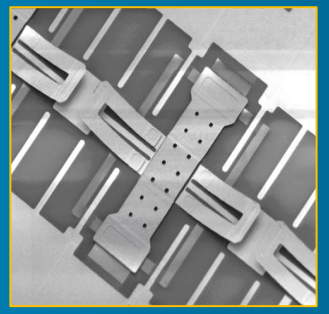
Sensitivity Comparison between Surface Acoustic Wave and Lamb Acoustic Wave Hydrogen Gas Sensors



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Overview

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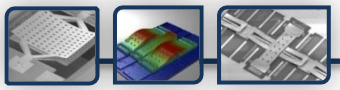
2. Methodology
3. Results and discussions
4. Conclusion and future work



Introduction

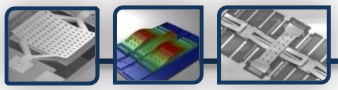
- Several applications for hydrogen gas sensors
  - Automation
  - Transportation
  - Environment
  - Health
  - Agriculture

  → Resulting in an increasing demand on more sensitive and more reliable hydrogen gas sensors

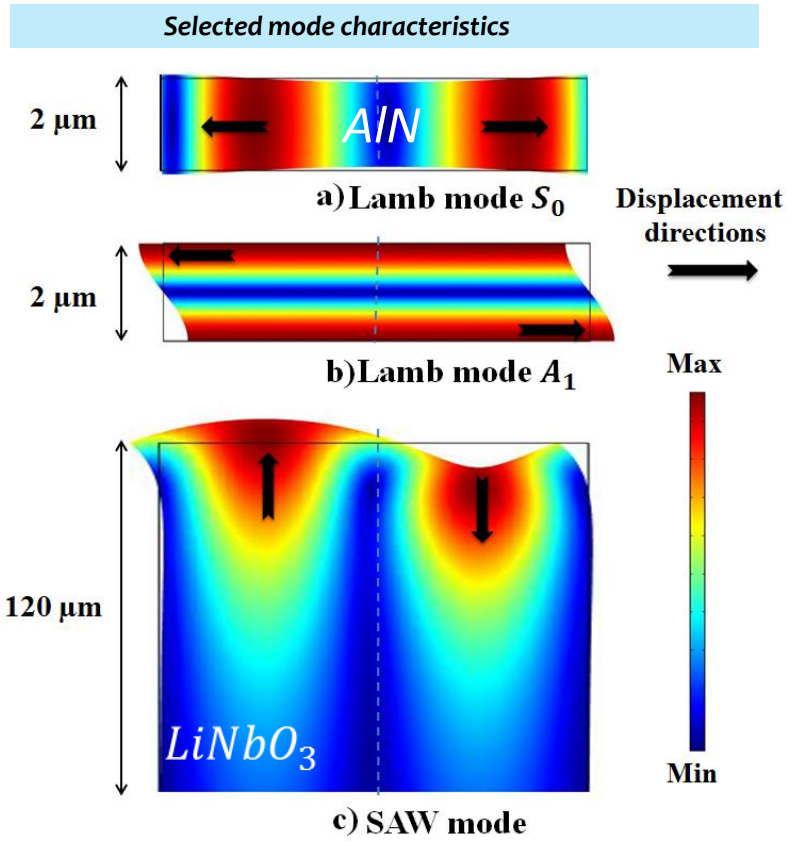
- Currently, acoustic technology based on Rayleigh mode (SAW) is often used
  - Reliable
  - Passive
  - Robust
  - Low fabrication cost

- Explore new technology based on Lamb waves
  - Sensitivity comparison with technology based on Rayleigh wave

- Sensitive layer: Palladium (Pd)
  - High hability to interact with hydrogen



Methodology



- S_0 Lamb mode
  - Low frequency
  - Symmetric
  - Compression or extension along the propagation direction
- A_1 Lamb mode
  - High frequency
  - Anti-symmetric
  - Shearing in the thickness direction
- SAW mode
  - High and Low frequencies
  - Elliptic displacement in the sagittal plane and is evanescent in the thickness of the medium

