COMSOL MULTIPHYSICS®

Prestressed Micromirror

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Prestressed Micromirror

Introduction

One method of creating spring-like structures or inducing curvature in plated structures is to plate materials onto a substrate such that the layer has a residual stress after the plating process. The plating process can control this stress, which can be either compressive or tensile, even for similar materials. The automotive industry has studied this phenomenon at length because highly stressed chrome is appreciably shinier than nonstressed chrome. MEMS device manufacturers sometimes use this effect to create curved cantilevers or spring-loaded micromechanical structures that lift off the substrate when deliberately undercut by an etchant.

One such device is the electrostatically controlled micromirror. It is typically quite small, and arrays of such devices can implement a projection system. They serve as optical redirectors and similar reflection devices. This section shows the fundamentals of how to set up and solve lift-off of a prestressed plated device.

Model Definition

This single-physics model uses 3D structural analysis. The micromirror has a stiff, flat, reflective center portion, which is supported by four prestressed plated cantilever springs. To keep the mesh size small and the solution time reasonable, this exercise studies the plated structure with two layers. It also assumes that the plating process creates equal and opposite (compressive and tensile) initial stresses in the top and bottom layers. This convenience makes the model straightforward to set up. You can make the initial-stress distribution as complex as desired and set it up as shown in this example. Depending on the magnitude of the deformations, you are likely best advised to solve such simulations with a large-deformation analysis using a nonlinear or parametric nonlinear solver, noting that the latter is more likely to converge. Thus this illustrative model uses the large-deformation analysis type with both the linear and parametric linear solvers.

Note in particular that a 3D structure with thin layers such as the one in this model leads to a very large unstructured tetrahedral mesh. To avoid this case, this example first generates a 2D quadrilateral mesh by mesh mapping and then extrudes it into 3D to produce a mesh with hexahedral (brick) elements. This way you can have the mesh generator create structured elements with a high aspect ratio.

One of the key process parameters you wish to determine in this class of problem is generally what prestress level is necessary to result in a desired lift-off. Another common concern is how much effect variations in the prestress might have on displacement. A parametric study answers this question.

Results and Discussion

The following two images compare lift-off for aluminum and steel plates. The steel, being harder than aluminum, deforms less.

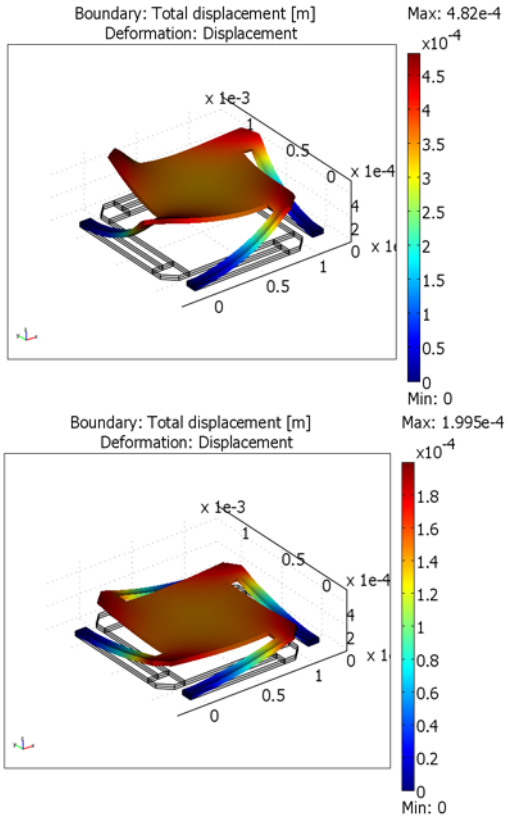

Figure 1: Lift-off for aluminum (top) and steel (bottom).

The following two figures show the mirror response to the different levels of applied prestress. According to Figure 2, the center point deflection is almost linearly dependent of the prestress. Figure 3 shows the mirror's curvature along its centerline

for different values of prestress. In line with expectations, increasing the stress bends the mirror more.

