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Design and Analysis of Hexagon Micromirror using Different Materials with Different Dimensions

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Abstract— *We have designed a MEMS based hexagonal shaped Micromirror using COMSOL Multiphysics Software. For simulation, parametric nonlinear solver is used to model the performance of Micromirror. We accomplish that the displacement can be controlled by using different shape and materials combinations of micromirror. In this paper, displacement of different materials are analysed. Three structural materials polysilicon, titanium and aluminium are also analysed as aluminium produces the maximum displacement at very low prestress of 3GPa .*

Keywords— *MEMS, hexagon, micromirror, material.*

I. INTRODUCTION

Adaptive optics and point-to-point communication, various micro mirror devices have been used to reshape the wavefront of a transmitting beam to recompense for deviation in the beam path. Such MEMS mirrors offer inherent advantages in speed, size and economy in comparison to their macro size equals. [6]. Mirrors are initial components of most optical systems. The microscaling of optical components has higher packaging density and fast speed of devices that manipulate light. Now a days the vast field of Microsystems technology, fabricated by Micro-Opto-Electro-Mechanical Systems (MOEMS), contains electronic, mechanical, and optical devices are integrated on single chip [4]. The various micromirror shapes to allow for determination of optimal, distortion minimizing Micromirrors [2]. Different shapes of micromirrors namely square , circular [3] and hexagon shaped [2] are designed and these micro mirror models are simulated by using COMSOL Multiphysics. Electrostatic actuation is used to defect the micromirror [1]. 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 [2]. Micromirror 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 or current between the two electrodes around the mirror arrays [7]. Micromirror is a versatile MEMS device, which finds use in many application areas. Previously there have been mainly three types of micromirror design namely rectangular, circular and hexagonal. Rectangular micromirror is basic micromirror design used in mems technology.

II. MODEL DESIGNING

To design a geometry to reduce bending and to minimize reflection losses, we have designed a hexagon geometry which can improve both the remedies.
In this paper we have designed three different hexagon geometries, with circle radius of 0.5 mm, 1 mm and 2 mm.

1) hexagon radius of 0.5 mm

To draw the hexagon we have to draw the circle of 0.5 mm so that a hexagon of equal side i.e. 0.5 can be drown. A hexagon with equal side and angle of 120 between adjacent sides, inside a circle. After completing the mirror geometry we have to design cantilever for mirror, to design cantilever beam we have to design cantilever support at the all six edges to draw six cantilever beams. Each cantilever is of 0.4 mm in length. The mirror thickness is of 40 um.

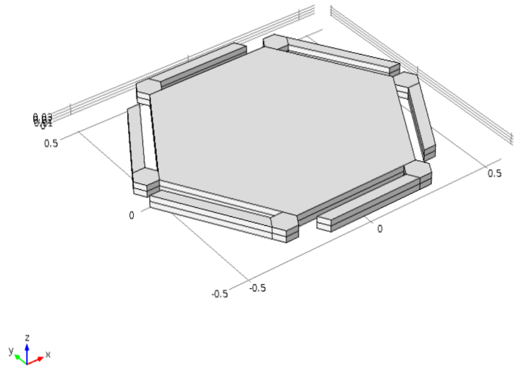

Figure 1: 3D hex_0.5

2) hexagon radius of 1 mm

To draw hexagon of side 1 mm we have to draw the circle of 1mm so that a hexagon of equal side can be drawn and with angle of 120 between adjacent sides, inside a circle. Six cantilever beams of 0.8 mm in length are attached to the mirror. The mirror is 40 um thick as shown in figure 2.

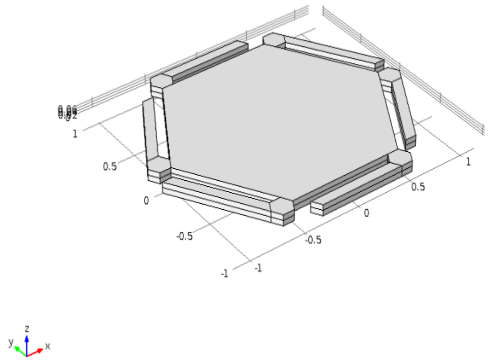

Figure 2: 3D hex_1

3) hexagon radius of 2 mm

Now to draw a hexagon of side 2 mm and each cantilever is of 1.6 mm in length with mirror thickness of 40 um is shown in figure 3.

