Setting the Standard for Automation™

Chemical Microsensor Development for Aerospace Applications

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Standards
Certification
Education & Training
Publishing
Conferences & Exhibits

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University of Illinois at Urbana-Champaign, 1998, Ph.D.

Case Western Research University, 1998-2000, Post Doctoral

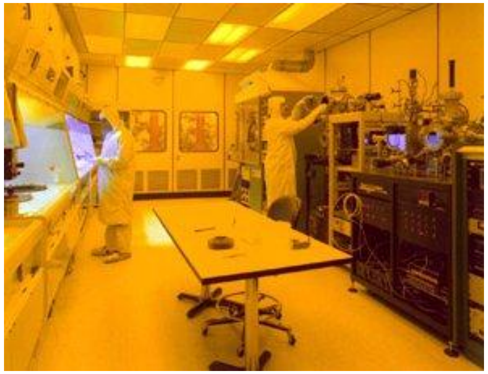
Sensor Development Co., Inc. 1999-2002, Material Scientist

NASA Glenn Research Center: 2002-present, Electronics Engineer

Chemical Sensor Development at NASA GRC

- **Microsensors and platforms**
  - ∗ H_2, CH_4, C_2H_4, C_3H_6, CO_2, CO, O_2, NOx, N_2H_4, HCl, HCN, and HF
  - ∗ Schottky diodes, resistors, and electrochemical cells
- **Approaches**
  - ∗ Smart sensor system: sensor arrays, signal processing and conditioning components, power and telemetry
  - ∗ "Lick and Stick" for full-field view of environment
  - ∗ Nanotechnology and batch microfabrication
  - ∗ Small size, low weight, cost, and power consumption
- **Applications**
  - ∗ Propulsion system, fuel depot leak detection
  - ∗ Low false alarm fire detection.
  - ∗ Harsh environment engine emissions monitoring
  - ∗ Human health monitoring and potential astronaut health evaluation
- **Sensor to be presented**
  - * **CO_2 sensors:** Electrochemical cells: amperometric and metal oxide nanomaterial modified, potentiometric sensors and resistors
  - * **H_2/C_xH_y Schottky diode sensors:** Diodes and diodes with contact pads
  - * **O_2 sensors:** High temp and room temp
  - * **NO sensor:** metal oxide resistor based

  - * **Metal oxide nanomaterials**



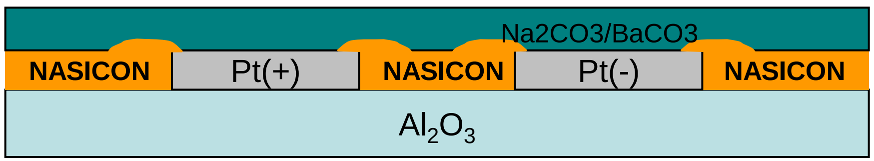
NASA GRC Sensors and Electronics Branch cleanroom

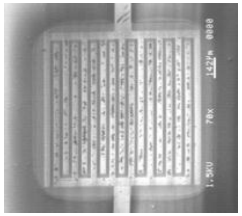
NASA GRC

Solid Electrolyte Carbon Dioxide Microsensors
(NASA GRC)

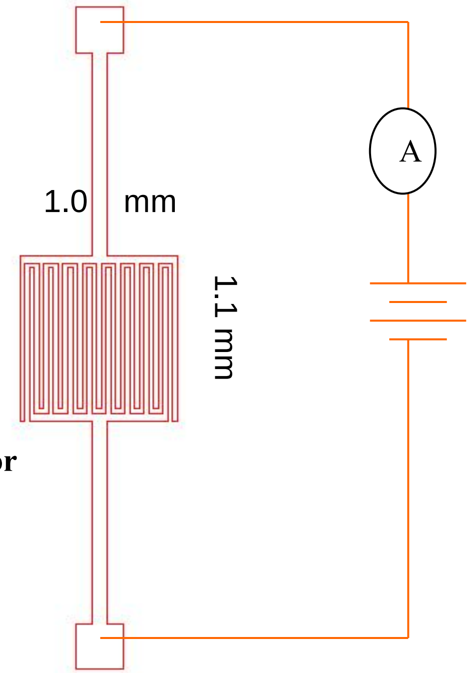
Side view of microfabricated CO_2 sensor

(Simplified with a pair of two electrodes)

