IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DESIGNING AND ANALYSING DIFFERENT SHAPES OF MEMS BASED ELECTROSTATICALLY CONTROLLED MICROMIRRORS

Pooja*, Dr. Kuldeep Bhardwaj
* M.Tech Scholar Department of ECE, OITM, Hisar, India.
Associate Professor Department of ECE, OITM, Hisar, India

ABSTRACT

In adaptive optics and point-to-point communication, various micro mirror devices have been used to reshape the wavefront of a propagating beam to compensate for aberrations in the beam path. Such MEMS mirrors offer inherent advantages in speed, compactness, and economy in comparison to their macroscale counterparts. [6].Mirrors are fundamental components of most optical systems. The miniaturization of optical components leads to higher packaging density and increased speed of devices that manipulate light. This is part of the vast field of Microsystems technology, designated by Micro-Opto-Electro-Mechanical Systems (MOEMS), in which electronic, mechanical, and optical devices are integrated on the micron scale [4]. This paper describes about various micromirror shapes to allow for determination of optimal, distortion minimizing Micromirrors .Different shapes of micromirrors namely square , circular[3] and hexagon shaped [5]are designed and these micro mirror models are simulated by using COMSOL Multi physics Software . Electrostatic actuation is used to defect the micromirror. The most important parameter involved in the working of micromirror during lift off is the surface deformation and here mirror is designed to reduce mirror deformation i.e., to maintain flat surface at top during lift off so that distortion can be minimized .So the results of all the three differently shaped micromirrors are analyzed in terms of less induced stress along edges of micromirror due to lift off ,least surface deformation during lift off and maximum displacement of the micromiror [1,2].

KEYWORDS:MEMS, Pre stressed Micro mirrors, COMSOL, DMD, 3D mesh.

INTRODUCTION

Microelectromechanical systems (MEMS) has been identified as one of the most promising technologies for the 21st Century and has the potential to revolutionize both industrial and consumer products by combining silicon-based microelectronics with micromachining technology[7].It is the technology of very small devices. MEMS are made up of components between 1 to 100 micro meters in size (i.e.0.001 to 0.1 mm)[9].

Micro mirror devices are devices based on microscopically small mirrors. The mirrors are Microelectromechanical systems (MEMS), which means that their states are controlled by applying a voltage between the two electrodes around the mirror arrays. There are digital micro mirror devices used in video projectors and optics and micro mirror devices for light deflection and control .The mirrors are arranged in a matrix and have two states, "on" or "off" (digital). The mirrors could not only be switched between two states, their rotation is in fact continuous. This could be used for controlling the intensity and direction of incident light [10].

MICROMIRROR DESIGN

The work is done to design a prestressed plated micromirror that is controlled electrostatically. The micromirror has a stiff, flat, reflective center portion, which is supported by four prestressed plated cantilever springs. All steps involved in the modeling process of a micromirror are defining geometry, meshing, and specifying physics[8]. First step in modeling a micromirror is to define geometry .Here we are designing three different shaped micromirrors .So, in order to draw desired geometry of the micromirror we have to create a required geometric figures used to draw different parts of the micromirror . For this to get the most accurate geometry possible, we should enter dimensions and coordinates using dialog boxes instead of drawing it. Creating and modifying objects graphically might seem easier, but in some cases that method can introduce small variations in numerical values .So to avoid geometric conflicts, we are entering parameters directly in dialog boxes. A complete micromirror is designed in three levels.

First of all central portion of mirror is designed than we attach a cantilever supports around mirror and finally we attach springs around mirrors on respective supports provided. Figure 1,2 and 3 shows the micromirror designs of square , circular and hexagon shaped micromirrors respectively.

