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Proceeding Paper

Textile Tactile Senor Based on Ferroelectret for Gesture Recognition †

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Abstract: Ferroelectret is a charged polymer with cellular void structures that create giant dipole moments across the material's thickness. In this work, we present the first realization of a wearable textile substrate tactile sensor based on Polypropylene (PP) ferroelectret material for gesture recognition. As a result, the sensitivity of the fabricated sensor is 0.21 V/kPa in the pressure range of 0–20 kPa. The ferroelectret tactile sensor adheres to a glove's surface for detecting human movements such as bending or the relaxation motion of the palm and the bending or stretching motion of each finger, enabling the successful detection of small finger gestures around a 400 mV output.

Keywords: ferroelectret; tactile sensor; gesture recognition

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1. Introduction

With the explosive growth of digital devices, the technologies enabling interaction between people and devices are required more than ever. Among them, gesture recognition technology has received a lot of research attention [1–3]. In essence, gesture recognitions are divided into two categories: contact sensors and non-contact sensors. Non-contact sensors are mostly based on visual technologies [4,5]. Non-contact sensors utilize various technologies to extract information about the shape and movement of the hand from instantaneous image, and then recognizes gestures based on this information. Alternatively, the most commonly used methods of recognizing gestures by contact sensors are Electromyography (EMG) sensors and force-sensitive resistors sensors (FSRs) [6–8]. However, the drawbacks of these two types of sensors are also obvious. For EMG sensors, the electric potential of muscles is too sensitive relative to electric noise, because the magnitude of the electric potential is in range of submillivolts. FSRs are more robust to noise compared to EMG sensors, but they require a continuous external power supply.

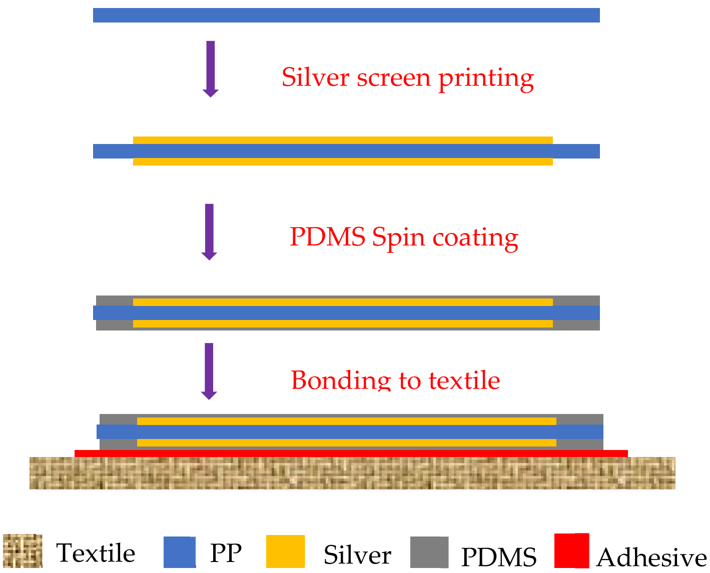
Sensor based on piezoelectric materials such as Zinc Oxide (ZnO), lead zirconate titanate (PZT), Molybdenum disulfide (MoS_2), poly(vinylidene fluoride) (PVDF) and its similar copolymer p(vdf-TrFE) exhibit piezoelectricity by converting mechanical signals into electrical outputs. For these conventional piezoelectric materials, PZT and PVDF, PZT possesses excellent dielectric and piezoelectric properties, owing to its very high Young's modulus (63 GPa). However, PZT is a rigid ceramic unsuitable for wearable e-textile applications [9]. In contrast, PVDF is a soft polymer with a low Young's modulus (2.9 GPa), and its piezoelectric charge coefficient d_{33} is an order of magnitude lower than of PZT (20pC/N), which is insufficient for certain applications that require high bending and high sensitivity requirements [9].

