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Design and Fabrication of Carbon Black Polymer Composite Based Pressure Sensor Array

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Abstract:
In this paper, we present the unique design, fabrication, and performance analysis of a flexible pressure sensor based on a composite of carbon black and polydimethylsiloxane (PDMS). This proposed sensor is capable of detecting localized pressure with little amount of deformation. It is fabricated using a simple and cost-effective method by dispersing carbon black particles into a PDMS matrix to form a conductive elastomer. The resulting composite exhibits excellent flexibility, mechanical durability, and piezoresistive behavior under varying pressure loads.

Keywords: Flexible, Pressure, Polymer, Piezoresistive, Sensor.

Background, Motivation and Objective

Flexible pressure sensors have garnered significant attention for application in wearable electronics, soft robotics, artificial skin, and health monitoring systems due to their ability to detect subtle mechanical stimuli while maintaining flexibility, durability, and sensitivity. Piezoresistive sensors are especially attractive owing to their simple design, ease of fabrication, and straightforward signal processing.

PDMS is widely employed as a flexible substrate for such sensors due to its favorable mechanical and chemical properties [1]. When combined with conductive fillers like carbon-based materials, PDMS can form piezoresistive composites that effectively convert mechanical deformation into electrical signals. Carbon black (CB), in particular, is a low-cost, conductive filler with high surface area and good compatibility with PDMS, making it a practical alternative to more complex nanomaterials [2][3].

This study presents the design, fabrication, and performance evaluation of a carbon black–PDMS composite pressure sensor array.

Description of the Method

The sensor fabrication process involved mixing the Silicone elastomer base and Curing agent at a 10:1 weight ratio to create a PDMS-based composite. Dimethylsiloxane was used as a base material, combined with a crosslinking agent, methyltrichlorosilane, to enable curing. The mixture was subjected to mechanical shear mixing for approximately 10-15 minutes to ensure uniform dispersion of the crosslinker throughout the matrix. Degassing step lasting 1 hour to remove any trapped air bubbles. This process was repeated to prepare multiple PDMS composite with varying CB content ranging from 5% to 20% by volume. Among these, the composite with 15% of CB exhibited the best performance in terms of piezoresistive response and mechanical integrity.

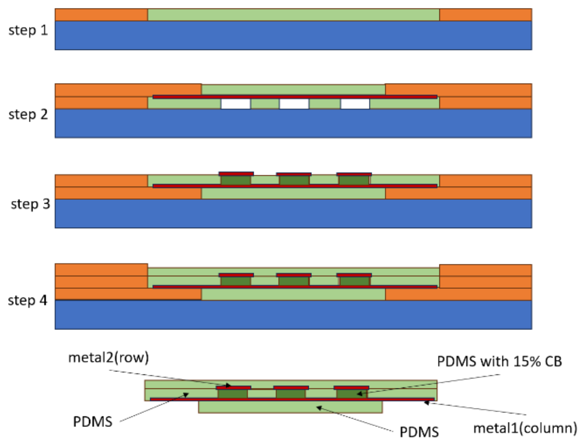

Fig. 1. Fabrication process of the sensor

We followed the proposed sensor fabrication process shown in Fig. 1. After each step, the sample was cured at 100 °C for 1 hour. Fig. 2 shows the fabricated sensor and its bending test. The sensing composite element has a cylindrical shape with a diameter of 3 mm and a thickness of 1 mm. Flexible copper strips were used as metal electrodes.

Results

The fabricated sensor was tested under various applied pressure levels. A cell evaluated at different pressure levels, as shown in Fig. 3. As the applied pressure increased, the sensor's resistance decreased due to the reduced distance between CB particles caused by the deformation of the PDMS matrix.

