Fast, Sensitive, Ultra-low Power Thermal Conductivity Micro Sensor

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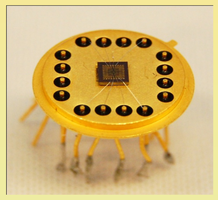
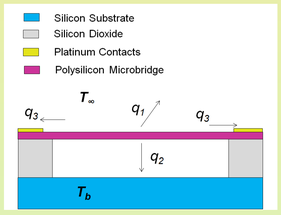
What is Thermal Conductivity Detector (TCD)?

A TCD obtains information about composition of surrounding gas medium by thermo-physical analysis of the gas.



Resistance of a suspended doped polysilicon structure is a function of temperature; if heated, its temperature depends on thermal conductivity and thermal capacity of the gas.



Motivations for microTCD

Conventional gas detectors suffer

- large power consumption
- slow time response
- Frequent re-calibration requirement
- Memory effects and frequent replacement

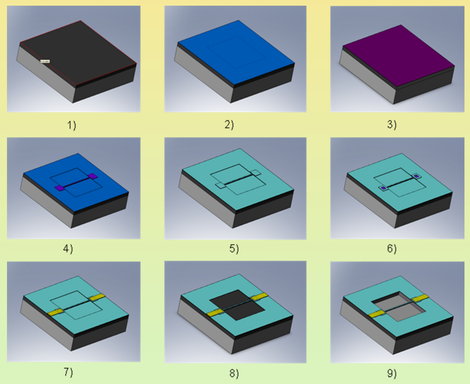
microTCD gas sensors offer

- Much lower power consumption
- Faster time response
- Enhanced sensitivity
- Lower cost

Applications of the present work

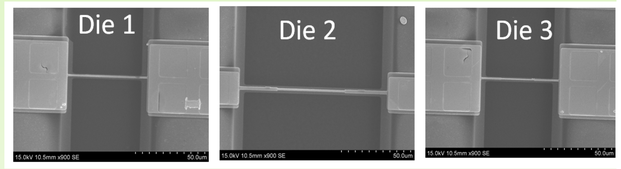
- Detection of Helium leaks in space station
- Detection of natural gas leak and detection of methane in mining
- Air quality monitoring.
- Combustion process monitoring and optimization
- Gas chromatography (GC) systems
- Health: breath analysis detection of NO, CO_2, O_2

Micro-Fabrication Process

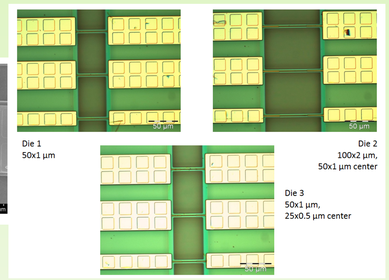


1. Thermally grown SiO2, 10 µm
2. Silicon Nitride Layer LPCVD, 0.4 µm
3. Polysilicon layer LPCVD, 1µm
4. P-type doping of Polysilicon
5. Silicon Nitride LPCVD, 0.2 µm
6. RIE for electrical contacts
7. Pt and Au evaporations for contacts
8. RIE of nitride to form a mask for SiO2 etching
9. BOE etching of SiO2, beam suspension

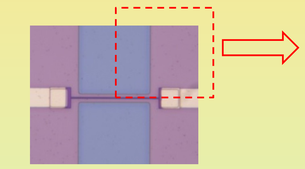
SEM images of the fabricated sensors



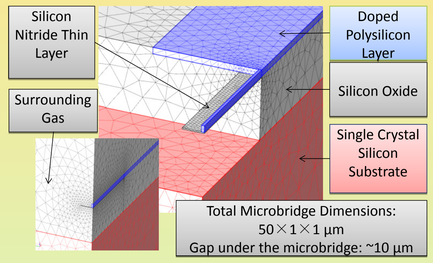
Optical images of multiple designs



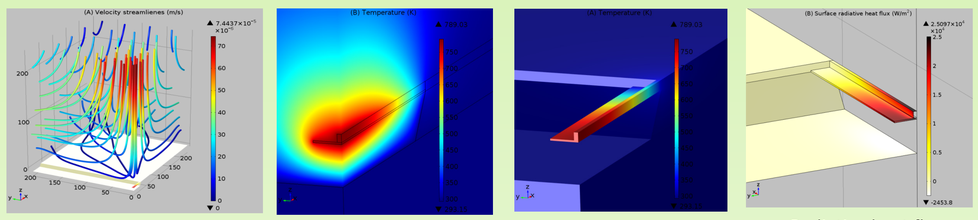
Computer Simulation of Sensor Operation



Two planes of symmetry



Modeling Results

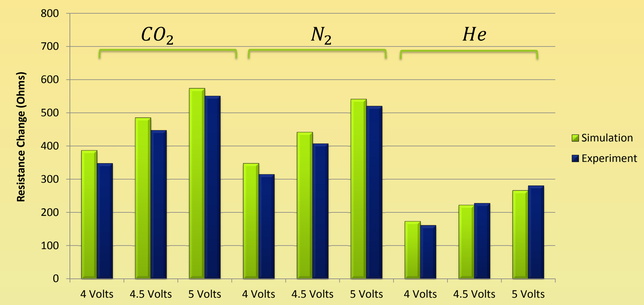


Free convection over sensor | Temperature gradient in the gas and on the bridge | Radiative heat flux

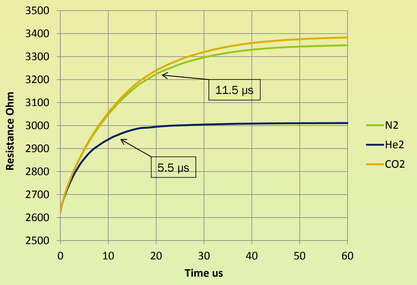
Simulation features

- Minimal simplifications
- Steady state and transient
- Takes into the accounts Conduction, convection and radiation
- Couples electrical current, heat transfer and fluid mechanics physics

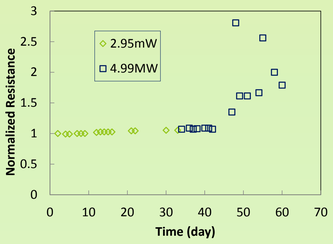
Experimental Results, Sensor Response



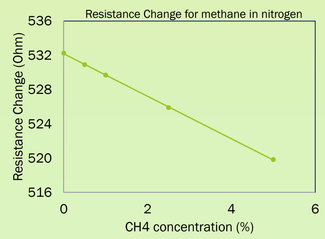
Ultra-fast transient response



Sensor Lifetime Test



Linear response to gas composition



Conclusions

- The sensor is extremely stable, lifetime exceeds 34 billion measurements.
- Ultra-fast response in less than 1 ms.
- No memory effect
- Low power consumption, of 50 microWatt
- Detection levels of few hundred ppm for methane and CO2

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Reference

Mahdavifar, Alireza, et al. "Simulation and Fabrication of an Ultra-Low Power Miniature Microbridge Thermal Conductivity Gas Sensor." *Journal of The Electrochemical Society* 161.4 (2014): B55-B61.

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