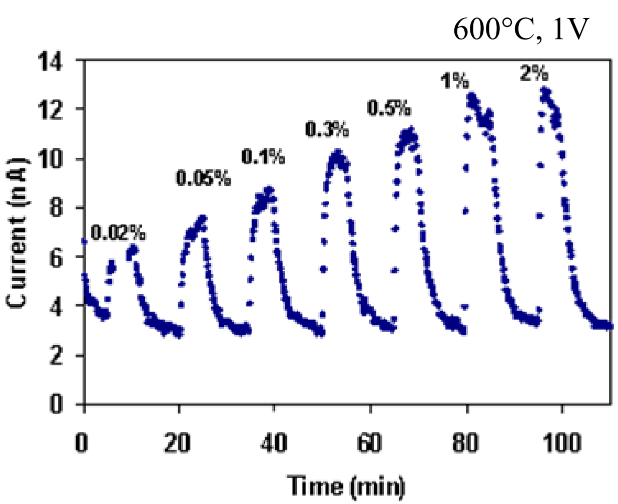


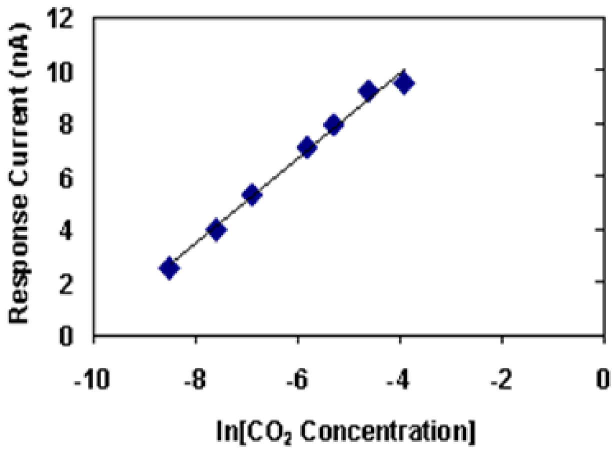


SEM image of a fabricated CO_2 sensor



Testing Results of Solid Electrolyte Carbon Dioxide Sensor

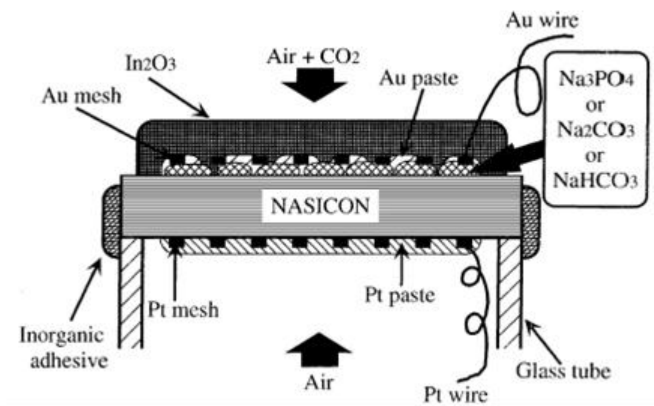




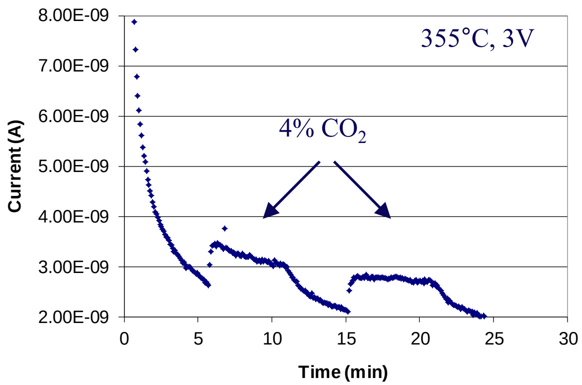
Addition of Tin Oxide Nanocrystallines Improves Solid Electrolyte Carbon Dioxide Sensor Performance

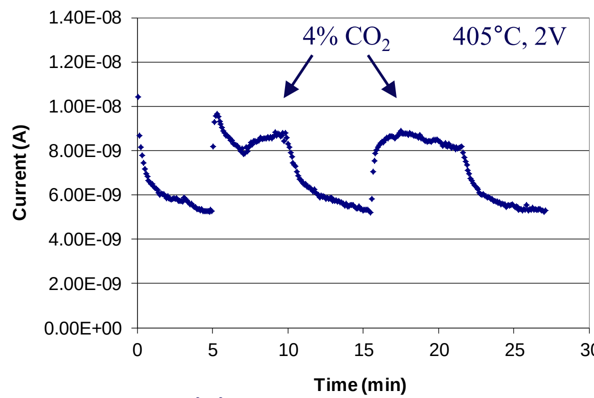
Tin oxide nanocrystalline layer added

K. Obata et al. / Sensors and Actuators B 76 (2001) 639–643

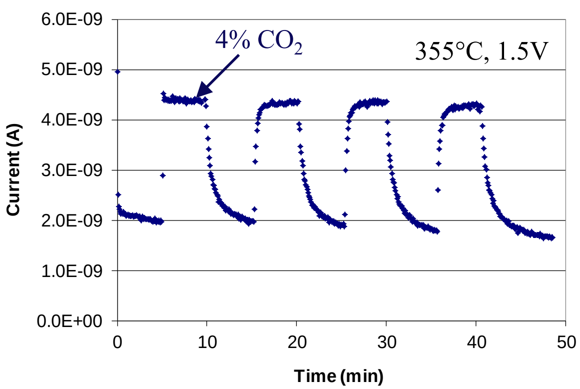


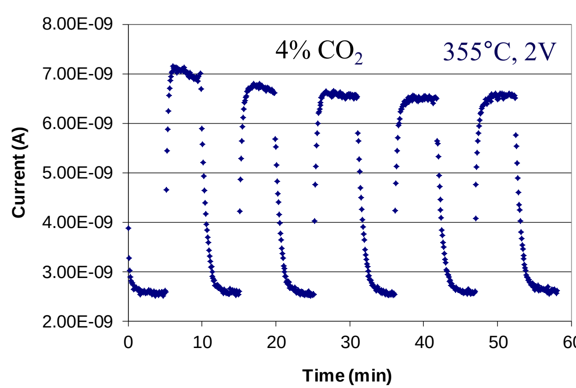
Sensors without tin oxide sol gel addition

