Design of FIDT for 3D Analysis of MEMS Based Gas Sensor Using SAW Technology

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1. INTRODUCTION

SAW
Surface Acoustic Wave

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2. APPLICATIONS

**Industry:** Passive wireless measurement of Temperature, Pressure, Strain, Vibrations.

**Energy:** Switch gear temperature monitoring, Wind turbine generator monitoring, Bearing Temperature Control in Electrical equipments.

**Power Plant:** Detection of dangerous gases like sulphur dioxide near chimney/ stack.

**Communication:** Mobile phones, as filters, oscillators, resonators, RFID sensors etc.

**Research:** Microfluidics, micropumps, micromixers, micro actuators, LOC, Inkjet Droplet based applications.

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**Chemical Plants:** Detection of gases like CO₂, CO, SO₂, O₂, O₃, H₂, Ar, N₂, NH₃ & volatile organic gases like carbon tetrachloride & trichloroethylene, etc.

**Home Appliances:** Cookware wireless monitoring, Wireless food probes, Wireless temperature control on rotating parts.

**Biomedical:** Patient monitoring / diagnostic sensors for lung cancer, biomarkers, MRI etc.

**Laboratory:** pH Levels, Biochemical sensors.

**Automation:** Production line monitoring, Conveyors tunnel oven, Roll temperature control.

**Automobile:** Humidity, wing deflection controlling, IVHM in Aerospace / Space vehicles.

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3. SIGNIFICANCE

- Passive,
- Wireless,
- Reliability,
- Portability,
- Ruggedness,
- Light Weight,
- Miniature size,
- High sensitivity,
- Faster response,
- Simplistic design,
- Mass- production,
- Variety of measurable phenomena.

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4. THEORY OF OPERATION

Components:

1. IDT, 2. Sensitive film, 3. Piezoelectric material
SURFACE ACOUSTIC WAVE GAS SENSOR

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5. COMSOL Multiphysics

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6. Model Design

Conventional 3D Model

3D cut model

2D Base Model

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Modeled SAW sensor design using FIDT

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**Materials:**

- Rectangular shaped electrodes made of **Aluminum**.
- Covered with **Polyisobutylene** (PIB) film.
- **Lithium Niobate** (LiNbO3) piezoelectric substrate.
- **Dichloromethane** (DCM)- CH2CL2 gas.

**Dimensions:**

- Substrate dimensions 6 μm x 4 μm x 1 μm
- PIB material of radius 1 μm, height 0.5 μm
- Electrode dimensions are 0.25 μm x 1 μm x 0.5 μm.

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<table>
<thead>
<tr>
<th>Description</th>
<th>Expression</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air pressure</td>
<td>$p$</td>
<td>101.325[kPa]</td>
</tr>
<tr>
<td>Gas constant</td>
<td>$R$</td>
<td>8.3145[Pa<em>m$^3$/(K</em>mol)]</td>
</tr>
<tr>
<td>DCM concentration in air</td>
<td>$c_{\text{DCM}}_{\text{air}}$</td>
<td>$100e-6<em>p/(R</em>T)$</td>
</tr>
<tr>
<td>Molar mass of DCM</td>
<td>$M_{\text{DCM}}$</td>
<td>84.93[g/mol]</td>
</tr>
<tr>
<td>PIB/air partition constant for DCM</td>
<td>$K$</td>
<td>30.346</td>
</tr>
<tr>
<td>Mass concentration of DCM in PIB</td>
<td>$\rho_{\text{DCM}}_{\text{PIB}}$</td>
<td>0.010534kg/m$^3$</td>
</tr>
<tr>
<td>Density of PIB</td>
<td>$\rho_{\text{PIB}}$</td>
<td>918.00kg/m$^3$</td>
</tr>
<tr>
<td>Young's modulus of PIB</td>
<td>$E_{\text{PIB}}$</td>
<td>10[Gpa]</td>
</tr>
<tr>
<td>Poissons ratio of PIB</td>
<td>$\nu_{\text{PIB}}$</td>
<td>0.48</td>
</tr>
<tr>
<td>Relative permittivity of PIB</td>
<td>$\varepsilon_{\text{PIB}}$</td>
<td>2.2</td>
</tr>
</tbody>
</table>

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7. Simulation

➢ Analysis of Surface Deformation.

➢ Calculation of Electrical Potential.

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Modes of propagation:

S0 LAMB MODE

A1 LAMB MODE

SAW MODE

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8. DISCUSSION

Deformed shaped plot of SAW model at Resonance.

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Deformed shaped plot of SAW model at Anti-Resonance.

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Electric potential distribution at Resonance.

Excerpt from the Proceedings of the COMSOL Conference 2015 PUNE.
Electric potential distribution at Anti-Resonance.

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### 9. RESULTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Focused IDT Model</th>
<th>Conventional Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Displacement at Resonance</td>
<td>2.2193 X 10(^{-3})</td>
<td>1.855 X 10(^{-3})</td>
</tr>
<tr>
<td>Surface Displacement at Anti-Resonance</td>
<td>4.7706 X 10(^{-3})</td>
<td>2.487 X 10(^{-3})</td>
</tr>
<tr>
<td>Electrical Potential at Resonance</td>
<td>5.9733</td>
<td>5.9748</td>
</tr>
<tr>
<td>Electrical Potential at Anti-Resonance</td>
<td>5.6031</td>
<td>5.3614</td>
</tr>
</tbody>
</table>

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10. CONCLUSION

- MEMS based SAW gas sensor is designed using Focused-IDT design for analysis of the resultant characteristics in a 3D model.

- FIDT design helps in concentration of more amount of acoustic energy on to the poly chemical coating layer.

- Enhanced results reflected the utility of this as an industrial gas sensor with better sensitivity.

- Significant to design new intense microacoustic sources, for instance for enhanced acouto-optical interactions.

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THANK YOU

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