UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Gas Sensitive Materials Enabled Optical Fiber- and SAW- Sensors for Hydrogen and Methane Monitoring

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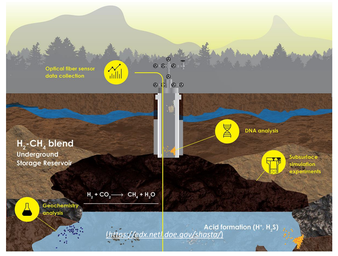
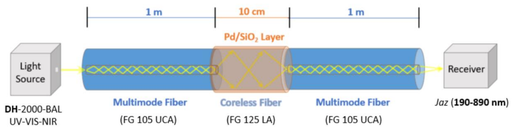
Optical Fiber Hydrogen Sensor

❑ H_2 Sensing in Subsurface Storage



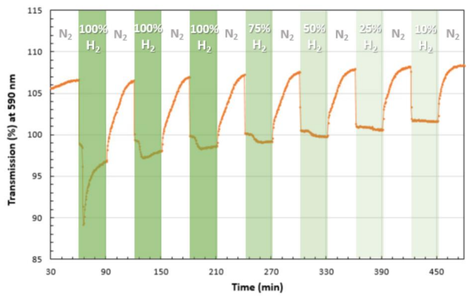
- H_2 subsurface storage to **ensure energy reliability** and **mitigate the impact of varying production rates**.
- Utilize underground NG storage fields such as **salt caverns, saline aquifer, and depleted oil/gas reservoirs**.
- Need to develop **H_2 monitoring sensors** to monitor H_2 concentration and manage H_2 leakage risks and assure safe H_2 storage in underground fields.

❑ Optical Fiber H_2 Sensor Based on Evanescent Field



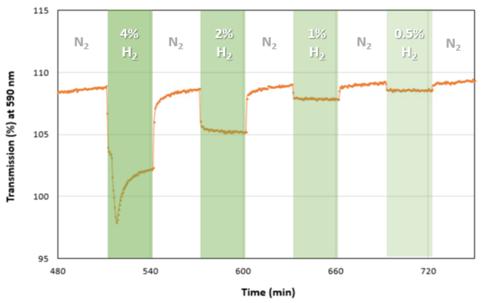
- **Optical Fiber:** multimode-coreless spliced fiber,
- **H_2 Sensing Material**: Pd Nanoparticle incorporated SiO_2 thin film
- **Sensing Tests**: at room temperature, 1 atm

❑ Hydrogen sensing responses from 100% to 10% H_2



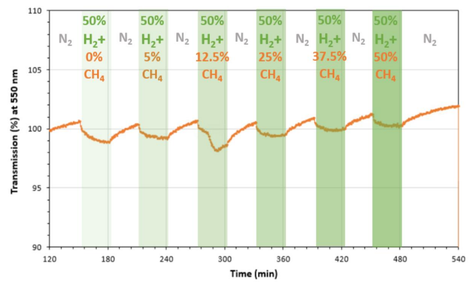
➢ Shows reversible H_2 sensing capability at broad concentrations of H_2.

❑ Hydrogen sensing responses from 4% to 0.5% H_2



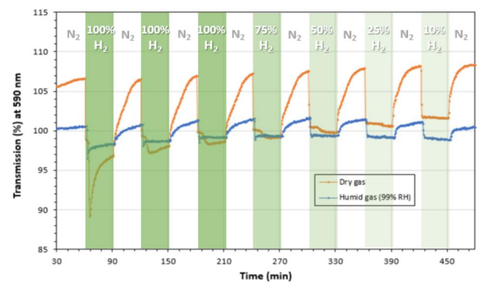
➢ Shows H_2 sensing capability below the lower flammable limit of H_2.
➢ Capable of low-concentration H_2 leak detection.

❑ Hydrogen sensing in the presence of CH_4



➢ Shows reliable H_2 sensing capability in the presence of CH_4.

❑ Hydrogen sensing under the humid condition



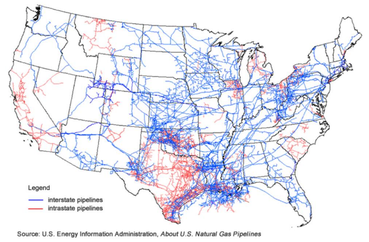
➢ Shows H_2 sensing capability under the humid condition (99% RH).

