Application Considerations for Passive Wireless Acoustic Wave Sensors

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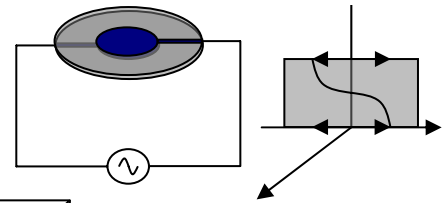
Outline:

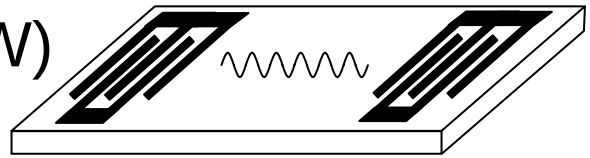
- Acoustic sensor device types
- General properties & application issues
- OFC sensor structure
- Applications
  - Temperature sensing
  - Concrete maturity monitoring
  - Cryogenic liquid level monitoring
  - Hydrogen leak detection
- Summary

Acoustic wave sensors – device types:

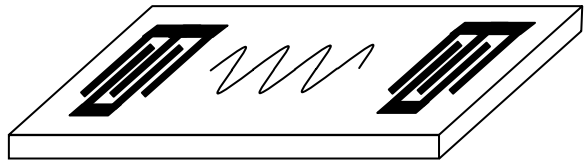
- Thickness shear mode (TSM or QCM)



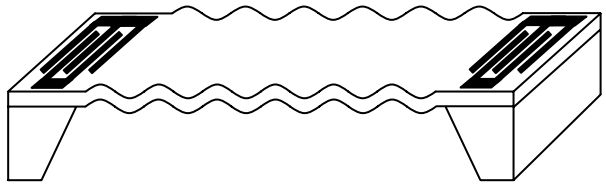
- Surface acoustic wave (SAW)



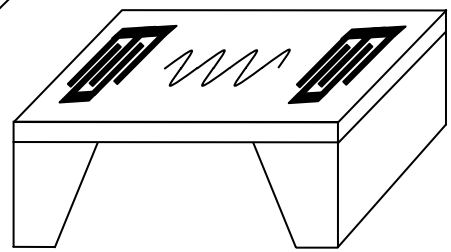
- Surface transverse wave (STW)



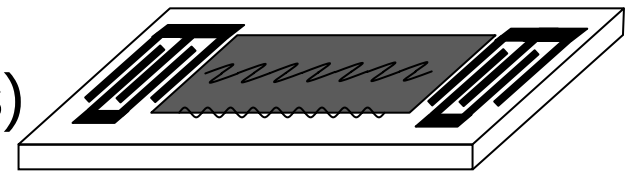
- Flexural plate wave (FPW)



- Shear horizontal acoustic plate mode (SH-APM)



- Love waves (layer guided waves)



Acoustic wave sensors – properties:

- Piezoelectric substrates
- Wireless
- Passive
- Low cost
- Rugged
- Long life
- Operate in extreme environments
  - Thermal extremes (cryogenic to >900^{o}C)
  - Radiation environments (no SEU)

Acoustic wave sensors – properties, contd.:

- Physical, chemical, and biological sensors
- Code for sensor identification
  - Many possible device & code implementations
    - Frequency diversity
    - Reflective “tags”
    - PN/PSK/FSK/OOK
    - OFC
  - Number of sensors depends on approach (generally limited compared to RFID)
- Limited range
- Point sensors (not distributed)

Orthogonal Frequency Coding(OFC):