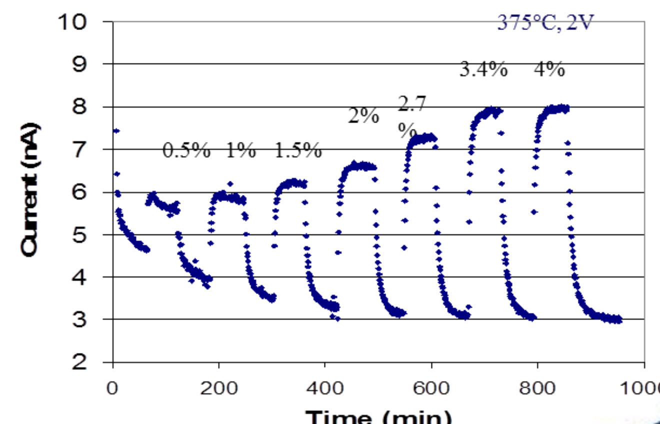




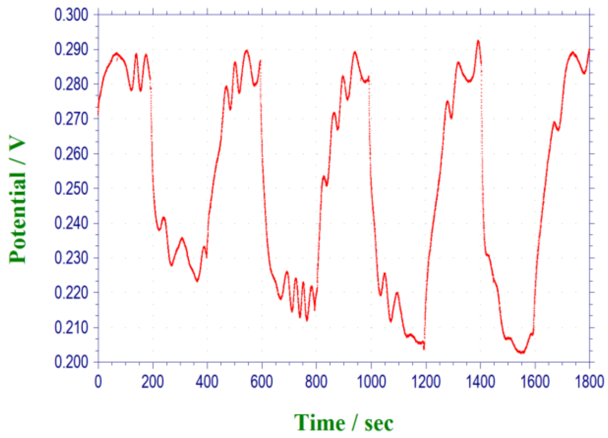
Sensors with tin oxide sol gel addition



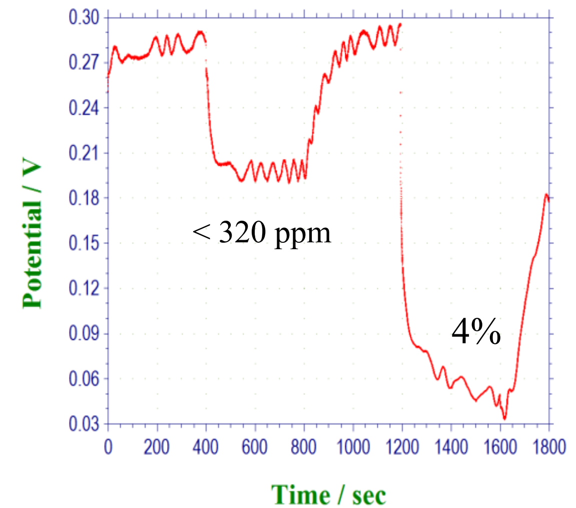




Potentiometric CO_2 Microsensors Developed



1%, 2%, 3%, 4% CO2 gases in air
at 500ºC, air for baseline



$$2Li^{+} + CO_2 + \frac{1}{2}O_2 + 2e- = Li_2CO_3$$ **Working**

$$2Li^{+} + TiO_2 + \frac{1}{2}O_2 + 2e- = Li_2TiO_3$$ **Reference**

Development of Diode Sensors with Contact Pads

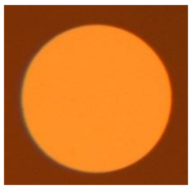
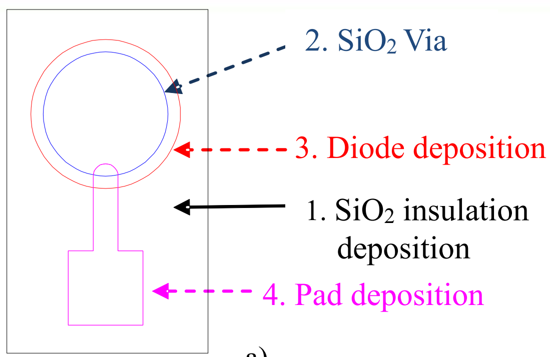
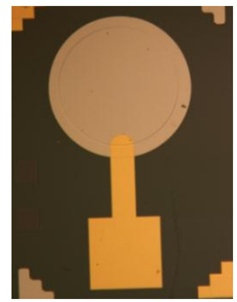


Fig. 1. A single metal/PdO_x/SiC based diode for H_2/C_xH_y detection.