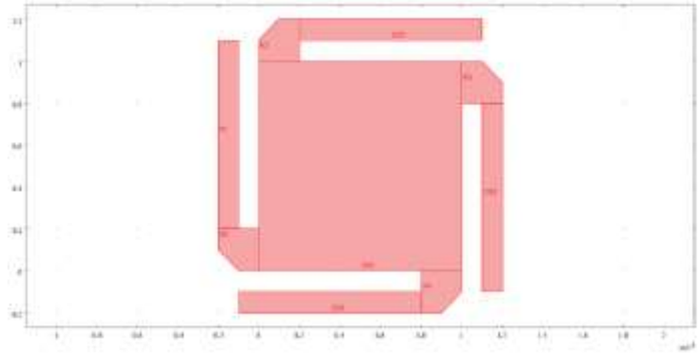


Fig 1:The geometry square shaped micromirror.

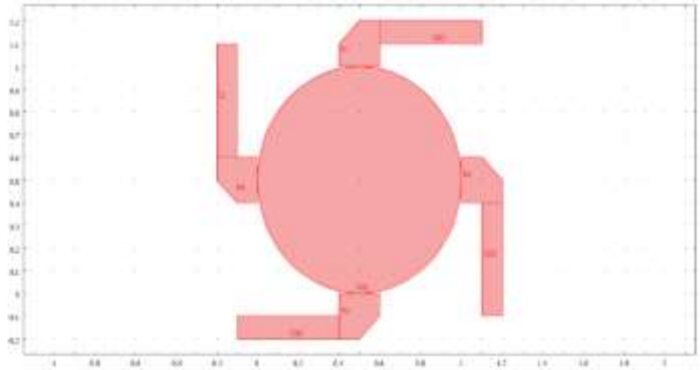


Fig 2: The geometry circular shaped micromirror.

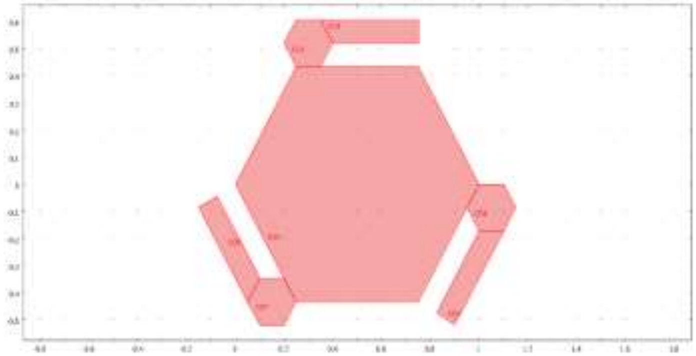


Fig 3: The geometry hexagon shaped micromirror.

In second step ,meshing is done .Here 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, we first generates a 2D quadrilateral mesh by mesh mapping and then extrudes it into 3D to produce a mesh with hexahedral elements. This way we can have the mesh generator create structured elements with a high aspect ratio. Figure 4,5 and 6 shows the 3D meshed geometries of square , circular and hexagon shaped micromirrors respectively.

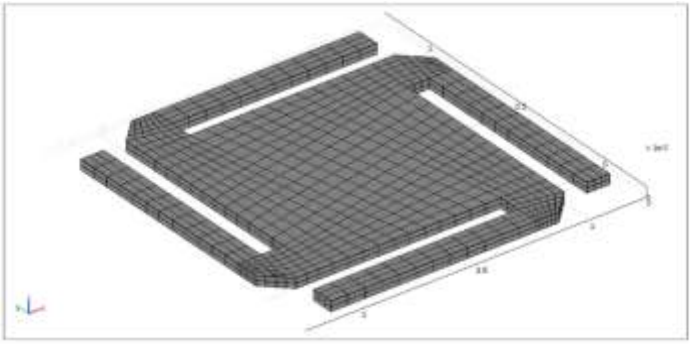


Fig 4: The square shaped geometry after extruding the mesh into 3D.

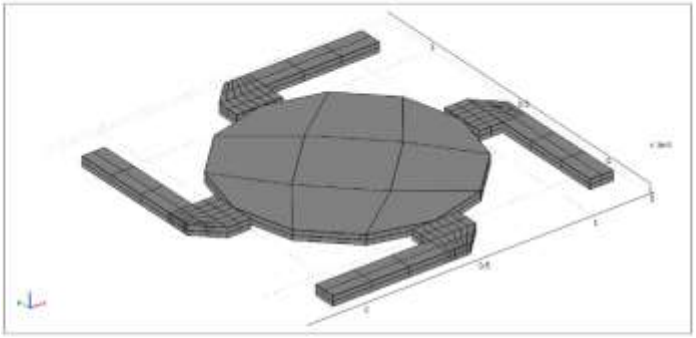


Fig 5: The circular shaped geometry after extruding the mesh into 3D.

