2.5D direct laser engraving of silicone micro-fluidic channels for stretchable electronics

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Concept.

Laser ablation as a means of engraving microchannels in silicone rubbers.

Combine with RT liquid conductor. Stretchable conductive traces can be created within a single working day.

2,5D.

Vary laser power or apply multiple passes during a single engraving production step. 2,5D structures are achieved.

e.g. capacitive pressure sensor

Further possibility: buried vias.

Use cases.

Whenever application calls for traces which are:

- single or few in number
- finely detailed
- low in resistance
- conformable
- self-healing

Component based solution not an integrated production method.

Stretchable electronics.

Stretchability.

 Mostly limited by silicone material properties.
Necking induces resistance change.
Self-healing capacity after channel pinch-off.

Applications.

Soft robotics
On-skin electronics
Wearables
Scientific results

Laser P vs passes vs depth

<table>
<thead>
<tr>
<th>POWER SET TO 10%</th>
<th>10x10xn</th>
<th>Depth</th>
<th>Calc depth</th>
</tr>
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<tr>
<td>1</td>
<td>74</td>
<td>78.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>132</td>
<td>132.7</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>191</td>
<td>187.3</td>
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<td>241.9</td>
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</tr>
<tr>
<td>5</td>
<td>299</td>
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<td>6</td>
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<td>7</td>
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<tr>
<td>8</td>
<td>398</td>
<td>460.1</td>
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</table>

Conclusions:

• Laser gets out of focus with engravement depth
  • higher power = deeper cuts with each pass = faster roughness increase with each pass

• More or less linear correlation (ignoring roughness)

• First passes are in focus; nice and smooth
  • do not modulate engravement depth by number of passes

➔ directly use laser power to set engravement depth
Scientific results

Mechanical characteristics of conductive encapsulant

Conclusions:
• Ag PU has a much lower starting resistance
• Ag PU does not adhere well at all
• Ag epoxy delaminates on untreated PDMS, explains ‘favorable’ measurement
• Ag epoxy makes for a stiffer match but adheres more or less ok when PDMS was pretreated with corona