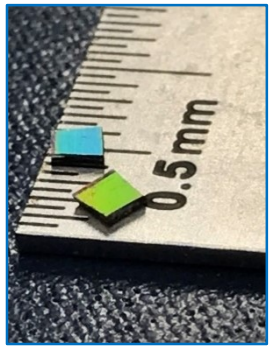
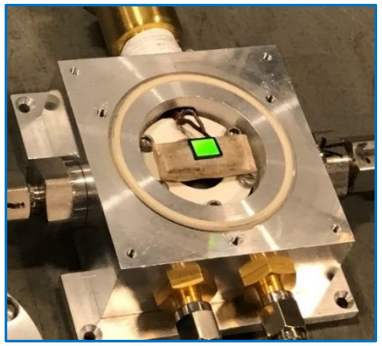






Multi-Gas Sensors for Enhanced Reliability of SOFC Operation

DOE/NETL Cooperative Agreement: DE-FE0031653

GE: Radislav Potyrailo, Joleyn Brewer, Richard St-pierre, Brian Scherer, Majid Nayeri, Chris Collazo-Davila, Andrew Shapiro

SUNY Polytechnic Institute: Michael Carpenter, Nora Houlihan, Vitor Vulcano Rossi, Laila Banu

NETL Program namager: Venkat K. Venkataraman

20th Annual SOFC Project Review Meeting, April 29 - May 01, 2019, Crystal City, Virginia, USA

Project goal and objectives

Goal:
to build gas sensors for in situ monitoring of H_2 and CO gases of SOFC systems

Objectives:
to achieve multi-gas monitoring capability with a single multivariable sensor and to achieve its long-term sensor performance

Real-time knowledge of H_2/CO ratio of anode tail gases:
will allow control of efficiency of reforming process in the SOFC system and will deliver a lower operating cost for SOFC customers

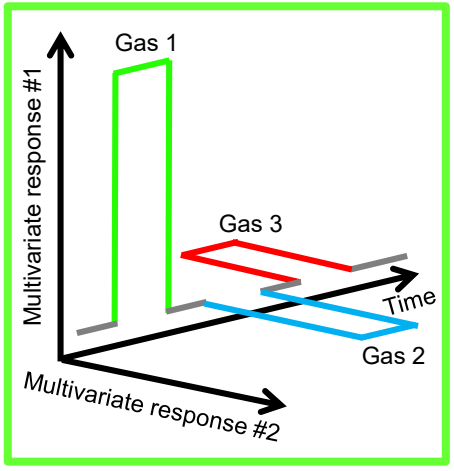
Project Team

GE Global Research
- Design rules for multivariable sensors
- Sensor fabrication with multi-material lamella
- Sensor-stability optimization

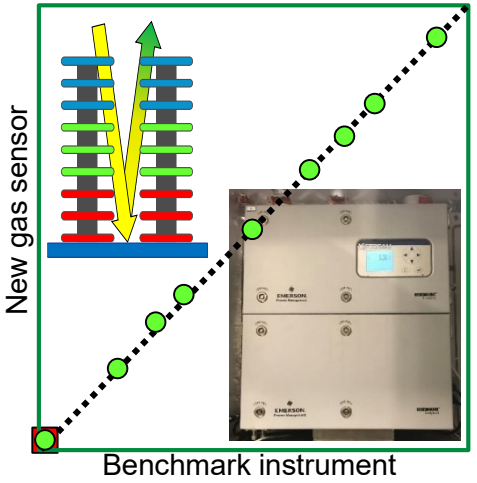
SUNY Polytechnic Institute
- Design rules for catalytic control of selectivity
- Sensor fabrication
- Characterization of sensing nanomaterials

GE Fuel Cells
- Optimized sensor flange design
- Benchmark instrumentation
- Sensor validation on 20 kW SOFC

Multivariable Gas Sensor



Field Test Correlation

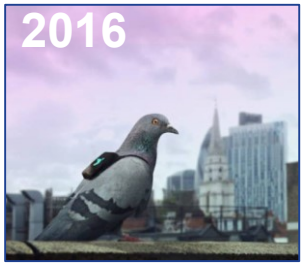


Status quo of conventional gas sensors

- Mature technologies
- Widely available
- Interchangeable
- Inexpensive

pre-sensor.com
alphasense.com
hub360.com.ng
engineersgarage.com
cooking-hacks.com
amphenol-sensors.com
aeppacific.co.nz
mipex-tech.com

