UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

Passive Wireless Sensing of Methane Leak and Monitoring Corrosion in Pipelines

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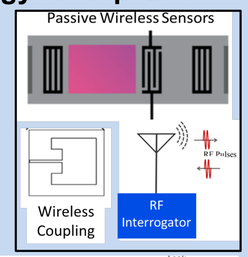
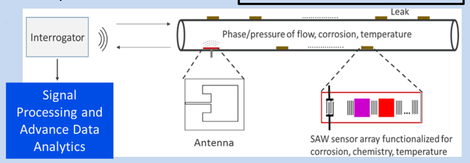
Motivation

- Conventional monitoring techniques identify leaks and events once they have occurred but are limited in capability to identify failures before they occur.
- Continuous and real-time monitoring technologies are helpful to better identify, locate, and quantify methane leaks and corrosion events.
- Passive wireless sensors and their network are emerging platforms for remote and real-time monitoring of long pipelines where human access is a challenge.
- We help operators to reduce monitoring costs and simplify the inspection process by developing a low-maintenance, remote and real-time capable multiparameter monitoring tool.

Proposed Wireless Passive Sensor Technology for Pipelines

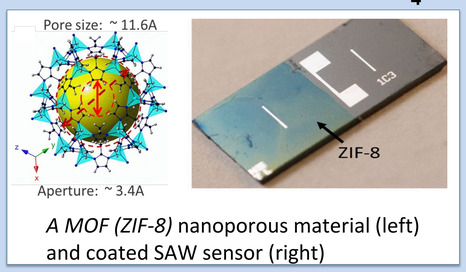
- Radio frequency (RF) Surface Acoustic Wave (SAW) microdevices with wireless capability.
- Matured technology with numerous applications including mobile communications, remote control, automotive sector, and sensors and actuators.
- Multi-parameter sensing capability (temperature, pressure, chemical species, corrosion, etc.).
- Guided wave-based propagation for long distance interrogation.



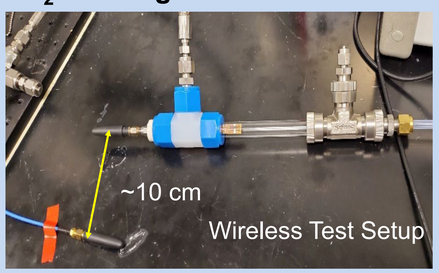


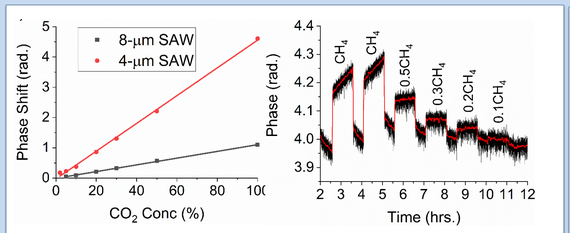
(US Patent: 11113594)

CH_4 and CO_2 Sensing

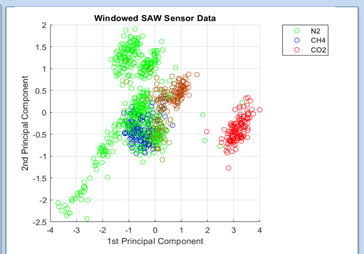


A MOF (ZIF-8) nanoporous material (left) and coated SAW sensor (right)





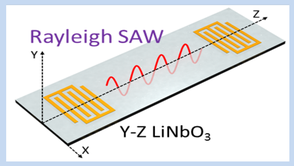
Mass-based sensing of CO_2 and CH_4 at room temperature



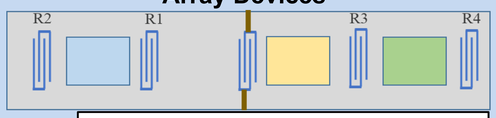
Principal component analysis of multi-component sensor data

Demonstrated the detection and monitoring of various concentrations of CO_2 and CH_4 in real time using MOF and polymer-coated SAW sensors of nominal frequencies 434 MHz and 868 MHz (Y-Z $LiNbO_3$/Al (120 nm)).

