Analyte Detection with the SensorBit 4-T Cell

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Abstract: The 4-Terminal, or 4-T, cell uses a combination of CMOS technology with organic materials for the detection of polar and non-polar analytes. This technology offers a significant step forward because of its small form factor, low manufacturing cost, and high detection sensitivity and versatility, expanding the areas of utilization. The signal analysis is improved with the design because information regarding the interaction between the analyte and the cell can be seen from responses in the silicon NMOS current and the organic resistance. The benefit is seen in increased information for qualitative and quantitative analyses and in a reduced calculation burden. This presentation will report on technology design and manufacturing and will cover the fundamentals of the design; the status of the development effort, including the measurements and interpretation of the data. Stability of the organic materials and measurements of polar organics and non-polar molecules will be demonstrated.

1 Introduction: This technology consists of an array of sensors, each treated with one of a variety of organic materials, causing each sensor to respond electrically to a given vapor in a unique fashion. The combination of all signals produced by the sensor array generates a characteristic digital signature for a given vapor. The transduction mechanisms for this cell are from the current measurements of the organic layer and the NMOS transistor in the silicon. This arrangement provide additional information concerning the interaction between the analyte and the cell because the organic resistance can change with adsorption and the silicon current can change if the adsorbed species produces a charged state.

2 Experimental: The SensorBit technology is based on a sensor cell patented by the University of Texas at Austin [1]. The sensor cell is referred to as a 4-T design because of the four electrically addressable points: two contacts to the Silicon wafer and two to the Organic layer. A cross-sectional drawing is shown in **Error! Reference source not found.**.

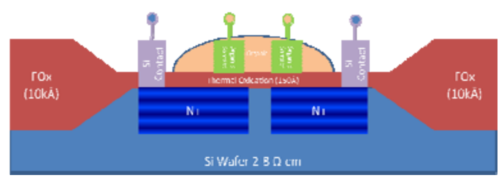

Figure 1. Cross-section of the SesnorBit 4-T Cell.

The manufacturing of this cell is done using standard CMOS techniques for all of the steps except for the organic layer deposition. The organic material is applied using an InkJet deposition system. InkJet deposition allows for work with a wide variety of Organic layers and receptor additions. **Error! Reference source not found.** shows a representative top-down optical image of the 4-T cell with the Organic layer in place. The die shown in **Error! Reference source not found.** has been packaged into a testable form and can be loaded into a socket for measurement.

Electrical data is taken from the gas test cell and analyzed as a function of the exposure to the analytes.

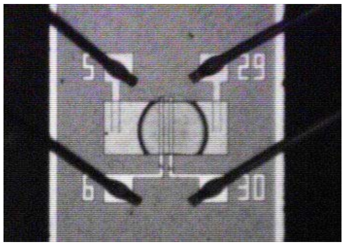

Figure 2. Top-down optical image of the 4-T cell with the Organic layer in place.

To this point the materials that have been deposited for the Matrix material include: a Polythiophene-derivative Organic semiconductor; Poly(2,2,2-Trifluoroethyl Methacyrlate); Poly(4-Vinylphenol); and an Fe-based Metal Organic Complex. The materials that have been deposited for the Receptor material include: PVP and Fe-MO. Some organic layers have been deposited without receptors. These materials have been selected from previous experience with organic electronics and from the published results from the JPL eNose group [2].

3 Results and Analysis: The initial focus of testing using this cell has been to answer the concerns regarding the choice organic materials. One of the questions regarding the usage of organic polymer layers, especially the organic semiconductor materials

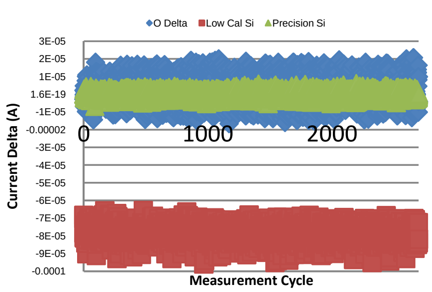

Figure 3. Long term stability of the Polythiophene-derivative semiconductor, with temperatures between 20°C and 40°C is shown through a 16-hour test.

is the long term stability. Figure 3 shows testing of the Polythiophene-derivative semiconductor through a 16-hour stability test. The three curves are shown for the current measurements of the organic layer and silicon channel. The temperature of the cell was also cycled during testing between 20 and 40°C to demonstrate the thermal stability of the organic layer.

The detection mechanism can be seen from the data taken for Figure 4. In this figure, the organic layer is composed of Polythiophene and PVP as the receptor, and the cell is exposed to Ethanol on two separate instances. The cell responds to the interaction by changes in the organic current only; silicon currents are unchanged during the exposure.

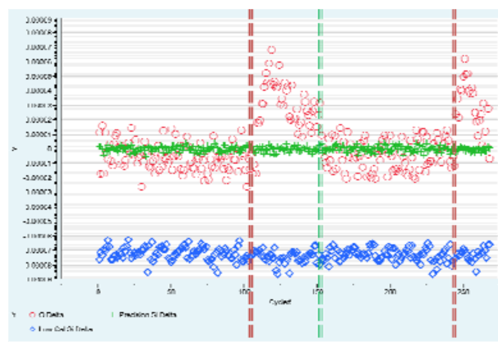

Figure 4. Exposure of the cell to Ethanol causes a response in the organic current only. The vertical Red line is Ethanol-On condition and the Green line is Ethanol-Off.

4 Conclusion: We have shown the build and initial responses of the 4-T cell. The stability of the organic layer under long term tests and thermal cycling appears to be very good. The cell has shown good response to polar organic analytes, such as Ethanol.

References

[1] Dodabalapur, et al., “Method of using a four terminal hybrid silicon/organic field effect sensor device.” US Patent 7,538,538, 26 May 2009

[2] Homer, et al. "Statistical methods for selecting the components of a sensing array." Computational Methods for Sensor Material Selection. Ed Margaret A. Ryan, et al. Springer, 2010. 245-300.