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Capacitive tactile sensor array for touch screen application

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ABSTRACT

In this paper, we propose and demonstrate a transparent and flexible capacitive tactile sensor which is designed for multi-touch screen application with force sensing. A sensor module is composed of 2D array tactile cells with a spatial resolution of 2 mm to measure the touch force at multiple positions. The device is fabricated by using transparent materials on a transparent plastic substrate. The optical transmittance of the fabricated tactile sensor is approximately 86% in the visible wavelength region, and the maximum bending radius is approximately 30 mm. The cell size is 1 mm × 1 mm, and the initial capacitance of each cell is approximately 900 fF. The tactile response of a cell is measured with a commercial force gauge having a resolution of 1 mN. The sensitivity of a cell is 4%/mN within the full scale range of 0.3 N.

1. Introduction

A touch screen is a display that can detect the presence and location of a touch on a display area. Currently, touch screens, because they provide very intuitive user interfaces, are widely used not only in computer systems in the industry but also in hand-held devices such as mobile phones, PDAs, and car navigation systems. The important characteristics of a touch screen that is used as a display include transmittance, resolution, resistance to surface contamination, durability (lifetime), multi-touch recognition, display size, and force sensing. Among these characteristics, multi-touch recognition, which has recently been incorporated in several models of mobile phones and portable electronic devices, enables a user to interact with a system by simultaneously using multiple fingers. As will be discussed briefly in this paper, it has been difficult to apply multi-touch recognition to most classical touch screen technologies.

Various sensing technologies have been developed using diverse approaches, and they are widely used in commercial products using touch screens. Resistive [1], capacitive [2], optical using infrared (IR) [3], and acoustic using surface acoustic wave (SAW) [4] detection methods have been used in most conventional touch screens. However, these types of touch screens recognize only a single touch point. There are several technologies for multi-touch recognition. The patterned capacitive-type touch screen consists of transparent row and column electrode arrays embedded within some insulating material [5,6]. This arrangement monitors the change in capacitance that occurs at the point on the screen where a finger is placed. Han reported multi-touch sensing on rear-projected interactive screens based on the frustrated total internal reflection technique, which required a video camera to monitor the finger locations [7]. The above-mentioned touch screen technologies are well-adopted to a flat panel display. However, nowadays, many studies have reported on flexible displays, because the flat panel display using a glass substrate is fragile and difficult to carry [8]. To be utilized in a flexible display, the tactile sensor for a touch screen should also exhibit flexibility. Therefore, in this work, a transparent and flexible tactile sensor has been designed for a multi-touch screen application. In addition, we are aiming at developing a touch sensor capable of force sensing in order to discriminate among different levels of touch strength.

In fact, touch sensors with force sensing have been researched for the last few years as tactile sensors mainly for artificial skin for robot applications [9,10], minimally invasive surgery [11,12], wearable computers [13], and mobile or desktop haptic devices [14]. Four popular pressure-sensing mechanisms for tactile sensors have been reported: resistive, piezoresistive, piezoelectric, and capacitive-sensing mechanisms. In resistive sensors, a resistance change induced from the resistive material squeezed between electrodes is measured [15]. A piezoresistive sensing mechanism uses a strain gauge to measure the deformation of a tactile cell [16]. A piezoelectric mechanism measures the accumulation of charges and the resulting voltage buildup as a membrane is forced. However, a piezoelectric sensor cannot detect static force [17]. A capacitive-sensing mechanism measures the capacitance change induced by the change in the gap between the electrodes [9]. However, most

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of these devices are not suitable for touch screen display systems because of the non-transparency of the materials they are made of. In order to meet the requirement for tactile sensors for multi-touch screens for flexible display applications, we have introduced a capacitive tactile sensor array constructed with polycarbonate (PC) films and indium–zinc-oxide (IZO) electrodes for flexibility and transparency. In this paper, we present the concept, fabrication, and experimental results of our sensor in detail.

2. Design

Fig. 1 shows the cross-sectional view and the dimension of a unit cell of the proposed tactile sensor array. The upper and bottom substrates are transparent PC films with a thickness of 120 μm. A thin transparent IZO layer was used as the electrodes and the signal lines. The two electrodes formed a capacitor separated by a distance of 13 μm by SU-8 spacers. The cell size and electrode size were 2 mm × 2 mm and 1 mm × 1 mm, respectively. The capacitance of a cell can be expressed as

$$C = \frac{1}{(t_a/\varepsilon_0 A) + (t_d/\varepsilon_d \varepsilon_0 A)}, \quad (1)$$

where ε_0 is the permittivity in free space, ε_d is the relative permittivity of the SU-8 insulation layer, t_a is the air-gap distance, t_d is the thickness of the SU-8 insulator layer, and A is the electrode area. The initial capacitance of a cell was estimated to be 926 fF using Eq. (1) assuming that the relative permittivity of SU-8 was 3.2. When a touch pressure was applied on the surface of the upper plate, the gap between the two plates decreased and the capacitance increased until the gap was closed. By measuring the capacitance for all the capacitive array cells, we could determine the touch position and the applied force on multiple locations.

