Microfabrication and Commercialization of a Chemical Gas Sensor

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Motivation

Typical fuel-cell and chromatography based devices for breath alcohol detection range from $100-$400+ per unit.

Project Objective: Design and fabricate a chemical gas sensor suitable for field breath-alcohol detection that is:

- Portable
- User-friendly
- Reusable
- Inexpensive
Sensor Design

- Designed using 6 inch platform to maximize real-estate
- Sensor consists of a single lithography step to define electrodes

Figure 1: Mask defined interdigitated electrode spacing - 25 µm

Figure 2: Device Cross-section
Final Device

Figure 3: 5X Optical photo of completed sensor

Figure 4: Completed sensor with chip pins attached
2 µm of (3,4-polyethylenedioxythiophene-polystyrenesulfonate) PEDOT polymer is applied to interdigitated electrodes and cured at 100 ºC for 30 minutes.
PEDOT is a conductive polymer which upon exposure to ethanol vapors, will adsorb the ethanol causing the polymer to swell which results in a measurable change of resistance across the electrodes.
Baseline Testing

PEDOT-Coated Sensor
Chamber Volume: 250 mL
Injected Ethanol Concentration: 50 µL
Temp: 27ºC

Ethanol injected into chamber → Sensor responds until polymer reaches saturation → Chamber is purged with Nitrogen
Although the sensor responded to various concentrations of ethanol, the device would not be suitable for commercial breath alcohol detection applications:

- Little or no distinction to increasing levels of ethanol concentrations
- Slow response time (5+ minutes to reach equilibrium)
- Sensitivity of the device needs to be improved!!
To improve sensitivity, 100 mg of carbon (metallofullerenes As atomized) is added to 1 ml of PEDOT. The carbon absorbs the ethanol vapors and allows the polymer to saturate and reach equilibrium much faster than the polymer alone, thus improving sensitivity.
Ethanol Response

PEDOT-Coated Sensor with carbon
Chamber Volume: 250 mL
Injected Ethanol Concentration: 50 µL
Temp: 27ºC

Sensor response time improved to 60 seconds
To simulate human breath, the test was performed at 37°C for ethanol concentrations ranging from 0.10 µl to 400 µl.

- The sensor easily distinguishes increasing concentrations of ethanol.
- Response time improved to 60 seconds.
**Commercial Application**

- The sensor exhibited a response time of 60 seconds with a recovery time of ~90 seconds even for the smallest tested ethanol concentration of 0.10 µl.
- 0.10 µl of ethanol in a 250 ml chamber is equivalent to a BAC level of 0.07*.
- When packaged with an external feedback circuit, the sensor may be suitable for field breath-alcohol detection.
- The proposed circuit operates on a 9V battery and would be lightweight and portable.

* NY State maximum vehicle operation BAC level: 0.08
Project Summary

- Developed fabrication process for chemical gas sensor
- Successful characterization of polymer (PEDOT) response to ethanol
- Successful fabrication of low-cost, reusable chemical gas sensors
- Design of possible external feedback network which when packaged with the sensor may be suitable:
  - As a field breath alcohol screening device
  - For environmental monitoring applications

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<th>Anticipated</th>
<th>Actual</th>
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<tbody>
<tr>
<td>Fabrication (cost)</td>
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<td>Fabrication (time)</td>
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<td>Materials (cost)</td>
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<td>Testing (time)</td>
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<td>Sensors produced (5 wafer lot)</td>
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<td>Cost per sensor</td>
<td>$0.57</td>
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