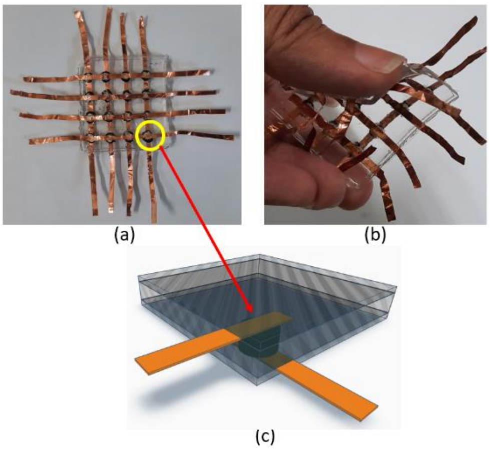

Fig. 2. (a) Fabricated polymer based pressure sensor. (b) Bending test of sensor. (c) Piezoresistive sensor cell.

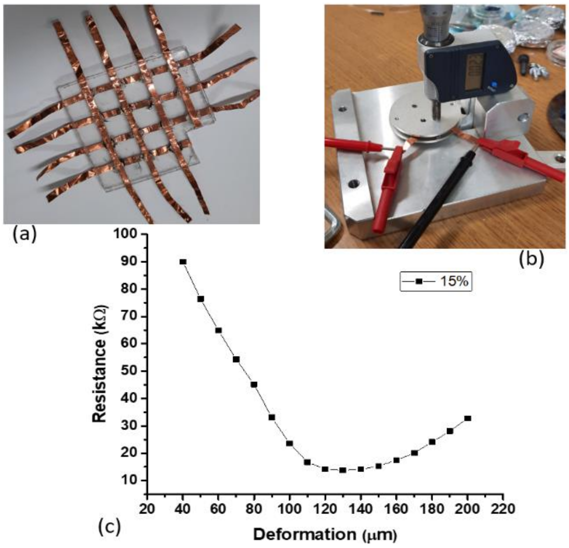

Fig. 3. (a) Sensor cell removed for individual test. (b) Cell test platform with pressure mechanism. (c) Resistance changes because of deformation.

However, beyond a certain pressure threshold, the resistance began to increase. This is attributed to excessive pressure causing particle displacement and strain-induced microstructural changes that disrupt conductive pathways.

Tab. 1: Weight list for sensor testing.

Obs.	Objects Name	Total weight (g)
(a)	Small metal balls	13
(b)	Glue stick	27
(c)	Hollow cylinder	34
(d)	Metal plate	150
(e)	Glass bottle	195
(f)	Orange	270

The entire sensor array was tested under different weight induced pressure levels. The list of applied weights is provided in Table 1, and the electronic setup along with the $\Delta I/I_0$ (%) response results are shown in Fig. 4.

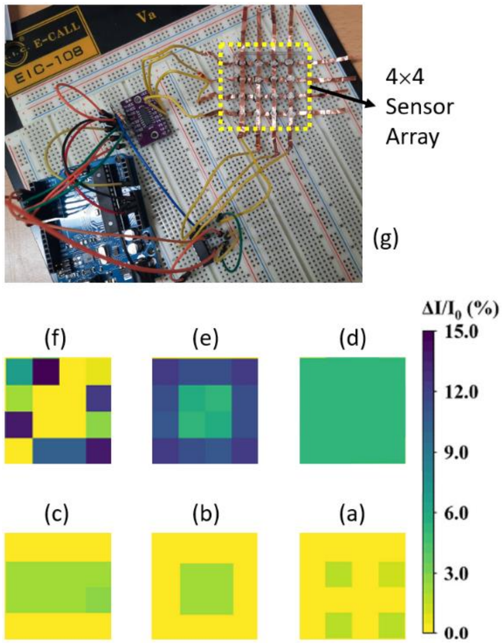

Fig. 4. (a)-(f): $\Delta I/I_0(\%)$ response test under different loading conditions. Loading details shown in Table.1 (g) Sensor testing platform with electronics.

Conclusion

At higher pressure levels, a slight increase in resistance was observed, likely due to particle displacement and structural strain within the matrix. The sensor array demonstrated good sensitivity, repeatability, and stability across a range of pressure conditions.

Acknowledgement

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