A ferroelectret is a thin film of polymer foam that can generate an electrical signal under mechanical force, similarly to piezoelectric materials. However, the piezoelectric effect in a ferroelectret is very different from piezoelectric materials. Its piezoelectricity comes from the separated positive and negative charges, which are trapped on the upper and lower surface of the voids [10]. Upon applying pressure or bending, the change in the dipole moments generates a change in the accumulated electric charge on each surface of ferroelectret. Due to its outstanding properties in comparison with other piezoelectric material, numerous applications have been proposed, such as acoustic transducers, higher frequency loudspeakers and keyboards [10,11].

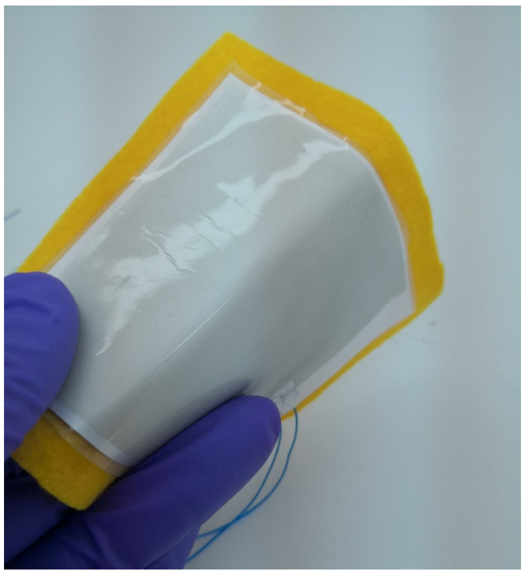
In this paper, a wearable ferroelectret tactile sensor based on PP for gesture recognition is presented. The proposed tactile sensor was fabricated based on PP ferroelectret with a polydimethylsiloxane (PDMS) encapsulation on a textile substrate and shows a high sensitivity to pressure, which can be utilized to monitor the movement of hands.

2. Sensor Fabrication

The schematic diagram of the fabrication processes of a ferroelectret tactile sensor is illustrated in Figure 1a. PP film sheets were commercially purchased from EMFIT. These films are cut into sample sizes that can be attached to a glove. A thin layer of silver electrodes was screen-printed on the top and bottom of the PP ferroelectret, respectively. These samples with printed silver electrodes need to be cured in an oven at 50 °C for 10 min. In order to obtain the sensor signal, a small piece of conductive tape was used to connect external wires to these electrodes. After that, a thin layer of PDMS was casted on the electrodes by spin coating as an encapsulation layer. The samples with the PDMS encapsulation layer were heated in an oven at 50 °C for 10 min, and the sample was then left at room temperature for one day to fully cure. The fabricated ferroelectret tactile sensor was bonded to a textile substrate (glove) by a thin layer of adhesive tape, as shown in Figure 1b.



(a)



(b)

Figure 1. (**a**) The fabrication process for the ferroelectret tactile sensor; (**b**) the photo of the fabricated tactile sensor.

3. Experiments and Results

To demonstrate the feasibility of using this sensor for gesture recognition, the fabricated tactile sensors were sequentially installed in each finger and palm to monitor the movement of these areas, as shown in Figure 2. An oscilloscope was used to record the voltage generated from this ferroelectret tactile sensor.