Methodology

Sensitivity comparison method

Parametric study with Comsol based on simultaneous variations of Palladium sensitive layer propeties

Density variation of $\pm 5\%$

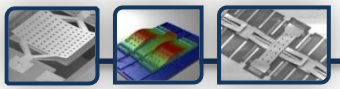
Young's modulus variation of $\pm 20\%$

Frequency determination for each study

Relation determination between f, E and ρ

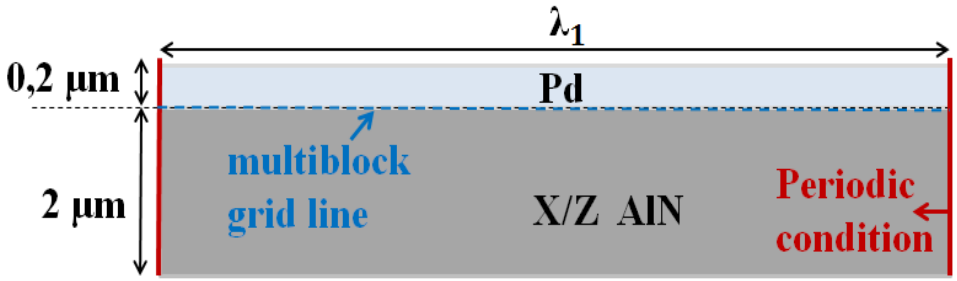
$$f = f_0\left(1 + b\left(\frac{E - E_0}{E_0}\right) + c\left(\frac{\rho - \rho_0}{\rho_0}\right) + d\left(\left(\frac{E - E_0}{E_0}\right)\left(\frac{\rho - \rho_0}{\rho_0}\right)\right)\right)$$

- 3% hydrogen concentration
- Curve fitting method
- Reduced equation to compare relative sensitivities

