

UPISC

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INFRASTRUCTURE
SENSING

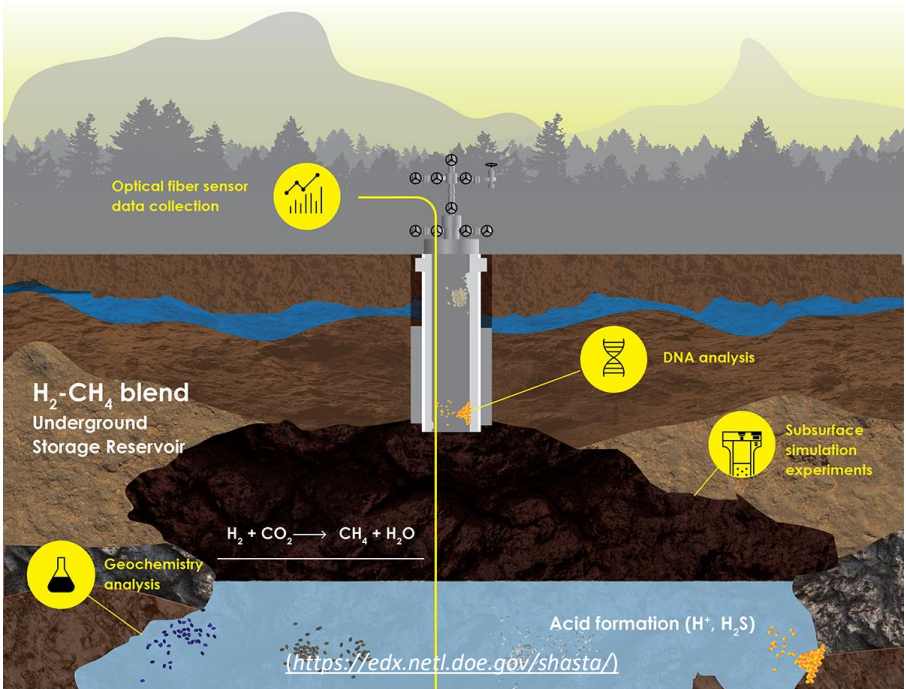
COLLABORATION WORKSHOP

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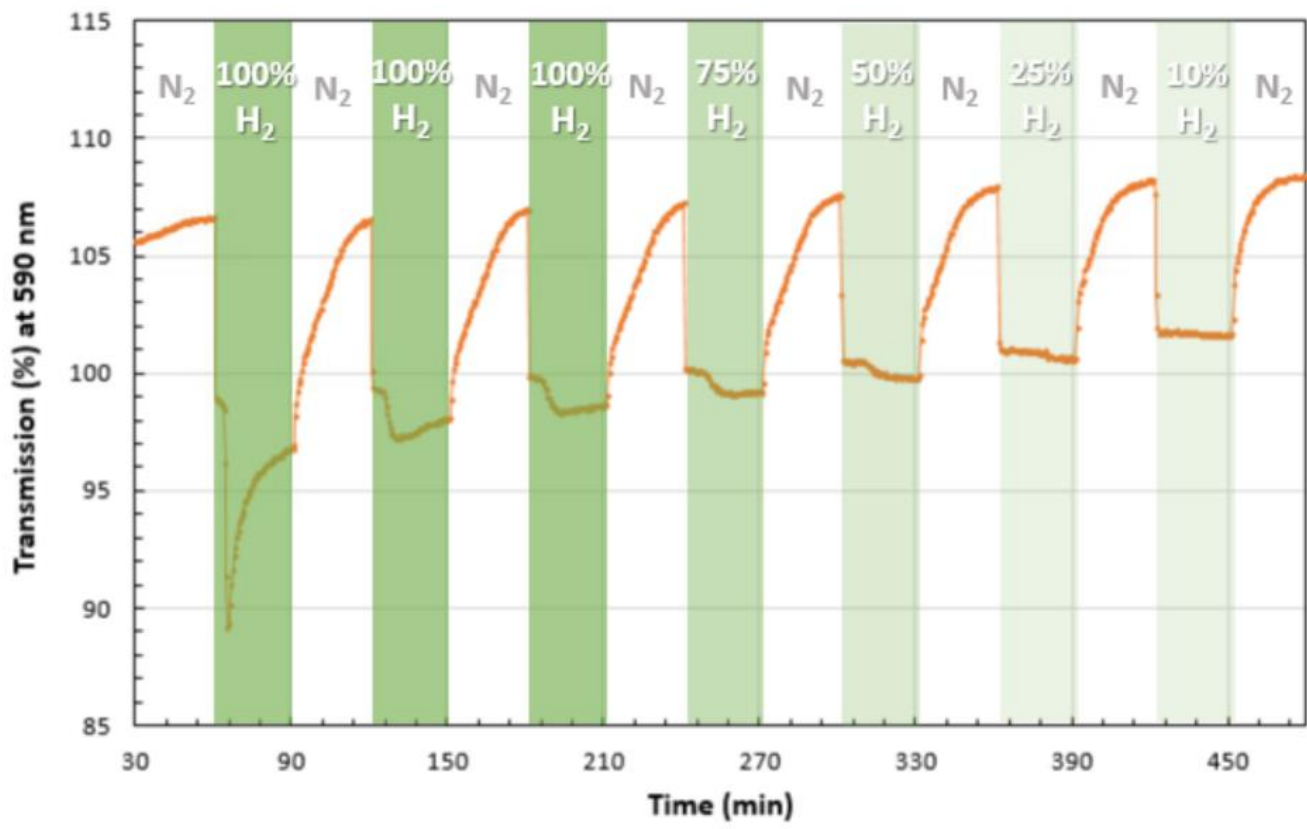
Optical Fiber Hydrogen Sensor