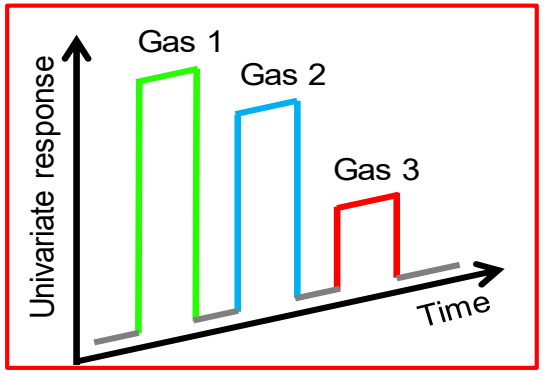
https://www.treehugger.com/clean-technology/air-quality-sensor-makes-a-fashion-statement.html



https://techcrunch.com/2017/01/03/plume-labs-flow-is-an-air-quality-tracker-to-avoid-pollution/

https://plumelabs.com/en/

https://www.itri.org.tw/eng/

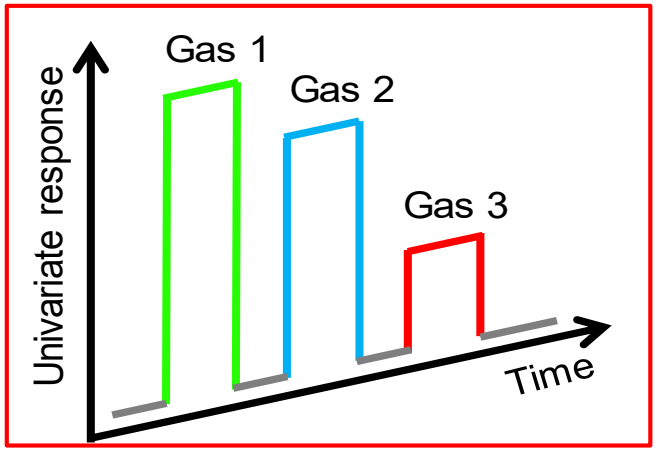


The biggest headaches are caused by interfering chemicals

Lewis, Edwards, *Nature* **2016**

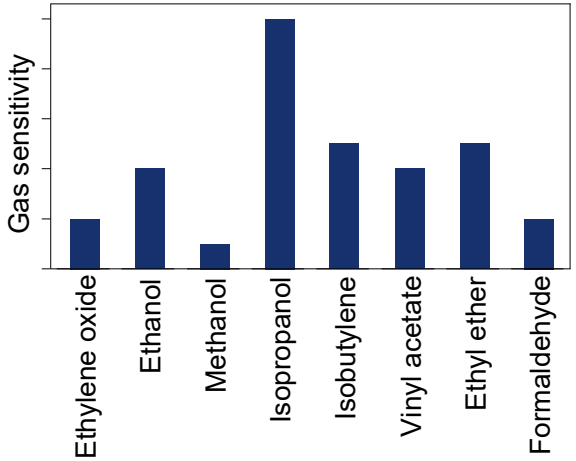
For the gas sensors revolution to take off, accuracy must improve