The membrane deflection and resultant capacitance change as the touch force applied must be considered for a capacitive cell design. These factors were examined by the finite element method (FEM) simulation for a capacitive cell with the dimensions given

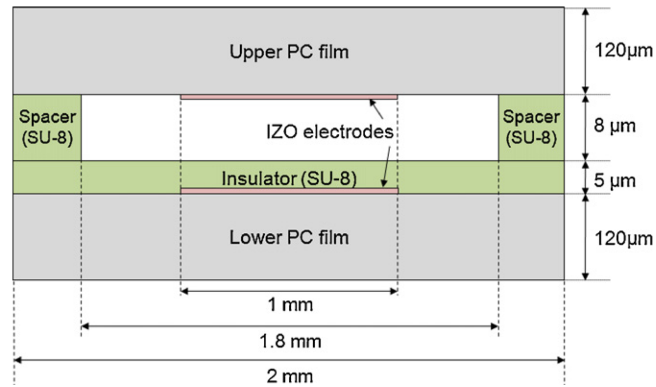

Fig. 1. Cross-sectional view of a tactile cell and its dimensions.

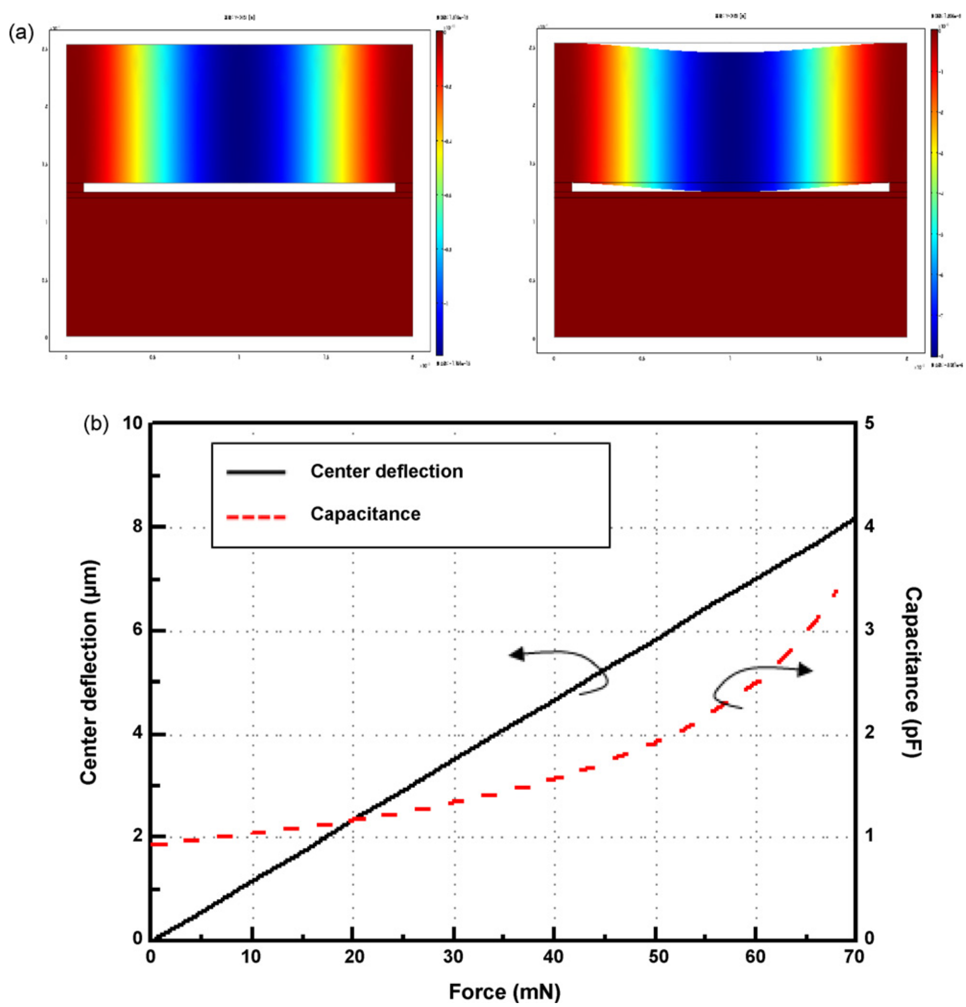

Fig. 2. Center deflection (solid line: calculated, dashed line: simulation) and capacitance (dash–dot line) for various applied forces.