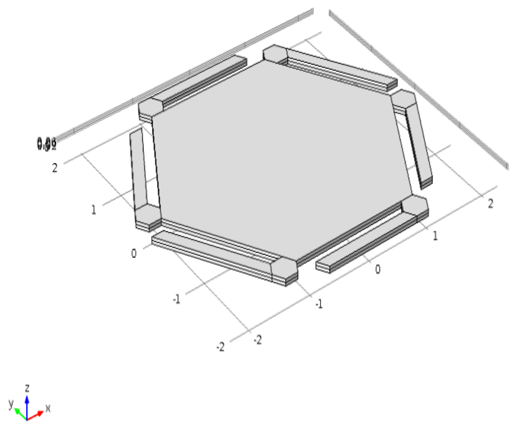

Figure 3: 3D hex_2

Table 1: Comparison of Dimension

NAME	SIDE (MM)	ANGLE (DEG)	CANTILEVR (MM)	THICKNS. (UM)
hex_0.5	0.5	120	0.4	40
hex_1	1	120	0.8	40
hex_2	2	120	1.6	40

Table 1 shows the comparison of the three different hexagon geometries i.e. hex_0.5, hex_1 and hex_2. Each side of hexagon is 0.5 mm, 1mm and 2 mm and cantilever with length 0.4 mm 0.8 mm and 1.6 mm respectively.

III. RESULTS

We have designed the different hexagon micromirror geometry with three different material. Now we will analyze displacement of all our designed. Firstly we will compare all the three geometries displacement with Poly-silicon as structural material.

Table 2 : Properties of Poly-Si

Density	2320 kg/m^3
Young's modulus	160 GPa
Poisson's ratio	0.22
Coefficient of thermal expansion	2.6 e-6 1/K
Heat Capacity	678 J (Kg.K)
Relative permittivity	4.5
Thermal Conductivity	34 W/m.K

Table 2 shows the properties of Poly-Si which effect working of any device. Young's modulus and Poisson's ratio of poly-si is given by 160 GPa and 0.22 respectively.

- Hex_0.5 with Poly-Si

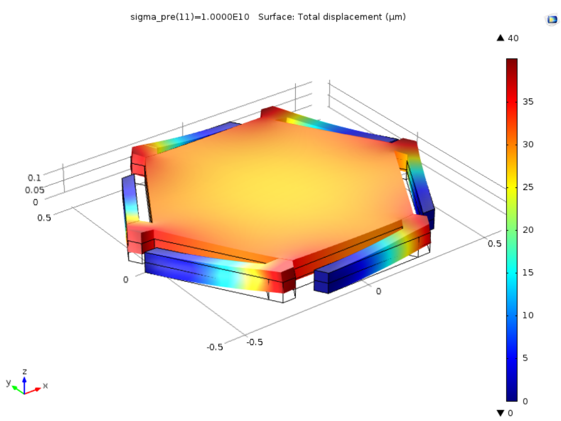

Figure 4:Displacement of hex_0.5 Poly-Si

The maximum displacement for hex_0.5 using poly-si as structural material is 40 um at 10GPa.

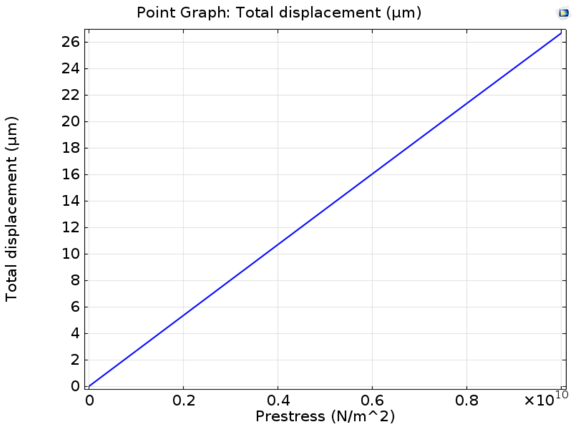

Figure 5: Displacement Curve r_0.5.