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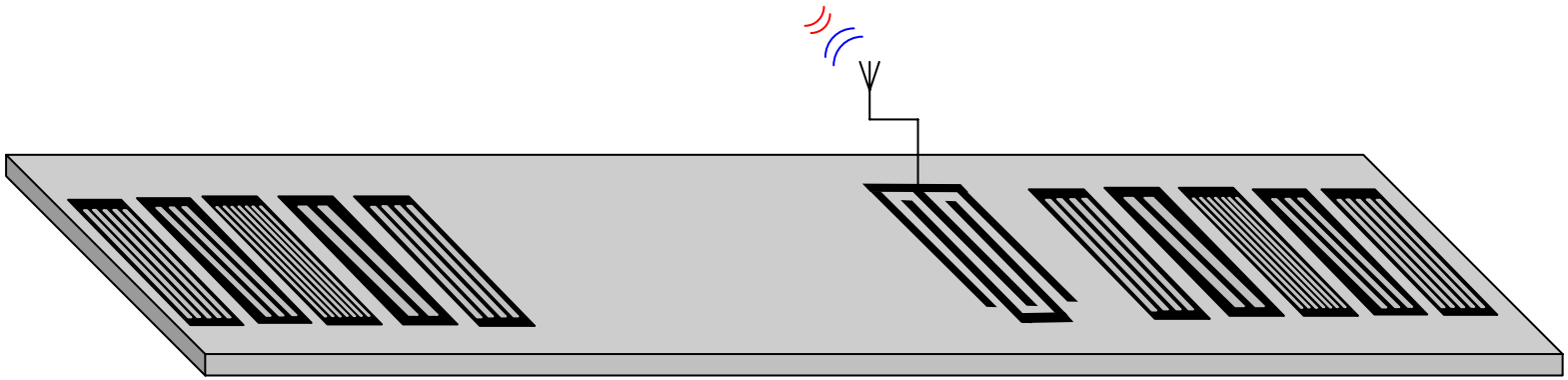
- Novel means for providing uniquely identifiable, passive, wirelessly interrogable sensors
- Invented at UCF and supported by STTR grants from:
  - Microsensor Systems Inc. (NASA NNK05OB31C) Temperature and pressure sensing
  - ASR&D Corp. (NASA NNK06OM23C) Cryogenic liquid level sensing
  - ASR&D Corp. (NASA NNK06OM24C) Hydrogen sensing
- Spread-spectrum approach
- Requires code correlation in transceiver
- Chirp excitation used for efficient power transfer

Orthogonal Frequency Coding(OFC):



- Uses sets of reflectors with orthogonal center frequencies and bandwidths
- Time placement of specific frequencies results in code
- Increases accuracy of measurement by narrowing correlated pulses

Temperature sensing:

(Data courtesy of the University of Central Florida (UCF))