Gas cross-sensitivity of conventional gas sensors

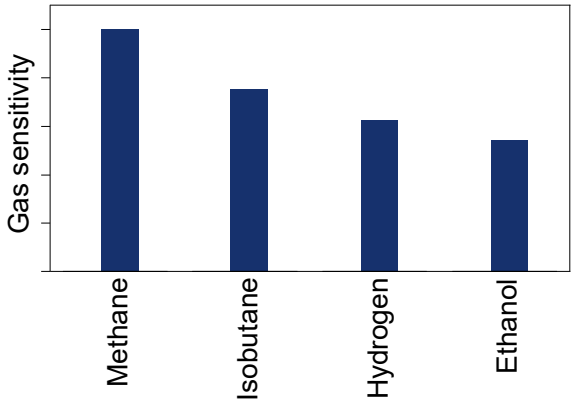


Potyrailo, *Chem. Rev.* **2016**
Potyrailo, *Chem. Soc. Rev.* **2017**

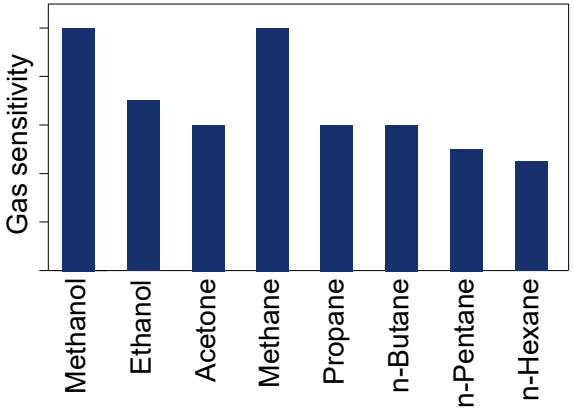
Electrochemical



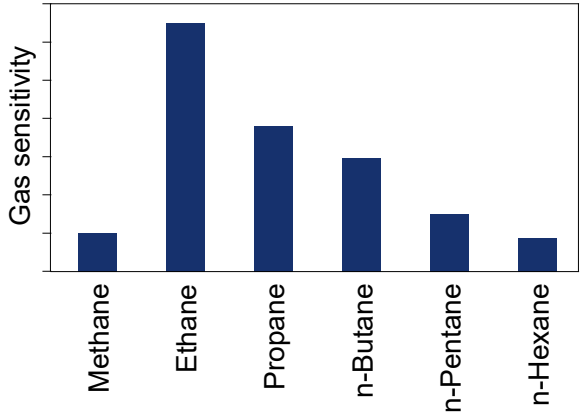
Metal oxide



Catalytic

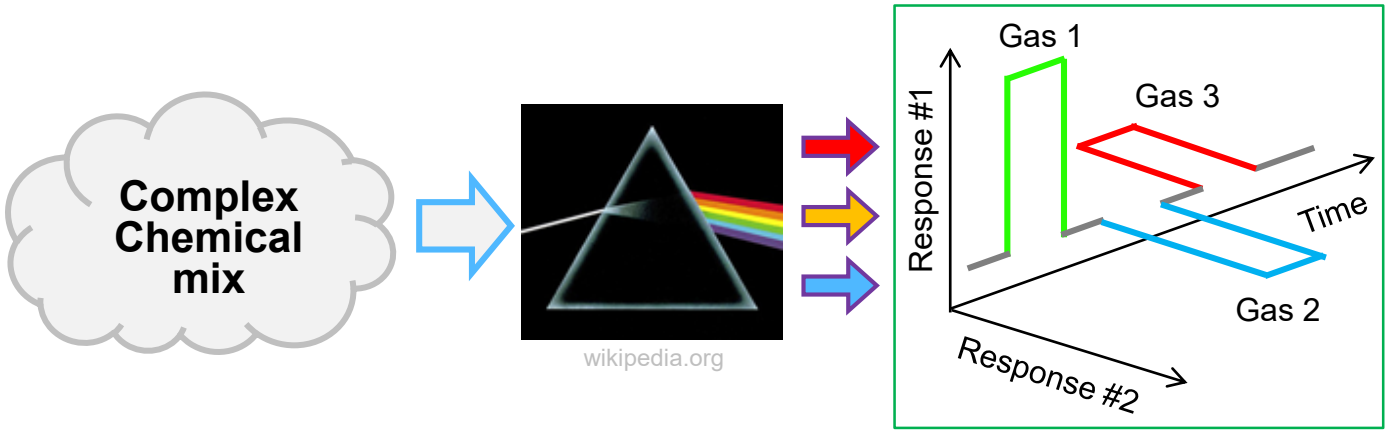


Non-dispersive IR



For the gas sensors revolution to take off, accuracy must improve

Mature gas-detection analytical technologies: accurate, multi-gas



Gas chromatography

afcintl.com

Mass spectrometry

Cooks, Purdue U.

