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Simulation of a Micro-Scale Out-of-plane Compliant Mechanism

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Introduction

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

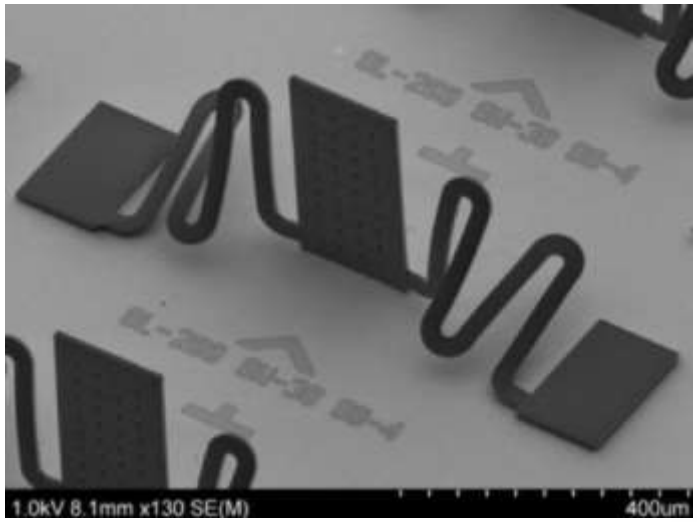


Fig. 1 SEM image of fabricated and assembled SU-8 Tsang Suspension.

Introduction

Tsang structures can be used in applications such as micro-mirrors [3], free-space optics [4-6] and RF systems [7]. Out-of-plane electro thermal actuators have been fabricated using the Tsang suspension, where an actuator design was connected to the springs instead of the plate [8]. Tsang suspensions have also been used in thermal isolation of sensors [9,10].

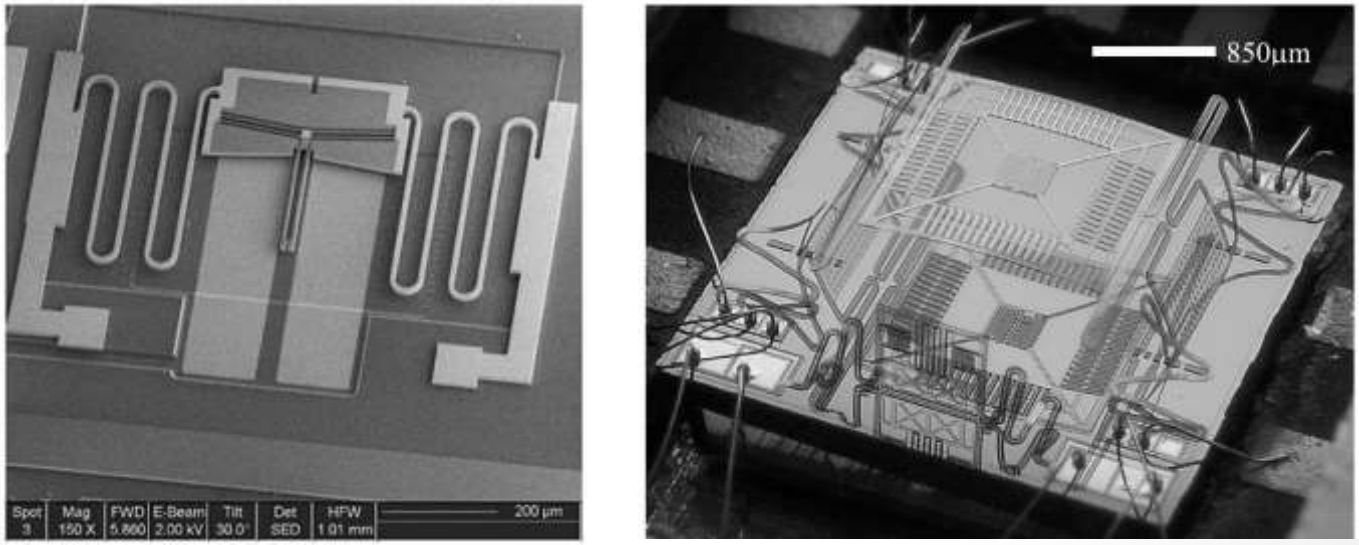


Fig. 2 Left: Electro-thermal micro-gripper for an out-of-plane mirror in Silicon [2]. Right: Several Tsang suspensions (Silicon and Polyimide) hold an elevated platform with a 2 axis thermal accelerometer [3] .