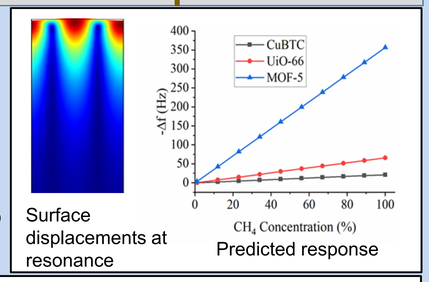
Sensor Devices Modeling and Design



Array Devices

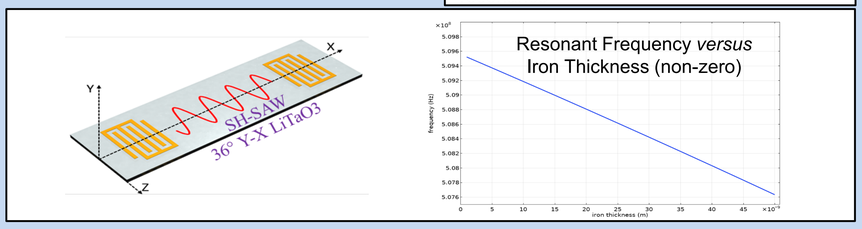


- Finite element modeling (FEM) was performed to predict the operating frequencies and optimize the device designs.
- Modeled "multi-component" devices and predicted the responses of metal-organic framework (MOF) coated SAW sensors to various gases.



Surface displacements at resonance

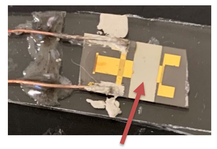
Predicted response



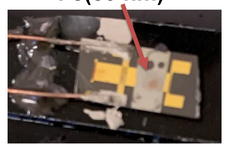
- Proposed shear-horizontal (SH-) SAW devices for monitoring corrosion in pipelines.
- FEM simulation predicted a change in operating frequency and magnitude of the acoustic signal with Fe film corrosion.

Sensors in Corrosive Environment

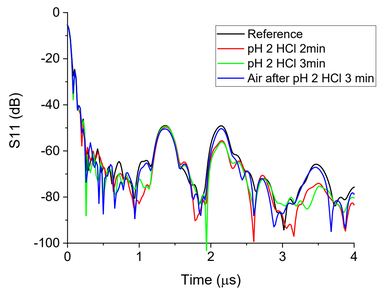
Before exposure



Fe(50 nm)

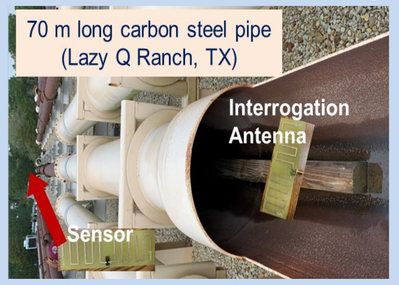


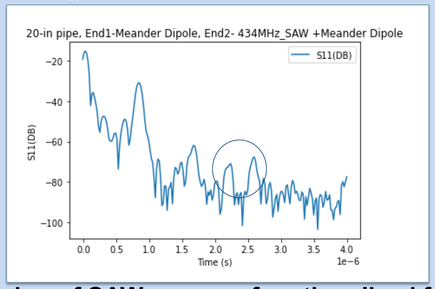
After exposure (3 min) to pH 2.0 solution



Response of a Fe(50 nm)-coated Shear Horizontal (SH-) SAW sensor as Fe (50 nm) film corrodes in HCl of pH 2.0.

In-Pipe Interrogation





Field demonstrated the remote monitoring of SAW sensors functionalized for corrosion and gas compositions that were installed inside a metal pipe.

(Quanta Services Lazy Q Ranch, La Grange, TX)

Summary

- Proposed wireless and passive sensor technology for large infrastructure monitoring.
- Demonstrated the wireless detection of leak-relevant methane and carbon dioxide in humid environments.
- Demonstrated the wireless monitoring of corrosion at high pressure (>500 psi) in wet CO_2 and in acidic solution.
- Field demonstrated the remote interrogation of functionalized SAW sensors inside 70-m long metal pipes.

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