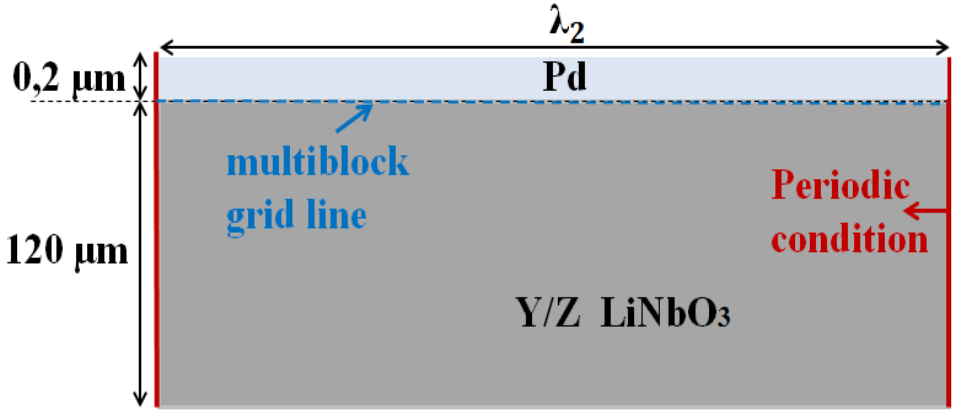


Methodology

Finite Element Model



a) Lamb mode



b) SAW mode

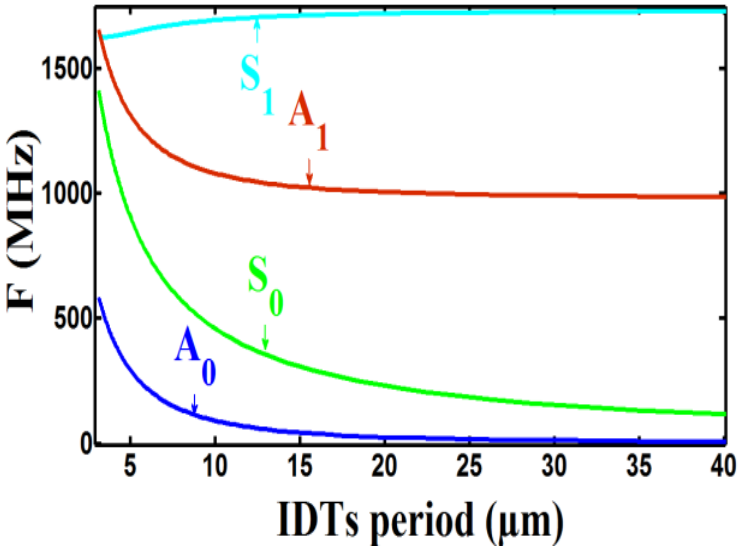
- Models used
  - Piezoelectric
  - Linear elastic
  - Electric
- Mesh
  - Multiblock
  - Conformal
- Boundary conditions
  - Floquet periodic

- Frequency Band Identification

Sensitivity study in ISM bands:

433 MHz – 435 MHz
902 MHz – 928 MHz

Dispersions curves of Lamb waves in 2 µm ZX AlN plate



Modes Selected	ISM Band (MHz)	Period (µm)	Wavelength (µm)
S0	433.05 – 434.79	10	20
A1	902 – 928	20	40
SAW	433.05 – 434.79 or 902 - 928	4 or 1.5	8 or 3

Results and discussions

Reduced equation for sensitivity study: $$f = f_0\left(1 + b\left(\frac{E - E_0}{E_0}\right) + c\left(\frac{\rho - \rho_0}{\rho_0}\right) + d\left(\frac{E - E_0}{E_0}\right)\left(\frac{\rho - \rho_0}{\rho_0}\right)\right)$$

- ***Sensitivity comparison***

Between S_0 and Rayleigh mode → 430 MHz ISM Band

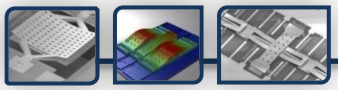
Mode sensitivity	b	c	d
S_0	0.0321	-0.1529	0.0027
Rayleigh	0.0421	-0.1070	0.0071

Mode	f_0 (MHz)	f with 3% hydrogen concentration (MHz)	Frequency shift (%)
S_0	476	476	0
Rayleigh	442	440	0.45

Between A_1 and Rayleigh mode → 920 MHz ISM Band

Mode sensitivity	b	c	d
A_1	0.0293	-0.1941	0.0195
Rayleigh	0.0774	-0.2130	0.0078

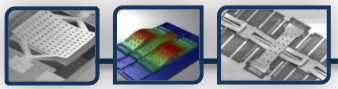
Mode	f_0 (MHz)	f with 3% hydrogen concentration (MHz)	Frequency shift (%)
A_1	1154	1155	0.09
Rayleigh	1082	1075	0.65



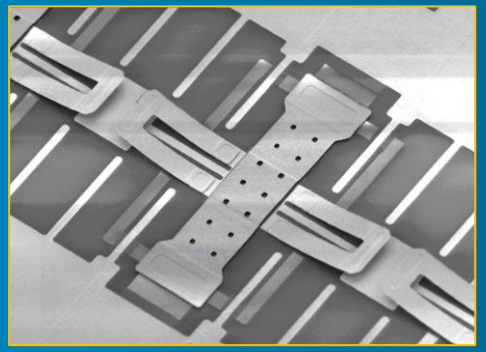
Conclusion and future work

To a 3% hydrogen concentration

- ✓ Rayleigh mode is more sensitive to changes in Pd stiffness than the S_0 mode
- ✓ S_0 mode is more sensitive to the mass loading effect than the Rayleigh mode
- ✓ Rayleigh mode is more sensitive to the simultaneous stiffness and mass variations than the Lamb waves.
- Explore other acoustics modes.
- Other comparisons to determine the influence of hydrogen concentration.
- Validation of theoretical results by experiments



Thank you !!!



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Chaire de recherche UQTR sur les microsystèmes RF pour les technologies de capteurs de gaz

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