Simulation Design

The Tsang suspension is composed of symmetric springs, an unanchored platform, and the anchor pads (substrate), as shown in Figure 3. An in-plane force applied to the bottom edge of the central platform produces a complex deformation of the springs, which produces the desired out-of-plane motion of the central platform.

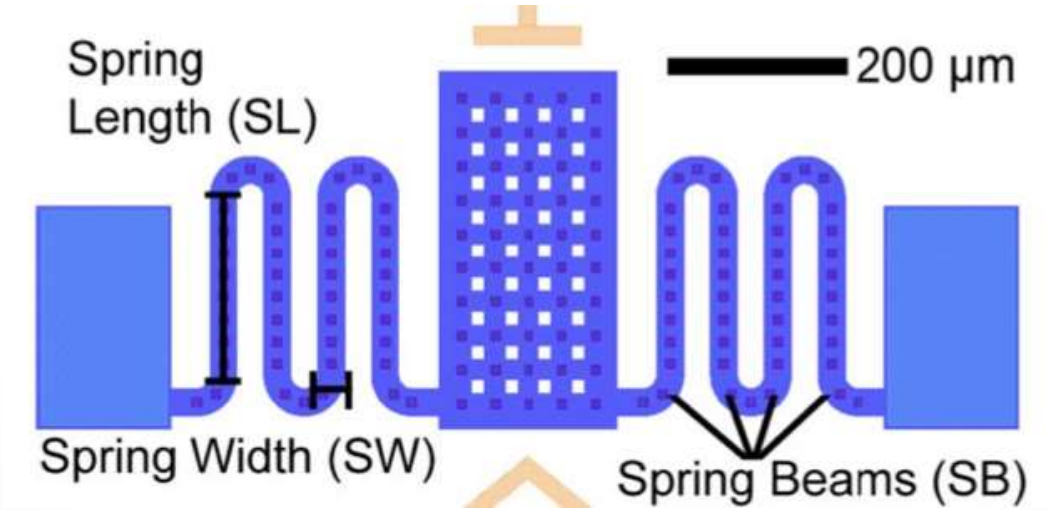


Figure 3: Illustration of a Tsang suspension layout with Spring Length (SL) = 200µm, Spring Width (SW) = 30µm, Number of Spring Beams (SB) = 4.

Simulation Design

- The design parameters investigated in this work were: the spring length (SL), the spring width (SW), and the number of spring beams (SB).
- The notation {SL, SW, SB} will be used to refer to a specific design. For example, the notation {300, 20, 6} refers to a Tsang suspension with SL = 300 μm, SW = 20 μm, and SB = 6.

