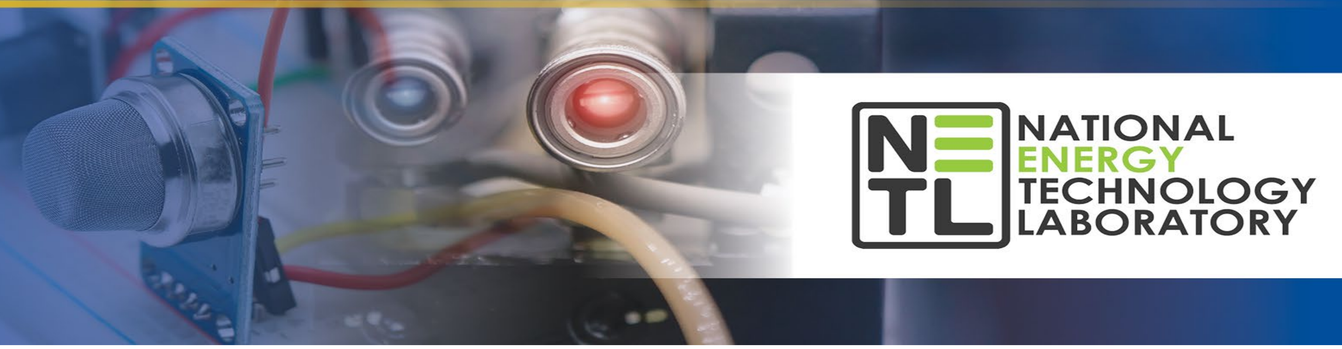
UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP



NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Optical Fiber Sensors Capable of Monitoring Harsh Subsurface Conditions for H_2 Storage Applications

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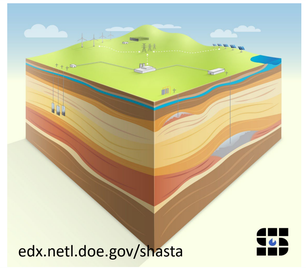
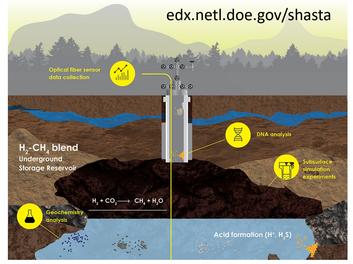
Subsurface Hydrogen Storage

- Subsurface hydrogen storage can be used to mitigate the impact of varying hydrogen production rates.
- Subsurface hydrogen storage costs three to five times less than above-ground tank storage.
- **Wellbore integrity monitoring** is crucial to ensure safety and reliability.

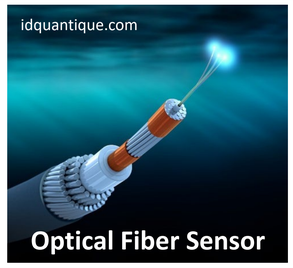


- In-situ optical fiber sensors are needed for real-time monitoring of **hydrogen**, **methane**, and **pH** at subsurface hydrogen storage conditions.
- Microbial conversion of hydrogen to methane occurs in subsurface wells.
- The sensors determine microbiological hydrogen consumption/depletion and pH change.



Advantages of Optical Fiber Sensors

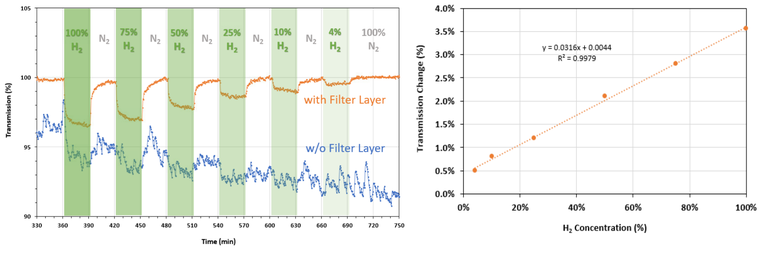
- **Stable** in subsurface harsh environments.
- **Safe** operation in the presence of flammable gases.
- **Long reach**, light weight, small size.
- **Functionalizable** for targeted parameters through functional materials.



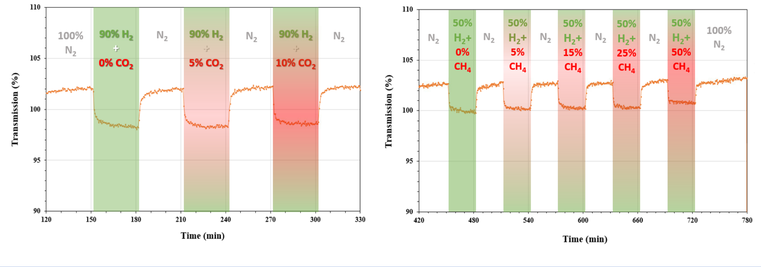
Optical Fiber Hydrogen Sensor

- An optical fiber H_2 sensor coated with **Pd nanoparticle/SiO_2** was developed.
- A new **filter layer** was overcoated on the sensing layer to increase selectivity and mitigate humidity interference.

