IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 7, July 2016

Analysis of Controlled Staircase Comb Actuator using Different Structural Materials

Rajesh Kumar

M .Tech Lecturer, Govt. Polytechnic, Hisar

Abstract: Staircase comb geometry using different materials are analysed. PTFE is also a type of polymer which produces maximum displacement of 3.6 µm at low voltage 3.5 V as compared to Poly silicon which produces same displacement at 62.1 V, 0.1V to 1.1V, then a Sharpe change in voltage occur between 1.1 to 2.3 V and then again a second slow movement of nearly 0.8 µm takes place between 2.3 to 3.5 V.

Keywords: Comb Drive, FEM, Actuator, Electrostatic

I. INTRODUCTION

Electrostatic actuation is the most common type of force generation, electromechanical energy conversion scheme in micromechanical systems. It is the most excellent example of an energy-storage transducer. Such transducers store energy when either mechanical or electrical work is done on them. Assuming that the device is loss less, this stored energy is conserved and later on converted to the other form of energy. Electrostatic actuation is produced by the electric field of a capacitor. Figure 1 illustrates the two basic configurations of a capacitor for electrostatic actuation of a MEMS device: the parallel plate and the interdigitated comb capacitor configurations. The interdigitated comb capacitor is dominated by the fringe electrostatic field, and the parallel plate capacitor is dominated by the direct electrostatic field [2]. In Parallel Plate Capacitor arrangement [4], one of the plates is made movable by applying bias voltage. When an electric field is excited between two parallel plates, there will be an attractive force acting on both plates to bring them closer and minimize the electrical potential energy of the system This produces displacement , a mechanical form of energy. The energy stored (W) at a given voltage, V is given by equation 1:

$$W = \frac{1}{2}CV^2 = \frac{\varepsilon A V^2}{2d} \qquad (1)$$

And force (F) between the plates is given by equation 2:

$$F = \frac{\varepsilon A V^2}{2d^2} \qquad (2)$$

Where, □=permittivity of material between the parallel plates
A=plate area
d=gap between the plates
C =capacitance between the plates
For a fixed voltage, the electrostatic force is inversely dependent on the separation squared between the capacitor plates. So, the electrostatic force drops as the plates get farther apart. This force is also linearly proportional to the plate area. Large area with close gap separation is required for generating force of significant magnitude which imposes fabrication difficulties. For a parallel plate capacitor shown in figure 1(b), the capacitance is inversely proportional to the gap between the capacitor plates and the force is inversely proportional to the gap between the capacitor plates square. The capacitance and the force of the parallel plate capacitor are highly nonlinear [4].

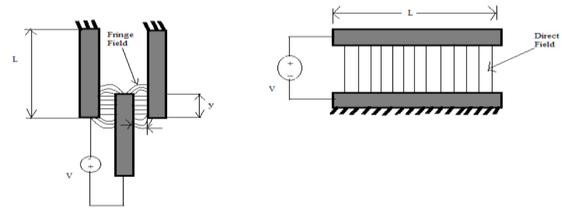

Figure 1(a): Interdigitated Comb Figure 1(b): Parallel Plate Comb

When a voltage under a certain threshold is applied, an electrostatic attractive force brings the plate closer to the ground whereas the displacement induced mechanical restoring force balances the electrostatic force, and system equilibrium is reached when the two forces equate.

II. DESIGNING OF COMB DRIVES:

The design is an adaptation to the jagged-shaped comb drive as shown in Figure 2, analysed in [10], in which the force–displacement is not linear, but it is also not constant, as in the case of rectangular comb drives. Instead, a stepwise continuous response of force versus displacement occurs. The move-and-lock mechanism is based on the change in the gap between the comb fingers with respect to engagement, which in turn is a function of the actuation voltage.