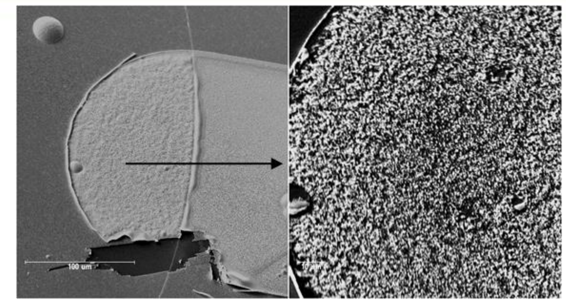


a)



b)

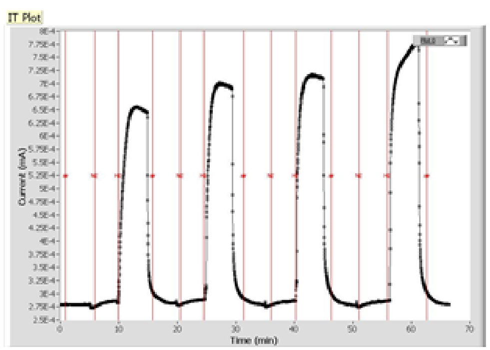
Fig. 2. a) Schottky diode with contact pad fabrication process. b). Image of a Pd/PdO_x/SiC diode with a Au/Ti contact pad. The dark area surrounding the sensor-pad is SiO_2



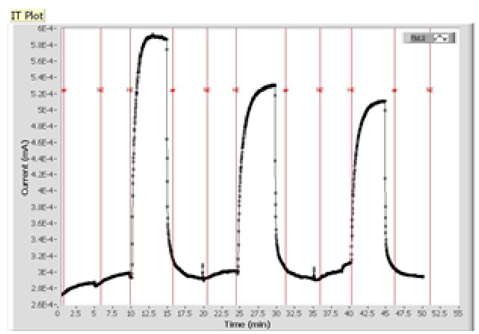
c) d)

Fig. 2. c) 400 x micrograph of Pt/Ti connect on diode; b) 1000x micrograph. The white area is metal silicide while the dark area is SiC

Fig. 3. Current version of diode with contact pad



a)



b)

Fig 4. a). Sensor with interconnect contact pad responses to 50 ppm, 100 ppm, 150 ppm, and 200 ppm H2 gases; b). Sensor responses to 50 ppm, 25 ppm, and 20 ppm H2 gases, at 300°C, 1V.

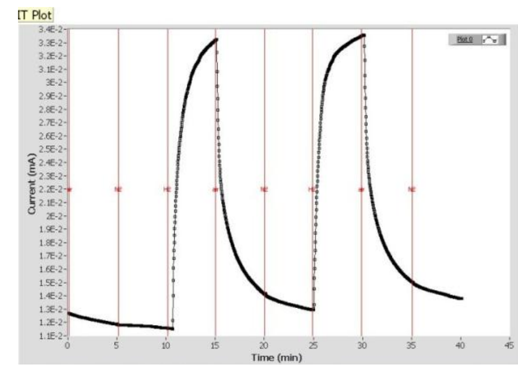
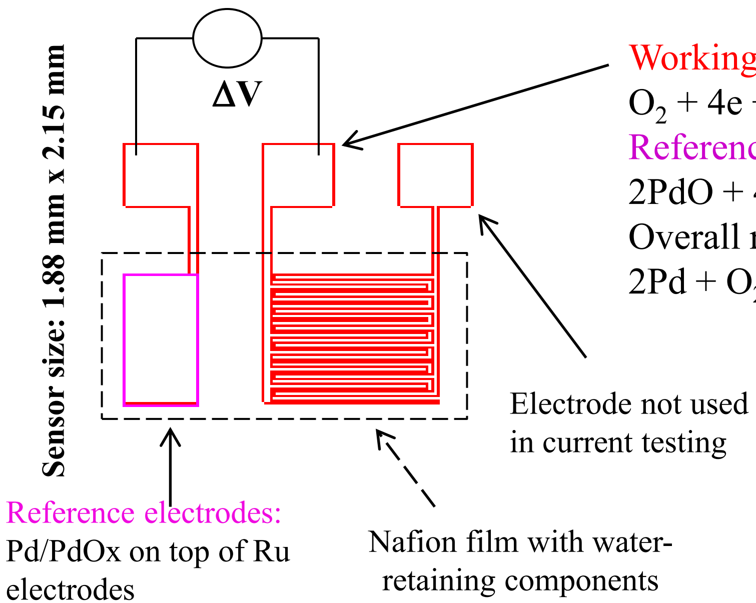


Fig. 5. Sensor with interconnect contact pad response to 0.5% H2 at 500°C, 1V

Developed Room Temperature Potentiometric Oxygen Sensors

Totally different structure: one of its kind



Working electrode:

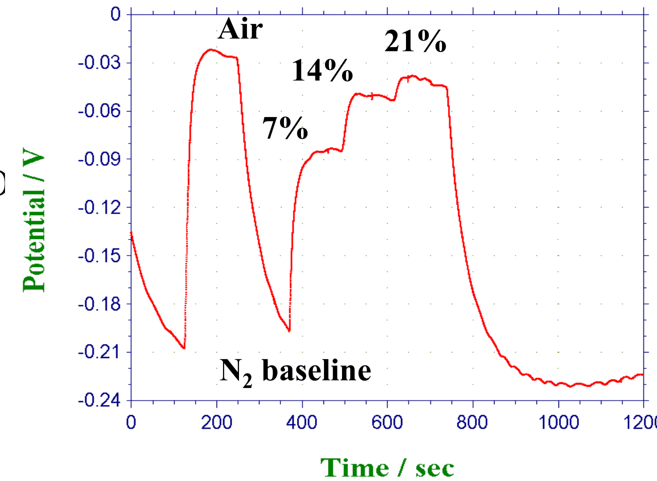
$O_2 + 4e + 4H^+ \rightarrow 2H_2O$

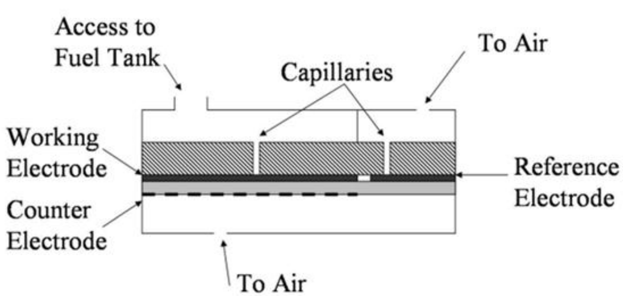
Reference electrode:

