# Selective, Sensitive, and Tunable Porous Silicon Gas Sensor

Peter J. Hesketh(1), Stephen Lewis(2), James Gole(2), and John DeBoer(1)
(1) School of Mechanical Engineering
Georgia Institute of Technology, Atlanta, GA 30332
(2) School of Physics,
Georgia Institute of Technology, Atlanta, GA 30332

Hybrid porous silicon proves to be an inexpensive and robust platform for fabrication of semiconductor sensors[i]. The hybrid porous silicon consists of a micro-porous framework whose walls are covered with a thin nanoporous layer. This extremely high surface area provides a mechanism for the device to detect ppm and ppb levels of a range of gases including ammonia, $NO_x$, and HCl. Additionally, a general method of coating electroless metal to the surface provides selectivity. With an electroless tin treatment, for example, a new sensing mechanism is provided which detects low ppm levels of CO. Other Electroless treatments including Pd, Pt, and Ag are being tested for detection of $H_2$, $H_2S$, and $SO_2$. This research is intended to characterize discrimination for these gases at concentrations below 1ppm.

The hybrid porous silicon gas sensor is fabricated in a low-cost, two-mask, process on a typical p-type Si wafer. The first mask defines a window in a silicon carbide layer on the wafer which locates the porous silicon anodization. An electrochemical etch process consisting primarily of HF in MeCN forms a thin (5-10 µm) microporous layer extending across the surface of the wafer. This layer has a nanoporous surface which provides a high surface area for adsorption. The second mask defines the location of the electrical contact to the device. Gold electrodes are placed on at least two sides of the porous silicon region. These electrodes are then attached to a Solartron 1260 impedance analyzer. The flow of 100 sccm gas over the surface of the device causes the impedance to change and this is readily monitored.

Figure 1 shows the real part of the impedance of a sensor measured (with a signal voltage of 100mV at 1kHz) over time. This test demonstrates the selectivity of the device to ammonia vs. NO, and demonstrates that the time for a response to be realized is at most several seconds.

**Figure 1: Exposure to Ammonia Pulses in 20ppm NO Background**

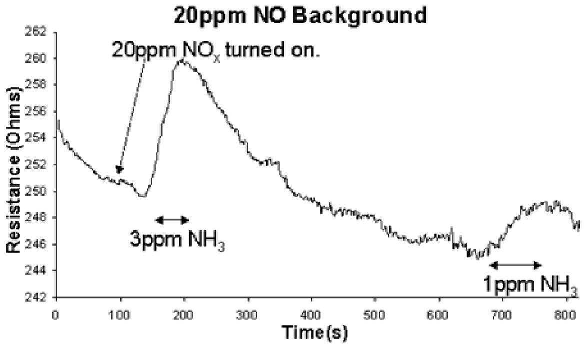


Figure 2 demonstrates the performance of a sensor to different levels of ammonia. This data shows the present LOD is near 250 ppb for ammonia. This sensor has not been treated in electroless gold, which in other devices has dramatically improved their sensitivity to ammonia.

**Figure 2: Linear Sensitivity of Device to ppm Levels of Ammonia in Nitrogen**

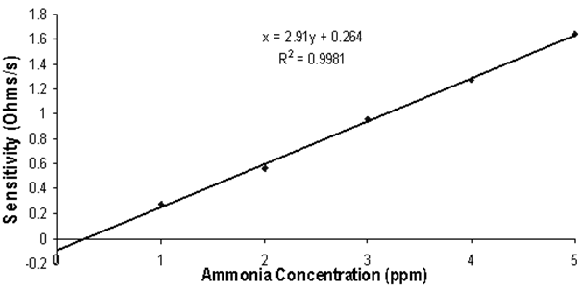
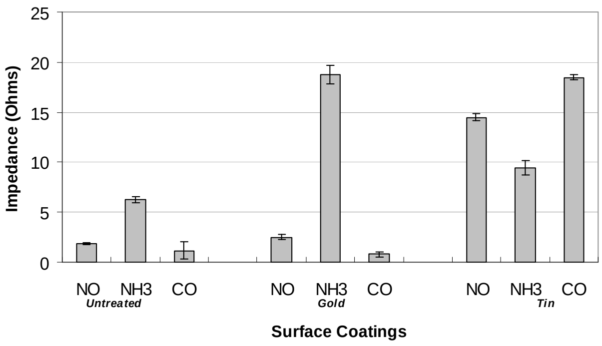


Figure 3 shows the response of devices treated with a metallization process to 20 ppm of various gases. Electroless gold and tin metallization was used in these experiments on a series of sensors. The impedance given in the figure is the average change of the impedance of the device after a 30 second pulse of test gas. The error bars signify the standard error for 30 pulses of gas.

**Figure 3: Change in Impedance Response Provided by Electroless Treatments**



Currently, investigation of additional gases and electroless coatings is being studied. Further, better packaging methods are being investigated to deliver the test gas packets more rapidly to the devices. Arrays of differently treated sensors on a single chip can provide an inexpensive and robust device for discrimination of analyte gases. A low-cost device with these capabilities may find an important role in automotive, medical, and construction applications[ii,iii,iv]. The implementation of a more precise testing apparatus and studies with a wider range of gases is needed to investigate the full potential of this device.

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