Laser spectroscopy

alliedscientificpro.com

Multi-detector system

emersonprocess.com

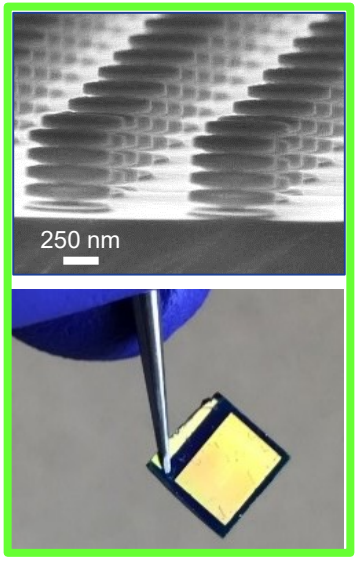
Field deployments in SOFC systems

Mature analytical technologies:
Significant technology accumulation is needed for their unobtrusive deployments

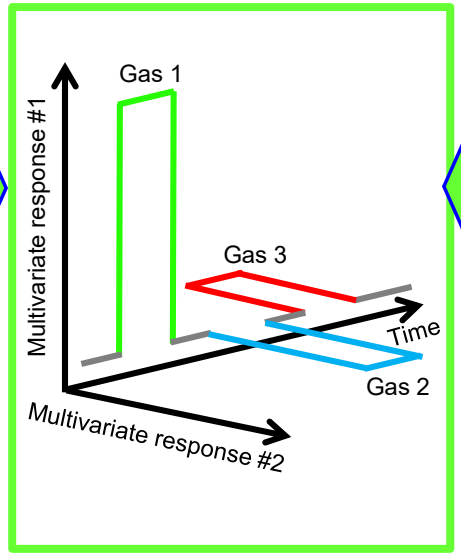
Our technical approach for multi-gas detection

Bio-inspired multivariable photonic sensors:
sensors with several outputs for accurate detection of diverse gases

Our approach:
Multivariable
gas sensors



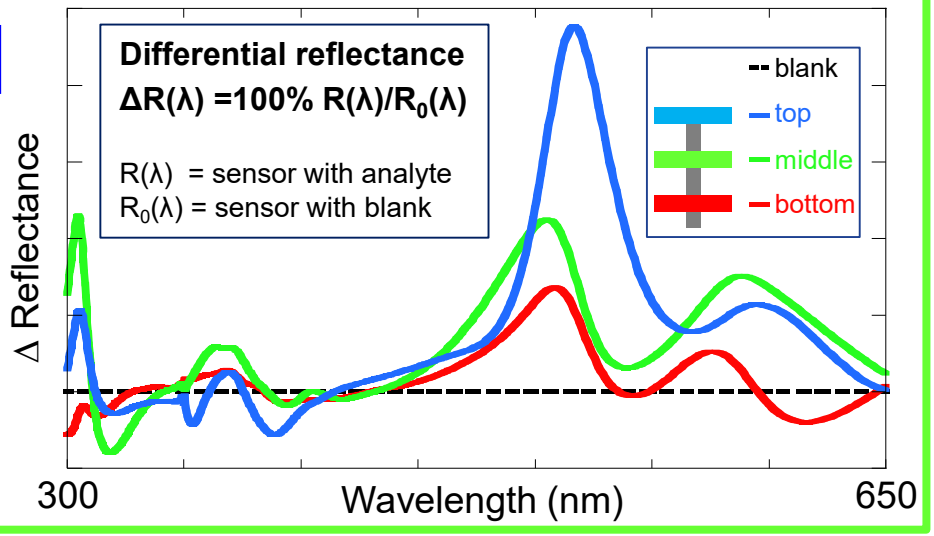
Performance need:
Multi-gas
discrimination



Potyrailo et al. *Nature Photonics* **2007**
Potyrailo et al., *Proc. Natl. Acad. Sci. U.S.A.* **2013**
Potyrailo et al. *Nature Communications* **2015**
Potyrailo, Carpenter, et al., *J. Opt.*, **2018**

Design rules for multi-gas control

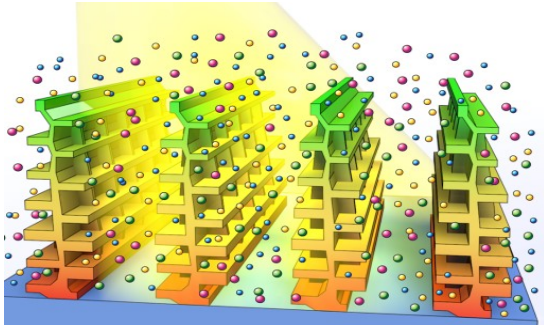
- Spatial orientation of surface functionalization
- Chemistry of surface functionalization
- Extinction and scattering of nanostructure