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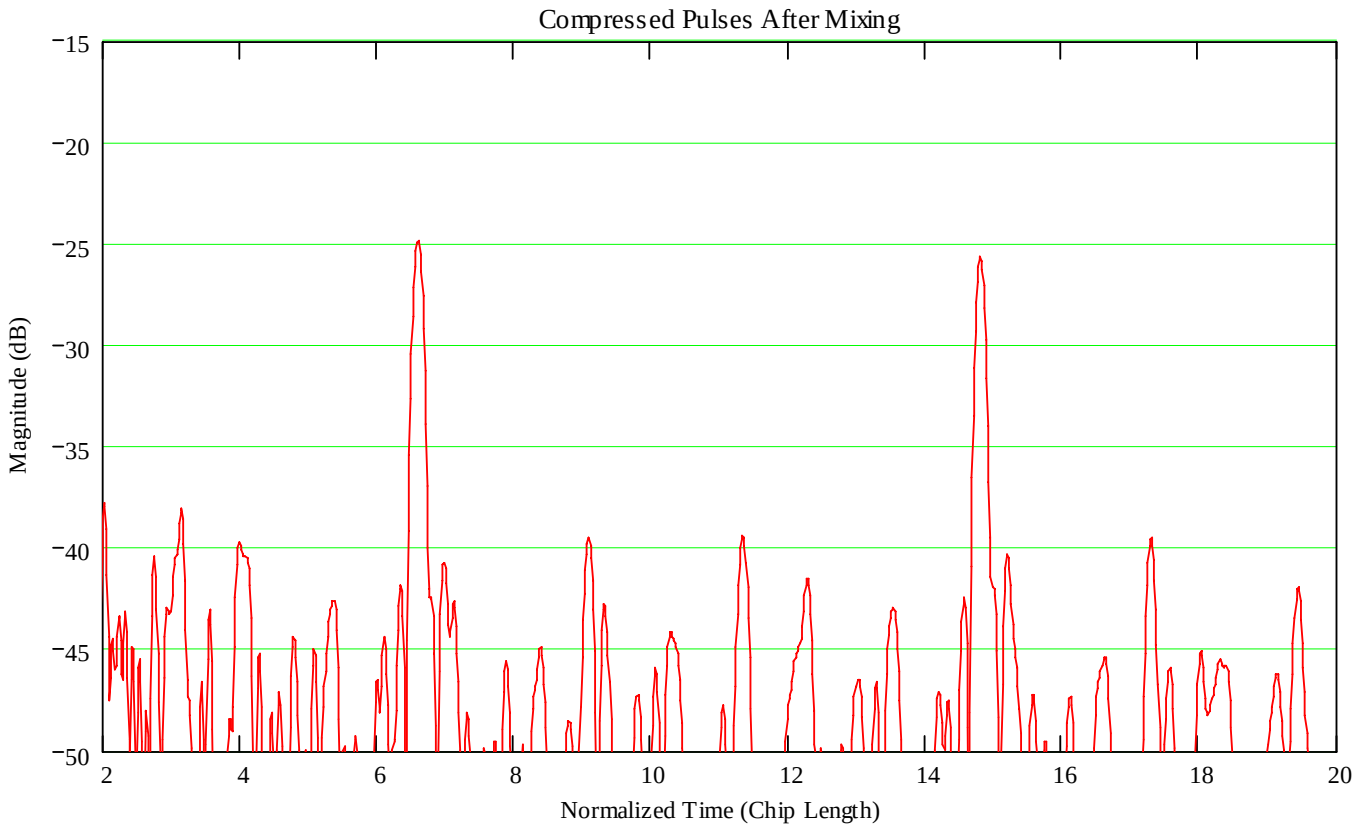
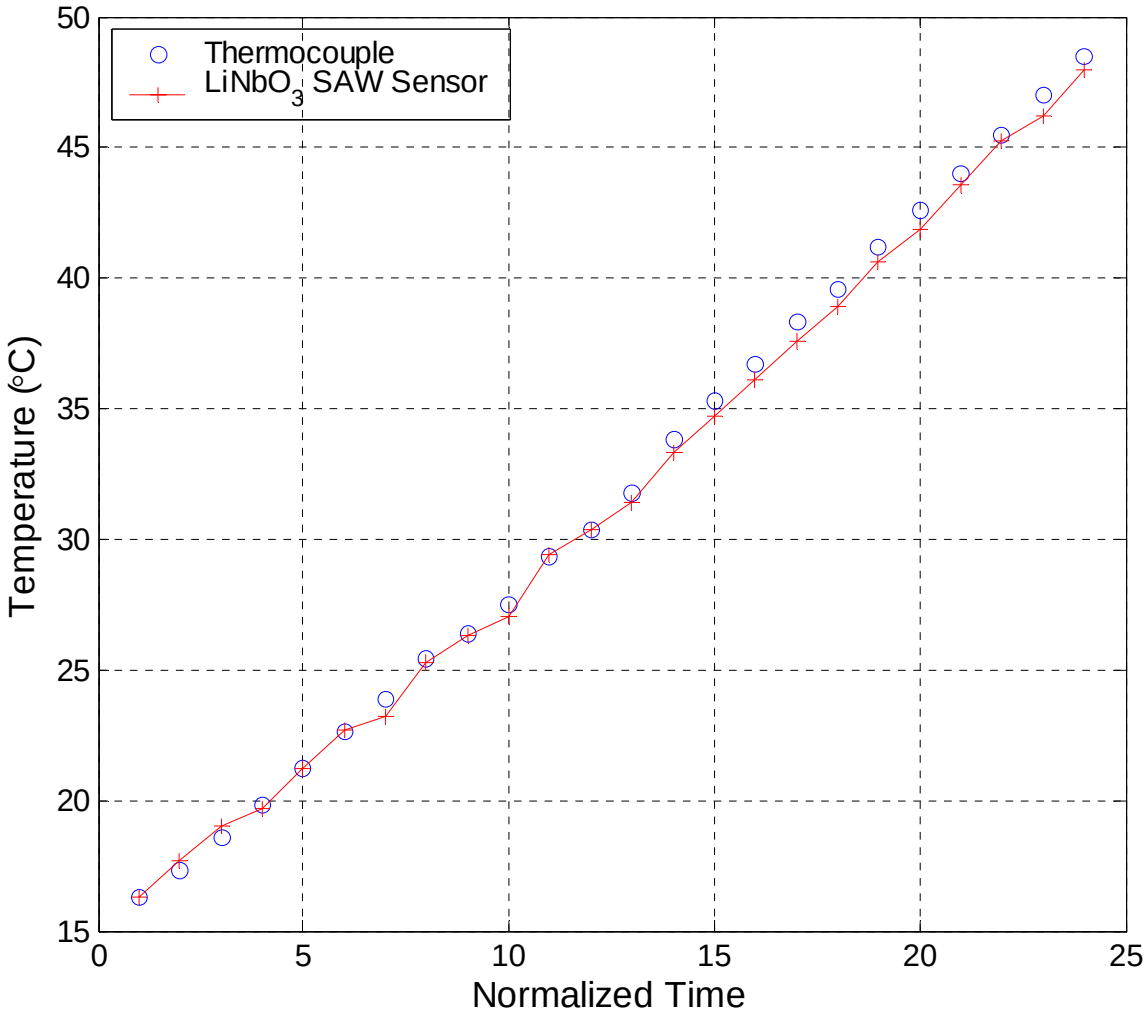
- Differential delay line structure
- Temperature related to difference in correlation peak delays



