

## Corrosion and pH Monitoring of Pipelines and Subsurface Wellbores Using Optical Fiber Sensors

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### Background

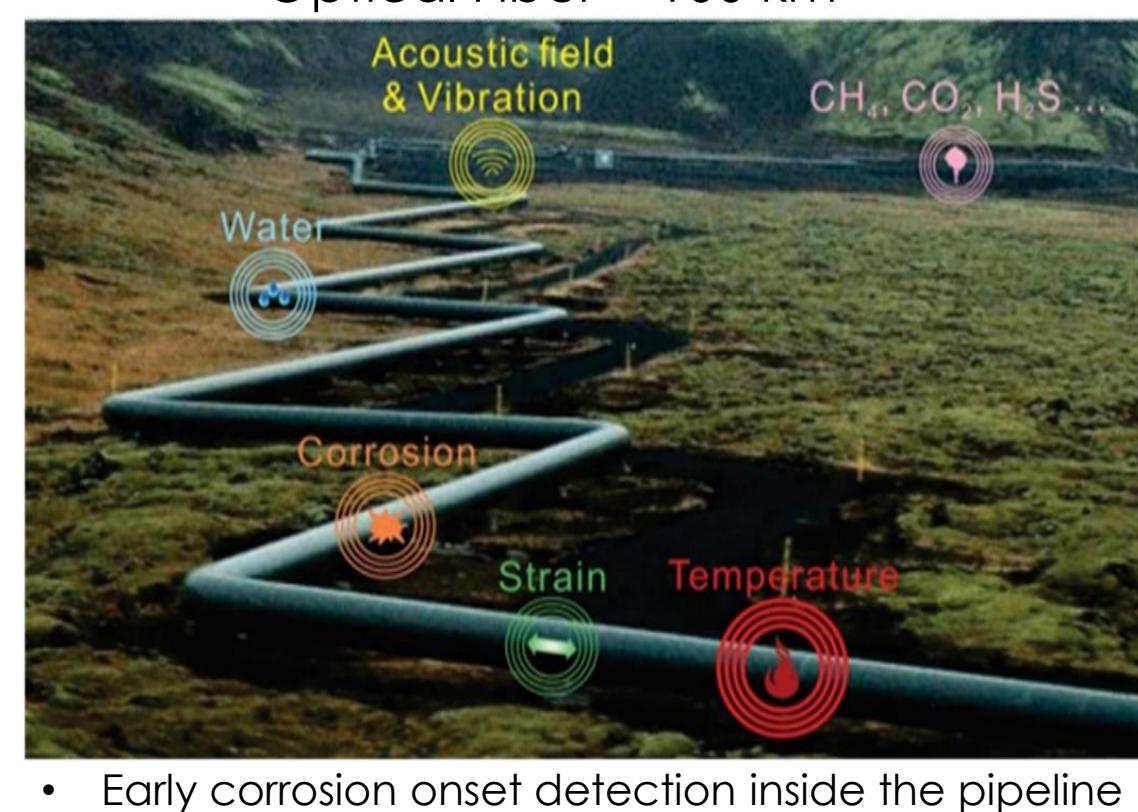
- Domestic oil and gas lost \$8.4 billion to corrosion in 2002 across pipelines and exploration
- Sensor technology is currently insufficient for continuous preventative monitoring
- Optical fiber sensors allow for long distance distributed sensing of corrosive conditions

Koch, G. H., et al. "Corrosion costs and preventive strategies in the United States" (2002).