H₂ Sensing in Subsurface Storage



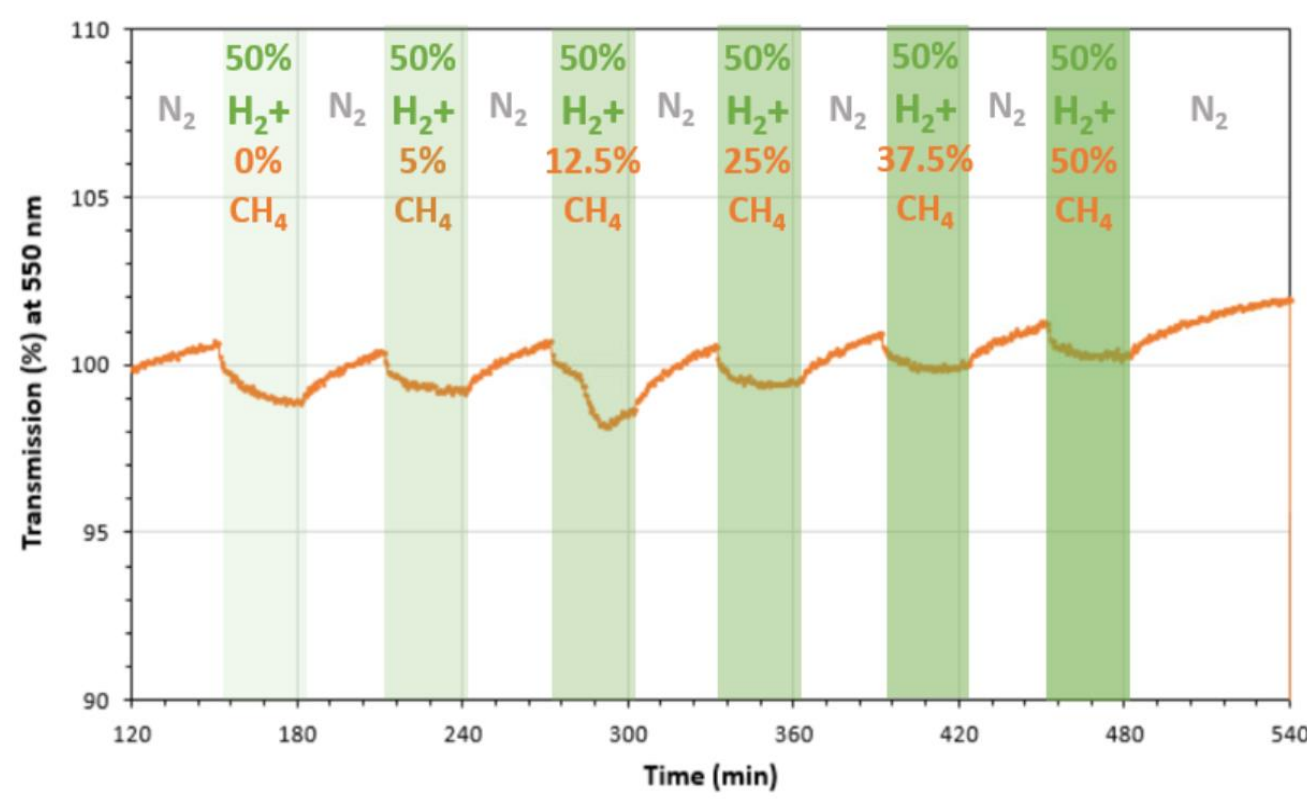
- H₂ subsurface storage to **ensure energy reliability** and to **mitigate the impact of varying production rates**.
- Utilize underground natural gas storage fields such as **salt caverns, saline aquifer, and depleted oil/gas reservoirs**.
- Need to develop **H₂ monitoring sensors** to manage H₂ leakage risks and assure safe H₂ storage in underground fields.

