Inflammatory Bowel Disease (IBD), comprising Crohn’s Disease (CD) and Ulcerative Colitis (UC), is a chronic inflammatory condition in the GI tract suspected to be caused by an unknown combination of genetic, microbiome, immune, and environmental factors. Pro-inflammatory cytokines IFN-γ and TNF-α inhibit intestinal ion transport channels, leading to an osmotic pressure imbalance and leakage of water and electrolytes through epithelial tissue. Inflammation linked to an increase in conductive ions and basal permeability of tissue surface.

**COMSOL Modeling and Spacing Optimization**

- Relative impedance contribution of mucosal tissue inversely proportional to electrode width
- Target depth increases linearly with respect to inner electrode spacing

**Sensor Fabrication**

- Use photomask to pattern sensors and deposit CIGS using electron-beam evaporator
- Parylene-C will serve as an insulation layer to protect traces from shorting

**Packaging**

- Negative mold cavity in Mold Electronics (MOLDER)
- Parylene-C mold would allow the impedance sensor strip to fold across the side wall of capsule.
- Negative molds for encapsulating capsule electronics in PDMS were 3D printed using Fused Filament Fabrication (FFF).

**RESULTS**

**Impedance Sensing Along an Agar Track**

<table>
<thead>
<tr>
<th>Concentration KCl (M)</th>
<th>Impedance Sensing at 10 kHz</th>
<th>Impedance with 20 gf and 70 gf Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>230.74±6.9</td>
<td>3400</td>
</tr>
<tr>
<td>0.1</td>
<td>97.0±1.1</td>
<td>2600</td>
</tr>
<tr>
<td>1</td>
<td>34.7±0.5</td>
<td>2000</td>
</tr>
</tbody>
</table>

**Significance:**

- Quantify impedance sensor response to no contact with agar in presence and absence of liquid and varying applied forces
- Evaluate impedance sensor measurement drift over time
- Assess impedance sensor response in various ion concentrations to simulate electrolyte loss through inflamed mucosal tissue

**Future Work**

- Quantify target depth with respect to electrode width and spacing to validate FEM model
- Use sensors to characterize permeability of porcine intestinal tissue
- Further investigate the effects of small bowel environmental conditions, such as contact pressure and intestinal viscosity, on in vitro capsule and implant tests
- Consider effect of speed or acceleration on impedance sensor results

**ACKNOWLEDGEMENTS**

This work was supported by the National Science Foundation ECCS #1339328, and NCS #1526793. The authors would like to thank NSF and the Translational Research Foundation (TRF) for travel support and acknowledge TeraSpin, Inc., and its facilities.

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**REFERENCES**