Displacement of the centre point of the mirror is shown in figure 5, r_0.5 hexagon with polysilicon gives maximum displacement of 26 um at 10 GPa.

- Hex_1 with Poly-Si.

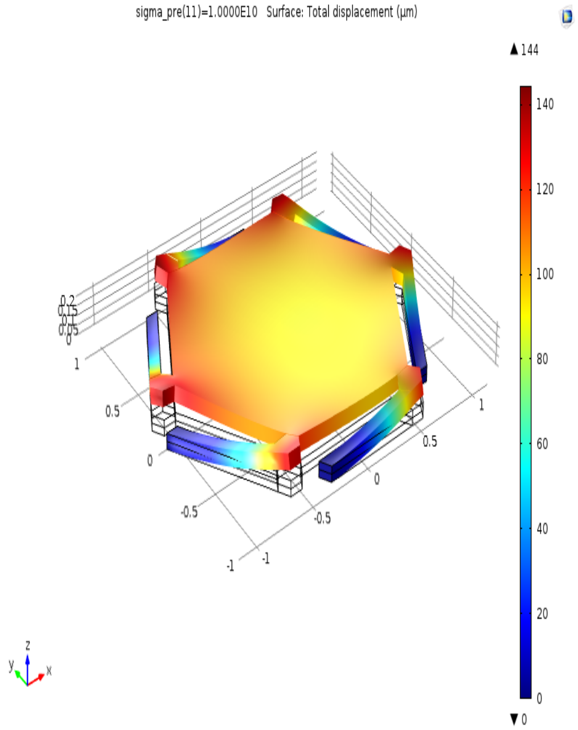

Figure 6:Displacement of hex_1 Poly-Si

The maximum displacement for hex_1 using poly-si as structural material is 144 um at 10GPa.

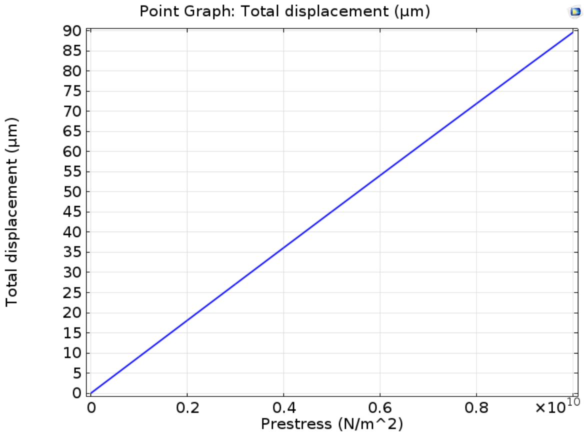

Figure 7:Displacement Curve hex_1 Poly-Si

Displacement of the centre point of the mirror is shown in figure 7, r_1 hexagon with polysilicon gives maximum displacement of 90 um at 10 GPa.