Temperature sensor vs. thermocouple:

(Data courtesy of UCF)



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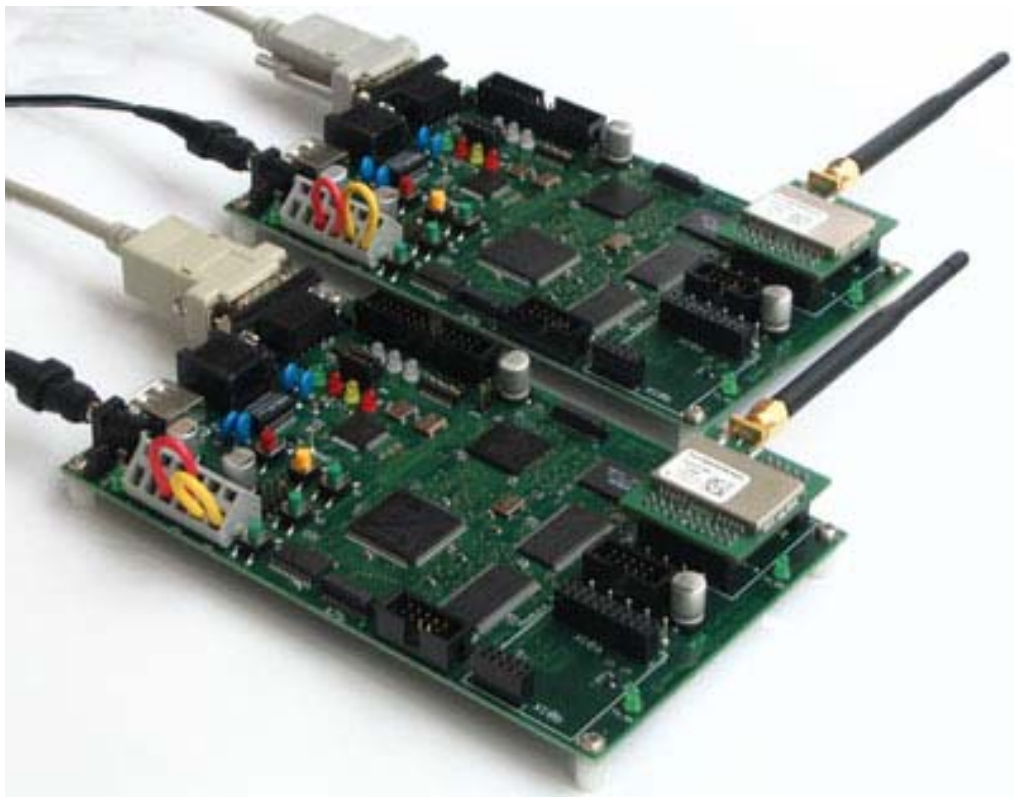
Interrogation system:

- Chirp spread spectrum radio
- Mixed signal IC available from Nanotron Technologies



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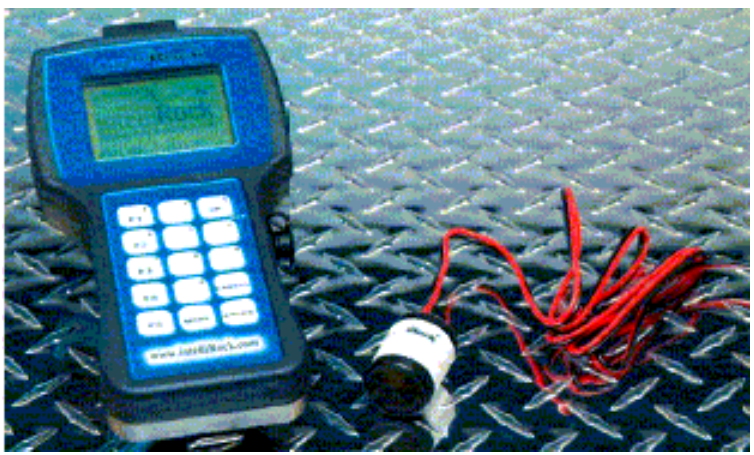
Spinoff application:

Concrete Maturity Monitor

- Temperature during cure determines strength
- In-situ real-time monitor
- Financial and safety incentive for contractor
- Low frequency for RF propagation
- Competitive technologies: wired & wireless



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Concrete Maturity Monitor, contd.:

Acoustic wave sensor advantages

- Wireless measurement
- Unique sensor ID and measurement
- Low cost (<1/10 current products)
- Totally passive
- Unlimited lifetimes

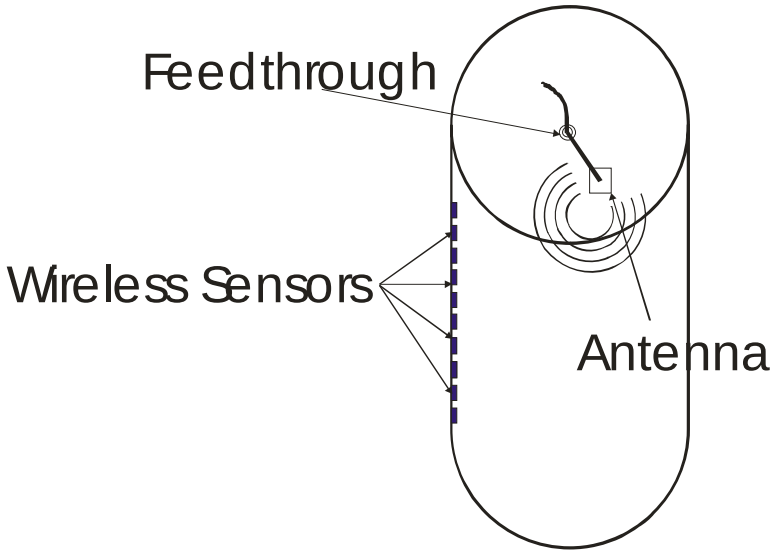
Challenges

- Limited range
- Networking/communication protocols
- Measurement of other parameters (humidity, stress/strain, corrosion)