- Demonstrates **reversible H_2 sensing** capability at broad concentrations of H_2 at **80 °C**, **99% RH** which replicates the condition in the subsurface H_2 storage facilities.

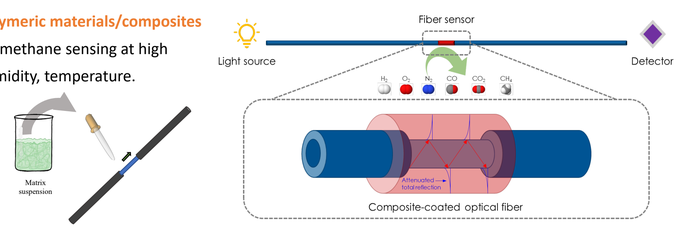


- Shows **negligible cross-sensitivity** with **CO_2** and **CH_4** at **80 °C**, **99% RH** which are used as cushion gas in the subsurface H_2 storage facilities to maintain the minimum pressure.

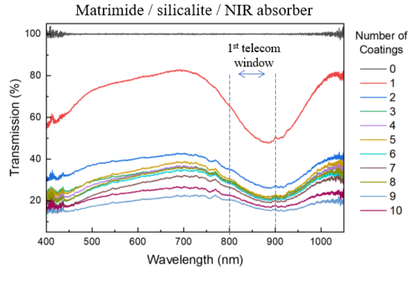


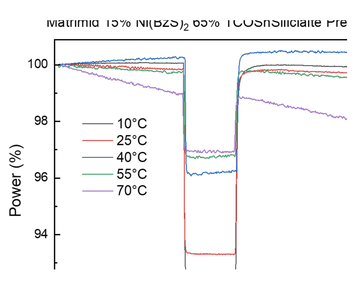
Optical Fiber Methane Sensor

- **Polymeric materials/composites** for methane sensing at high humidity, temperature.

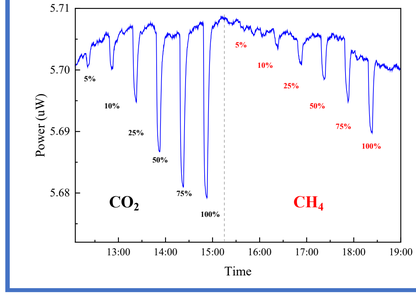


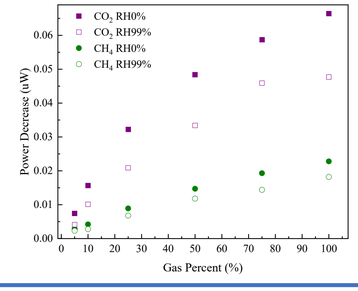
- **Tuned the wavelength to NIR (near infrared) range** to be readily compatible with commonly used distributed optical fiber sensor interrogators.
- Shows **fast response time**.





- Successful demonstration of optical fiber methane sensor in humid conditions at 99% RH.
- Calibration curve of CO_2 and CH_4 from 5% to 100%.

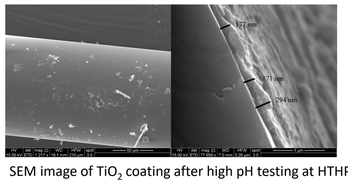




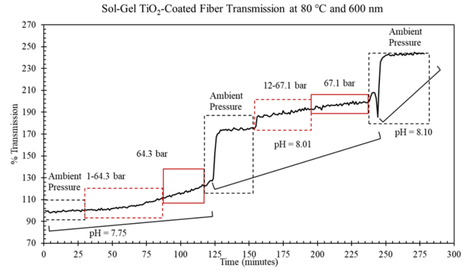
Optical Fiber pH Sensor

- **TiO_2 coated optical fiber pH sensor** was demonstrated at high-temperature high-pressure (**HTHP**).

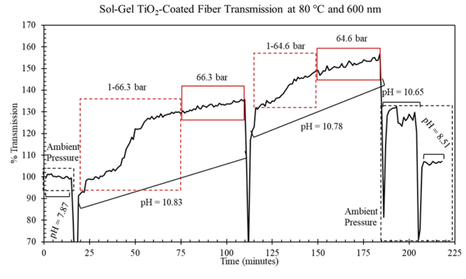
- Multi-phase HTHP autoclave for pH sensor testing



- SEM image of TiO_2 coating after high pH testing at HTHP



- Gradual pressurization did not immediately impact the sensor response, even when rapidly depressurized.
- After pressurization, the response rapidly jumps when the solution is exchanged.



- Compared to neutral conditions, **basic pressure response** is more stable to solution exchange.
- This may be thickness-dependent, as base exposure lowers coating thickness.
- Stress-based cracking from pressure may be decreased for thinner coatings.