DOI 10.5162/SMSI2025/P09

Piezoelectric pressure mapping sensors using the poling effect induced by surface chemical modification

Daisuke Tadaki[1*], Shintaro Matsumoto[1], Shin Yamamiya[1], Teng Ma[2], Yuji Imai[3], Ayumi Hirano-Iwata[1], Michio Niwano[1]
[1] Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
[2] Beijing Institute of Technology, 5 Zhongguancun South Street, Haidian District, Beijing 100811, China
[3] National Institute of Technology, Sendai College, 4-16-1 Ayashi-Chuo, Aoba-ku, Sendai 989-3128, Japan
daisuke.tadaki@tohoku.ac.jp

Summary:
This paper presents a fabrication technology for a piezoelectric pressure mapping sensor with a PVDF film sandwiched between metal wire electrodes. A new approach is proposed for a poling treatment of the polymer films, which is generally required to obtain a sufficient voltage output from the sensor, using a simple solution-based method of drop-casting onto the chemically modified electrode surface. Here we report on the fabrication method and an investigation of the functionality of the fabricated novel mapping device, which can detect the applied position for a two-dimensional pressure mapping.

Keywords: pressure sensor, piezoelectric, PVDF, poling, surface modification

Introduction

Poly(vinylidene fluoride) (PVDF), an organic piezoelectric polymer, has so far been extensively studied for applications in flexible pressure sensors. To obtain a sufficient voltage output from pressure sensors based on piezoelectric polymer materials, including PVDF, a poling treatment of the polymer films is generally required. The conventional poling method usually requires a rather high electric field or a high annealing temperature, which leads to an increase in the sensor fabrication cost. A new approach to poling piezoelectric polymers, on the other hand, has been proposed using a simple solution-based method [1,2]. By drop-casting a PVDF solution in a polar solvent onto a chemically modified gold (Au) electrode surface, we have successfully formed a *β*-PVDF film with high piezoelectric properties and improved the sensitivity of PVDF pressure sensors [3]. For application to tactile sensing, which has recently attracted attention in healthcare fields, we are currently trying to develop a novel mapping device that expands the PVDF sensor to a two-dimensional (2D) system. In terms of obtaining the flexibility of a 2D device, these sensors using piezoelectric organic films have the advantage of requiring quite a simple fabrication method, whereas inorganic materials-based sensors usually require a complicated nanofabrication process to disperse the compressive stresses generated when pressure is applied. Here, we report on the fabrication method of a piezoelectric pressure mapping sensor with a *β*-PVDF film-based simple structure, and an investigation of the functionality of the novel device to detect the applied position for a 2D pressure mapping.

Experimental

Figure 1 shows (a) a top view and (b) a schematic diagram of the fabricated mapping sensor. Au (~60 nm) is mask deposited on a plastic (PET) substrate as the bottom (x) electrode and its surface is chemically modified with 1*H*,1*H*,2*H*,2*H*-perfluorodecanethiol (PFDT), a thiol agent with a high dipole moment. Subsequently, a PVDF solution containing hexamethylphosphoric triamide (HMPA) and acetone is drop-casted onto the substrate and thermally dried to form a PVDF film (~100 µm). Au (~60 nm) is finally mask deposited as the top (y) electrode perpendicular to the bottom (x) electrode. This novel method can thus provide the simplicity in fabrication process and reduction of the fabrication cost. The width of each Au wire on the sensor region is 150 µm, and the wire gap is 50 µm; i.e., the planar resolution is 200 µm. Electrical measurements were made independently at a single point (each three-dimensional intersection of the x and y electrodes) when a pressure jig with a square protrusion of 600 µm per side was periodically applied to the sensor region (Fig. 2).

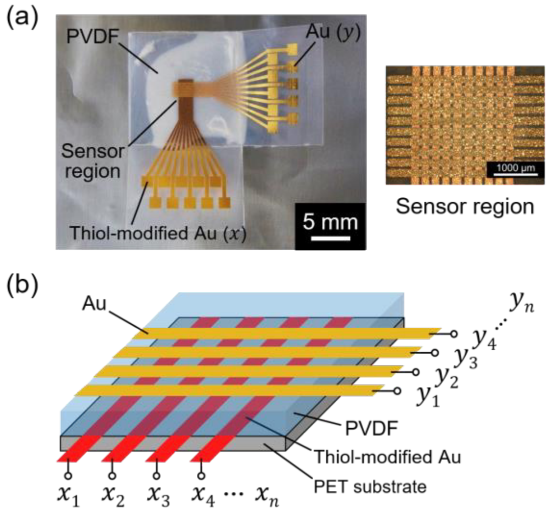

Fig. 1. (a) Photo image of the fabricated mapping sensor with an enlarged view of the sensor region. (b) Three-dimensional schematic of the sensor region. Each intersection of the x (bottom) and y (top) electrodes becomes a single measurement point.