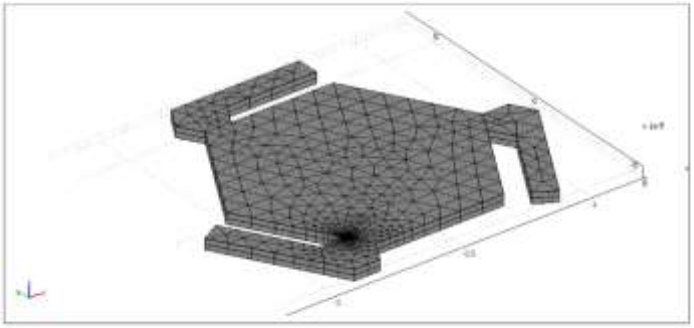


Fig 6: The hexagon shaped geometry after extruding the mesh into 3D.

Third step is to specify the physics. After creating 3D mesh , next step is to select a material to be used for micromirror. Here we are using Aluminum 3003-H18 for all subdomains (i.e.,18).Then Initial stress is applied .Now subdomains are selected carefully for all three different micromirror shapes . For square shaped micromirror , initial stress "+Stress" is applied to subdomains 4,6,12 and 18 and "-Stress" is applied to subdomains 3,5,11 and 17. For circular shaped micromirror, initial stress "+Stress" is applied to subdomains 4,6,14 and 18 and "-Stress" is applied to subdomains 3,5,13 and 17. For hexagon shaped micromirror, initial stress "+Stress" is applied to subdomains 2,12 and 14 and "-Stress" is applied to subdomains 1,11 and 13.

Next we have to fix the end points of the springs to provide fix base to the geometry during lift off. For square ,circular and hexagon shaped micromirror, boundaries (15, 16, 17, 20, 92, 95, 102, 103) , (15, 16, 17, 20, 100, 103, 110, 111)and (1,4,69,70,71 ,74) are selected respectively and Constraint condition list is changed to Fixed.

The steel, being harder than aluminum, deforms less .Therefore, Steel AISI 4340 is applied at the center of the micromirror .This will stiffen the center of the geometry and provide effective results during lift off.

SOLVING AND VISUALIZING RESULTS

Now we will discuss about the simulation results of the mirror and discuss how its surface deforms during lift off .The fig. below show the lift off of the square shaped micromirror .As shown in the figure 7 the surface of the micromirror lifts up and the four springs or legs of the micromirrors are fixed at the base.

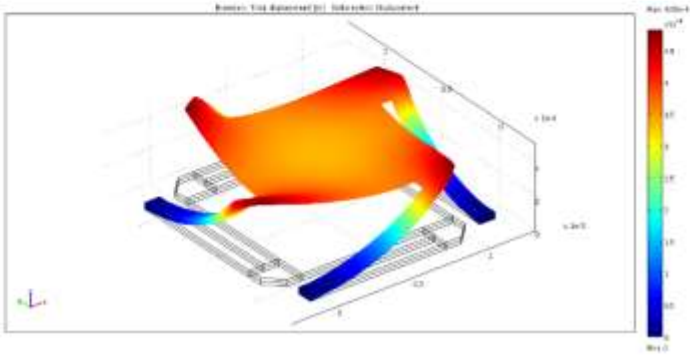


Fig 7: Lift-off in square shaped micromirror (aluminum)

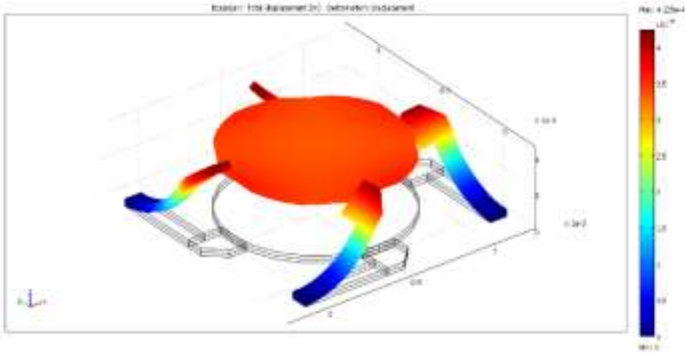


Fig 8: Lift-off in circular shaped micromirror (aluminum)

The figure 8 and 9 shows the lift off of the circular shaped and hexagon shaped micromirrors respectively .