Solving existing need for real-time monitoring of H_2 and CO gases
with unobtrusive, cost-effective solution

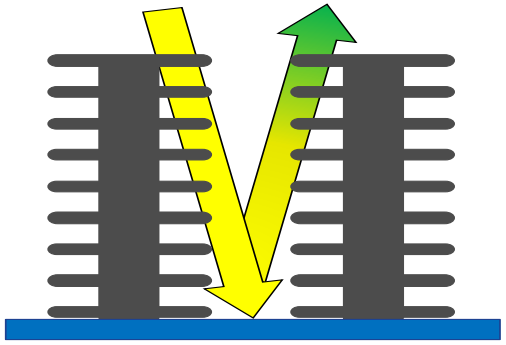
Advancing design rules of nanostructures for high temperature gas-sensing applications

Selectivity control for vapors at room temp.



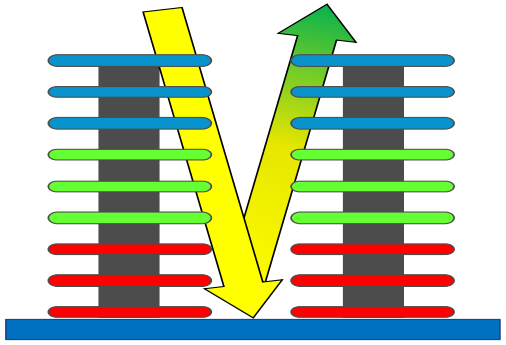
- Polymeric nanostructure
- Absorption and adsorption of vapors

Selectivity control for gases at high temp.