Conclusions

- Developed the **optical fiber H_2 sensor** capable of sensing hydrogen at broad range of concentrations **from 100% to 100 ppm H_2**.
- Demonstrated hydrogen sensing capability **under 99% relative humidity**.
- The developed optical fiber H_2 sensor showed **negligible cross-sensitivity to CH_4**.

Surface Acoustic Wave (SAW) Methane Sensor

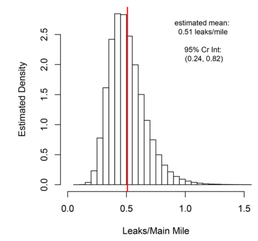
❑ Natural Gas Pipelines in the U.S.



Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

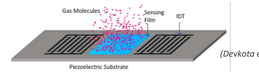
Natural gas **transmission** pipelines: 305,000 miles, ~12 times earth's circumference)

❑ Estimated NG Leaks Per Mile



(Source: *Environ. Sci. Technol. 2020, 54, 14, 8958–8967*)

❑ Surface Acoustic Wave (SAW) Sensor:

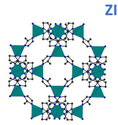


(*Devkota et al. Sensors 2017, 17, 801*)

RF signal <---> surface acoustic wave
piezoelectric substrate
(based on mass change in the sensing film)

- High sensitivity, fast response time, reversibility
- Small size, low cost, wired or wireless modes

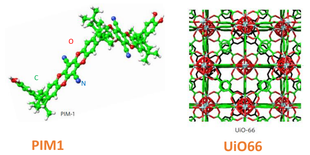
❑ Multi-Elements SAW Array Sensor



(Source: *Nature Comm. 9 (2018) 1429*)

Gas sensitive coating composition:

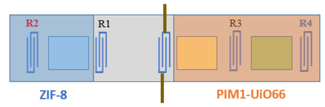
- ZIF-8: highly stable sensing material
- PIM1: high flexibility & porosity
- UiO66: chemical stability

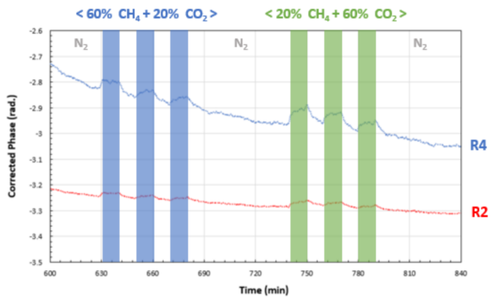


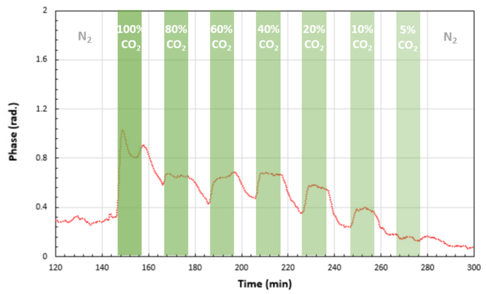
PIM1-UiO66

(Source: *Nature Energy 2 (2017) 17086*)

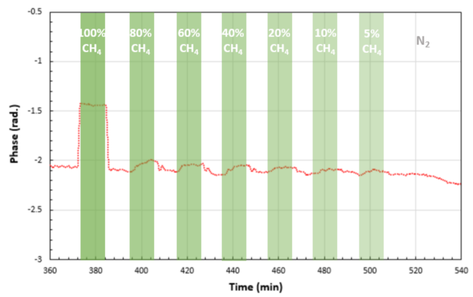
- Humidity: 43% RH
- Test: **wireless** mode







➢ CO_2 sensing response at different concentrations



➢ CH_4 sensing response at different concentrations

Conclusions

- Developed the **multi-elements surface acoustic wave sensor** capable of sensing CH_4 and CO_2.
- Demonstrated gas sensing capability under 43% relative humidity in **wireless mode**.
- Currently exploring **different types of polymer and sorbent** to improve sensitivity to methane gas.