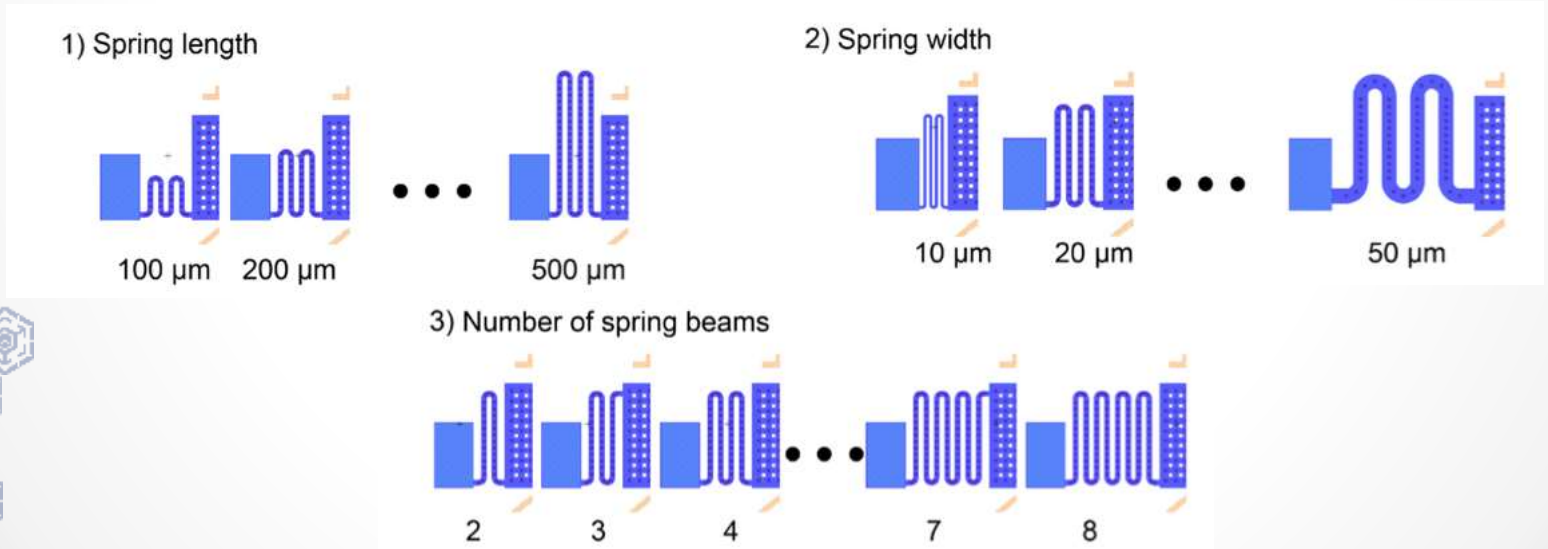


Figure 4: Representation of the parameters that were varied.

Simulation Design

In order to facilitate comparisons between various designs, a "standard design" Tsang suspension was established with the parameters SL = 200 μm, SW = 30 μm, and SB = 4 {200, 30, 4}. This was used as the base point for the various parameter variations investigated. The standard design was chosen since experience with SU-8 fabricated devices, has previously shown it as a reliable and stable design.

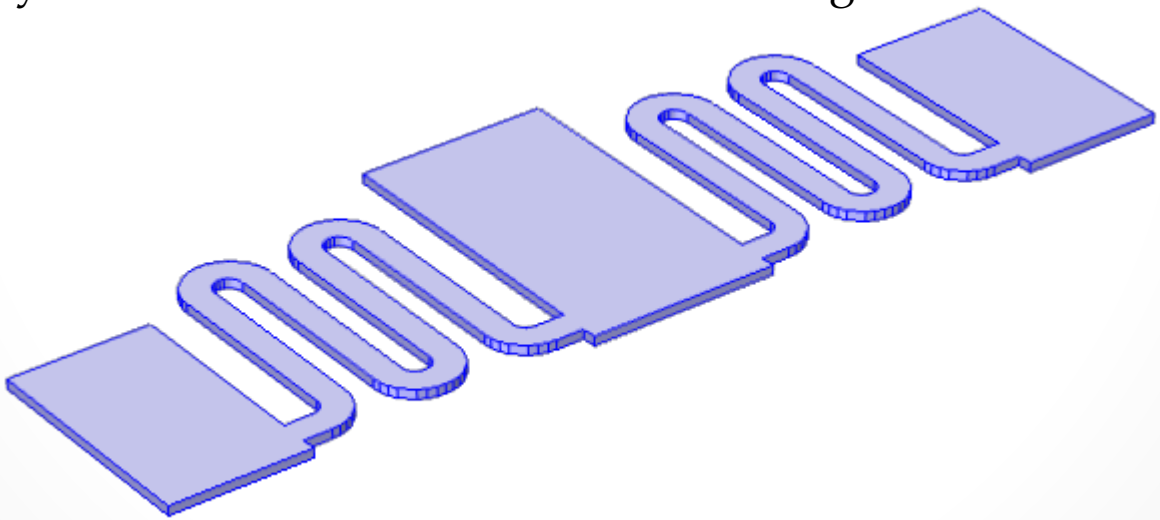


Figure 5: COMSOL model of a Tsang {200, 30, 4}

Use of COMSOL

- One of the challenges of Micro Electromecahnical 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.

COMSOL Simulation

- The structures were parametrically modeled in COMSOL.
- Material and boundary conditions were selected to represent the assembly process
- The highly nonlinear option was selected to contemplate the large displacements of the structure.