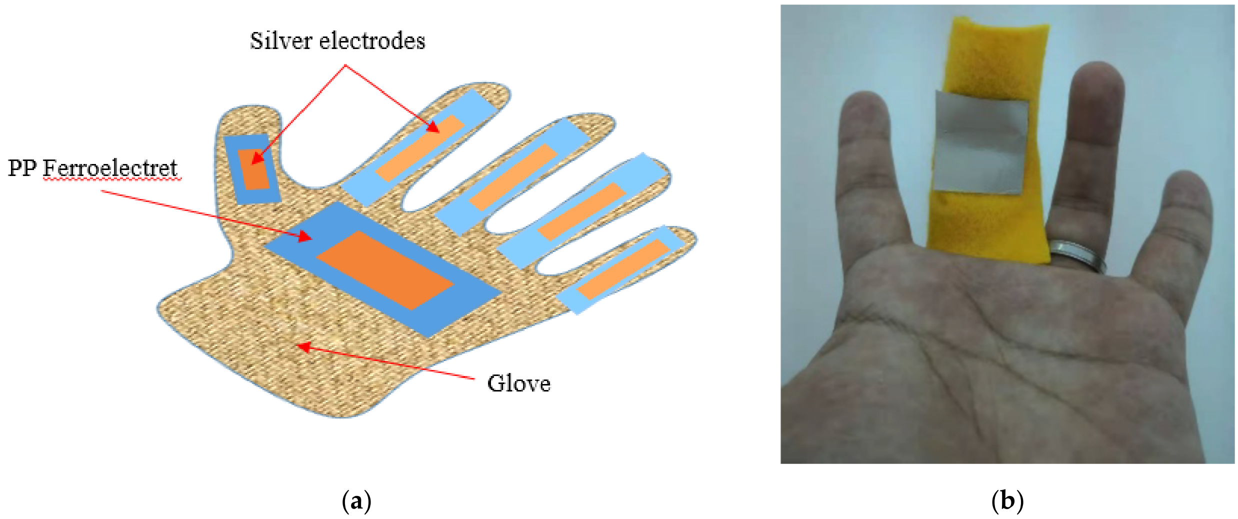


Figure 2. (**a**) The schematic of diagram of the ferroelectret tactile sensor system for gesture recognition; (**b**) the image of ferroelectret tactile sensor for finger bending.

During a fist gesture, the output voltages of the tactile sensor installed at different hand positions are in the form of a voltage pulse, as shown in Figure 3. The maximum output voltages of the sensors from the middle finger, pinky finger and palm positions are 0.8 V, 0.4 V and 0.9 V, respectively. In particular, the durations of the output voltage spike for different tactile sensor positions are significantly different.

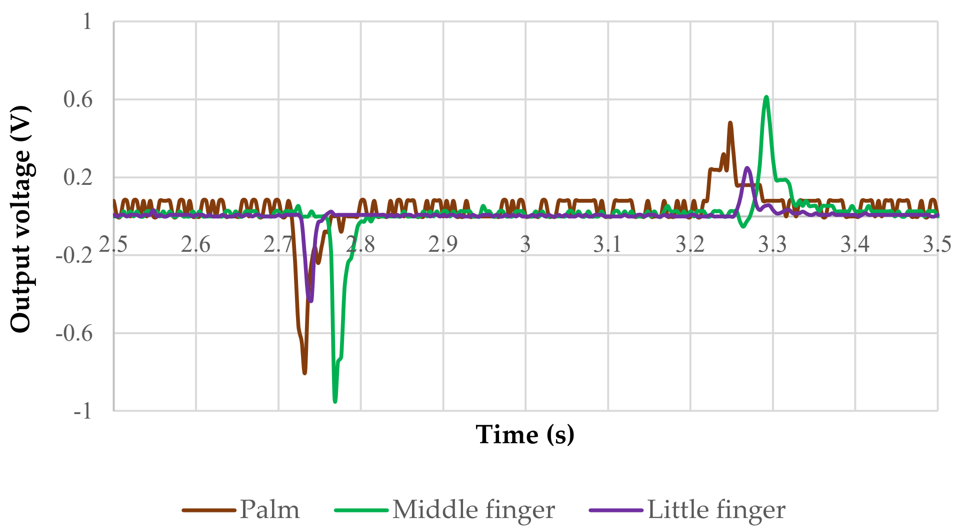


Figure 3. The output voltage of the tactile sensor installed at fingers and palm during a fist gesture.

