UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

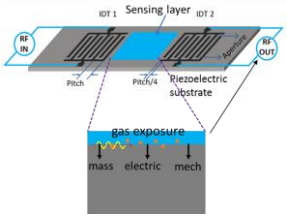
Passive Wireless Surface Acoustic Wave Sensors and Wireless Telemetry

Jagannath Devkota[1,2], Richard Pingree[1,2], David W Greve[3,4], Daejin Kim[1,2], Jeffrey Culp[1,2], Nathan Diemler[1,2], Ruishu Wright[1]

[1] U.S. Department of Energy, National Energy Technology Laboratory (NETL), 626 Cochran Mill Road, Pittsburgh, PA 15236, USA [2] NETL Support Contractor, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA
[3] Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA [4] DWGreve Consulting, Sedona, AZ 86336

Surface Acoustic Wave (SAW) Sensing Principles

Radio Frequency (RF) Energy is converted to a SAW via the Piezoelectric effect.



$$\frac{\Delta v}{v_0} = \frac{\Delta f}{f_0} = \frac{\Delta \phi}{\phi_0}$$

The following sensor parameters are optimized such that the phase velocity of the SAW changes are in correlation with parameters of interest.

- Substrate material and cut angle relative to crystal structure
- Inter-Digital Transducer Electrode material, geometry, and spacing
- Sensing Layer material and geometry
- Resulting surface perturbation property changes
  - Mass
  - Elasticity
  - Conductivity
  - Permittivity

Parameters Measured

- Gas Detection
- Corrosion Detection
- Temperature
- Pressure
- Relative Humidity
- Strain
- pH

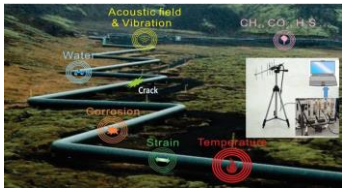
Other Applicable Industries

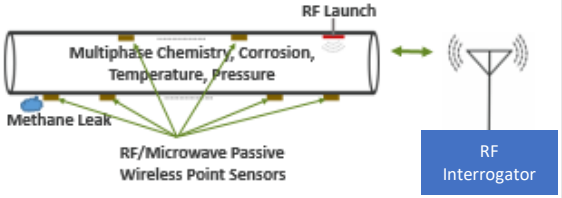
- Subsurface Wellbores
- Harsh Environments in Energy Generation
- Automotive
- Aerospace
- Manufacturing

Advantages

- Ruggedness – Functional in harsh environments
- Passive – No stored energy or wiring required
- Wireless operation compatibility
- Small Size – Sensing element in cm scale
- Cost Effective – Target cost < $1ea

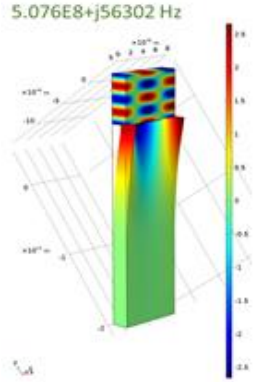
Pipeline Monitoring with Passive Wireless Sensors

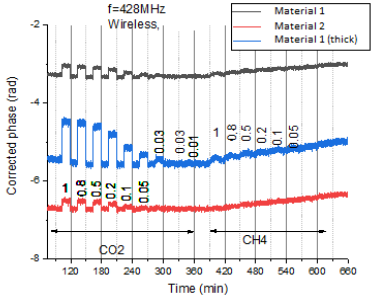




NETL SAW Sensor Development

Simulation/Modeling: Design optimization and Simulation of SAW device performance metrics using COMSOL and the High-Performance Computer cluster at NETL.

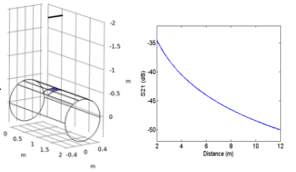




Experimental Results from multi-element SAW sensor array: Optimization and testing of multi-parameter gas (CH_4 and CO_2) sensing within the same sensing device

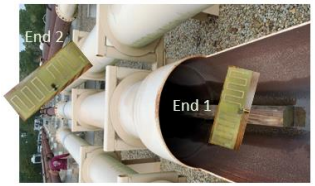
NETL Wireless Telemetry Development

- Simulation and optimization of antennas both internal and external to the pipeline via COMSOL and ANSYS HFSS using the High-Performance Computer cluster at NETL.



- Fabrication of planar antennas utilizing a 2D circuit board plotter at NETL.

- Pilot-scale demonstration of RF wireless propagation inside 70-meter steel pipe.



This project was funded by the United States Department of Energy, National Energy Technology Laboratory, in part, through a site support contract. Neither the United States Government nor any agency thereof, nor any of their employees, nor the support contractor, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.