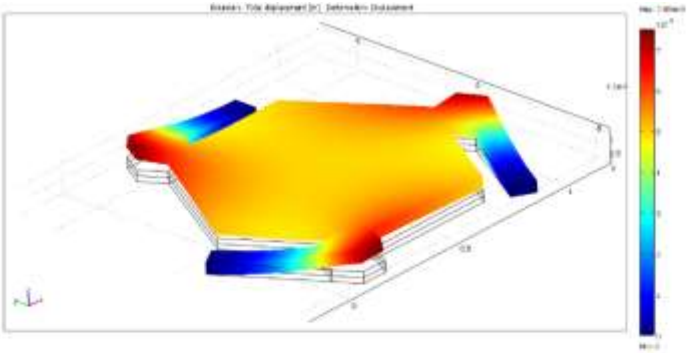
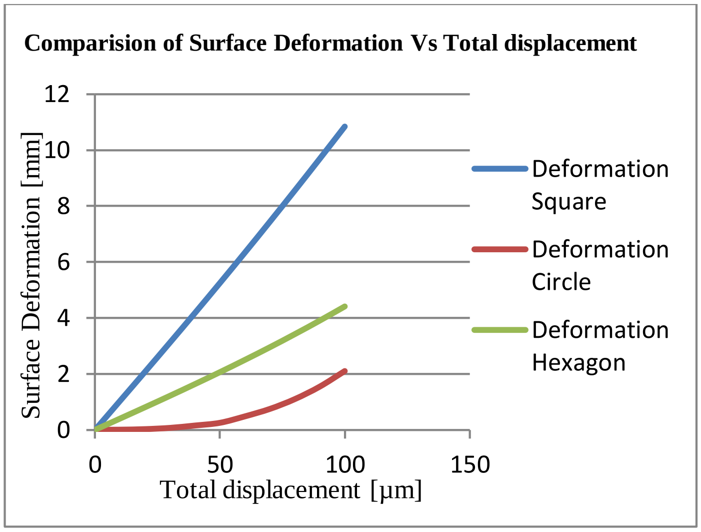


Fig 9: Lift-off in hexagon shaped micromirror (aluminum)

Now we plotted a graph showing relationship between surface deformation and total displacement in micromirrors of different shapes.

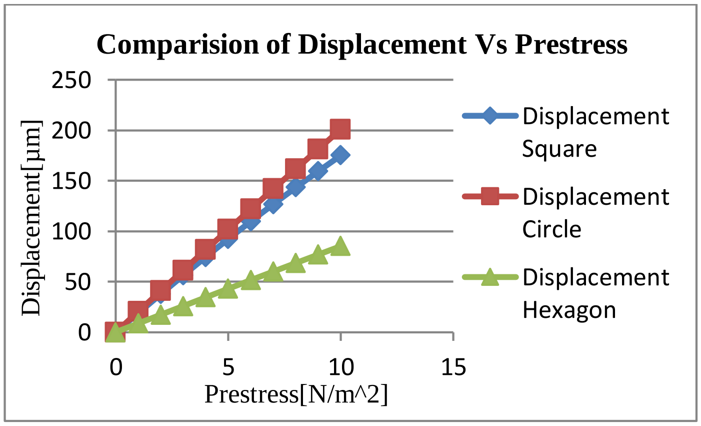
As indicated by the Graph 1, it is clearly observed that in case of square shaped micromirror the surface deformation is directly proportional to the lift off height of the micromirror .On comparing three different shapes ,it is quite clear that square shaped micromirror shows maximum surface deformation with the increase in lift off height .On the other hand ,surface deformation is very less in case of both hexagonal and circular shaped micromirrors .