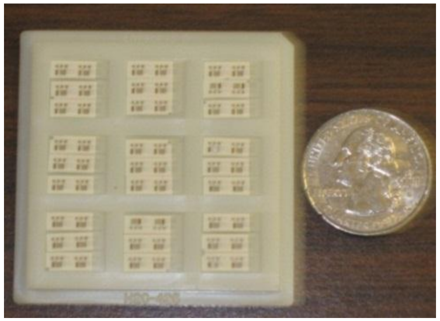
$2PdO + 4e + 4H^+ \rightarrow 2Pd + 2H_2O$

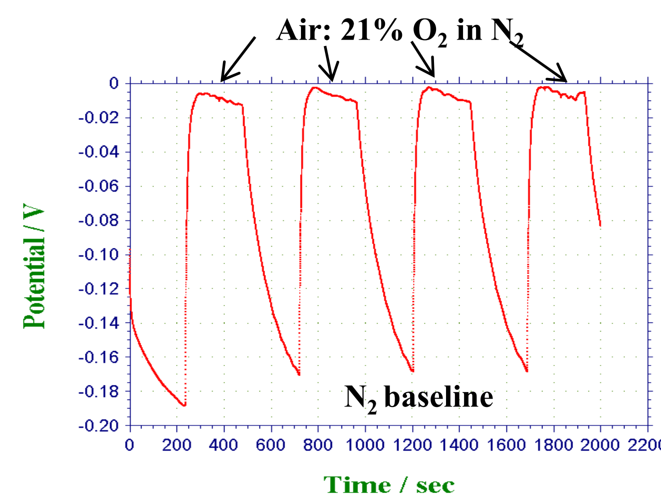
Overall reactions:

$2Pd + O_2 \leftrightarrow 2PdO$



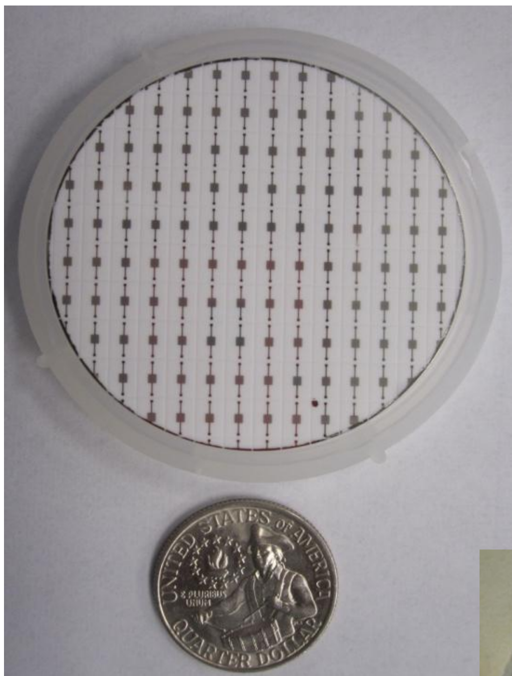






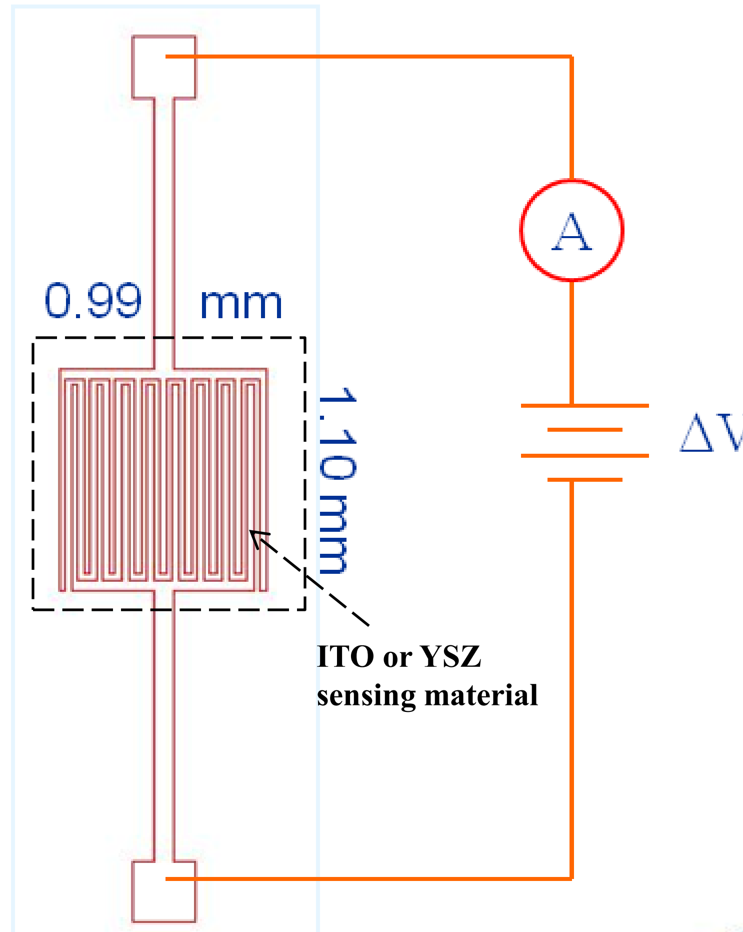
Development of Nitric Oxide and Oxygen Sensors

