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Non-Toxic Liquid-Metal 2-100 GHz MEMS Switch

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Non-Toxic Liquid-Metal 2-100 GHz MEMS Switch
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1. Motivation
The first liquid-metal shunt capacitive switch has been demonstrated
- for high power applications
- < 0.05 dB insertion loss at 2-20 GHz
- >20 dB isolation at 20 GHz

However, the liquid metal used is mercury which is toxic and not environmental friendly

Objective:
- Search potential substitutions for mercury
- Design switches with comparable RF performance

2. Design Idea
Replace mercury by non-toxic liquid metal — Galinstan (Ga/In/Sn)

<table>
<thead>
<tr>
<th>Property</th>
<th>Mercury</th>
<th>Galinstan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity (S/m)</td>
<td>1.04x10^6</td>
<td>2.3x10^6</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>38.83</td>
<td>-19</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>356.73</td>
<td>1300</td>
</tr>
<tr>
<td>Viscosity (Pa s)</td>
<td>1.53x10^-6</td>
<td>2.4x10^-6</td>
</tr>
<tr>
<td>Density (g/cm^3)</td>
<td>13.5</td>
<td>6.4</td>
</tr>
</tbody>
</table>

3. Galinstan Slug Movement
Challenge:
Galinstan oxides quickly in air
Its oxide adheres to almost every surface

Solution:
Immerse Galinstan in Teflon solution (Teflon AF)

4. Complete Device

5. RF Performance

Loss budget:

<table>
<thead>
<tr>
<th>Frequency [GHz]</th>
<th>CPW</th>
<th>CPW + PDMS</th>
<th>CPW + PDMS + Teflon</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>0.12</td>
<td>0.23</td>
<td>0.2</td>
</tr>
<tr>
<td>400</td>
<td>0.51</td>
<td>0.71</td>
<td>0.66</td>
</tr>
<tr>
<td>1000</td>
<td>0.81</td>
<td>1.7</td>
<td>1.28</td>
</tr>
</tbody>
</table>

Extracted switch loss

Insertion loss:
<0.5 dB up to 100 GHz including packaging

Teflon solution is transparent in the microwave region

Isolation:
>20 dB at 20-100 GHz
~180-nm Teflon solution layer between Galinstan and CPW