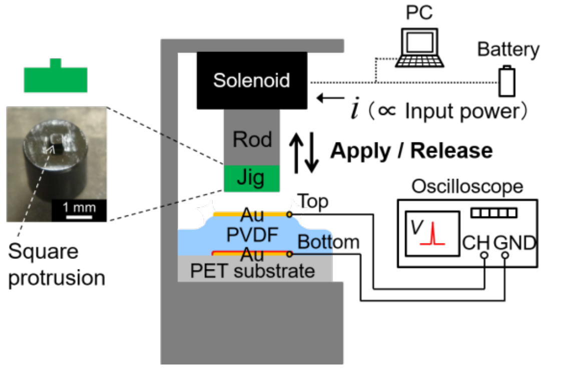

Fig. 2. Measurement system of the sensor device. A pressure jig with a square protrusion of 600 μm per side was periodically applied to the sensor region.

Results

Figure 3 shows the output voltage waveforms measured from point ($x7$,$y5$). It can be seen that a peak with an almost constant output voltage is reproducibly obtained by the periodically applying of the jig with protrusion. An increase ratio of the output voltage with the jig to without the jig is the largest at this point, reaching 34% (0.29 V → 0.39 V). Figure 4 shows a mapping of the output increase ratio (%) obtained from each point (64 points in total). It was found that the pressure applied to each point was clearly differentiated with a resolution of 200 μm, from which the approximate area of the applied position (black dashed box in the map) can be detected. We thus concluded that a 2D pressure mapping was successfully demonstrated with the fabricated novel device. Our main current issue is to further improve the output voltage (sensor sensitivity) for detecting more detailed 2D shapes of the applied objects.

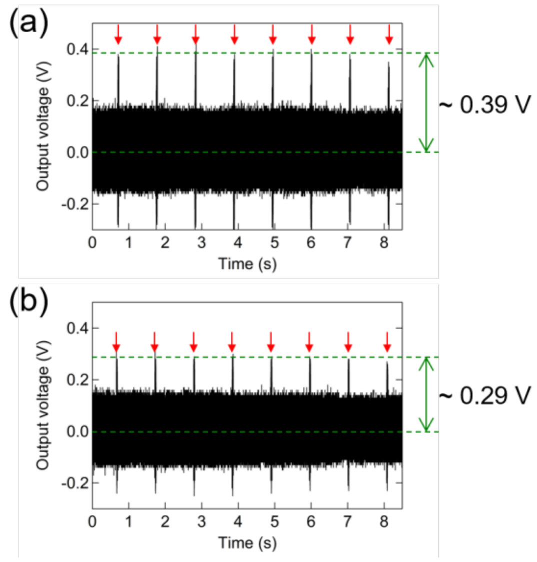

Fig. 3. Output waveforms at point (x7,y5) for the case of (a) with the jig and (b) without the jig (uniformly applied to the whole sensor region). The red arrow indicates each applied instant (~5 N, ~40 ms). The output increase ratio reaches 34% at this point.

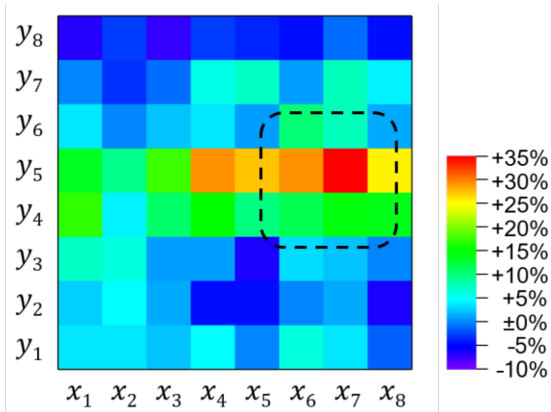

Fig. 4. Color distribution map of the output increase ratio (%) at each measurement point. Each segment corresponds to the planar resolution of 200 μm per side. The black dashed box indicates the approximate area of the applied position (600 μm per side).

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