Effect of Bending on Flexible Temperature Sensors

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Background

Body Temperature Monitoring

- hypothermia
- heatstroke
- infectious diseases

Conventional Thermometers

- rigid
- bulky
- point measurements

Flexible Temperature Sensors

- wearable
- continuous real-time measurements

Laser-Induced Graphene

- mechanically flexible
- highly conductive
- electrical resistance decreases as temperature increases

Laser-Induced Graphene Sensors

- flexible LIG sensors
- deformation caused by bending on the performance of flexible temperature sensors

Objective

- Investigating the effect of mechanical deformation caused by bending on the performance of flexible LIG temperature sensors

R = \frac{\rho L}{A}

where
- R = resistance
- \rho = material resistivity
- L = length
- A = area

Methods & Results

Fabrication

- Design
- Laser Engraving
- Laser-Induced Graphene Sensors

Testing

- electrode
- voltmeter
- thermocouple

The resistance of the electrode at each temperature was recorded with every 5°C increase.

The experiment was repeated with the electrode bent.

Results

Not Bent / Flat:

<table>
<thead>
<tr>
<th>Trial</th>
<th>#1 (°C)</th>
<th>#2 (°C)</th>
<th>#3 (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>-0.001245</td>
<td>-0.0001018</td>
<td>-0.001045</td>
</tr>
<tr>
<td>R² value</td>
<td>0.9828</td>
<td>0.984</td>
<td>0.9845</td>
</tr>
<tr>
<td>Relative Standard Deviation</td>
<td>-11.2334</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bent:

<table>
<thead>
<tr>
<th>Trial</th>
<th>#1 (°C)</th>
<th>#2 (°C)</th>
<th>#3 (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>-0.1155</td>
<td>-0.07599</td>
<td>-0.07998</td>
</tr>
<tr>
<td>R² value</td>
<td>0.9892</td>
<td>0.9814</td>
<td>0.9442</td>
</tr>
<tr>
<td>Relative Standard Deviation</td>
<td>-24.0602</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While the resistance of the three electrodes were each across different ranges, they had consistent slopes.

Bending electrodes increased overall resistance, slope, and relative standard deviation. Nonetheless, the graphs maintained a linear trend.

References


Future Directions

- Test more complex deformations such as bending + stretching and twisting on laser-induced graphene temperature sensors
- Compensate for changes in resistance by employing a back-to-back design
- Use a more flexible substrate than polyimide film such as polydimethylsiloxane (PDMS).

Acknowledgements

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Conclusion

- Bending laser-induced graphene temperature sensors caused an increase in overall resistance and a greater slope.
- Still, the sensors were able to maintain a nearly linear decrease in resistance with increase in temperature.
- Laser-induced graphene based temperature sensors are able to give reliable measurements in temperature when mechanical deformation is caused by bending.