Platform Isolation Using Out-of-plane Compliant Mechanism

by Aryps Arevalo
PhD Candidate in Electrical Engineering
Computer, Electrical and Mathematical Sciences and Engineering (CEMSE)
King Abdullah University of Science and Technology

8th October 2014, Boston, MA, USA
Introduction

In this work we present the simulation of a platform that is isolated using micro-scale large displacement compliant mechanism called the Tsang suspension [1]. The Tsang suspension consist of a flat micro-plate anchored down by two springs on either side, which can rotate out-of-plane and maintain its vertical assembly by simple single-axis actuation.

Fig. 1 SEM image of fabricated and assembled SU-8 Tsang Suspension.

Figure 2: Illustration of a Tsang suspension layout with Spring Length (SL) = 200µm, Spring Width (SW) = 30µm, Number of Spring Beams (SB) = 4.
Introduction

- The world of Micro Electro Mechanical Systems (MEMS) is flat!
- Out-of-plane structures can help separate devices from the substrate, to provide good electrical and thermal isolation.
Tsang structures can be used in applications such as micro-mirrors [3], free-space optics [4-6] and RF systems [2, 7], amongst others. Several Tsang suspension can be attached to a common plate for electrical and thermal isolation of sensors [9,10].

Figure 4 Left: Out-of-Plane Dual Band (60 and 77 GHz) Antenna on Buckle Cantilever, using Polyimide and Gold for the metal layer [L. Marnat, A. Arevalo et al., IEEE TAP, 2013]. Right: Several Tsang suspensions (Silicon and Polyimide) hold an elevated platform with a 2 axis thermal accelerometer [3].
Use of COMSOL

• One of the challenges of Micro Electromechanical Systems (MEMS) is the direct measurement of their mechanical properties, due to the fact that the device’s dimensions are small, typically <1mm.
• We deal with a large displacement compliant mechanism with torsion.
• Complex to model analytically.
• Common solution is to use nonlinear finite element modeling.
The first design parameters investigated were: the spring length (SL), the spring width (SW), and the number of spring beams (SB).

Figure 5 Representation of the parameters that were varied.
Simulation Design

- Design parameters used in COMSOL

Figure 6 Platform configuration design
Simulation Results

- Scanning Electron Microscopy (SEM) was used to capture the top-view of the assembled structures.
- The simulation had good agreement with the experimental assembly.

Figure 7: Top view of simulation and SEM image. An example comparison angle, “theta-a” and “theta-b”. And displacement to vertical “d” are shown.
The direction of the spring reaction force changes as the rotation angle of the plate increases. This reaction force initially attempts to restore the plate to its original flat position. A critical "toggle point" (change-over point) is reached, where the reaction force begins to act towards the substrate. (Self locking mechanism)

Figure 8

a) Angle of rotation versus lateral displacement of the Tsang suspension with SL = 200 µm, SW = 30 µm, SB = 4.

b) Spring reaction force versus lateral displacement, with same design parameters.
The structures were parametrically modeled in COMSOL. Materials and boundary conditions were selected to represent the assembly process. The highly nonlinear option was selected to contemplate the large displacement.
## Simulation Results

<table>
<thead>
<tr>
<th>Material</th>
<th>Final Platform Height (µm)</th>
<th>Von Misses Stress (MPa)</th>
<th>Tensile strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI 2611</td>
<td>405</td>
<td>293</td>
<td>350</td>
</tr>
<tr>
<td>SU-8</td>
<td>404</td>
<td>71.8</td>
<td>73.3</td>
</tr>
<tr>
<td>Polysilicon</td>
<td>404</td>
<td>5748</td>
<td>1200</td>
</tr>
</tbody>
</table>

Figure 10 Left: Von Mises Stress vs Lateral Assembly Displacement graph. Right: Isometric View of the simulated assembly showing the von Mises Stress.

King Abdullah University of Science and Technology
Conclusions

• We have used COMSOL to simulate the assembly of an out-of-plane compliant structure, which robustness and stability heavily depends on the dimensions and materials properties of the spring structures used.
• Polyimide and SU-8 are adequate materials for this design.
• Polysilicon structures are likely to fail with the proposed design, but design parameter variation can be evaluated.
Thank You!
References


Questions?