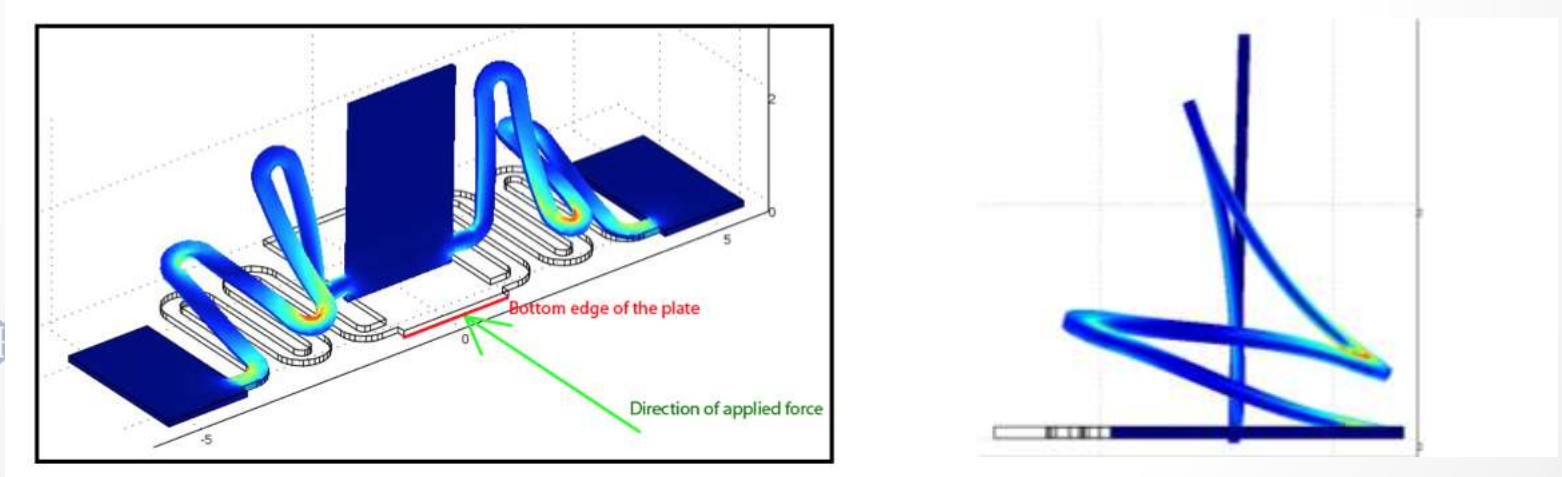


Figure 6: Tsang suspension assembly in COMSOL.

Simulation Results

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

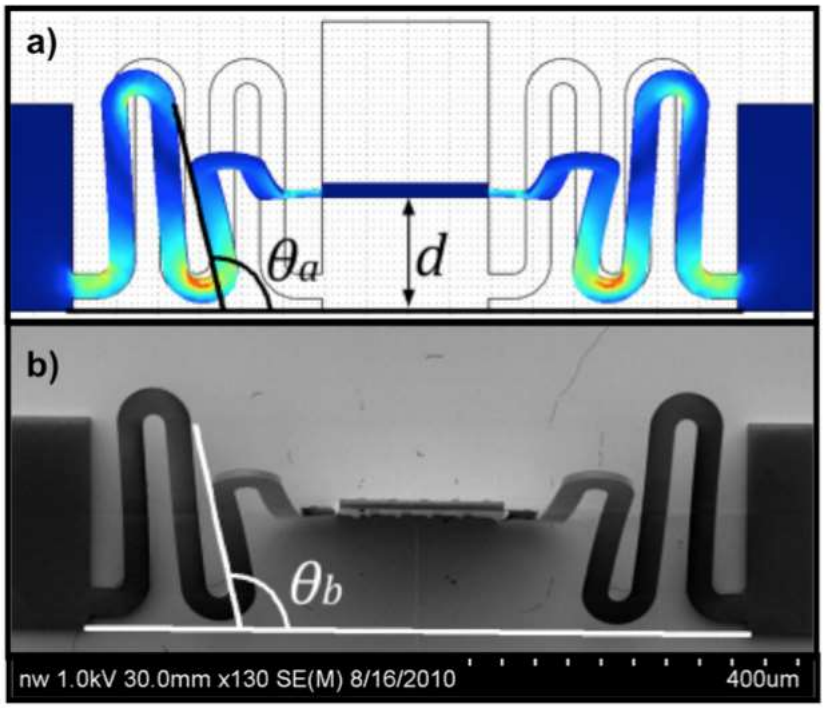
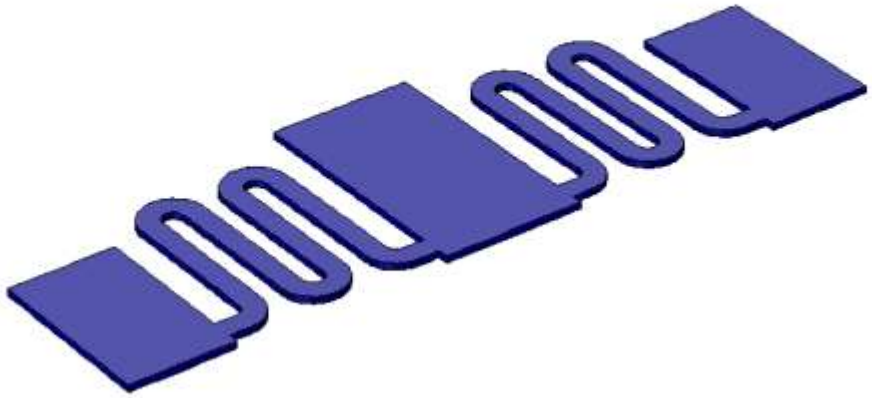


Figure 7: Top view of simulation and SEM image. An example comparison angle, "theta-a" and "theta-b". And displacement to vertical "d" are shown.