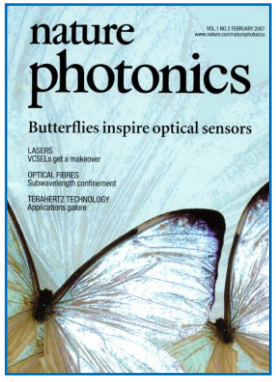


- Inorganic nanostructure
- Catalytic reactions of gases

Interference rejection control

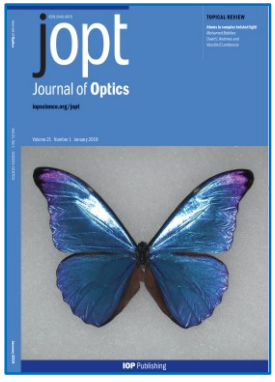


- Multi-material inorganic
- nanostructure
- Catalytic reactions of gases

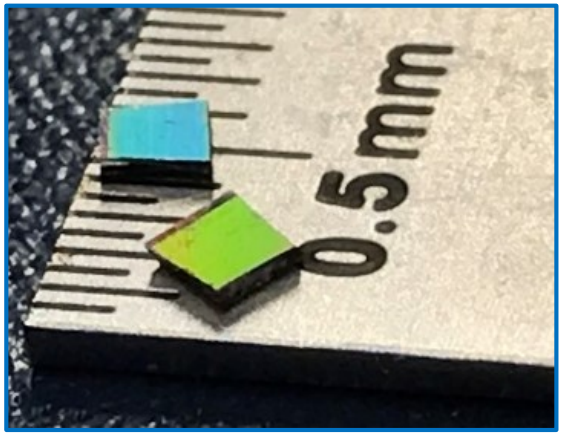


Potyrailo et al. *Nature Photonics* **2007**

Potyrailo *Chem. Soc. Rev.* **2017**

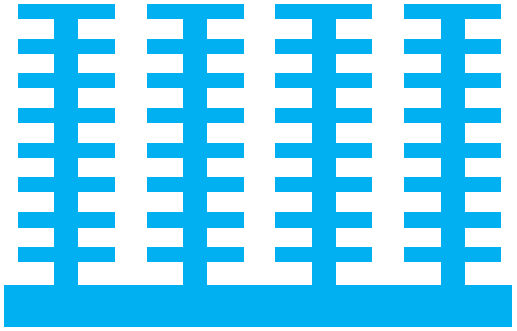


Potyrailo, Carpenter, et al., *J. Opt.* **2018**



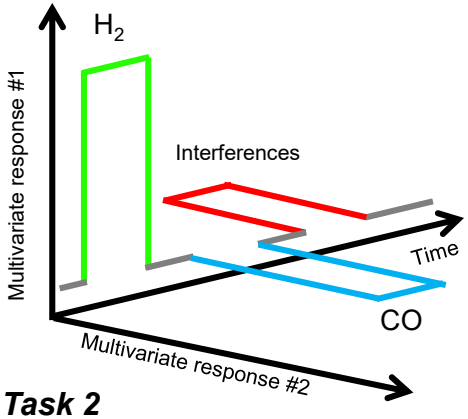
Technical tasks of the project

