UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING

COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

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

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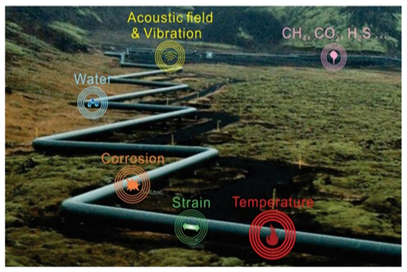
Background

- Domestic oil and gas lost $13.4 billion annually to corrosion across pipelines and exploration
- Real-time monitoring is needed to detect and mitigate pipeline risks.
- Optical fiber sensors allow for long distance distributed sensing of pipeline conditions

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

Ref: Corroded production casing pipe sample from downhole (University of North Dakota Energy & Environmental Research Center)

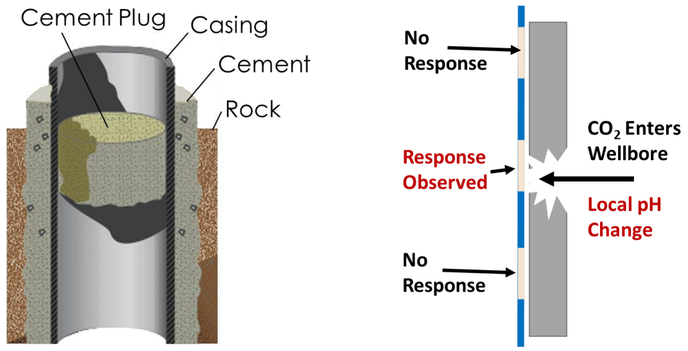
Pipeline Corrosion Monitoring to Ensure Safety and Reliability



- Early Corrosion Onset Detection inside the Pipeline
- Methane Leak Detection outside the Pipeline

Pilot-scale Demonstration of NETL Optical Fiber Sensors

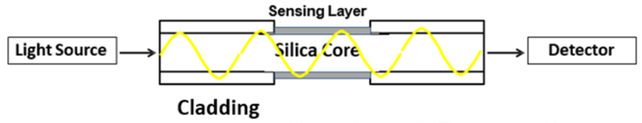
Wellbore Integrity and Geochemical Monitoring: pH sensor



Sensing Mechanisms for pH and Corrosion

- Sensor coatings when exposed to pH changes or corrosion will change light absorption/transmission or scattering.
- Optical backscattering reflectometry (OBR) provides spatially distributed measurements.

Sensing Principle of Evanescent Wave Sensors

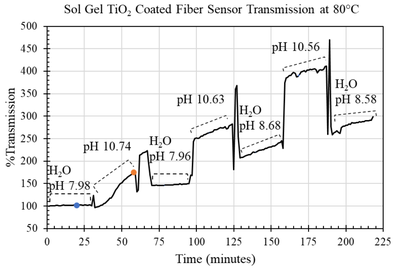


Advantages of Optical Fiber Sensors

- Stable in harsh subsurface environments
- Allows pipeline and wellbore contents to be monitored non-destructively
- Sensing mechanisms and fiber characteristics allow for long distance monitoring
- Compatible with distributed or multi-parameter interrogation
- Improved safety in the presence of flammable gases compared to electrical based sensors

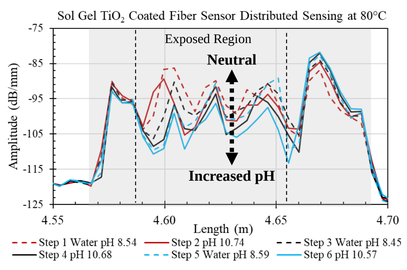
pH Sensing at High Temperatures

Point Optical Fiber pH Sensor



- Sol gel TiO_2 coated optical fiber
- Increased pH causes an increase in light transmission
- pH sensing up to 80°C and pH 10.5

Distributed Optical Fiber pH Sensing

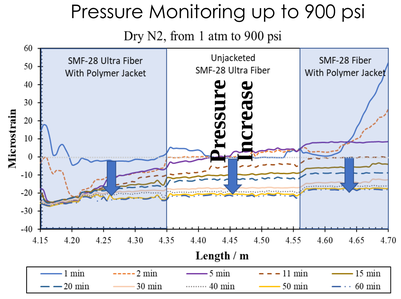


- Increased pH causes a decrease in backscattered light
- Only the exposed coating responds
- pH can be measured at any section with a coating along the fiber

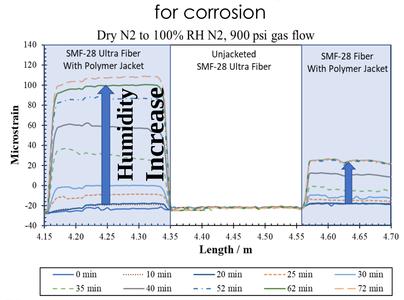
Selected Patent: Metal Oxides Enabled Fiber Optic pH Sensors for High temperature High pH Subsurface Environments *(Patent Pending)*

Gas Pipeline Corrosion Sensing

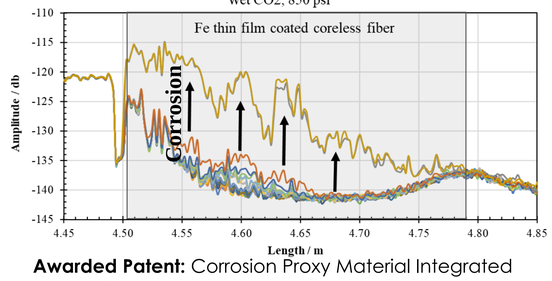
Pressure Monitoring up to 900 psi



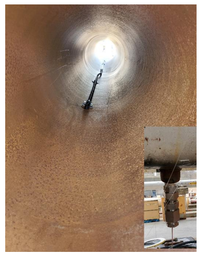
Humidity/Water Monitoring, precursor for corrosion



Direct Corrosion Monitoring in wet CO_2 gas



Optical Fiber Sensor inserted inside a pressurized natural gas pipeline for a pilot demonstration

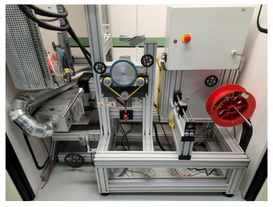


Awarded Patent: Corrosion Proxy Material Integrated Sensor Devices For Distributed Sensing Of Early Corrosion Onset And Corrosion Quantification, *US 11,262,289 B1*

- Corrosion of Fe thin film on fiber surface causes changes in backscattered light intensity.
- Polymer-jacketed fiber experiences strain increase when exposed to water
- Optical fiber sensors using this methodology have been field tested

NETL Sensor Preparation and Testing Capabilities

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



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