Graph 1: Comparision of Surface Deformation Vs Total displacement.

Next we plotted a graph showing relationship between applied prestress and the displacement achieved in the micromirror. The displacement(in µm) is observed when the range of prestress(in N/m2) in varied from range 0 to10e9 with step size 1e9 .The graph below shows the total displacement of the mirror with respect to the applied prestress .

As indicated by the Graph 2 with the increase in applied prestress level , the total displacement increases linearly. Comparision shows that the maximum total displacement is achieved with circular shaped micromirror It gives the total displacement of 220 µm at maximum prestress i.e. 1×〖10〗^10 [N/m^2] followed by square shaped and hexagonal shaped micromirror with displacements 180 µm and 90 µm respectively.



Graph 2: Comparision of Displacement Vs Prestress.

CONCLUSON

In this paper, we have investigated a MEMS based electrostatically controlled micromirror .We have presented the simulation results of various mirror shapes to allow for determination of optimal, distortion minimizing Micromirrors. By analyzing the results produced by simulationg three different mirror shapes ,we can suggest that best shape introduced here is circular micromirror with least or negligible surface deformation and highest lift off .It gives the total displacement of 220 µm at maximum prestress i.e. 1×〖10〗^10 [N/m^2] and least stress at the edges of centilever .Hexagon shaped mirromirror also provide good results ,it also has less surface deformation and less stress at the edges of centilevers as compare to square shaped micromirror but displacement is very low .The lift off of square shaped micromirror is good ,it gives the total displacement of 180 µm at maximum prestress i.e. 1×〖10〗^10 [N/m^2]. But not as high as circular shaped micromirror and the problem with square shaped micromirror is that it has maximum surface deformation during lift off .The central part of the mirror surface bends down during lift off and area around its four corners rises up high .Due to this uneven lift off of the surface , the stress at the edges of the cantilever is very high .This difference in distortion introduced by the square ,circular and hexagonal micromirrors indicates that an optimal mirror shape must exist that allows for minimal surface distortion and highest lift off .

REFERENCES

[1] M.Archana et al.(2014) " Structural Mechanical Analysis of MEMS Micromirror using COMSOLMultiphysics" IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 9, Issue 4, Ver. V (Jul - Aug. 2014), PP 21-23 Pooja Bansal, Anurag Singh et al(2014)
[2] Proposed " Design and Analysis of Stress Level in Elecrostatically Controlled Micromirror"PISER -Progress In Science and Engineering Research Journal ISSN 2347-6680 (E)
[3] Hazian Mamat et al. [2013] designed "A COMSOL Model to Analyse the Structural Mechanical Problem in an Electro statically Controlled Prestressed Micro-Mirror" World Applied Sciences Journal 26 (7):pp. 950-956, 2013
[4] Z. Moktadir∗,1 C. Gollasch,1 E. Koukharenko,1 M. Kraft et al.(2004) "Fabrication of micro-mirrors with pyramidal shape using anisotropic etching of silicon" arXiv:physics/0409021 v1 2 Sep 2004.
[5] Quan Sunet et al.[2010] Optimization designed large-stroke MEMS micromirror for adaptive opticsDecember 10, 2010 / Vol. 8, No. 12 / CHINESE OPTICS LETTERS
[6] T. G. Bifano and J. B. Stewart, High-speed wavefront control using MEMS micromirrors, Boston University [5895-27].
[7] An Introduction to MEMS (Micro-electromechanical Systems) Published in 2002 by PRIME Faraday Partnership Wolfson School of Mechanical and Manufacturing Engineering Loughborough University, Loughborough, Leics LE11 3TU COMSOL 3.5a Model Micromirror.
[8] From Wikipedia, the free encyclopedia http://en.wikipedia.org/wiki/Microelectromechanical_systems viewed on 08/09/2014.
[9] Micromirrors: From Wikipedia, the free encyclopedia http://en.wikipedia.org/wiki/Micromirror_device viewed on 08/09/2014.