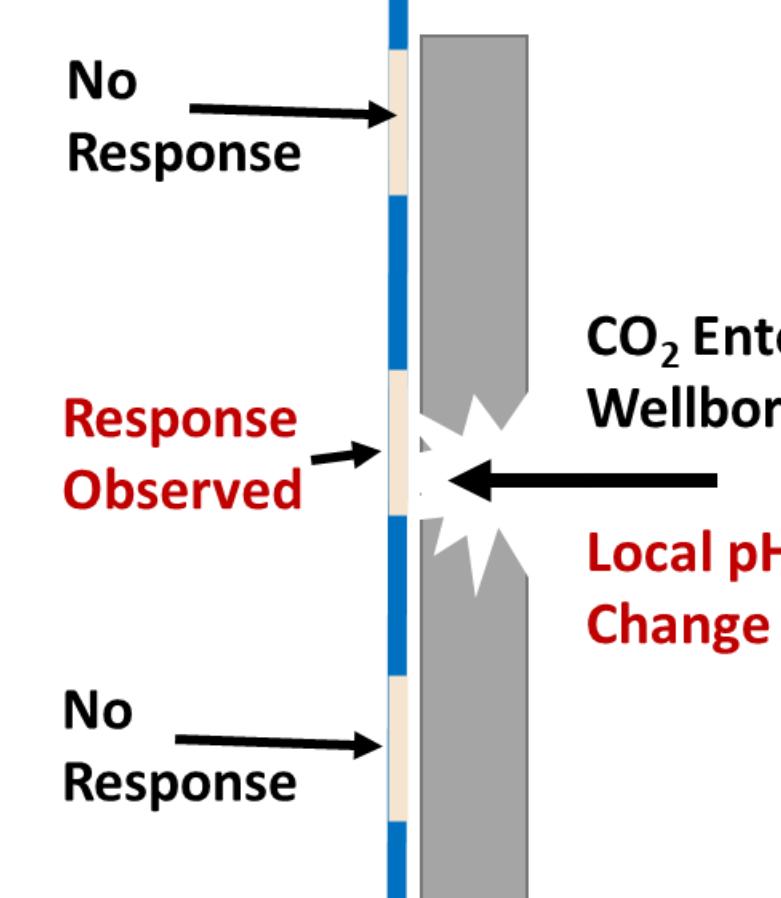
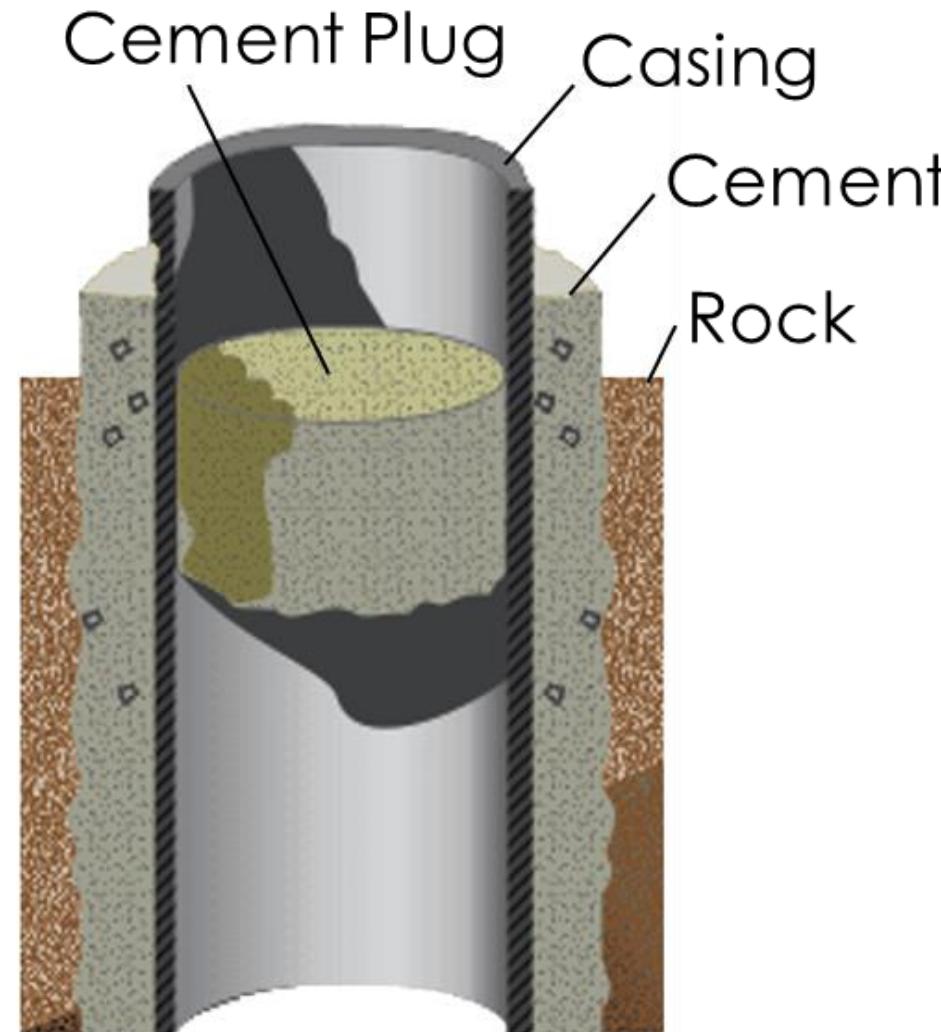
Corroded Production Casing Pipe Sample from Downhole  
(University of North Dakota Energy & Environmental Research Center)