Fabrication of optical transducer



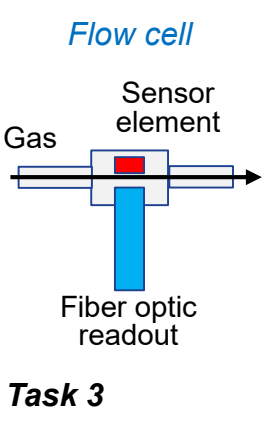
Task 1

Laboratory validation



Task 2

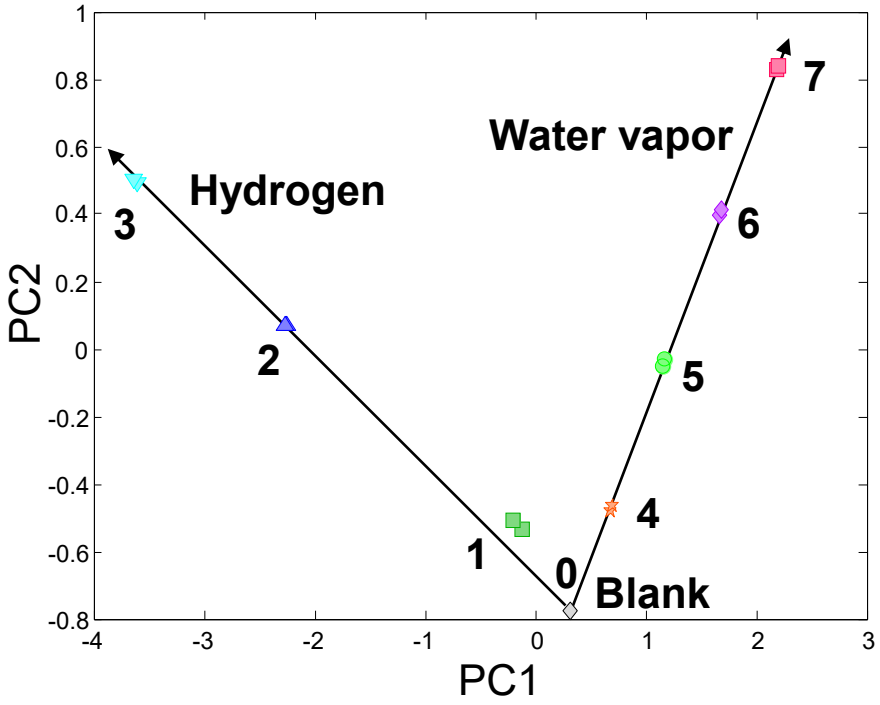
Field validation



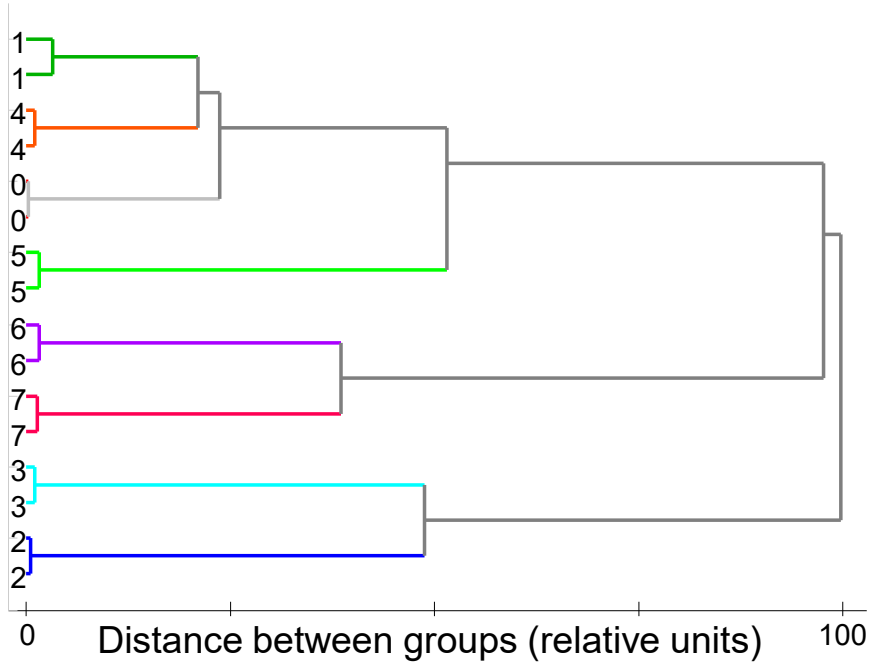
Task 3

Example of sensor operation:
Discrimination between hydrogen and water vapor

Principal components analysis



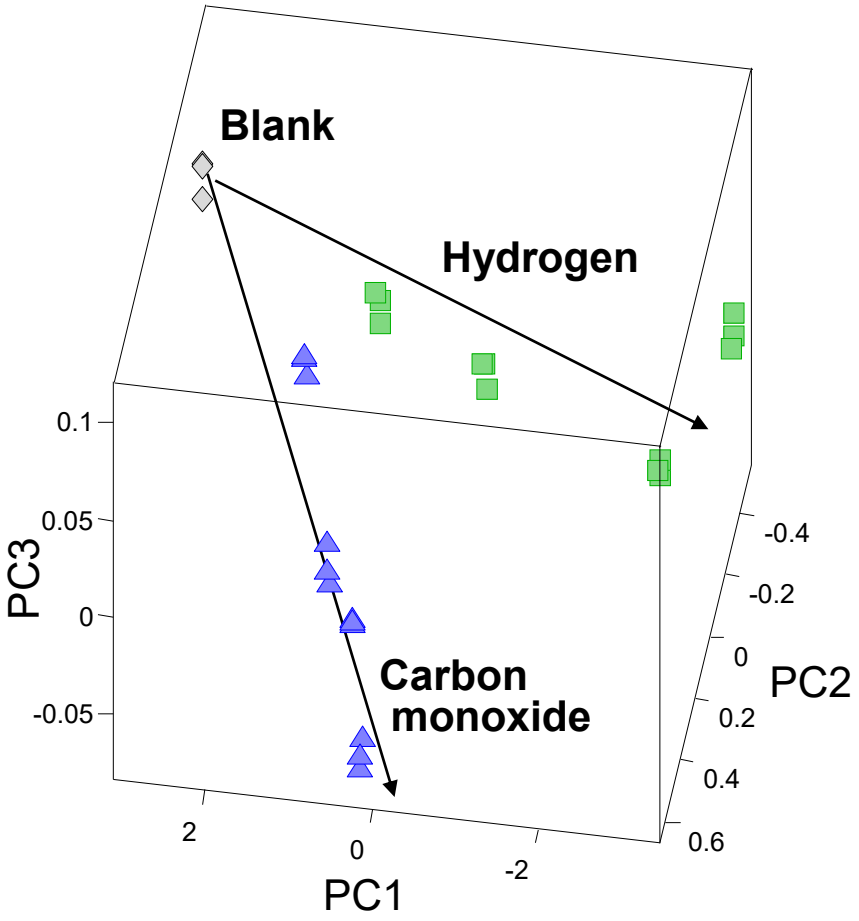
Hierarchical cluster analysis



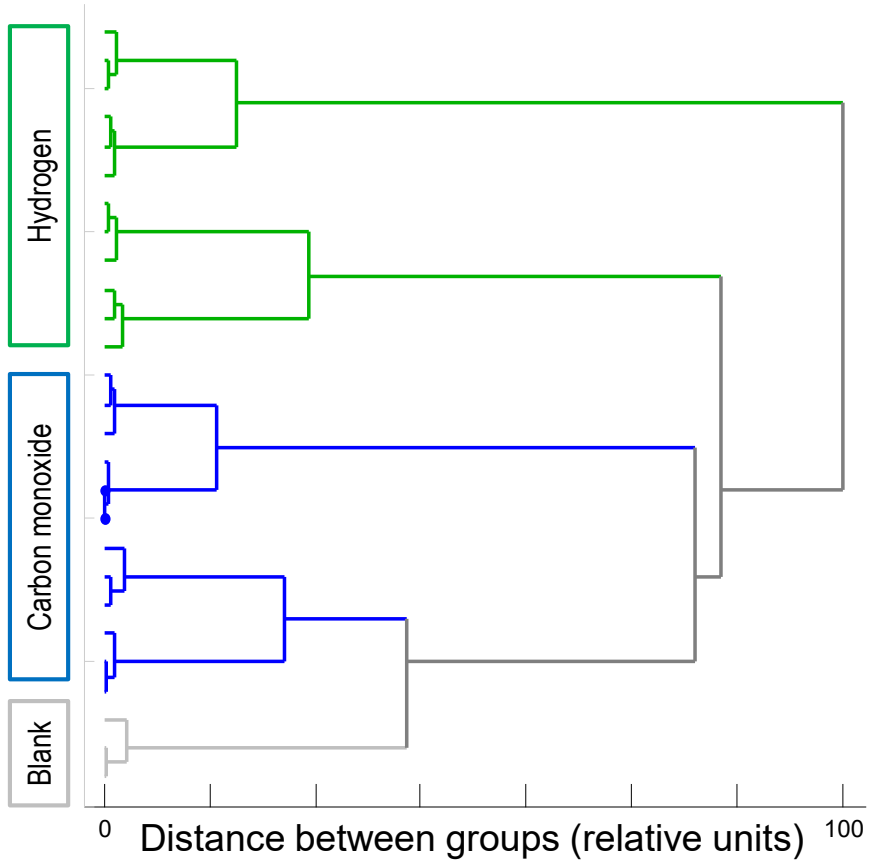
Resolution between individual concentrations of H_2 and H_2O