Hydrogen sensing at 100% to 10% H₂



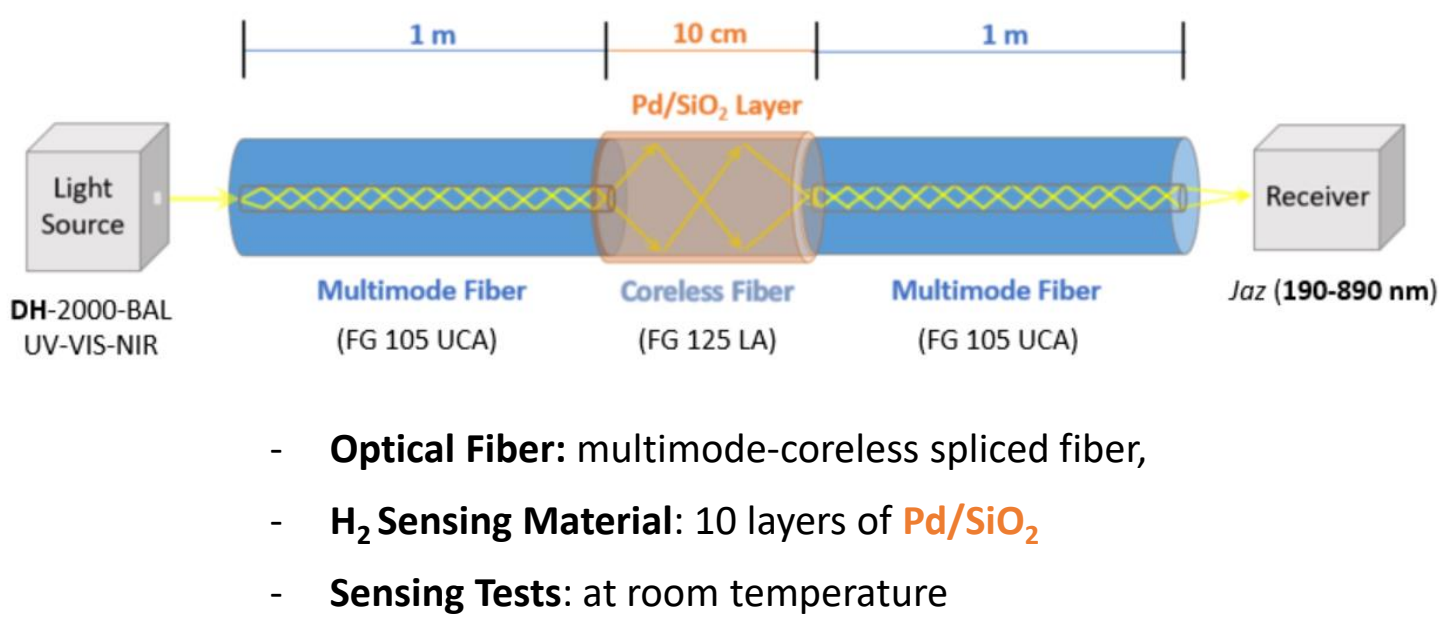
➤ Shows H₂ sensing capability at broad concentrations of H₂.