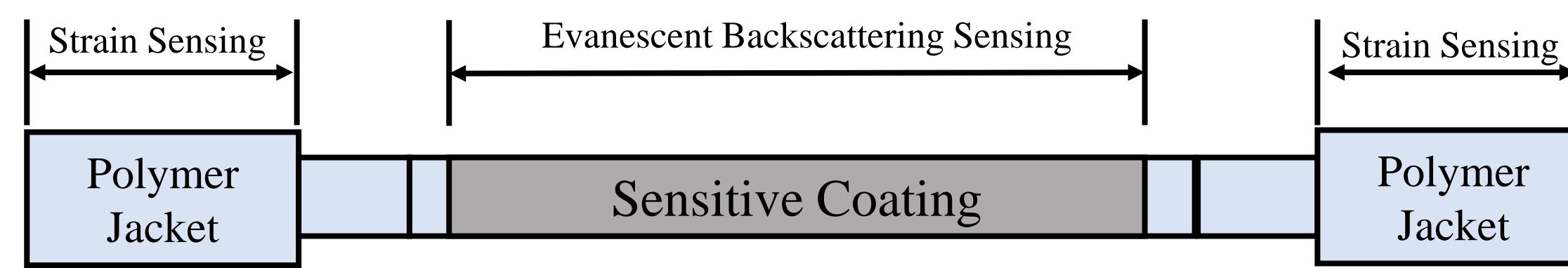
Pipeline Integrated with Distributed  
Optical Fiber > 100 km



- Early corrosion onset detection inside the pipeline
- Methane leak detection outside the pipeline