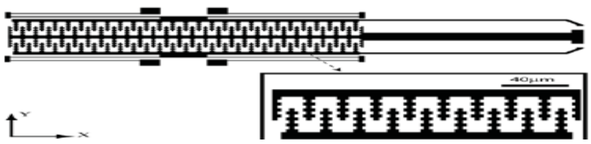

Figure 2: Shaped Comb Drive [10].

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 7, July 2016

Hence the structure behaves as a variable capacitor following the rate of change in ∂C/∂Y, as given in equation 3.

$$F_{es} = \frac{\partial W_e}{\partial Y} = -\frac{1}{2}\frac{\partial C}{\partial Y}V_o^2 \quad (3)$$

The staircase geometry as shown in figure 3 simulated corresponds to a set of 10 fixed fingers and 9 movable fingers. The designs has a few dimensions in common, namely the length of each finger, which was 60 µm long with notches at 5 µm intervals, and the structural thickness of 2 µm. The set of movable fingers start at a rest position corresponding to a 31µm engagement.

The design has minimum 1µm, intermediate 7µm and maximum 13µm gap distances between fingers. The symmetric jagged comb drive [10] design suffers from slippage problem. The staircase shape as shown in figure 3 of comb drive is able to overcome the problem of slippage considerably and will provide more controllability at low actuation voltage. The gripping pads and final micro tweezers testing are left for future work.

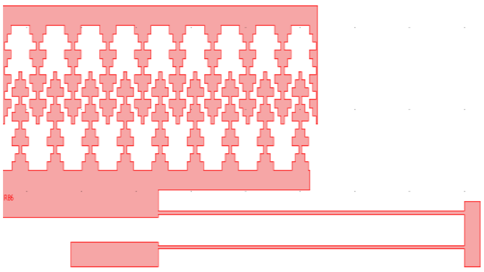

Figure 3: Staircase Micro tweezers.

The electrostatic problem can be physically described by equation 4:

$$E = -\nabla V \quad (4)$$

It follows that, since the comb drive is a capacitive device with air as the dielectric material, the region where the problem is defined is charge free ($\rho_v = 0$). The electrostatic problem is then described by the Laplace equation 5 in rectangular coordinates.

$$\nabla^2 V = \frac{\partial^2 V}{\partial X^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial Z^2} = 0 \quad (5)$$

The objective of the FEM analysis is to find the potential distribution which satisfy equation 5 for a given electrode geometry at a predefined actuation potential Vo. The electrostatic force derived from the equation 3 serves as the load force for the mechanical displacement, according to equation 6.

$$F_{mech} = k\Delta Y \quad (6)$$

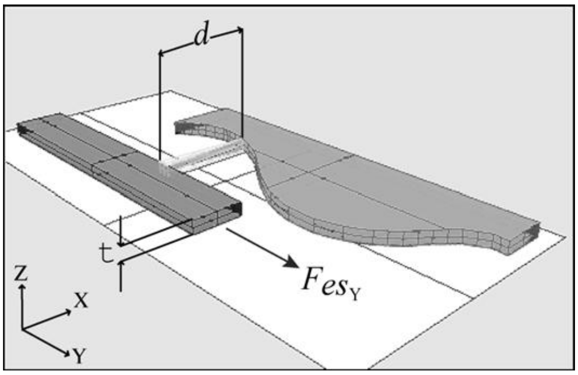

Figure 4: Variable Gap Comb Fingers [10].

III. RESULTS

It is desirable to design structures which are suitable for large displacement at smaller actuation voltage and force. Low actuation power consumption is favorable not only for economic reasons, but also for heat generation considerations. So, here are some comparative results for the work presented on different micro actuator design structural materials.

- Staircase Geometry With Different Structural Materials

As we have discussed earlier that staircase geometry is more efficient then jagged comb drive geometry. Now to make it more efficient we can try different structural material for comb geometry. As we know that polymers plays very important role in MEMS designing. We have analysed various polymers as structural material for comb drives.

Presently poly silicon is used commonly but there are number of materials which can be used for applications like micro actuators which will lead to low cost, reliable, low power consumption devices and one of the materials that can be considered are as follows.