Hydrogen sensing in the presence of CH₄



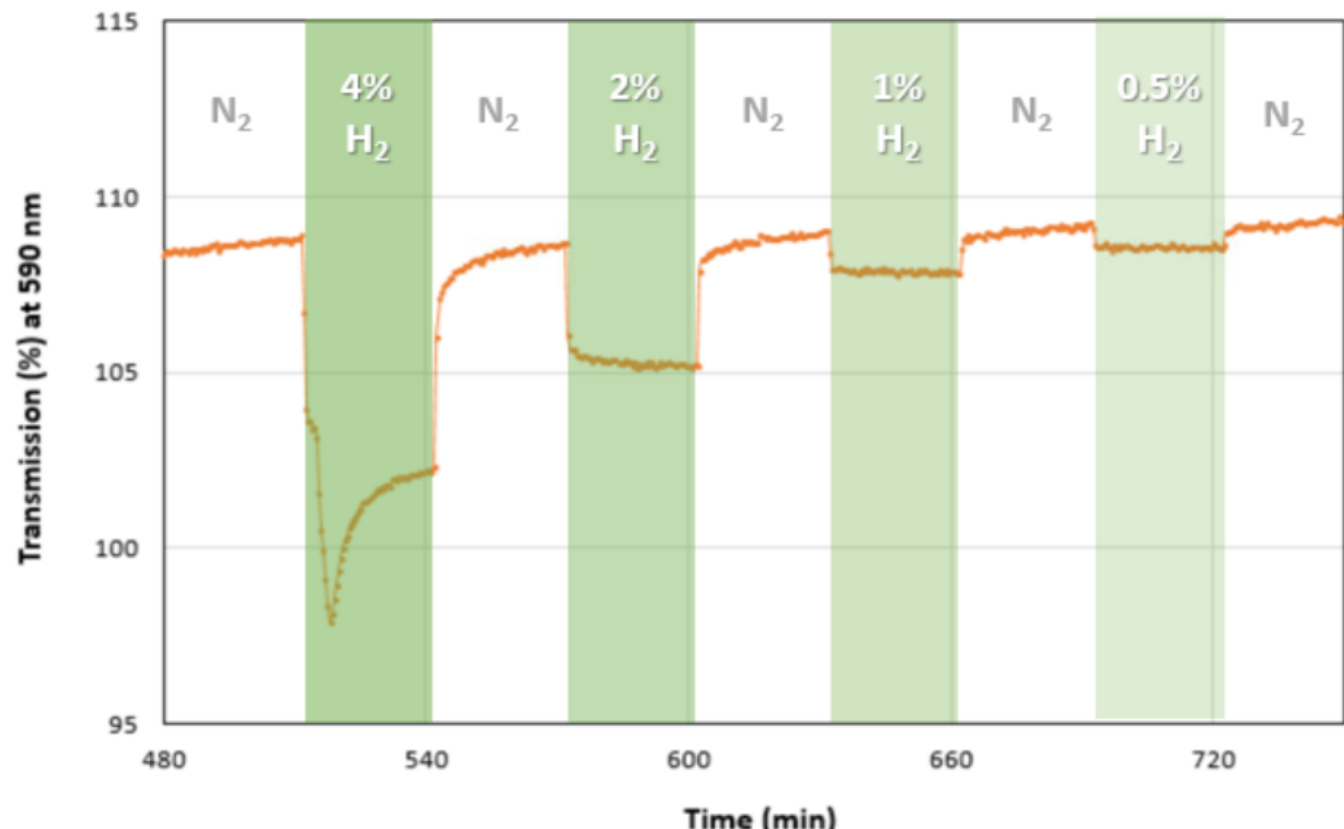
➤ Shows reliable H₂ sensing capability in the presence of CH₄.

Optical Fiber H₂ Sensor Based on Evanescent Field



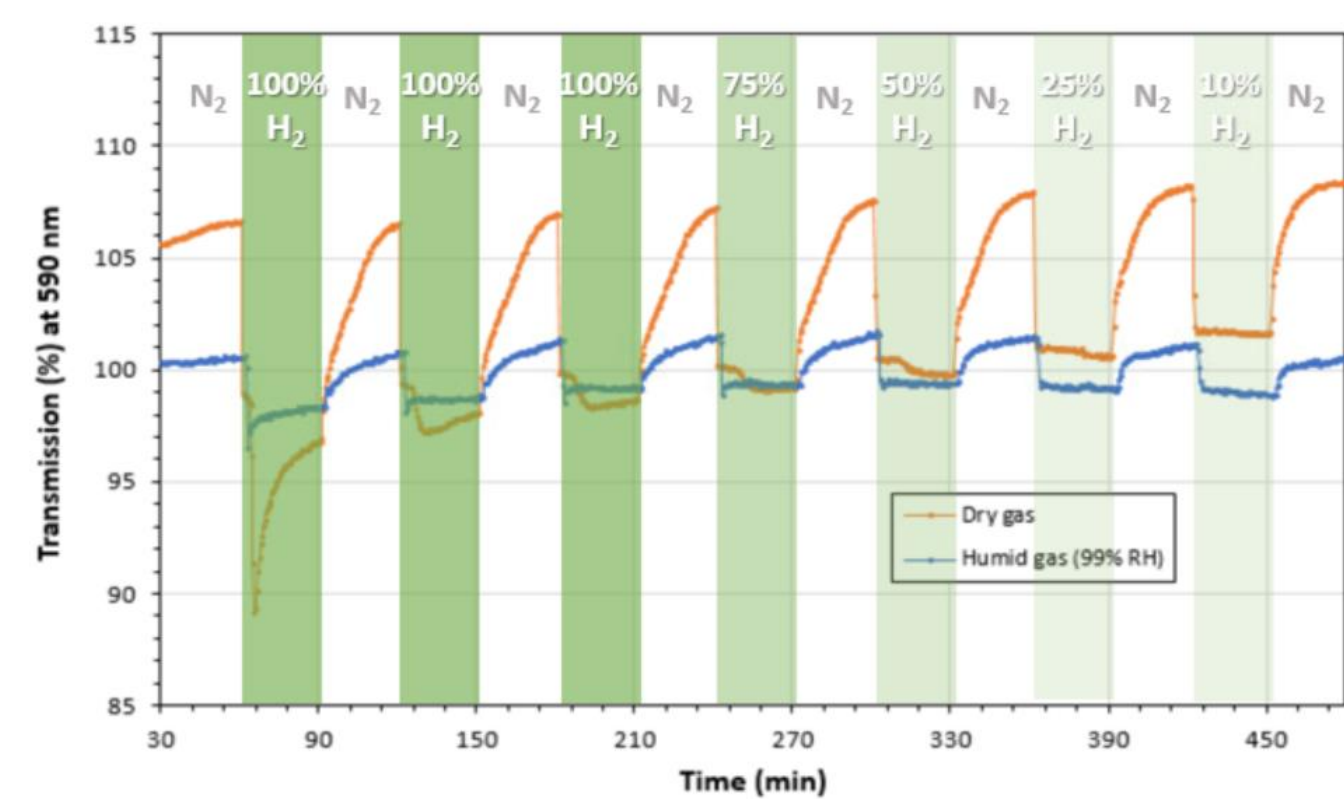
- **Optical Fiber:** multimode-coreless spliced fiber,
- **H₂ Sensing Material:** 10 layers of **Pd/SiO₂**
- **Sensing Tests:** at room temperature

