

Structural Mechanical Analysis of MEMS Micromirror using COMSOL Multiphysics

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Abstract: MEMS Micromirrors are used in various applications like Digital light projector (DLP), Highdefinition (HD) display, endoscopic Optical Coherent Tomography and also in defense applications. This paper deals with the analysis of structural mechanical properties of electrostatically driven prestressed Micromirror using COMSOL Multiphysics 4.3b software. The proposed design was compared for the lift-off stress generated at the edges due to the plating process and the associated displacement at a given prestress level.

Keywords: MEMS, Micromirrors, Cantilever, COMSOL Multiphysics, Serpentine beam.

I. Introduction

The development of MEMS technology shows a huge step forward in biomedical, automotive and communication industries. MEMS Micromirror technology is highly versatile and adaptable to various applications. Electrostatic driven MEMS mirrors are used in applications where a high pointing stability is required [2], [3] and it is the solution of choice for advanced fibre optic light processing. In this paper, a Micromirror model is simulated using COMSOL Multiphysics 4.3b; the results obtained from the simulation help to reduce the displacement associated with the stress developed due to the plating process during the fabrication of MEMS Micromirror.

II. Existing Design Of Mems Mirror

The existing model consists of a square shaped Micromirror with four straight shaped cantilever beams as actuators [1]. The initial stress was set as 5[GPa] and the distribution of the stress over the entire surface was made as complex as possible, as advised from the COMSOL proposed model.

The results obtained for different material combinations showed that the best material combination was Aluminium 3003 for the cantilever legs and structural steel for the Micromirror substrate [1] as it reduced the stress at the edges and cantilever lift-off. The reason for selecting steel for the Micromirror substrate is to reduce the surface deformation as it is stiffer than Aluminium.

III. Proposed Design

In the existing system it has been shown that the surface deformation and cantilever was at high stress level. Although the stress was reduced with the best material combination, the lift off stress and the displacement was still higher for the design of devices at micro scale. So the performance of the Micromirror was improved by reducing the stress on the cantilever edges by modifying the straight shaped cantilever beam design to a serpentine or zigzag shaped beam. Figure 1 shows the structure of serpentine beam with a square shaped Micromirror.

The design was simulated using COMSOL Multiphysics 4.3b [4] with an initial stress of 5[GPa]. The graph of prestress versus displacement was plotted (Figure 3). Different values of prestress were taken, from 0 to 10e⁹, to obtain the level of dependence of the displacement on the stress. The results were then compared and tabulated (Table 1).

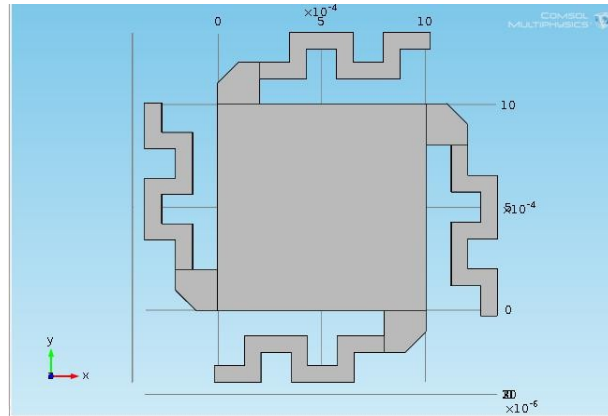


Figure 1 Proposed structure using COMSOL

IV. Results And Discussion

The lift-off level and the associated stress for the Micromirror with S-shaped cantilever beams is 36×10^{-6} m and 0.032 N/m^2 respectively, which is lesser than that of the Micromirror with straight shaped cantilever beams (lift-off= 50×10^{-6} m and stress level= 0.0543 N/m^2) as shown in figure 2.

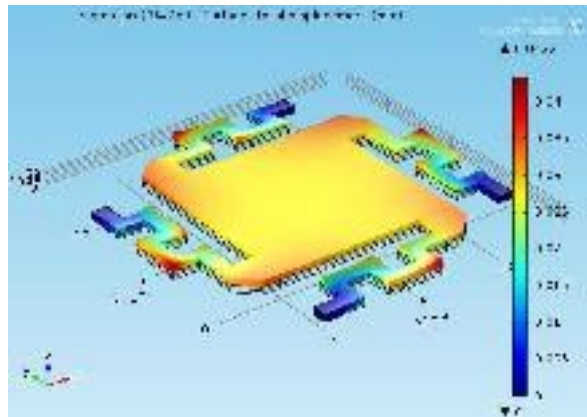


Figure 2 Results for proposed design

The results obtained from the simulation of straight shaped cantilever beams and s-shaped cantilever beams are tabulated.

Micromirror shape	Cantilever Shape	Lift-off	Stress level
square	Straight	50×10^{-6}	0.0543
square	s-shaped	36×10^{-6}	0.032

Table 1 Comparison of lift-off and stress level of straight and s-shaped cantilever beams.

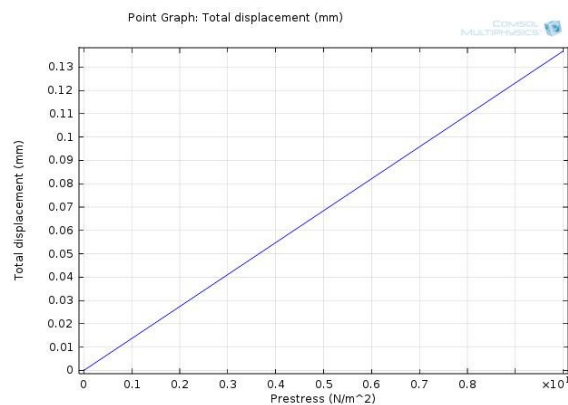


Figure 3 Displacement v/s Prestress curve for an s-shaped cantilevered Micromirror

The results obtained from Figure 3 have shown that the center point deflection for the s-shaped cantilevered beam is less than the straight shaped cantilevered beam at the provided prestress level. This design with a reduced level of stress is more suitable for fabrication.

V. Conclusion

The design proposed in this paper mainly focuses to reduce the lift-off level and the stress, created during the plating process. Hence, the reduced lift-off due to the stress resulted in the reduction of distance between the mirror and the bottom electrode thereby reducing the required actuation voltage. This also helped to achieve large scan angle ^[5] with relatively small actuating voltage. The design can be further analyzed using static and dynamic parameters that will improve the performance of the Micromirror.

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