Isometric View



Top View

Side View

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.

Simulation Results

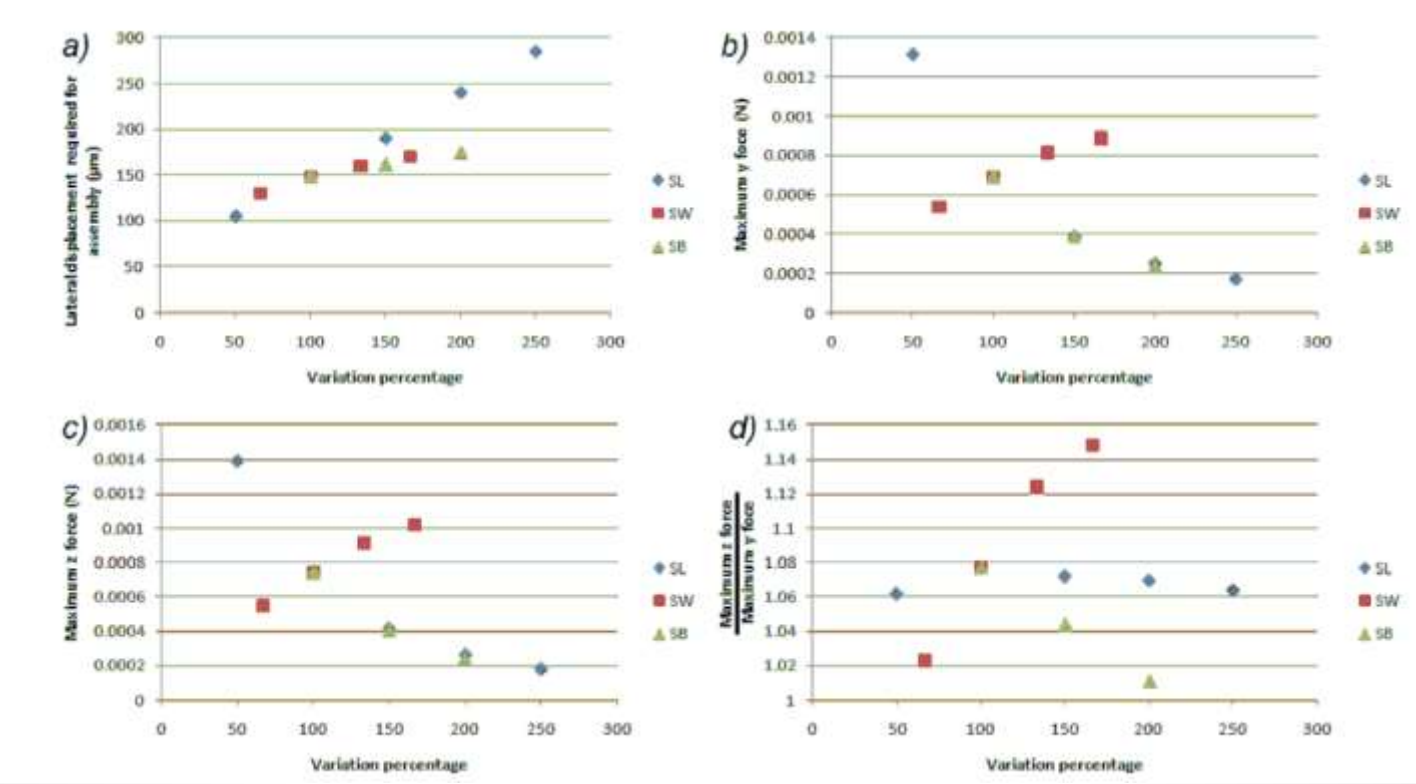


Figure 8: Graphs showing the effect of varying the different parameters as percentage variation of the standard design {200,30,4}

Conclusions

- The Tsang suspension and its design parameters were studied using COMSOL Multiphysics.
- Changes in the reaction forces and displacement required for assembly were determined.
- Clear trends are observed when varying design parameters.
- This work provides greater insight into the operation of Tsang suspensions and provides designers with tools for designing their own implementation.

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Thank You!

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