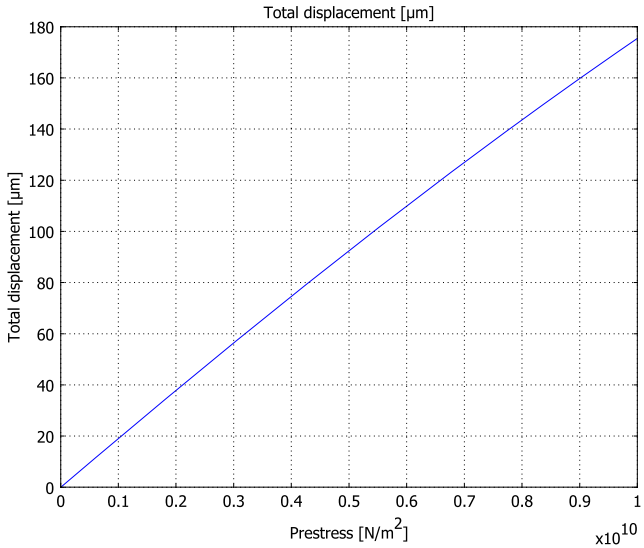

Figure 2: Vertical deflection of the center of the mirror for different prestress levels.

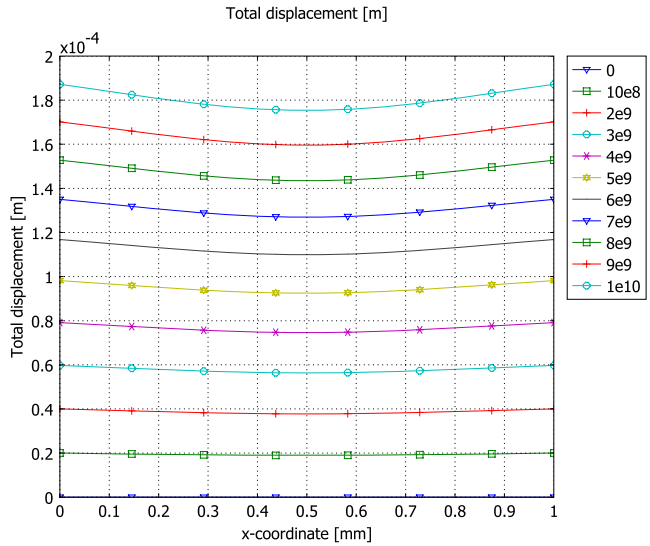

Figure 3: Mirror curvature along the centerline for different prestress levels.

Because of bonding the structure cannot move freely when it cools down, which causes residual stresses. The following plot shows this released stress state using the first principal stress after deformation.

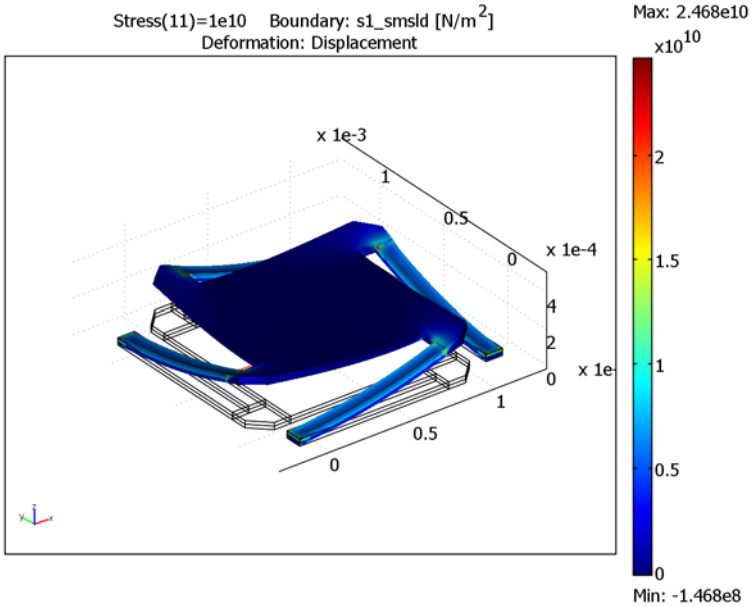

Figure 4: Plot of the first principal stress after deformation.

Reference

1. G. Kovacs, *Micromachined Transducers Sourcebook*, WCM McGraw-Hill, 1998.