Platform Isolation Using Out-of-Plane Complaint Mechanisms

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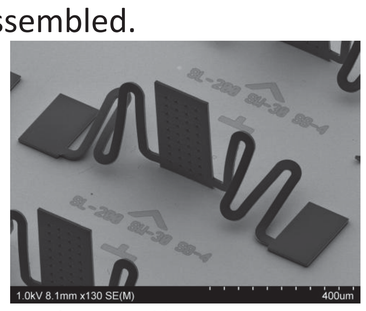
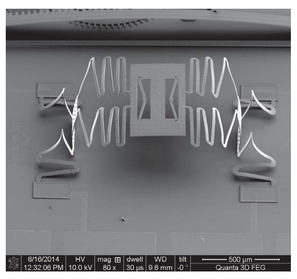
Introduction

- Tsang suspensions are large displacement compliant mechanisms that can be assembled into out-of-plane configurations [1].
- They consist of a flat micro-plate anchored down by two springs on either side, assembled by a simple single-axis actuation.
- Several Tsang suspensions can be attached to a common plate, which is elevated from the substrate when the suspensions are assembled.

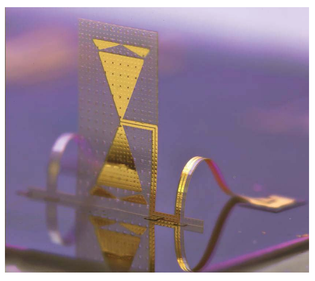




Left: SEM of an assembled SU-8 Tsang Suspension. Right: SEM of an assembled elevated platform, supported by two Tsang suspensions.

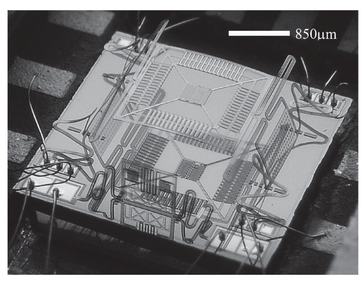
- The world of Micro Electro Mechanical Systems (MEMS) is flat! Out-of-plane structures can help separate devices from the substrate, providing good electrical and thermal isolation:

Antennas



Out-of-plane antenna on a buckled cantilever plate, in gold and Polyimide [2].

Thermally-isolated sensors

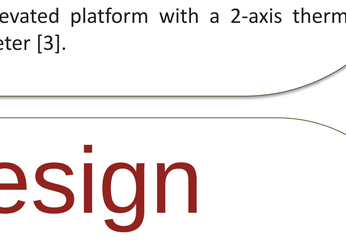


Several Tsang suspensions (Silicon and Polyimide) hold an elevated platform with a 2-axis thermal accelerometer [3].

Simulation Design

- We want a better understanding of the mechanical performance and behavior of the platform elevated by Tsang suspensions.
- Because of their size, MEMS mechanical properties are difficult to measure directly.
- Large-displacement compliant mechanisms with torsions are complex to model analytically. Nonlinear finite element modeling is a common solution.

Devices with the following design parameters were drawn and modeled in COMSOL:



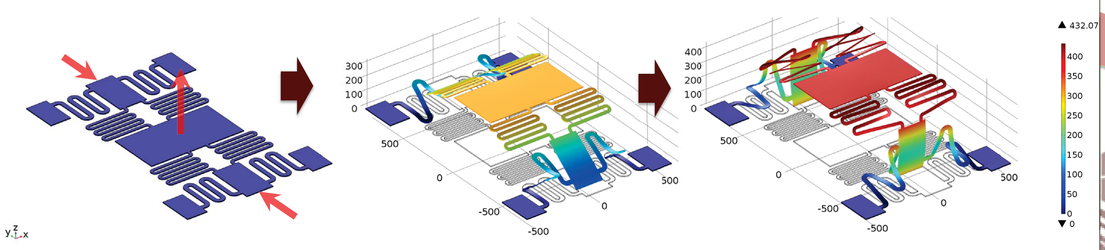
List of material properties used.

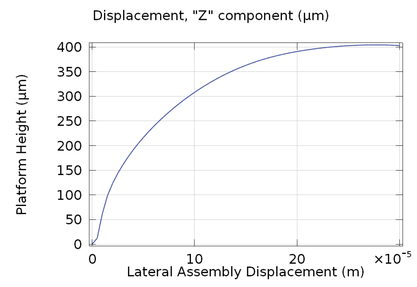
Material	Young's Modulus (GPa)	Poisson's Ratio	Tensile Strength (MPa)	Ref
Polyimide PI 2611	8.5	0.34	350	PI 2611 Data Sheet
SU-8	2	0.22	73.3	SU8 Data Sheet
Polysilicon	160	0.22	1200	[15]

- Assembly actuation simulated by applying a displacement boundary condition on the lower edge of the platform.
- Automatic tetrahedron mesh tool.
- SPOOLES solver with (i) highly nonlinear and (ii) large deformation.

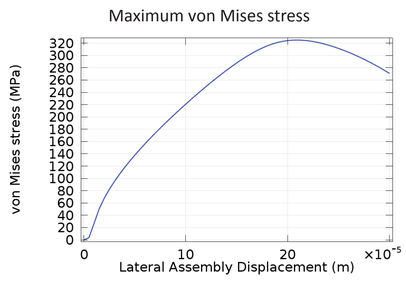
Simulation Results

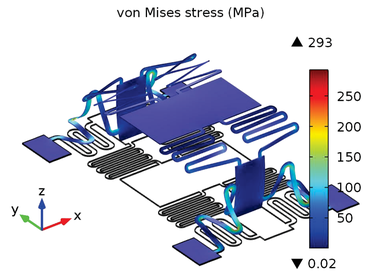
Displacement of the platform throughout assembly





Von Mises stress throughout assembly.





Results for 3 different simulated materials.

Material	Final Platform Height (µm)	Von Misses Stress (MPa)	Tensile strength (MPa)
Polyimide PI 2611	405	293	350
SU-8	404	71.8	73.3
Polysilicon	404	5748	1200

Conclusions

- We have used COMSOL to simulate the assembly of an out-of-plane compliant structure, whose robustness and stability heavily depends on the dimensions and materials properties of the springs.
- Polyimide and SU-8 are adequate materials for this design.
- Polysilicon Structures are likely to fail with this particular design but one can use this simulation to evaluate a larger number of design variations.

References

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2. L. Marnat, A. Arevalo Carreno, D. Conchouso, M. Galicia Martinez, I. Foulds, and A. Shamim, "New Movable Plate for Efficient Millimeter Wave Vertical on-Chip Antenna," 2013.
3. Tsang, See-Ho, et al. "Monolithically fabricated polymermems 3-axis thermal accelerometers designed for automated wirebonder assembly." *Micro Electro Mechanical Systems, 2008. MEMS 2008. IEEE 21st International Conference on*. IEEE, (2008)