

Enabling Large-Area Tactile Imaging via Multiplexed CB–PDMS Flexible Pressure Sensor Arrays

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Abstract:

In this work, a large-scale flexible pressure sensor array based on a carbon black–polydimethylsiloxane (CB–PDMS) conductive composite is presented. The array is configured in an approximately 110×16 matrix, enabling high-resolution spatial pressure mapping. Crosstalk and leakage are minimized through optimized scanning with precise timing control. A multiplexed row–column addressing scheme is employed for efficient data acquisition with reduced interconnect complexity. The proposed system is scalable, low-cost, and suitable for applications like electronic skin, human–machine interfaces, and tactile imaging.

Keywords: Flexible pressure sensor, Conductive, CB–PDMS, Multiplexed readout, Crosstalk.

Background, Motivation and Objective

Flexible pressure sensor arrays have attracted significant attention for applications such as tactile sensing [1], electronic skin [2], wearable devices, and human–machine interfaces [3]. Among various sensing materials, piezoresistive composites based on carbon fillers dispersed in polydimethylsiloxane (PDMS) are widely utilized due to their low cost, mechanical flexibility, and ease of fabrication [4].

However, the development of large-area, high-density sensor arrays presents several technical challenges, including increased wiring complexity and degraded signal integrity. As the array size scales up, issues such as crosstalk, leakage currents, and switching errors become more pronounced, leading to reduced measurement accuracy and reliability. Furthermore, conventional readout architecture often requires a large number of interconnects and complex circuitry, which limits scalability.

In this work, we present the design, fabrication, and performance evaluation of a high-resolution CB–PDMS-based flexible pressure sensor array, addressing the key challenges associated with large-scale integration.

Description of the Method

The pressure sensor array is fabricated using a CB–PDMS conductive composite as the sensing layer. The composite is prepared by dispersing carbon black particles into the PDMS matrix at a concentration of ~ 15 wt%, which is near the percolation threshold to achieve high sensitivity for the intended application. The PDMS matrix

consists of a silicone elastomer base and a curing agent mixed at a 10:1 weight ratio. The mixture is thoroughly stirred and degassed for 1 hour to ensure uniform dispersion. The conductive polymer mixture is then poured onto the flexible PCB die using a drop-casting method and cured at 100°C for 1 hour to form a flexible conductive film shown in Figure 1.

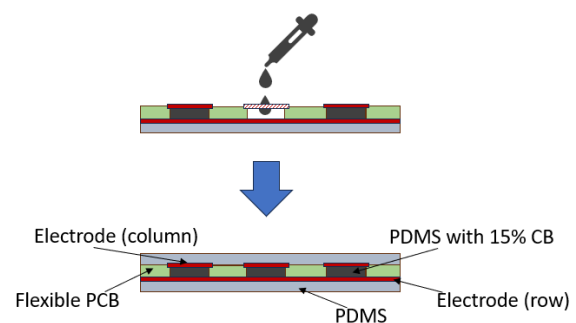


Fig. 1. Fabrication process of the proposed sensor.

The flexible sensor PCB is structured in a “U” shape, as the system is designed to map the localized pressure of the human jaw, as shown in Figure 3(a). The sensor consists of an approximately 110×16 matrix formed by arranging row and column electrodes, where each intersection represents an individual sensing unit, as shown in Figure 3(b). When pressure is applied, the resistance at each node changes due to deformation of the conductive network within the CB–PDMS layer.

For electrical readout, a multiplexed row–column addressing scheme is employed, as illustrated in Figure 2. Multiple analog multiplexers are used

to sequentially select rows, while column signals are measured through an ADC readout path. Each selected row is driven by a controlled voltage, and the corresponding column response is recorded. Parasitic effects such as crosstalk and leakage currents are minimized using the Zero Potential Method (ZPM), along with optimized scanning and circuit design.