Pt interdigitated electrodes fabricated on a 2-inch alumina wafer

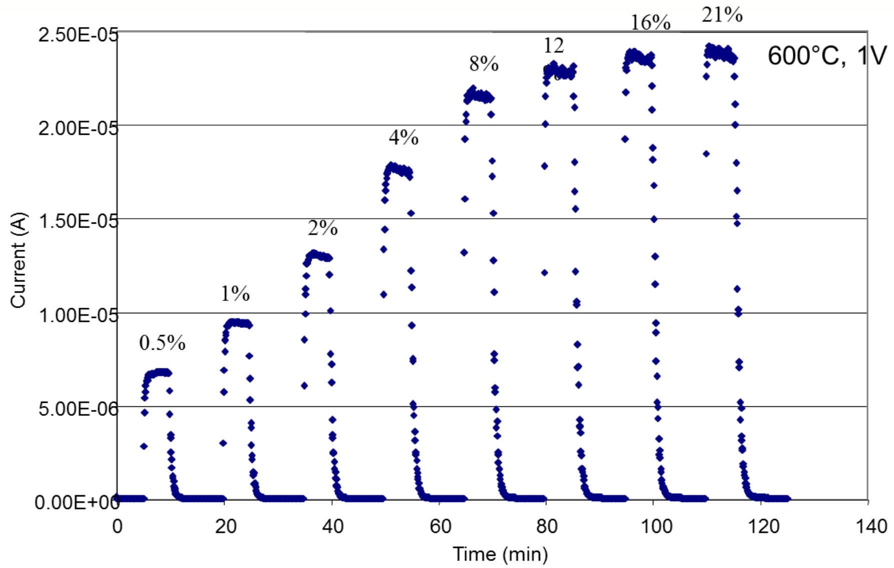


Gas testing chamber: Probe contact

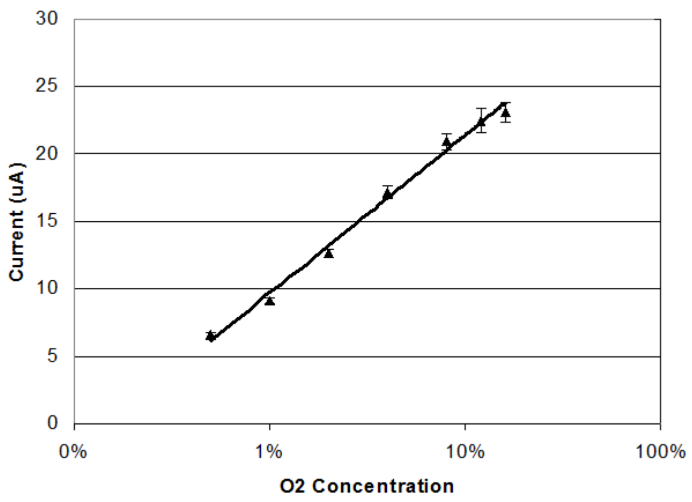
Electrode structure and schematic of gas testing setup