Hydrogen sensing at 4% to 0.5% H₂



➤ Shows H₂ sensing capability below the lower flammable limit of H₂.

Hydrogen sensing under the humid condition



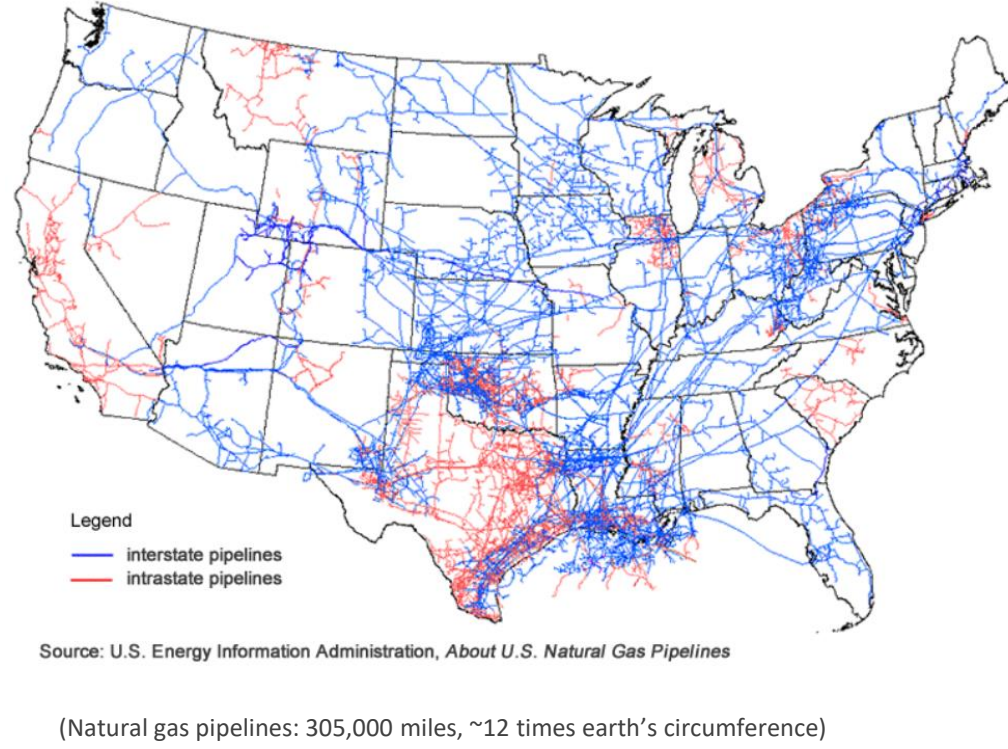
➤ Shows H₂ sensing capability under the humid condition (99% RH).

Conclusions and Next Steps

- Developed the **optical fiber H₂ sensor** capable of sensing hydrogen at broad range of concentrations **from 100% to 0.5% H₂**.
- Demonstrated hydrogen sensing capability **under 99% relative humidity**.
- The developed optical fiber H₂ sensor showed **negligible cross-sensitivity to CH₄**.
- Planning to coat a **protective layer** over the Pd/SiO₂ sensing layer to improve H₂ selectivity and sensitivity under the harsh environment of subsurface storage.