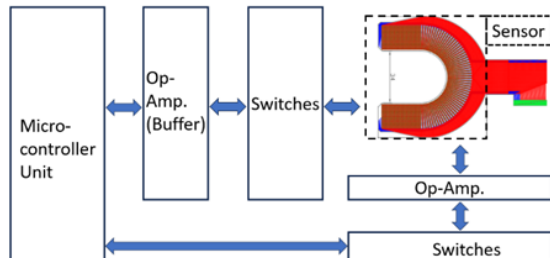


Fig. 2. Block diagram of the data readout system.

Results and Discussion

A buffer circuit is shared across the row lines before the switching stage to reduce leakage currents through unselected rows.

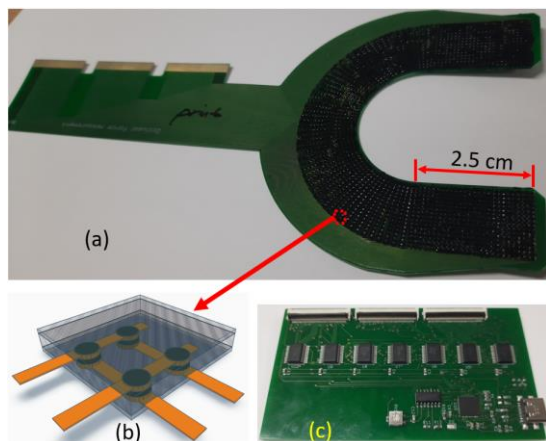


Fig. 3. Fabricated design of (a) sensor array, (b) sensor node within the array, and (c) proposed electronic data readout system.

For the column lines, each channel is connected to an operational amplifier to maintain unselected columns at virtual ground. The implemented electronic hardware system is shown in Figure 3(c). Data acquisition is performed through a sequential scanning process. Data acquisition test platform shown in Figure 4(b).

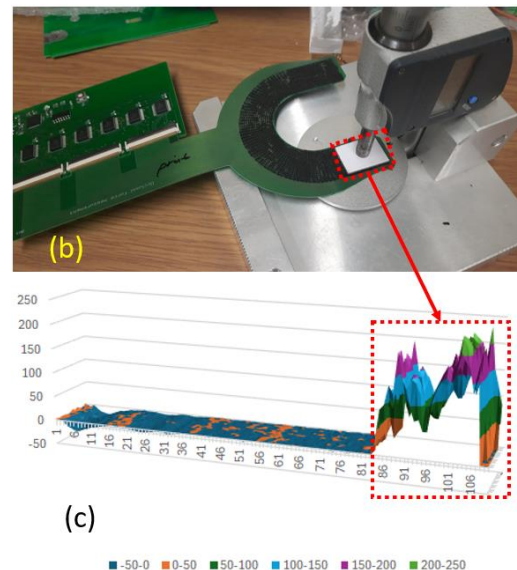
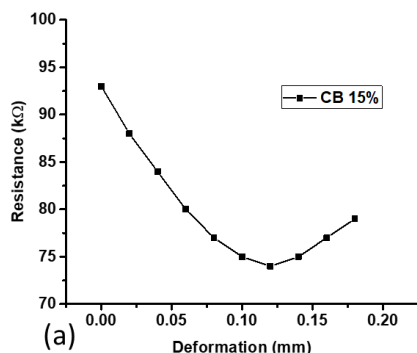


Fig. 4. (a) Response of a single cell of the sensor array, (b) Data acquisition test platform, and (c) Localized pressure mapping using the sensor array.

As pressure increased, resistance decreased due to reduced spacing between CB particles in the PDMS matrix. Beyond a certain threshold, resistance increased again, likely due to particle displacement and structural changes that disrupt conductive paths shown in Figure 4(a). Figure 4(c) shows the localized pressure map, where the x-axis represents the number of rows and the y-axis represents the pressure level. The acquired signals are processed using a microcontroller-based system to reconstruct the spatial pressure distribution across the array.

Conclusion

At high pressures, resistance slightly increased, likely due to particle displacement and matrix over strain. The sensor array showed good sensitivity, repeatability, and stability over a wide pressure range.

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