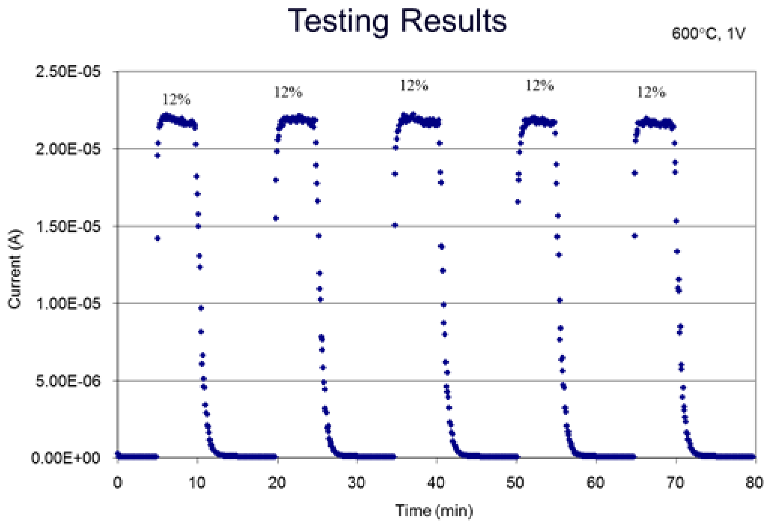


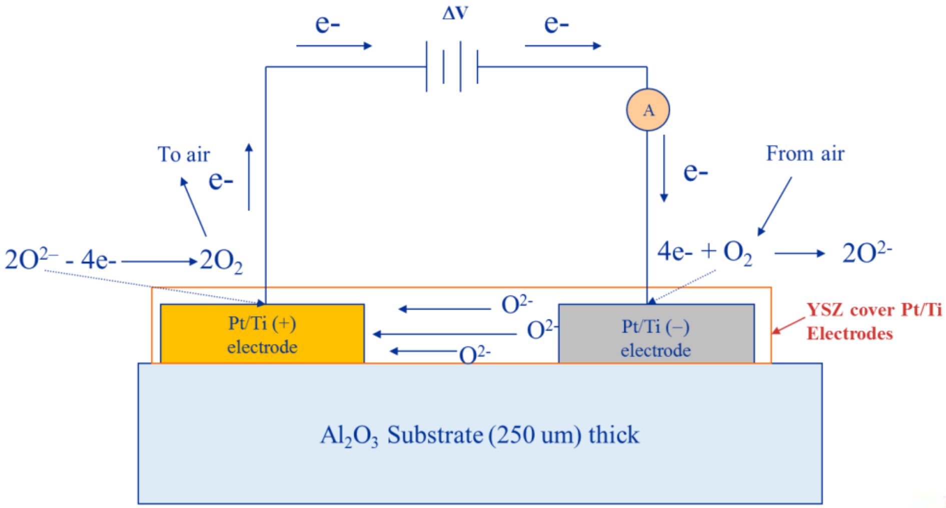
High Temperature YSZ Oxygen Sensor Testing Results



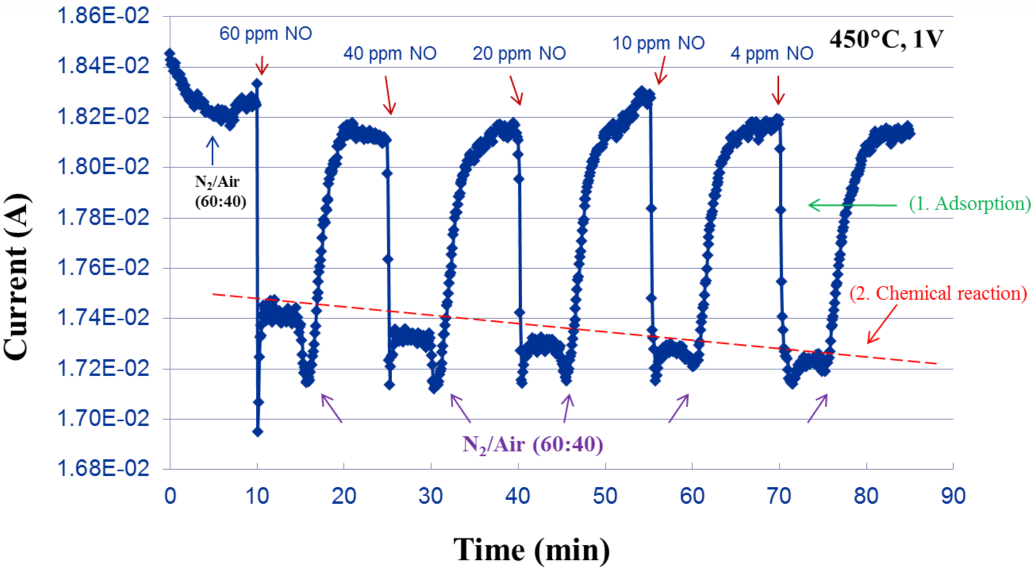
(Linear fitting from 0.5% to 16%)