Cryogenic liquid level monitoring:

Near “ideal” application:

- Tank provides Faraday cage
- FCC considerations relaxed:
  - Higher power radiated
  - Operating frequency
- Moderate number of sensors
- SAW sensor advantages:
  - Single tank penetration
  - Operate at cryogenic temperatures
  - Low cost



Cryogenic liquid level monitoring – contd.:

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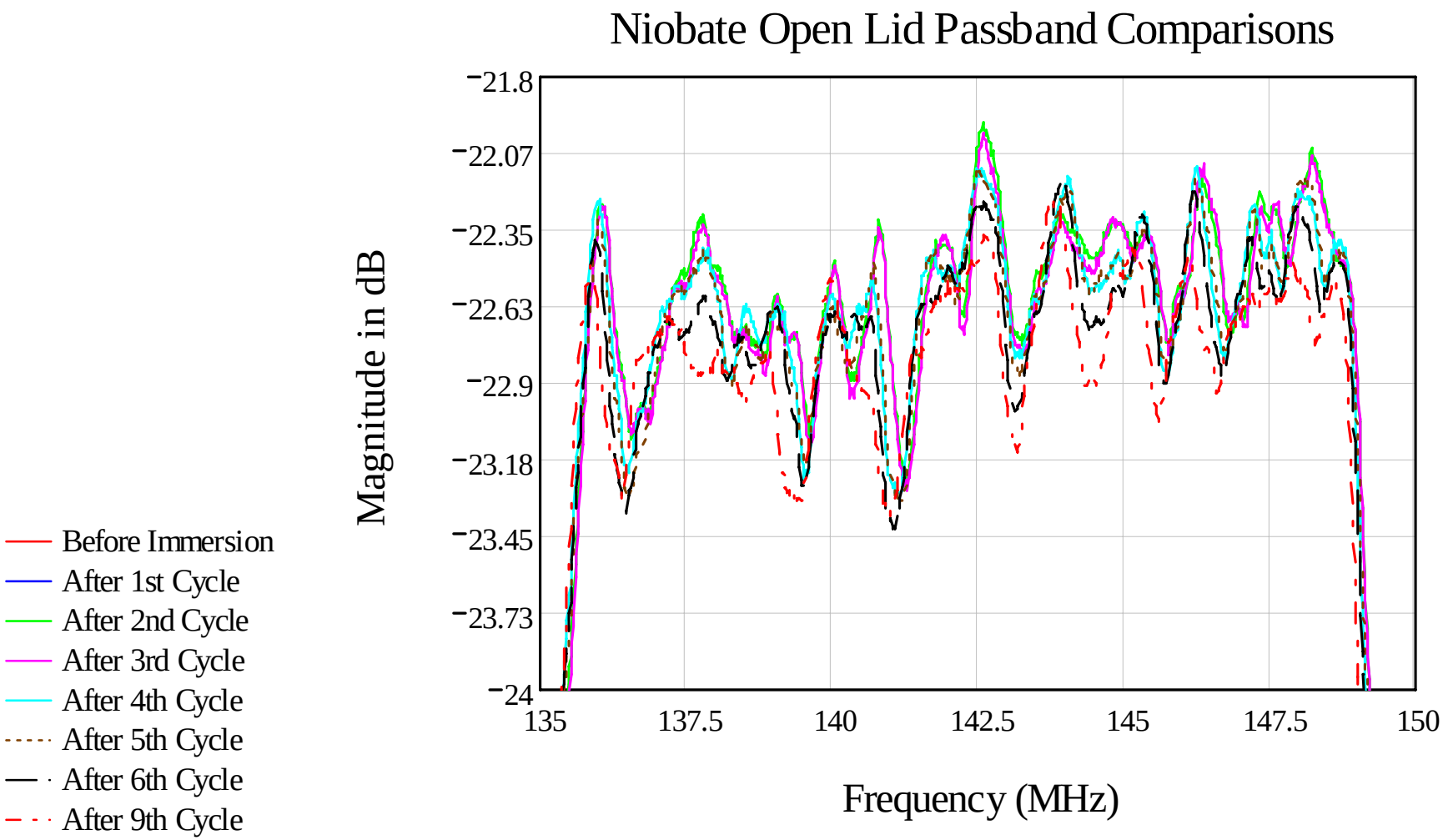
Phase I demonstrated:

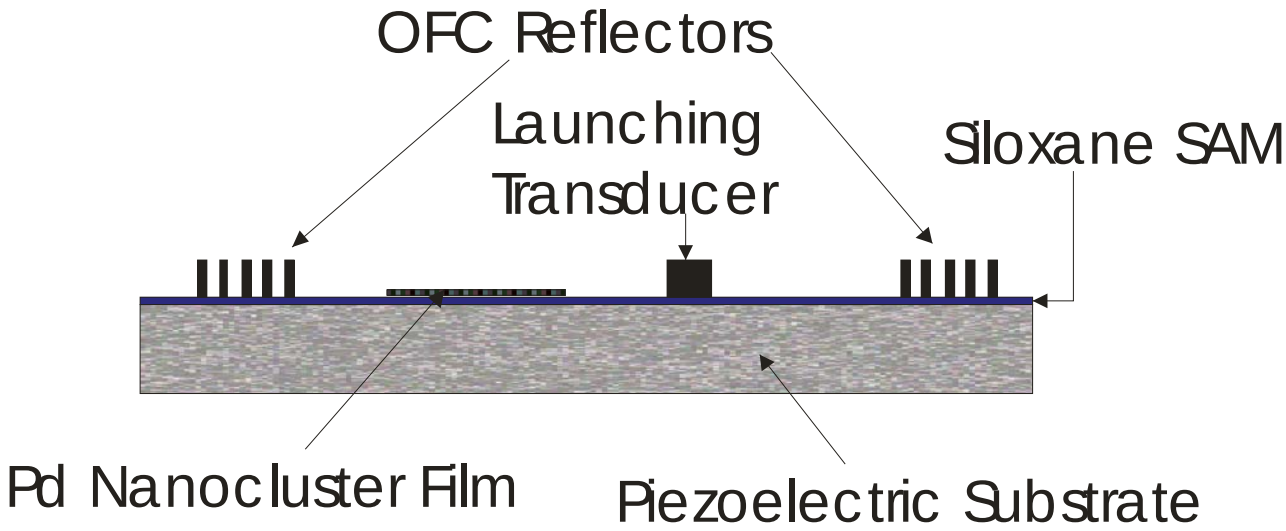
- Mechanical robustness of SAW devices
  - Standard commercially manufactured devices tested
  - Survived thermal cycling to liquid nitrogen temperatures
- Successful device operation
  - Turn-off times < 1 second
  - Device recovery in 4-6 seconds
- Current devices limited to low pressure tank applications (<150 psi)

Cryogenic liquid level monitoring – contd.:

(Courtesy of UCF)