- Poly silicon

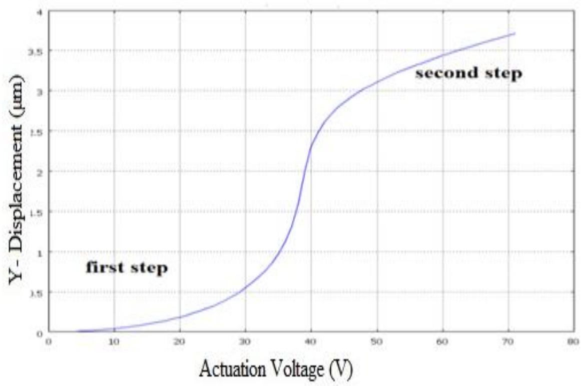

Figure 5: Displacement Vs Voltage Curve.

Poly silicon is most basic structural material for MEMSs devices, with staircase geometry poly silicon shows first step of prescribed displacement of up to 0.5 µm starts nearly from 10V to 30V, then a Sharpe change in voltage occur between 30 to 45 V and then again a second slow movement of nearly 0.8 µm takes place between 45 to 70 V.

IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319 5940
International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 7, July 2016

- Polyimide

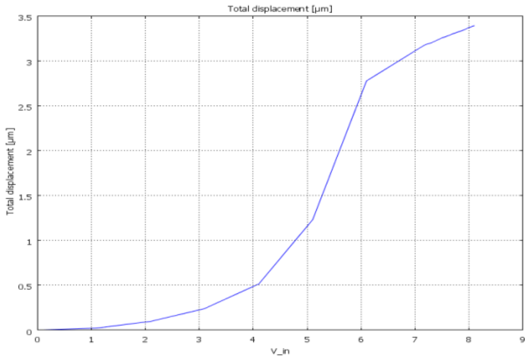

Figure 6: Displacement Vs Voltage Curve polyimide.

Polyimide is a type of polymer which produces maximum displacement of 3.4 µm at low voltage 8.1 V as compared to Poly silicon which produces same displacement at 55.1V.which gives 82.3% improvement over Poly silicon. The first prescribe movement up to 0.5 µm starts nearly from 1V to 4V, then a Sharpe change in voltage occur between 4 to 6 V and then again a second slow movement of nearly 0.8 µm takes place between 6 to 8 V.

- PMMA

PMMA is also a type of polymer which produces maximum displacement of 3.6 µm at low voltage 9 V as compared to Poly silicon which produces same displacement at 62.1V.which gives 85.5% improvement over Poly silicon. The first prescribe movement up to 0.5 µm starts nearly from 1V to 4V, then a Sharpe change in voltage occur between 4 to 6.1 V and then again a second slow movement of nearly 0.8 µm takes place between 6 to 9V.

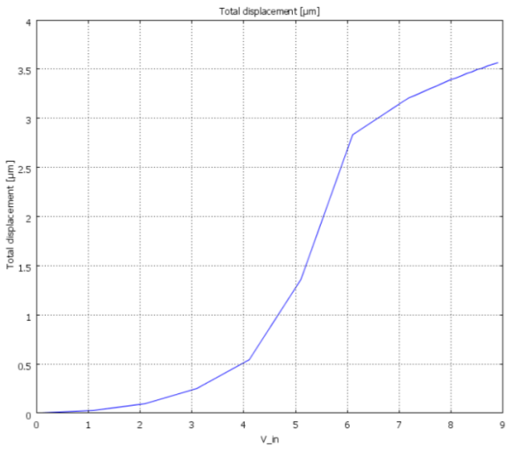

Figure 7: Displacement Vs Voltage Curve PMMA.

- SU-8

SU-8 is also a type of polymer which produces maximum displacement of 3.2 µm at low voltage 6.1 V as compared to Poly silicon which produces same displacement at 52 V, Which gives 88.2% improvement over Poly silicon. The first prescribe movement up to 0.4 µm starts nearly from 1V to 3V, then a Sharpe change in voltage occur between 3 to 5.1 V and then again a second slow movement of nearly 0.4 µm takes place between5 to 6.

