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Fabrication and Chracterization of Polymer-Based Ethanol Gas Sensor

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Abstract:

In this study, we present the fabrication and characterization of polymer-based ethanol gas sensors developed for environmental ethanol detection. The sensors were fabricated using MEMS process. A protective SU-8 film was applied to the sensing area, followed by the deposition of various polymer films, including PNPD, to enhance gas-sensing performance. The base resistance was measured to evaluate the sensor's stability. Ethanol gas responses were evaluated at 3000 ppm, 5000 ppm, and 10,000 ppm. The results confirm the potential of the fabricated sensors for reliable and effective environmental ethanol detection.

Keywords: Gas sensor, Ethanol sensor, SU-8, PNPD polymer, Response-recovery

Background, Motivation and Objective

Ethanol is widely used in industrial, biomedical, and domestic settings, making its detection and monitoring increasingly important for safety and environmental management. Prolonged exposure to ethanol vapors poses health risks and fire hazards, especially in confined spaces. Therefore, reliable ethanol gas sensors with high sensitivity, stability, and fast response times are essential. Among various sensing technologies, polymer-based gas sensors have garnered attention due to their low cost, ease of fabrication, and tunable sensitivity through polymer functionalization [1][2]. Integration with microfabrication techniques, such as photolithography and RF sputtering, further enhances the precision and reproducibility of sensor devices.

Traditional metal oxide-based sensors often require high operating temperatures, which limit their use in low-power or wearable applications. In contrast, polymer-based sensors can operate effectively at room temperature, offering a safer and more energy-efficient alternative. By incorporating functional polymers like PNPD, it is possible to tailor the sensor's selectivity and sensitivity toward ethanol gas [3]. The use of SU8 as a passivation layer also improves mechanical stability and surface protection during operation. A need remains for fabricating and testing such sensors with well-defined structures and reliable response characteristics to varying ethanol concentrations.

The primary objective of this work is to design and fabricate ethanol gas sensors using a polymer-based approach supported by microfabrication processes. This study aims to demonstrate the potential of such polymer-based sensors for use in practical environmental ethanol monitoring applications.

Materials and Methods

The fabrication process began with the preparation of a clean substrate suitable for photolithographic processing. A photoresist layer was deposited onto the substrate using a spin coater to ensure uniform coverage and desired film thickness. Fig 1. shows the schematic diagram of the sensor.

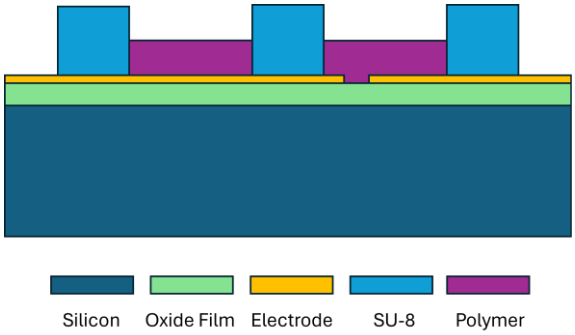

Fig. 1. Schematic diagram of ethanol sensor

Ti/Au electrodes were patterned on oxidized silicon wafers via the lift-off porcess with RF sputtering. An SU-8 photoresist was patterned to act as a containment barrier for the polymer during

subsequent processing. Following dicing into individual sensor chips, functional polymer layers were deposited onto the sensing area. Poly (N-phenyl diaminopyridine) (PNPD) polymer was selected as the active material due to its strong chemical affinity for ethanol vapors and its stable electrical properties. The Polymer was appled using drop-casting technique, with the the deposition parameters adjusted based on the desired film morphology and thickness. The fabricated sensors were susbsequently dried at room temperature. A shematic illustration of the sensor structure is provided in Fig. 2.