- Hex_2 with Poy-Si

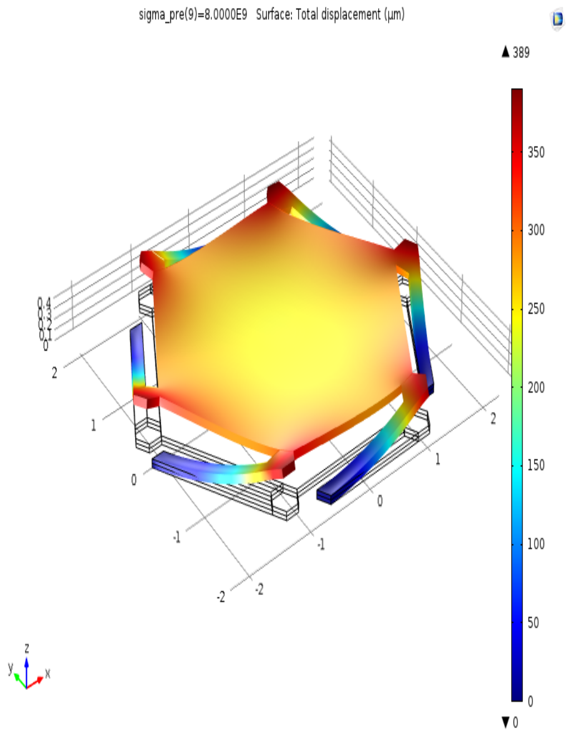

Figure 8 : Displacement of hex_2 Poly-Si.

The maximum displacement for hex_2 using poly-si as structural material is 389 um at 8GPa only.

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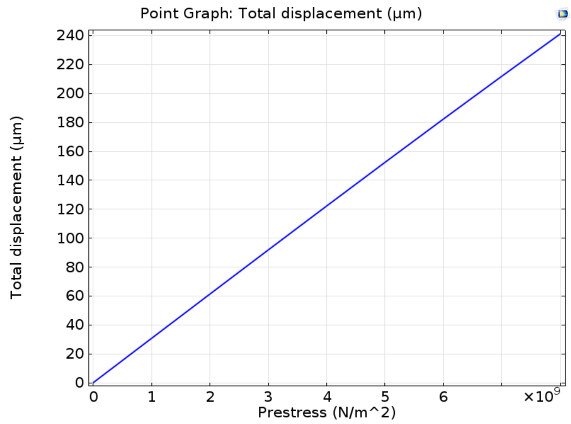

Figure 9 : Displacement Cure hex_2 Poly-Si.

Displacement of the centre point of the mirror is shown in figure 9, r_2 hexagon with polysilicon gives maximum displacement of 240 um at 8 GPa.

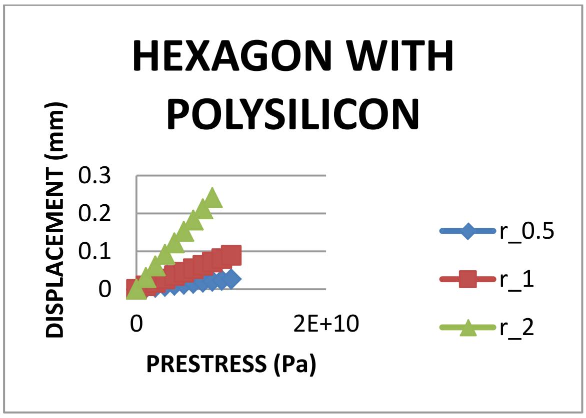

Figure 10: Comparison of Geometries.

As seen from the figure 10, the hexagon with side 2 mm i.e. r_2 gives the best displacement among all the geometries. So we will apply Titanium and Aluminium on r_2 geometry to analyze further.

- **Titanium**

Titanium is also very popular material used in many MEMS devices now days.
Young's modulus and Poisson's ratio of Ti is given by 115.7 GPa and 0.321 respectively. Density of 4506 kg/m^3 and electrical conductivity of 2 e6 s/m.

Table 3 : Properties of Ti

Density	4506 kg/m^3
Young's modulus	115.7 GPa
Poisson's ratio	0.321
Coefficient of thermal expansion	8.61 e-6 (1/K)
Heat Capacity	522 J (Kg.K)
Electrical Conductivity	2.6 e6 {s/m}
Thermal Conductivity	21.9 W/m.K

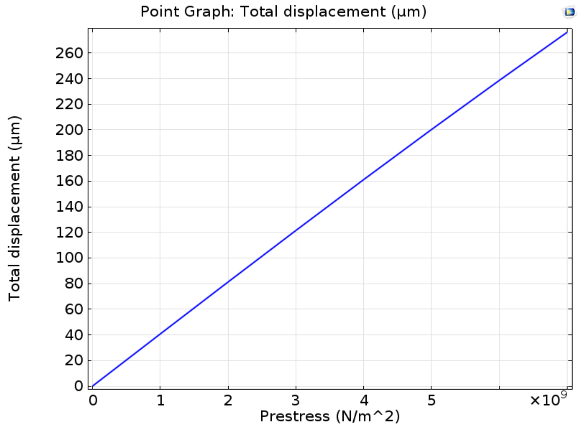

Figure 11: Displacement curve of r_2 with Ti.