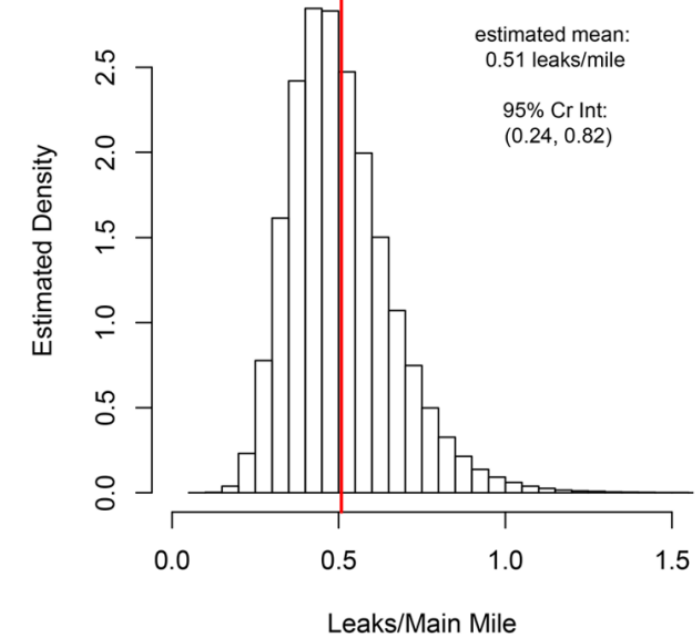
Surface Acoustic Wave Methane Sensor

Natural Gas Pipelines in the U.S.



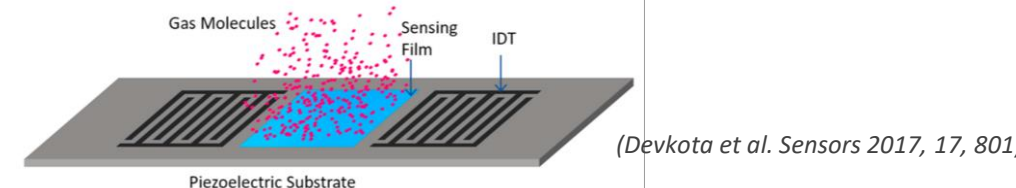
Source: U.S. Energy Information Administration, About U.S. Natural Gas Pipelines
(Natural gas pipelines: 305,000 miles, ~12 times earth's circumference)

Estimated Natural Gas Leaks Per Mile



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

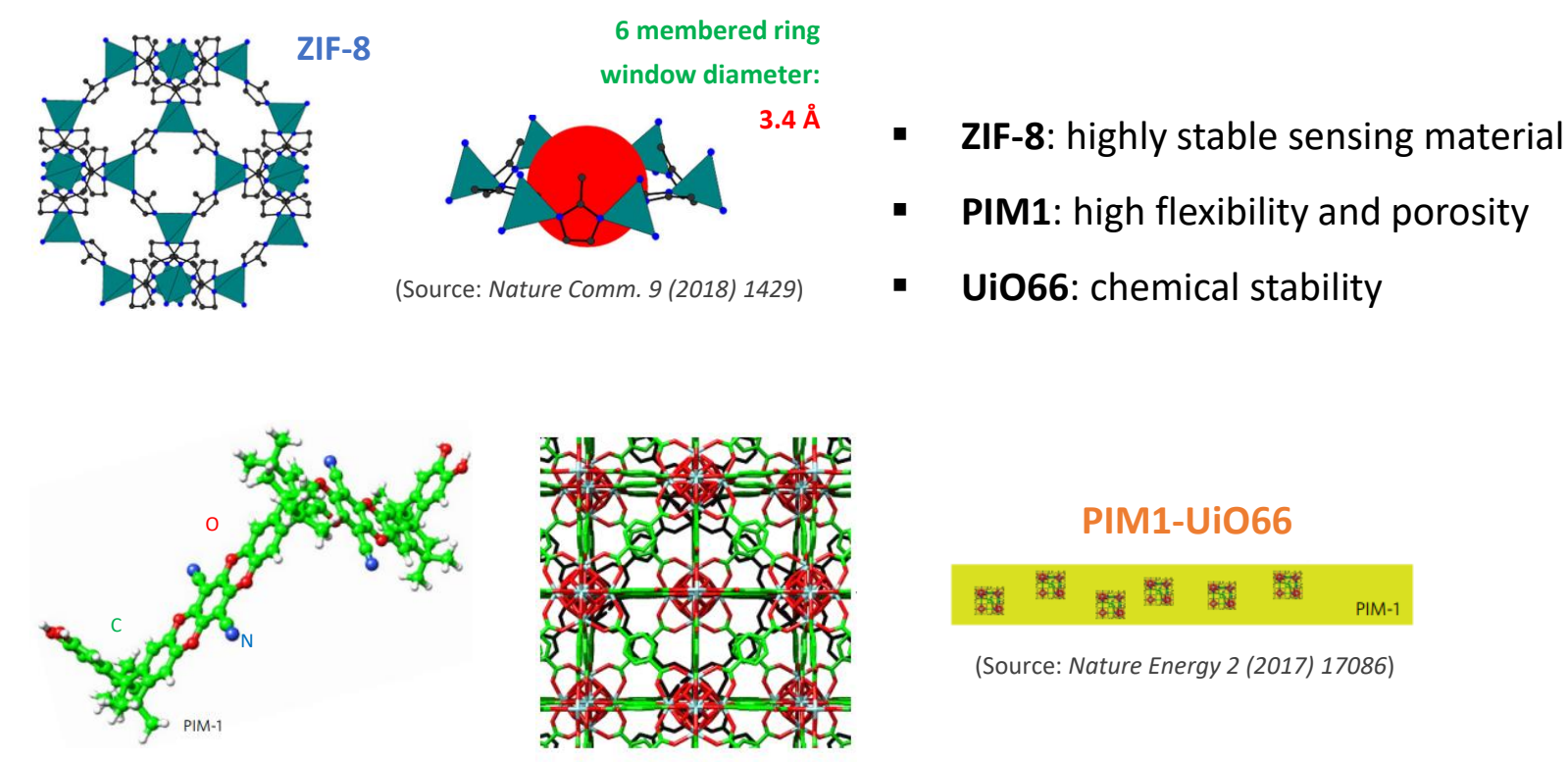
Surface Acoustic Wave (**SAW**) Sensor:



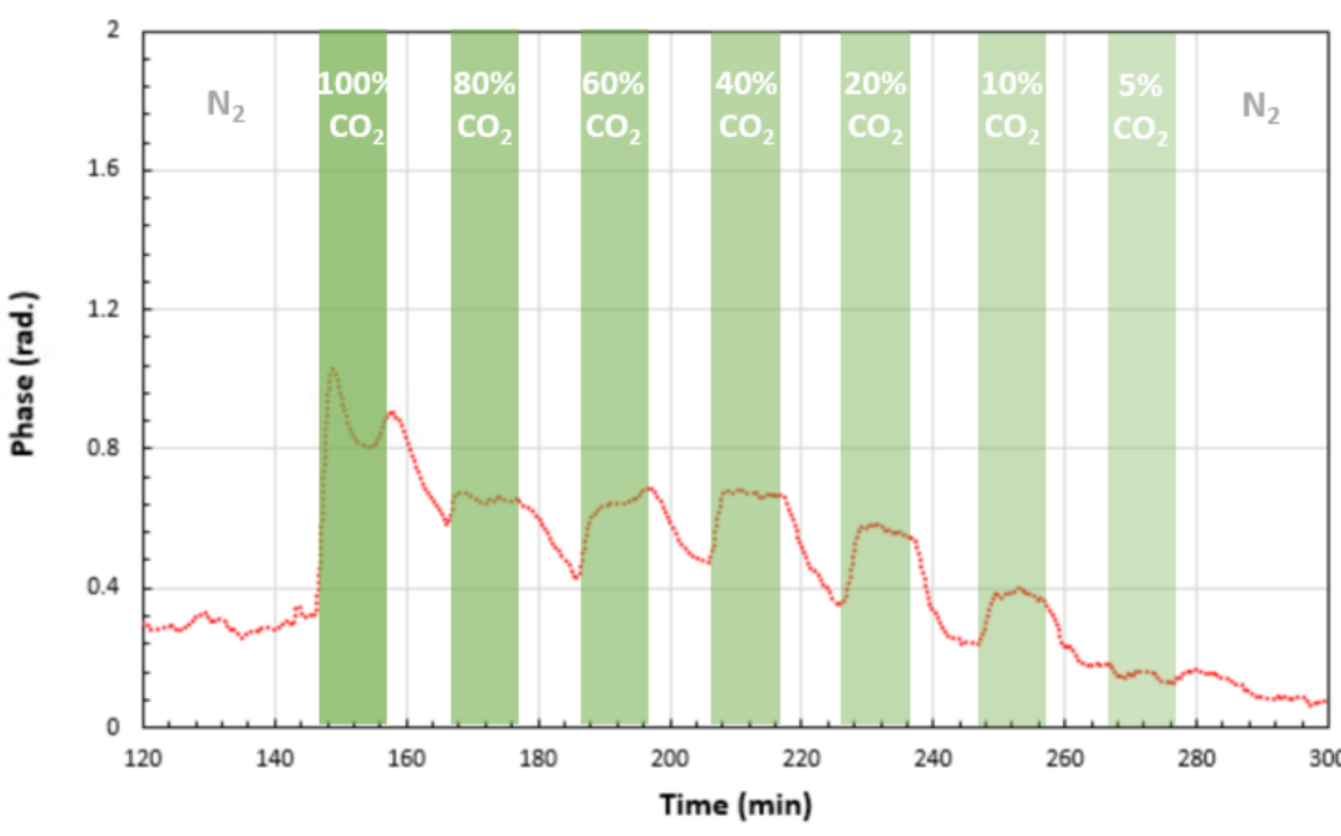
electrical signal <----> surface acoustic wave
piezoelectric substrate
(based on mass change in the sensing film)