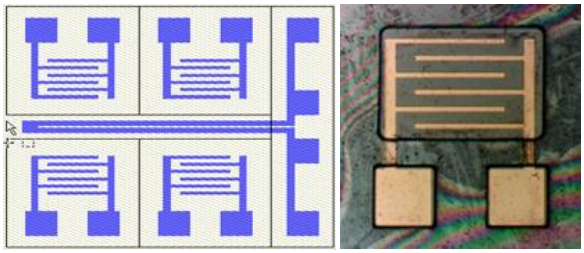

Fig. 2. Electrode layout(left) and the fabricated picture(right) of ethanol sensor

Results and Discussion

Fig. 3 illustrates the resistance response of the fabricated polymer-based ethanol gas sensor when exposed to ethanol concentrations of 3000 ppm and 10,000 ppm over time. In both cases, a sharp decrease in resistance is observed upon ethanol exposure, indicating good sensitivity and prompt response to the gas. After each exposure cycle, the resistance returns close to its baseline, confirming the sensor's repeatability and recovery behavior. The response magnitude is more pronounced at 10,000 ppm, showing that higher ethanol concentration leads to a larger resistance change.

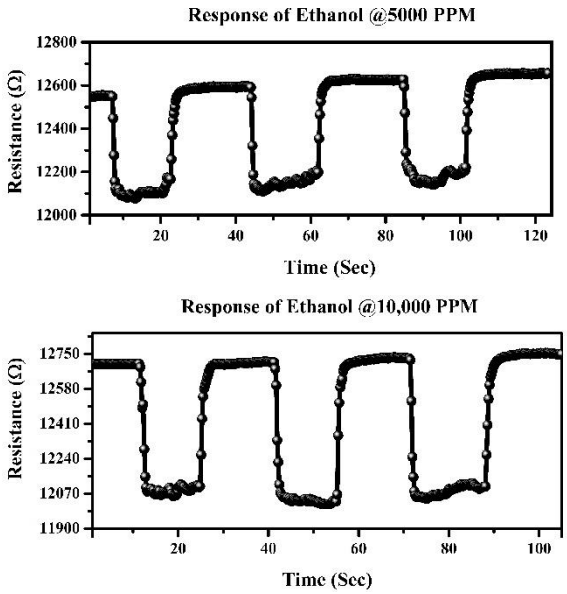

Fig. 3. Response characteristics of ethanol sensor

These results confirm that the sensor is capable of detecting ethanol at various concentrations with consistent performance.as the ratio of resistance change upon gas exposure to the baseline resistance.

Fig. 4 shows the relationship between the resistance change rate (%) of the sensor and the square root of ethanol gas concentration. A strong linear correlation is observed, with a correlation coefficient R^2 = 0.9992, indicating excellent sensor response predictability. The linear trend (slope = 0.0507) confirms that the sensor's response increases proportionally with higher ethanol concentrations. This result validates the sensor's capability for quantitative ethanol detection with high sensitivity and reliability.

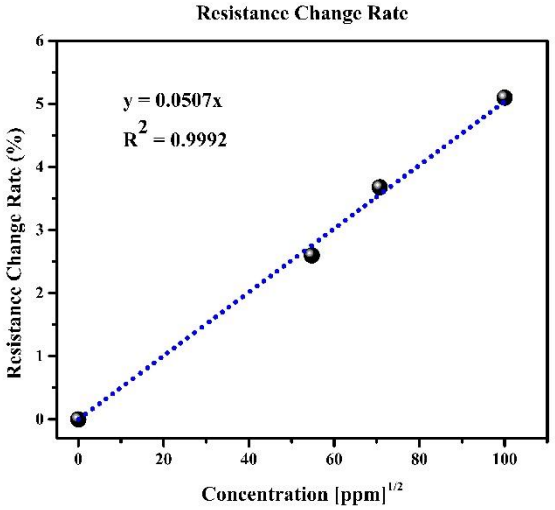

Fig. 4. Resistance change ratio for PNPD polymer

Conclusions

To address the need for low-cost, room-temperature ethanol sensing, a PNPD-baed polymer gas sensor was fabricated using microfabrication techniques. The sensor exhibited high sensitivity, repeatability, and fast reponse.

Acknowledgements

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