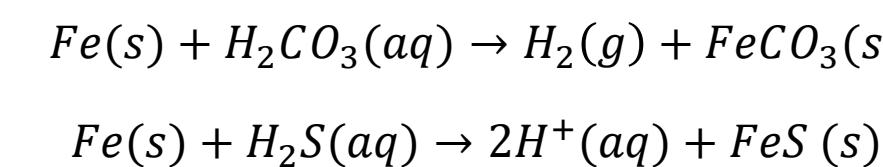


### Sensing Mechanisms for pH and Corrosion



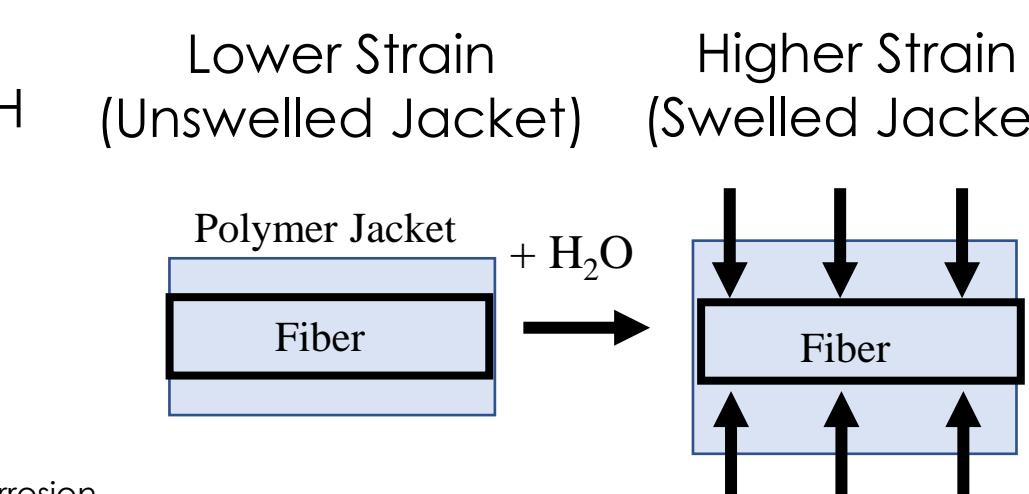
#### Important Corrosion Metrics

- Corrosion occurs when water is present
- CO<sub>2</sub> and H<sub>2</sub>S corrosion generally reduce pH
- Iron in steel is oxidized during corrosion



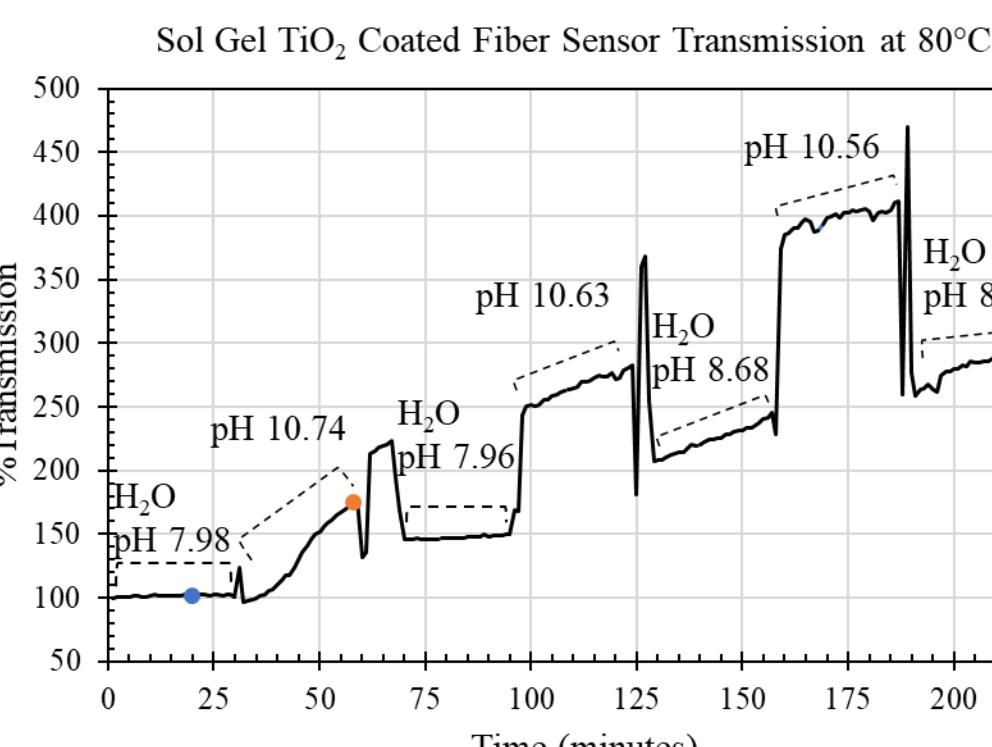
Popoola, L. T.; Grema, A. S.; Latinwo, G. K.; Gutfi, B.; Balogun, A. S. Corrosion Problems during Oil and Gas Production and its Mitigation. *Int J Ind Chem* 2013, 4 (1), 35. <https://doi.org/10.1186/2228-5547-4-35>.