To understand the sensing mechanism for gesture recognition, the output voltage curve of the ferroelectret sensor during the entire process from bending to the relaxation of the finger is shown in Figure 4a. Compared with the process of releasing, maximum voltage amplitude increases to 0.93 V during finger bending. Afterwards, the voltage returns to its original value when no further pressure is applied. A maximum voltage amplitude 0.61 V was measured when releasing. To quantify the sensitivity of the fabricated tactile sensor, the sensor was tested under an external pressure applied by an electrodynamic instrument (ElectroPuls E1000, Instron Ltd., Buckinghamshire, UK). The "open circuit" peak voltage, measured across a 10 MΩ probe impedance, as a function of external pressure is shown in Figure 4b. There is a direct linear relationship between the measured open voltage and the external pressure. The sensitivity of the tactile sensor is 0.21 V/kPa in the pressure range of 0–20 kPa.

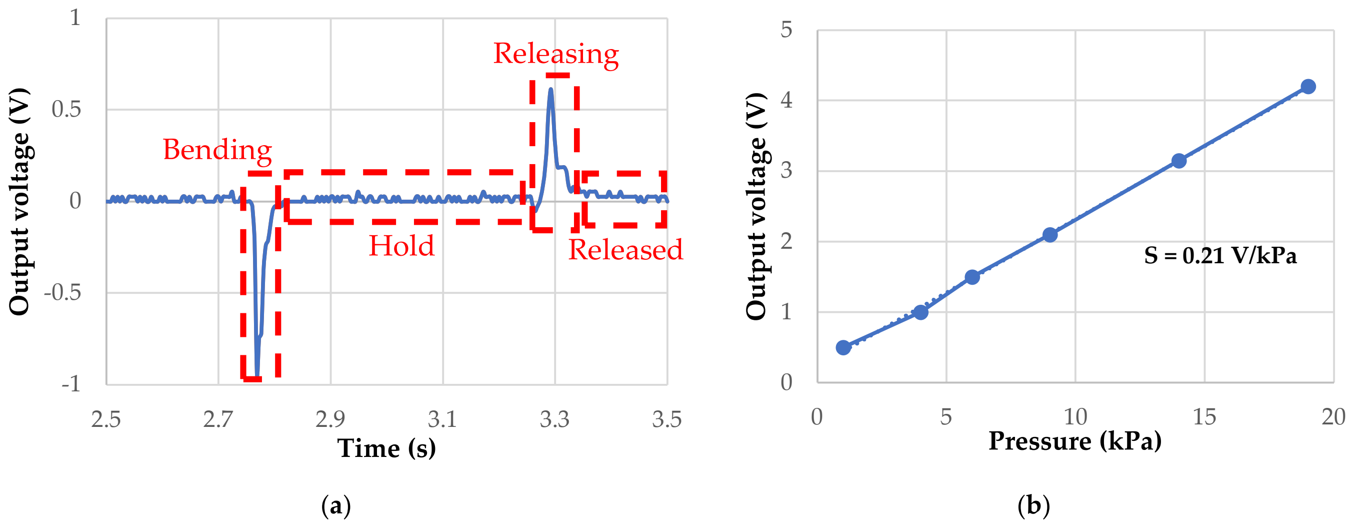


Figure 4. (**a**) Output voltage of the ferroelectret tactile sensor under different states for a finger bending; (**b**) output voltage response under different pressure.

4. Conclusions

In this work, we presented the first realization of a wearable tactile sensor implemented on a textile substrate based on PP ferroelectret material for gesture recognition. The sensitivity of the fabricated sensor was achieved at 0.21 V/kPa in a pressure range of 0–20 kPa. The ferroelectret tactile sensor demonstrates the feasibility of detecting human movement, such as bending/relaxation motions of the palm and bending/stretching motion of each finger, and can successfully detect pinky finger gestures with an output of about 400 mV.

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Conflicts of Interest: The authors declare no conflict of interest.

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