Example of sensor operation:
Discrimination between hydrogen and carbon monoxide

Principal components analysis



Hierarchical cluster analysis



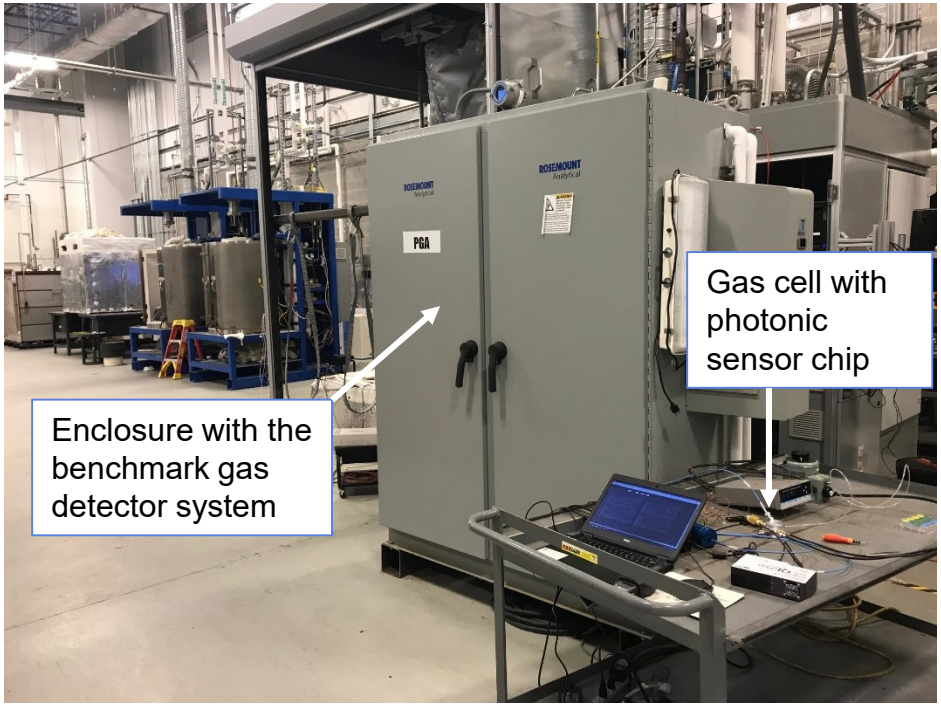
Resolution between individual concentrations of H_2 and CO

Setup at GE Fuel Cells factory

for field validation of the bio-inspired multivariable photonic sensor

Example of two SOFCs

Benchmark and sensor systems



Acknowledgements

US Department of Energy Cooperative Agreement DE-FE0031653

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