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

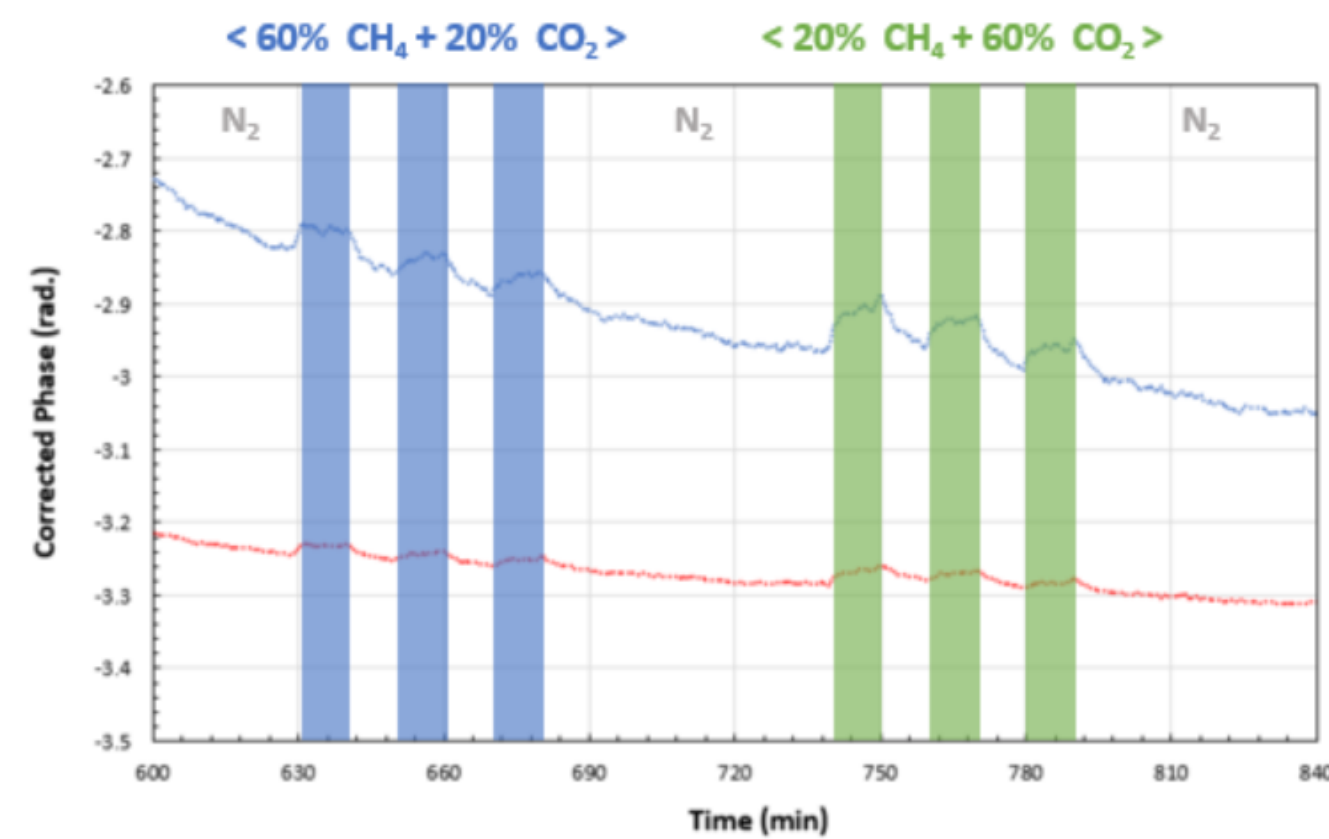
Multi-elements SAW array sensor (ZIF-8 and PIM1-UiO66)



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



➤ CO₂ sensing response at different concentrations



➤ CH₄ sensing response at different concentrations

Conclusions and Next Steps

- Developed the **multi-elements surface acoustic wave sensor** capable of sensing CH₄ and CO₂.
- 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.
- Planning to optimize the **SAW configuration and coating sensing layers** to maximize methane sensitivity under humid condition.