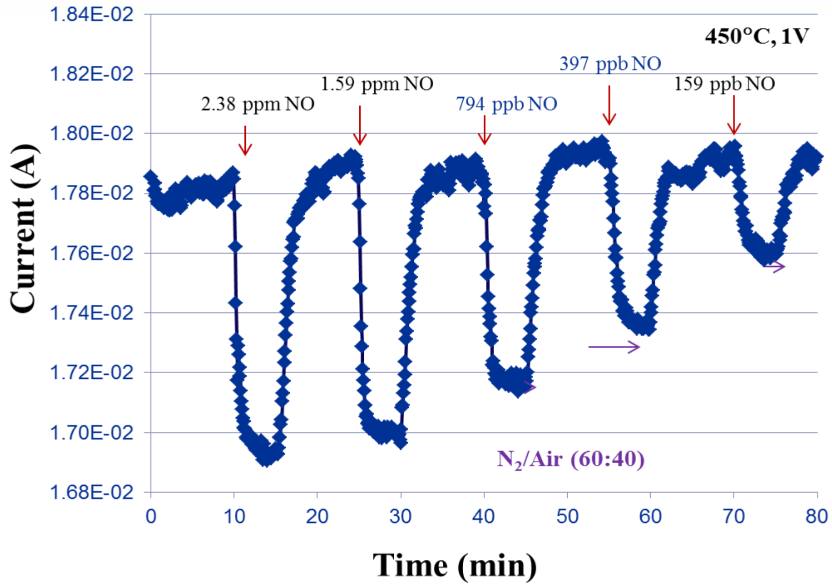




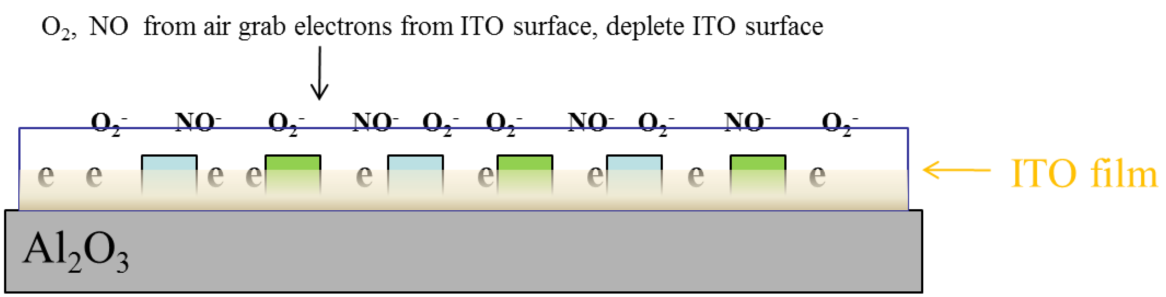


Sputtered ITO Microsensor Response to Nitric Oxide Gas

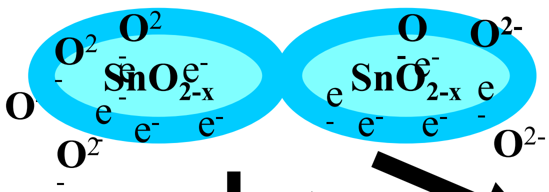




- Low concentration (ppb to low ppm): adsorption
- High concentration (ppm): adsorption and NO oxidation reaction:

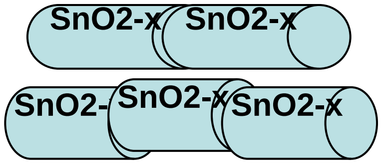


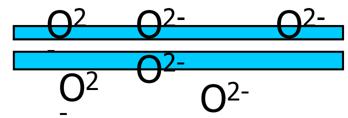
Metal Oxide Nanomaterials for Reducing Gas Sensing

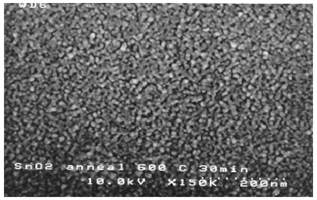


More controlled crystalanity

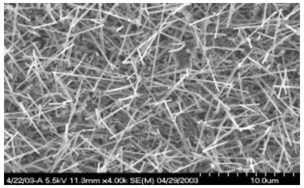
Increased nano grain boundary contact



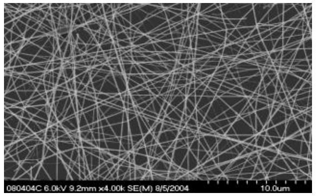




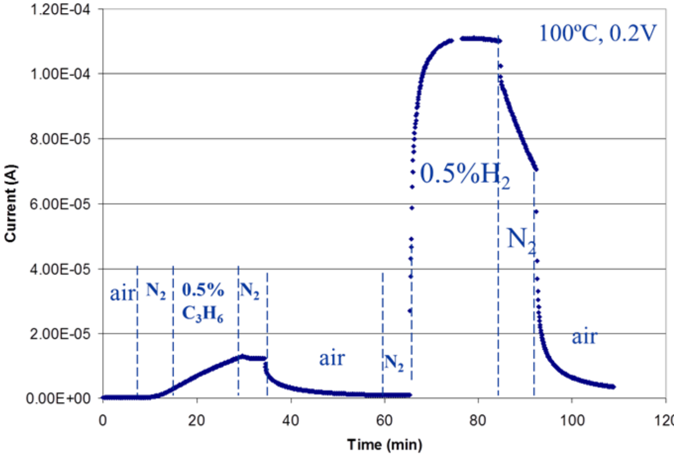
SnOx nanocrystallines by sol gel process

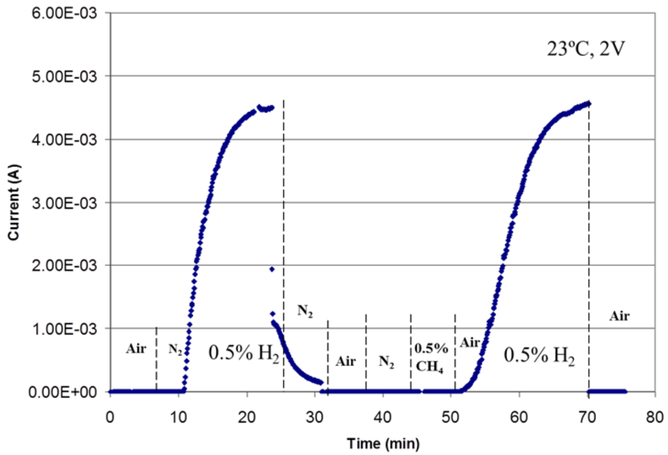


Single crystal nanorods by CVD



Polycrystal SnOx nanofibers by electrospun process





Left: Palladium Doped SnOx Nanofibers Detect Hydrogen and Hydrocarbons

Summary

- A variety of chemical microsensors development for aerospace applications
- Different sensor structures and sensing mechanisms were used in the sensor designs
- Carbon dioxide sensors, oxygen sensors, Schottky diode sensors, nitric oxide sensors, and nanomaterials discussed
- Small size, batch fabrication, low cost and power consumption, and harsh environment applications
- Applications: fire detection, engine emission and health monitoring, and environmental monitoring. In ambient and harsh environments

Acknowledgements

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