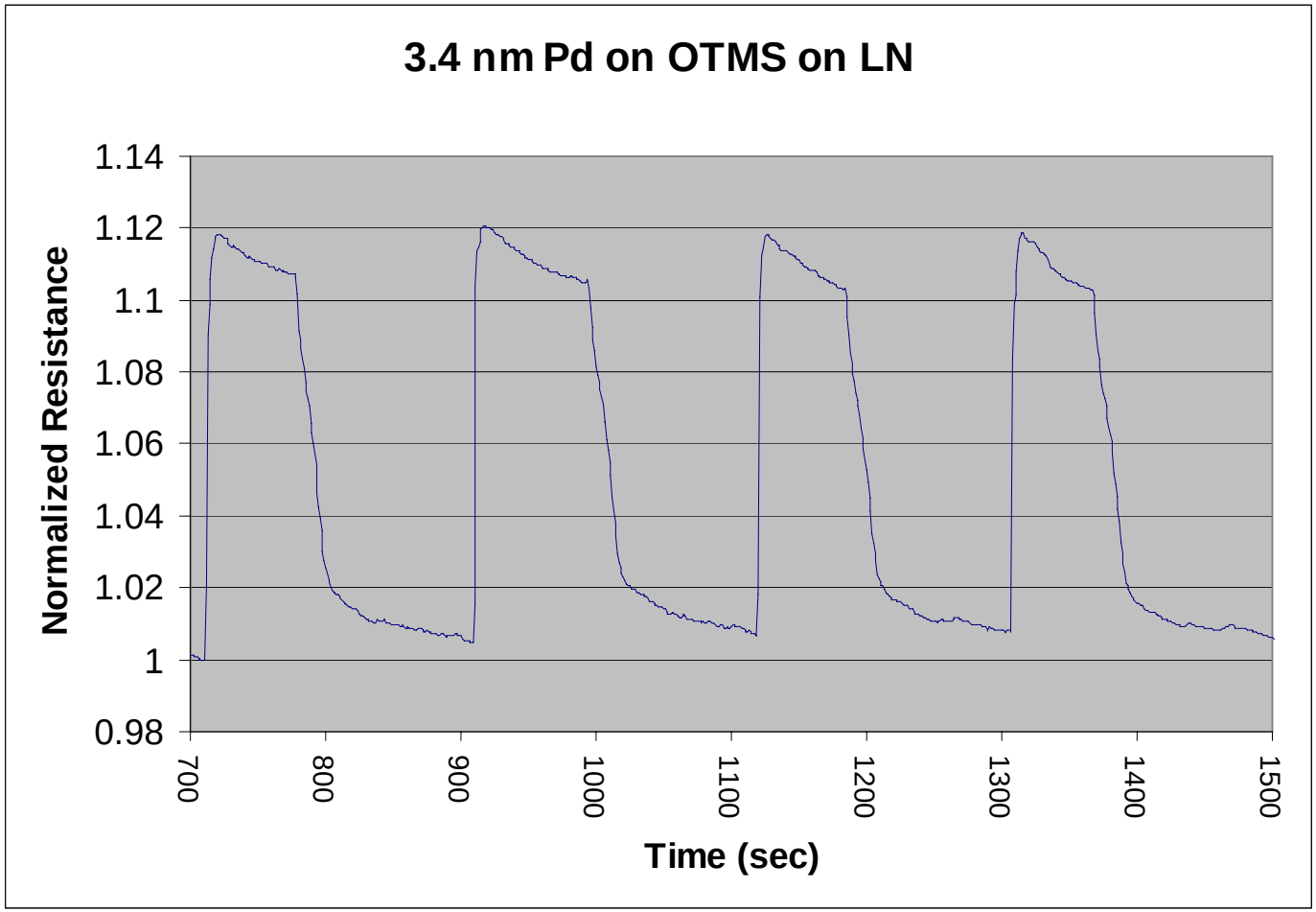
Hydrogen leak detection:



Phase I demonstrated:

- SAM formation on piezoelectric substrates
- Pd deposition and nanocluster formation
- Process compatibility with OFC device fabrication
- Rapid, reversible change in film conductivity w/H_2 exposure
- Change in acoustic delay due to conductivity change

Hydrogen leak detection – contd.:



Rapid, room temperature reversible hydrogen response

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Summary:

- Passive wireless acoustic wave sensors feasible for:
  - Temperature sensing
  - Cryogenic liquid level sensing
  - Hydrogen sensing
- For all of the above, product attributes need to be defined:
  - Size
  - Cost
  - Performance
  - Operating environment
  - Communications/networking protocol
- Input on specific applications would be welcomed

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ASR&D is poised to provide innovative, acoustic wave sensor solutions that meet the emerging needs of our customers.

For further information, or to discuss your specific sensor requirements, please contact:

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