#### Strain Sensing Mechanism



### pH Sensing at High Temperatures and pH

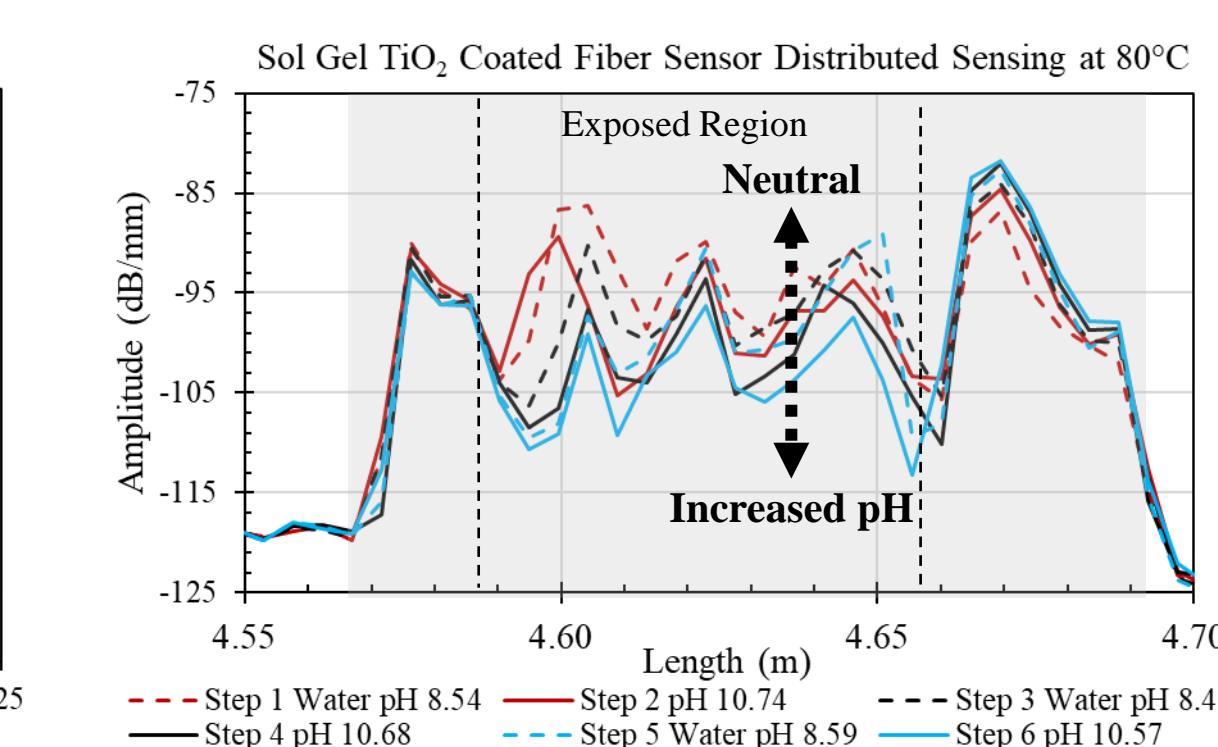
#### Point-Sensor Optical pH Probe



- Sol gel TiO<sub>2</sub> coated optical fiber
- Increased pH causes an increase in transmission
- pH sensing at up to 80 °C and pH 10.5