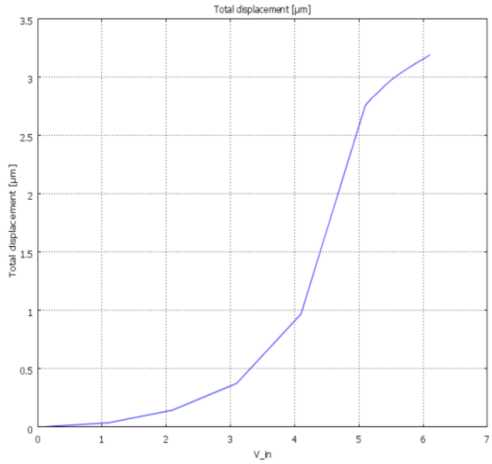

Figure 8: Displacement Vs Voltage Curve SU-8.

- PTFE

PTFE is also a type of polymer which produces maximum displacement of 3.6 µm at low voltage 3.5 V as compared to Poly silicon which produces same displacement at 62.1 V,

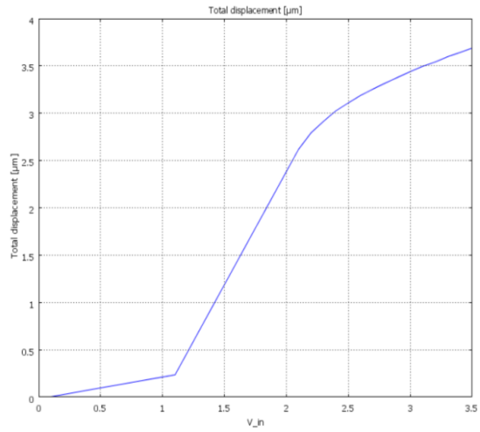

Figure 9: Displacement Vs Voltage Curve PTFE.

Which gives 94.3% improvement over Poly silicon. The first prescribe movement up to 0.25 µm starts nearly from 0.1V to 1.1V, then a Sharpe change in voltage occur between 1.1 to 2.3 V and then again a second slow movement of nearly 0.8 µm takes place between 2.3 to 3.5 V.

IV. CONCLUSIONS

Staircase comb geometry using different materials are analysed. Poly silicon is most basic structural material for mems devices, with staircase geometry poly silicon shows first step of prescribed displacement of up to 0.5 µm starts nearly from 10V to 30V, then a Sharpe change in voltage occur between 30 to 45 V and then again a second slow movement of nearly 0.8 µm takes place between 45 to 70,polyimide which gives 82.3% improvement, which gives 85.5% improvement,PMMA which gives 85.5% improvement, SU8 Which gives 88.2% improvement, PTFE Which gives 94.3% improvement over Poly silicon.

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 7, July 2016

REFERENCES

[1] M.Pavithra, S.Sathya, Dr.S.Muruganand, "DESIGN AND MODELING OF NONLINEAR COUPLED MEMS RESONATOR USING ELECTROSTATIC ACTUATION FOR L-BAND MOBILE SATELLITE COMMUNICATION", Int.J. Chemtech Res.2014-2015,7 (2),Pp 678-684.

[2] Kesteven J, Kannan MB, Walter R, Khakbaz H, Choe HC, "LOW ELASTIC MODULUS TI-TA ALLOYS FOR LOAD-BEARING PERMANENT IMPLANTS: ENHANCING THE BIODEGRADATION RESISTANCE BY ELECTROCHEMICAL SURFACE ENGINEERING" , Mater SciEng C Mater Biol Appl. 2015 Jan;46:226-31

[3] Qing Liu, QingkunMeng, Shun Guo and Xinqing Zhao, "α′ TYPE Ti–Nb–Zr ALLOYS WITH ULTRA-LOW YOUNG'S MODULUS AND HIGH STRENGTH", Journal of Progress in Natural Science: Materials International, Vol.23, Issue 6, pp.562-565, November 2013.

