Large Stroke Actuators for Adaptive Optics

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Abstract

A 3-dimensional MEMS fabrication process to prototype large stroke (>10 μm) actuators as required for use in future adaptive optics systems in astronomy and vision science is presented. The Electrochemical Fabrication (EFAB™) process creates metal micro-structures by electroplating multiple, independently patterned layers. The process has the design freedom of rapid prototyping where multiple patterned layers are stacked to build structures with virtually any desired geometry, but in contrast has much greater precision, the capability for batch fabrication and provides parts in engineering materials such as nickel. The design freedom enabled by this process has been used to make both parallel plate and comb drive actuator designs that can have large vertical heights of up to 1 mm. As the thickness of the sacrificial layers used to release the drive actuator designs can have large vertical heights of up to 1 mm. As the thickness of the sacrificial layers used to release the actuator is specified by the designer, rather than by constraints of the fabrication process the design of large-stroke actuators is straightforward and does not require any new process development.

Objective

- Create parallel plate and comb drive actuator designs
- Obtain a Pull-in Voltage <= 200V
- Obtain a large-stroke > 10μm

Requirements

- Large-Stroke (>10μm)
- Low-Voltage (~<200V)
- Large-bandwidth (10KHz)
- Linear Response

Sample Cross-Section

Figure 4 & 5: Top view of parallel plate cross sections. Dimensions shown are in μm.

Expected Results

Table 1: Pull-in voltage for parallel plate actuators

<table>
<thead>
<tr>
<th>Stroke (μm)</th>
<th>K_eff (N/m)</th>
<th>V_p (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>104</td>
<td>96</td>
</tr>
<tr>
<td>500</td>
<td>316</td>
<td>277</td>
</tr>
<tr>
<td>400</td>
<td>1745</td>
<td>1006</td>
</tr>
</tbody>
</table>

Table 2: Pull-in voltage for comb drive actuators

<table>
<thead>
<tr>
<th>Stroke (μm)</th>
<th>K_eff (N/m)</th>
<th>V_p (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1280</td>
<td>2</td>
<td>55</td>
</tr>
<tr>
<td>1120</td>
<td>6</td>
<td>79</td>
</tr>
<tr>
<td>960</td>
<td>10</td>
<td>121</td>
</tr>
<tr>
<td>800</td>
<td>203</td>
<td>203</td>
</tr>
</tbody>
</table>

Conclusion

We have designed and fabricated two designs for large-stroke actuators using the EFAB process. The first design is a hexagonal ganged parallel plate actuator with 4.67 μm of stroke. The second design is a rectangular comb drive actuator with 24 μm of stroke. The pull-in voltage for the hexagonal actuators is in good agreement with analytical calculations. We have measured a stroke of 28 μm for the largest comb drive actuators. Both the hexagonal parallel plate actuators and the rectangular comb drive actuators show signs of stress related deformations that are now being characterized with non-contact profilometry.

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References

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