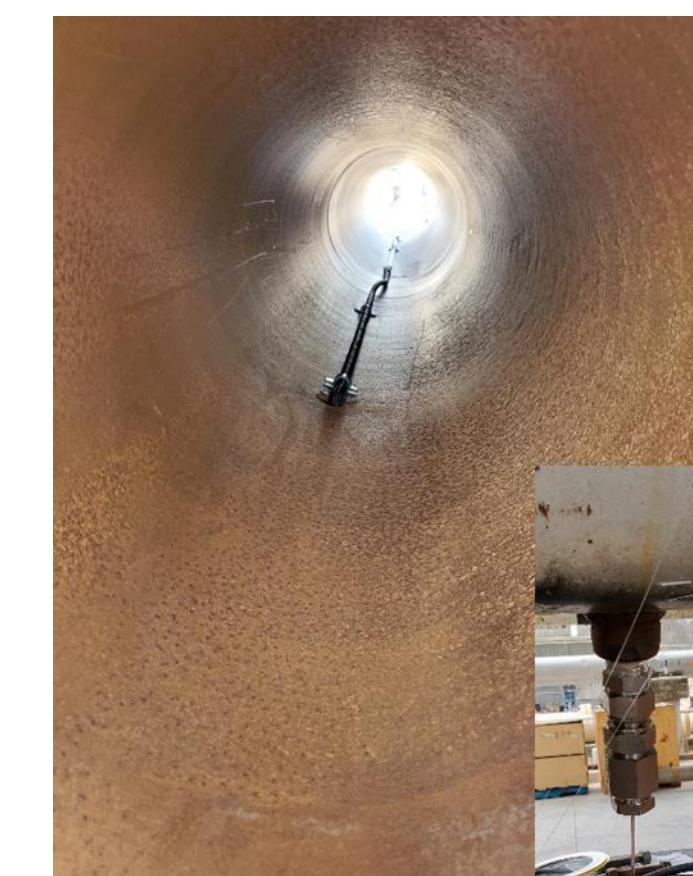
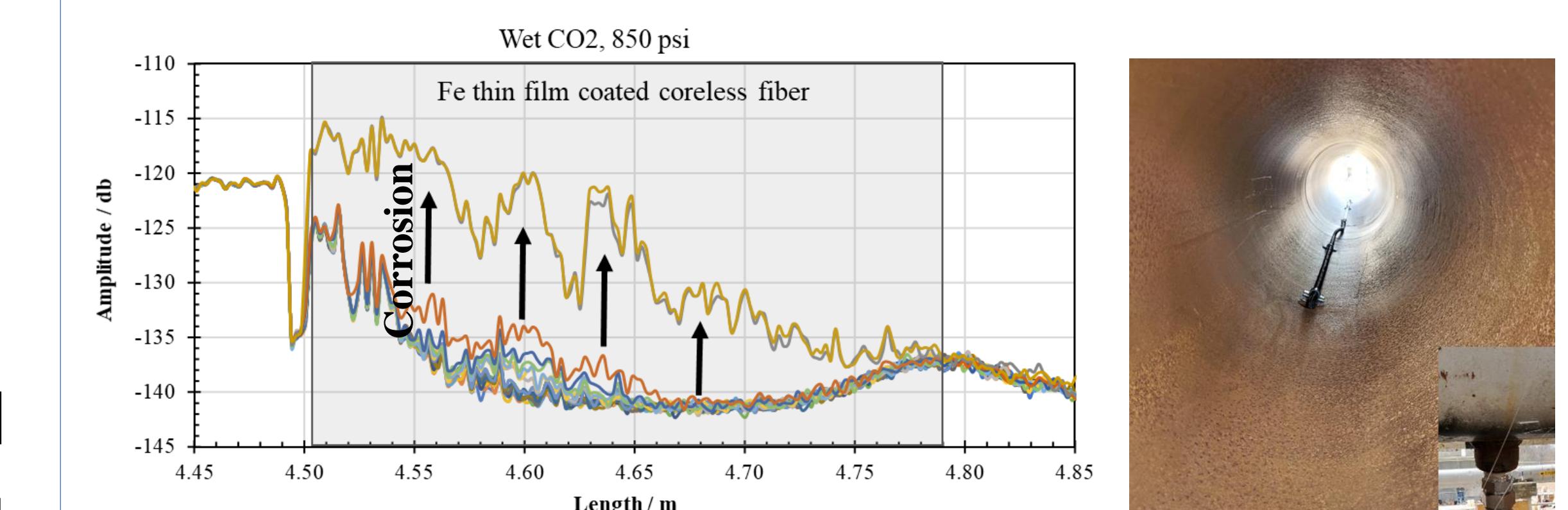
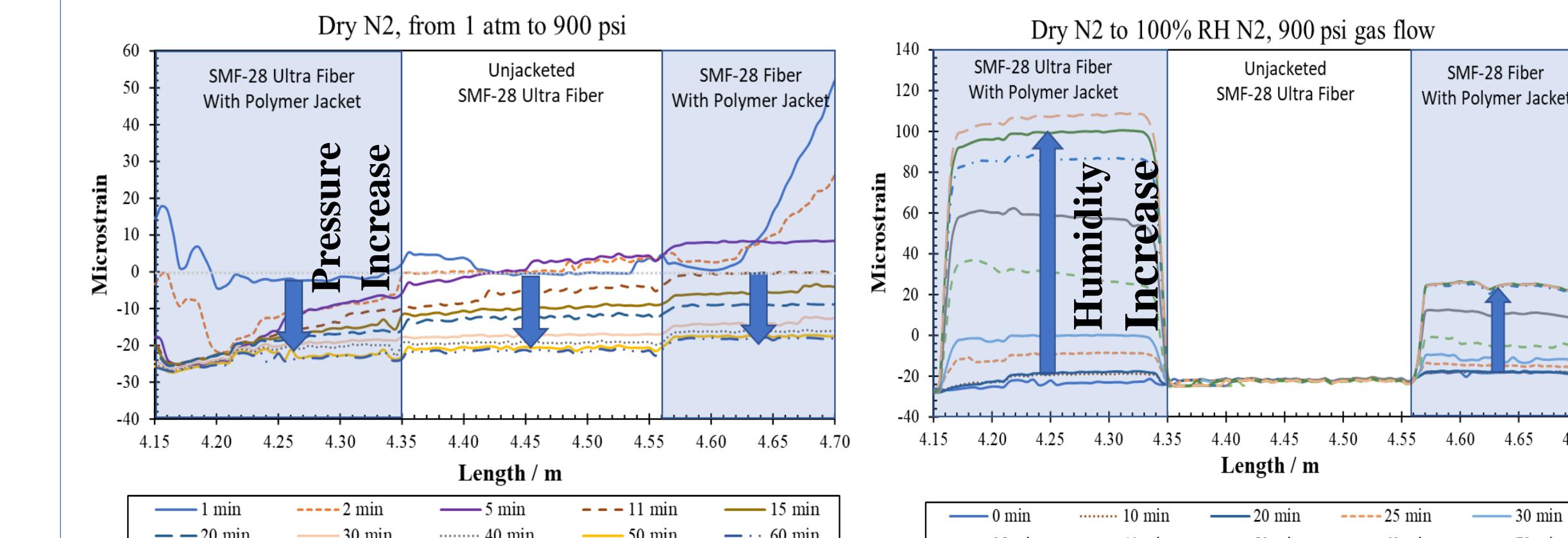
Selected Patent: Metal Oxides Enabled Fiber Optic pH Sensors for High Temperature High pH Subsurface Environments (Patent Pending)

#### Distributed Optical Fiber pH Sensing



- Increased pH causes a decrease in backscattered light
- Only the exposed coating responds
- pH can be measured at any section with a coating along the fiber

### Corrosion Sensing Coatings



Selected Patent: Corrosion Proxy Material Integrated Sensor Devices for Distributed Sensing of Early Corrosion Onset and Corrosion Quantification, US 11,262,289 B1

- Corrosion of Fe thin film on fiber surface causes changes in backscattering
- Commercial jacketed fiber experiences strain increase when exposed to water
- Corrosion monitoring using this methodology has been field tested

### NETL Capabilities

- High Pressure/High Temperature Reactors
- Autoclave Preparation Chambers
- Flow-Through Reactors
- Pilot Scale Reel-to-Reel Processing Equipment

