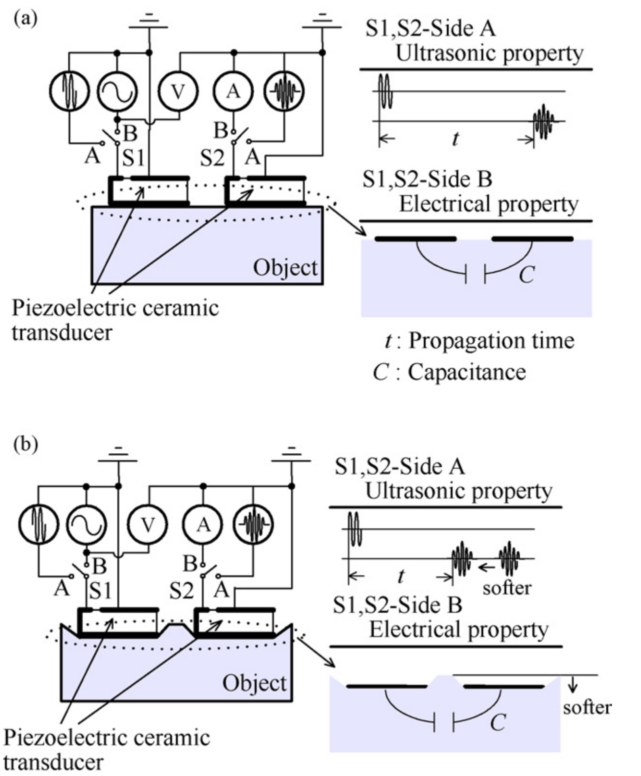

Fig. 1. Measurement method of the proposed touch sensor. (a) Contact condition-I (non-sensor pressure) and (b) contact condition-II (a constant sensor pressure).

electrodes of each piezoelectric ceramic transducer when the switches S1 and S2 are connected to the B terminals. At the same time, the backside electrodes of each piezoelectric transducer are connected to the ground for shielding and for simultaneous measurements of the ultrasonic and electrical properties. Therefore, the ultrasonic and electrical properties of the object are measured by the same sensor based on a pair of piezoelectric ceramic transducers. In this way it is possible to obtain information about the object, such as the quality of the material and the thickness, from these measurement values. As well, the hardness of the material is detected by changes in the ultrasonic and electrical properties measured at different contact conditions such as non-sensor pressure and constant sensor pressure because measurement values between the contact conditions are changed by the hardness of the material, as shown in Fig. 1(b). For example, propagation time, as the ultrasonic property, becomes shorter as the object becomes softer. As the object becomes softer, capacitance, as the electrical property, changes because the surface form of the material would be changed and the electric field between the surface electrodes of a pair of piezoelectric ceramics, that is, the permittivity distribution on the surface of material, would also be changed.

3. Experiments

Fig. 2 is a schematic diagram of the measurement system. The proposed sensor used two rectangular piezoelectric ceramic transducers (1 cm × 0.5 cm × 0.1 cm) with a resonance frequency of 2 MHz. These were fixed to the centre of acrylic resin blocks (0.5 cm × 3 cm × 0.6 cm). A pair of rectangular piezoelectric ceramic transducers with 1 cm distance between their centers was arranged on an acrylic plate (4 cm × 3 cm × 0.5 cm), the upper side of which was coated with a copper sheet for shielding. Silicone rubber of 0.05 cm thickness was pasted onto the surface of each piezoelectric ceramic piece to stabilise contact conditions between the sensor and the measurement material. The material under test was then placed on the surface of a wooden table (20 cm × 20 cm × 1.5 cm, MDF: medium density fiberboard) with a relative permittivity of 2.6. Capacitance, as the electrical property, and propagation time, as the ultrasonic property, were measured by the sensor placed on the measurement material under two contact conditions. Contact condition-I was contact under the weight of the sensor (9 g); for contact condition-II we placed a load of 80 g on the sensor. Propagation time was obtained from the time interval between transmitted and reflected waves.

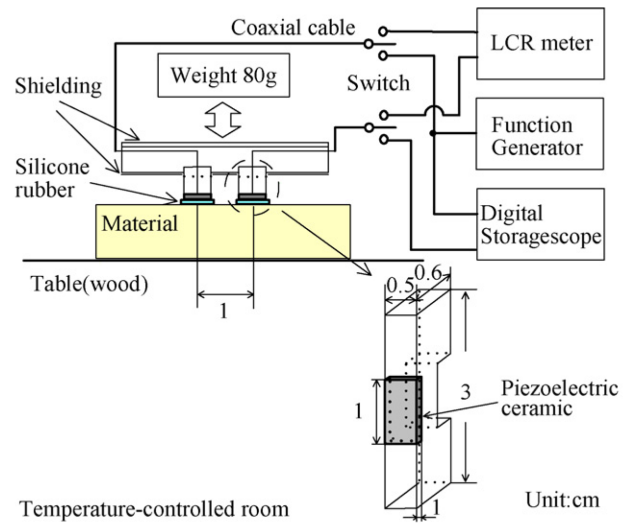

Fig. 2. Schematic diagram of the measurement system using the proposed touch senor.

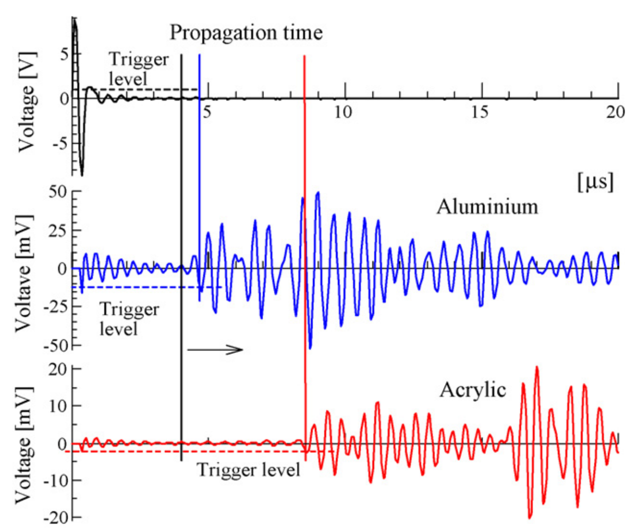

Fig. 3. Transmitted and received waves.