Displacement of the centre point of the mirror is shown in figure 11, r_2 hexagon with titanium gives maximum displacement of 260 um at 7 GPa.

- **Aluminium**

Aluminum is always preferred where good conductivity and flexibility is required.

Table 4 : Properties of Al

Density	2700 kg/m^3
Young's modulus	70e9 GPa
Poisson's ratio	0.33
Coefficient of thermal expansion	23 e-6 (1/K)
Heat Capacity	522 J (Kg.K)
Electrical Conductivity	3.774 e7 {s/m}
Thermal Conductivity	238 W/m.K

Young's modulus and Poisson's ratio of Al is given by 70 GPa and 0.33 respectively.

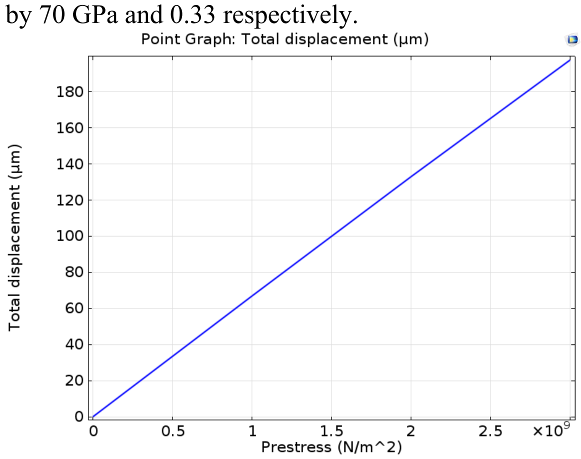

Figure 12: Displacement with Al.

Displacement of the centre point of the mirror is shown in figure 12, r_2 hexagon with titanium gives maximum displacement of 180 um at 3 GPa.

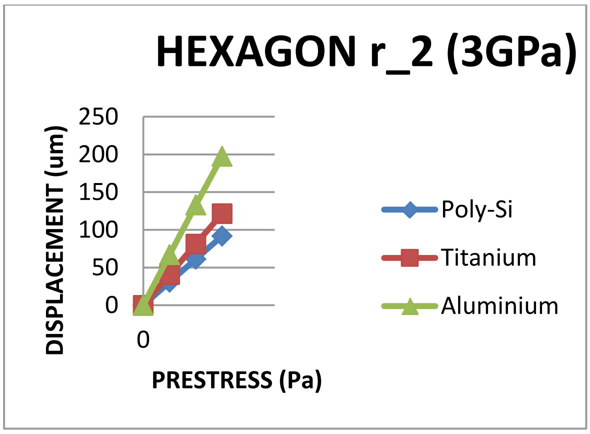

Figure 13: Compression of Materials at 3GPa..

As it is found from figure 10,11 and 12 that hexagon geometry r_2 can be solved for 8GPa, 7GPa and 3 GPa respectively for poly-si, ti and Al. so by comparing the displacement of hexagon micromirror at 3GPa as shown in figure 13, Al produces the maximum displacement as compared to Ti and Poly-si,

IV. CONCLUSION

In this paper three hexagon micromirror geometries with side length of 0.5 mm, 1 mm and 2 mm are designed and compared. hexagon with side length of 2 mm produces the maximum displacement among all. Three structural materials polysilicon, titanium and aluminium are also analysed as aluminium produces the maximum displacement at very low prestress of 3GPa . This mirror geometry gives less lift off to the mirror but as we can see from the results that instead of getting a curved surface like in case of square shaped micromirror, we are getting a flat surface during lift off. Here no bending problem is arising at the center of the surface inward. This is what our goal to achieve surface with no deformation during lift off.

V. REFERENCES

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