[4] S M Ataka and H. Fujita, "MICRO ACTUATOR ARRAY ON A FLEXIBLE SHEET - SMART MEMS SHEET", ieee26th international conference on micro electro mechanical systems (mems), pp 536-539, jan. 2013.

[5] Anurag Singh and Vijay Kumar Anand "SIMULATION OF SHAPED COMB DRIVE WITH IMPROVED SLIPPAGE AS A STEPPED ACTUATOR FOR MICROTWEEZERS APPLICATION", Journal of Information System and Communication, Vol.III, Issue I, pp.179-181, March 2012.

[6] Binglei Wang and Shenjie Zhou; "SIZE DEPENDENT PULL-IN INSTABILITY OF ELECTROSTATICALLY ACTUATED MICRO BEAMS BASED ON MEMS", Journal of Micromechanics and Microengineering, Vol. 21 No. 2, pp 304-309, Feb. 2011.

[7] Zakri Ghazalli, Asnul Hadi Ahamad, Mohd Fazli Ismail and Khairul Fikri Muhamad "DESIGN OF ELECTROSTATIC COMB ACTUATORS BASED ON FINITE ELEMENT METHOD" International Conference on Enabling Science and Nanotechnology, Malaysia, pp 1-3,Dec. 2010.

[8] Ndu O sonwanne and Jason V. Clark "MEMS COMB DRIVE GAP REDUCTION BEYOND MINIMUM FEATURE SIZE: A COMPUTATIONAL STUDY"; Excerpt from the Proceedings of the COMSOL Conference, Boston, pp 317-322, 2010.

[9] G.K. Ananthasuresh, K.J. Vinoy, K.N. Bhat, S. Gopalakrishnan and V.K.Aatre; "MICRO AND SMART SYSTEMS" Wiley –India; First Edition, pp 115-129 2010.

[10] J. Varona, E. Saenz, S. Fiscal- Woodhouse and A.A. amoui; " DESIGN AND FABRICATION OF A NOVEL MICROGRIPPER BASED ON ELECTROSTATIC ACTUATION" , 52nd IEEE International Midwest Symposium on Circuits and Systems, pp 827-832, Aug. 2009.

[11] Badariah Bais and Burhanud din Yeop Majlis; "LOW-G AREA-CHANGED MEMS ACCELEROMETER USING BULK SILICON TECHNIQUE" American Journal of Applied Sciences Vol.5, Issue 6, pp 626-632, 2008.

[12] Stephen A. Wilson and Renaud P.J. Jourdain "NEW MATERIALS FOR MICRO-SCALE SENSORS AND ACTUATORS: AN ENGINEERING REVIEW" Materials Science and Engineering R: Reports, Vol. 56, Issue 6, pp 119–129 2007.

[13] W. Merlijn van Spengen and Erwin C. Heeres "A METHOD TO EXTRACT THE LATERAL AND NORMAL COMPONENT OF THE MOTION FROM THE CAPACITANCE CHANGE OF A MOVING MEMS COMB DRIVE" Journal of Micromechanics and Microengineering, Vol. 17, No. 3, pp 447-451, 2007.

[14] G. Somlay, Z. Szucs, A. Poppe and M. Rencz "SIMULATION OF A COMB DRIVE FOR FRACTURE LIFETIME MEASUREMENTS" Excerpt from the Proceedings of the COMSOL Users Conference, Grenoble, pp 149-152, 2007.

[15] Isabelle P.F. Harouche, C. Shafai and Richard Gordon, "DESIGN AND SIMULATION OF MICROTWEEZERS USING A CONTROLLED DISPLACEMENT COMB DRIVE" Canadian Conference on Electrical and Computer Engineering, Ottawa, pp 341-343, May 2006.