Design and Finite Element Analysis of Electro Thermal Complaint Actuators

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Excerpt from the Proceedings of the 2011 COMSOL Conference in Bangalore
Electro thermal actuators

• Electro thermal actuators are capable of providing larger displacements compared to electrostatic actuators. [1-12]

• Thermal actuators are of two types.
  – Bimorph thermal actuator
  – Single material Electro Thermal Compliant (ETC) actuator.[1]

• Bimorph actuators are composite structure made of two or more layers of different materials.[2]

• In this work ETC device has been studied for different geometry.
Design–Displacement Improvement

• Designs
  – Rectangular beam without gold layer
  – Rectangular beam with gold layer
  – Tapered beam design 1 with gold layer
  – Tapered beam design 2 with gold layer.

• The gold layer deposition increases the displacement

• A maximum deflection of 38 μm is obtained with tapered beam design 2.
# Basic ETC Actuator

![Fig 1: Electro Thermal Actuator](image)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Dimension (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Total beam length; length of an element</td>
<td>200</td>
</tr>
<tr>
<td>L&lt;sub&gt;c&lt;/sub&gt;</td>
<td>Length of cold beam</td>
<td>160</td>
</tr>
<tr>
<td>g</td>
<td>Gap between cold and hot beam</td>
<td>2</td>
</tr>
<tr>
<td>t&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Hot beam width</td>
<td>2</td>
</tr>
<tr>
<td>t&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Cold beam width</td>
<td>15</td>
</tr>
<tr>
<td>L&lt;sub&gt;p&lt;/sub&gt;</td>
<td>Length of pads</td>
<td>66</td>
</tr>
<tr>
<td>L&lt;sub&gt;m&lt;/sub&gt;</td>
<td>Length of anchors</td>
<td>56</td>
</tr>
<tr>
<td>W&lt;sub&gt;p&lt;/sub&gt;</td>
<td>Width of pads</td>
<td>50</td>
</tr>
<tr>
<td>W&lt;sub&gt;m&lt;/sub&gt;</td>
<td>Width of anchors</td>
<td>20</td>
</tr>
<tr>
<td>L&lt;sub&gt;c1&lt;/sub&gt;</td>
<td>Length of gold layer</td>
<td>150</td>
</tr>
<tr>
<td>t&lt;sub&gt;3&lt;/sub&gt;</td>
<td>Width of gold layer</td>
<td>9</td>
</tr>
</tbody>
</table>
## Material properties & COMSOL Model

### Table 2: Material Properties

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Material</th>
<th>Properties</th>
</tr>
</thead>
</table>
| 1     | Poly silicon | Young’s modulus: 169 [GPa]  
Poisson’s ratio: 0.3  
Coefficient of Thermal expansion: 2.568e-6 [1/K]  
Electrical Conductivity: 0.25e5 [S/m] |
| 2     | Gold     | Young’s modulus: 80 [GPa]  
Poisson’s ratio: 0.3  
Coefficient of Thermal expansion: 14.2e-6 [1/K]  
Electrical Conductivity: 45.6e6 [S/m] |
| 3     | Aluminum | Young’s modulus: 70 GPa  
Poisson’s ratio: 0.3  
Coefficient of Thermal expansion: 23.1e-6 [1/K]  
Electrical Conductivity: 35.5e6 [S/m] |

**Fig 2: COMSOL Model of an Electro Thermal Actuator**
Use of COMSOL Multiphysics

• Three coupled physics namely electric current conduction

• Heat conduction and

• Stresses due to thermal expansion.

• Bottom surfaces of the anchors are fixed in all degrees.

• DC voltage of 10 volts is applied at the bonding pads.

• Temperature of 300K is applied as the ambient temperature.
Results

1. Tip Displacement of Rectangular beam

For rectangular beam without gold layer a tip displacement of about 9 µm is obtained.
2. Current density of Rectangular beam
Tip Displacement of Rectangular beam with gold layer

For rectangular beam with gold layer a tip displacement of about 28 µm is obtained. The direction of deflection is towards hot beam side.
Tip Displacement of Tapered beam design 1 with gold layer

For Tapered beam design 1 with gold layer, a tip displacement of about 34 µm is obtained. The direction of deflection is towards thin beam.
Tip Displacement of Tapered beam design 2 with gold layer

For Tapered beam design 1 with gold layer, a tip displacement of about 38 µm is obtained. The direction of deflection is towards hot beam.
Conclusion

• A two dimensional finite element model of an electro thermal actuator was developed.
• The gold layer deposition increases the displacement and also the direction of deformation towards hot beam.
• Two more design as tapered beam design 1 and tapered beam design 2 is also developed.
• A maximum deflection of about 38 µm is obtained with tapered design 2.
References


