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Design & Simulation of Low actuation Voltage Perforated Shunt RF MEMS Switch

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Abstract— **Fixed-fixed RF MEMS switch is element that fixed at both ends. The electrostatic actuation process occurs on the beam and generates electrostatic forces which will deflect the switch from its original position. The electrostatic force is increases as the applied voltage increases due to effect of this the displacement produced in z-direction of the beam. When the pull in voltage receives the beam will pull down and connected to the electrode. The paper explores the concept of low actuation voltage, low power consumption ,increases flexibility, increased switching speed and reduce the squeeze film damping. The various types of switches are design and simulated it which provides distinct displacement corresponding to voltage. The Fixed-Fixed RF MEMS switch using perforation for size of 2µm-5µm and various meanders to provide low actuation voltages. The simulation and design are done on the software of COMSOL MULTIPHYSICS 4.3b.**

Index Terms— **Fixed-Fixed switch; Material; MEMS Switches; Low actuation voltage; Perforation.**

I. INTRODUCTION

A micro-electromechanical system (MEMS) is a process technology used to produce miniature integrated devices or systems that merge electrical and mechanical components. RF-MEMS switches revolution in the growth of the modern communications systems. The MEMS switches have the potential to combine advantages of electro-mechanical and semiconductor switches. MEMS switches present the high RF performance and low DC power consumption of electro-mechanical switches but with the decreasing size and cost features of semiconductor switches [1]. RF MEMS switches have grown at a very fast pace, and have entered into many applications in wireless communication and space sub-systems. RF MEMS switches have replaced the conventional GaAs FET and microwave switches in RF and microwave system. The MEMS switches having negligible power consumption of a few µ-watts, as well as low insertion loss, high isolation, much lower inter modulation distortion, small footprints, low cost, and light weight [2]. Fixed-fixed beams under voltage driving are widely used in many MEMS sensors and actuators, including MEMS switches.

These MEMS devices are relatively simple to design and fabricate as well as to integrate on a chip with CMOS circuits. However, voltage driving may exhibit an inherent instability situation known as the pull-in phenomenon [3]. An RF MEMS device includes a MEMS variable capacitor, MEMS tunable inductors, phase shifters, resonators and RF MEMS switches. MEMS switches are devices that operate based on mechanical movement to achieve a short circuit or an open circuit in the RF transmission line. The actuation mechanisms to obtain the required forces for the mechanical movement in MEMS switches include electrostatic, electromagnetic, magnetic, piezoelectric and thermal. However, the electrostatic actuation mechanism is the most common method used because of its low consumption [4]. Shunt switches are designed for applications at 10-100 GHz. On the other hand, series switches are designed with a low ohmic contact for the lower Gigahertz range [4]. Due to the near-zero power consumption and linearity, electrostatic actuation is most widely used, in which electrostatic force is generated between a fixed electrode and a movable membrane for switching operation. Several disadvantages include slow switching speeds, high actuation voltage, and hot switching in high-power RF applications [5]. The paper represents the comparative study of cylindrical perforated RF MEMS switch with various meanders. The electrostatic actuation technique is used for actuation mechanisms .

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II. DESIGN OF FIXED-FIXED SWITCH USING PERFORATION

The Fixed–Fixed RF MEMS switch is both end are fixed above free gap. The Fixed -Fixed switch all dimensions are in micrometers. The switch is designed by using hafnium oxide. The HfO_2 material is having a high dielectric constant value in the comparison of the silicon, silicon dioxide (SiO_2), silicon nitride (Si_3N_4), aluminium oxide (Al_2O_3). In this switch is designed by using cylindrical perforation is done on fixed area with various meanders. The Fig.1 show the three dimensional structure of cylindrical perforated RF MEMS Switch. The dimension of shunt switch is shown in Table 1. The dimension of meanders is shown in Table 2. The dimension of perforation is shown in Table 3.

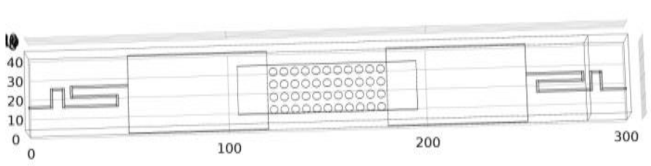

Fig.1 Schematic 3D of cylindrical perforation on Fixed-fixed RF MEMS switch

Parameters	/Block1	Block2	Block3
Length	70µm	90 µm	70µm

Width	40µm	25 µm	40µm
Height	2µm	2 µm	2µm

Table 1 Dimension of Shunt Switch

The designing used various types of meanders which provide the greater flexibility and high switching speed. The electrostatic actuation process in which the use of electrostatic force induced by the potential difference between micro actuator and electrode. The electrostatic actuation is popular actuation methods for microactuators fabricated by MEMS technologies. At high actuation voltage and limited operation range due to the pull-in phenomenon. Another advantage is that electrostatic actuators can be easily built by many fabrication methods, which are well-suited with most CMOS technologies that are employed in order to manufacture modern analog and digital devices. In the figure show the modeling of Fixed–Fixed MEMS switch with perforation. The pull in voltage and displacement curve is plot with various type of perforation. The beam is made of Hafnium oxide with a Young's modulus, *E*, of 280 GPa, and a Poisson's ratio, ν, of 0.24. The pull-in voltage is given such type [6]:

$$V_{PI} = \sqrt{\frac{4c_1 B}{\varepsilon_0 L^2 c^2 \left(1 + \frac{c^3 g_0}{W}\right)}}$$

The role of pull in voltage that when the applied voltage value gradually increases then the displacement of MEMS switch in the z-direction is decreases, as pull in voltage received the switch and ground electrode contact to each other.

Terminal	Input Terminal					Output Terminal				
Parameters	M 1	M 2	M3	M4	M5	M6	M7	M8	M9	M10
Length	10	15	10	15	29	10	15	10	15	29
Width	1	1	1	1	1	1	1	1	1	1
Height	2	2	2	2	2	2	2	2	2	2

Table 2 Dimensions of Meanders

III. SIMULATION OF FIXED-FIXED SWITCH

The results of simulation of switches are shown in figures. The shown the model with cylindrical perforation at applied voltage .Here pulls in voltage is 24.1volt, As the Fixed-Fixed MEMS switch flexibility, switching speed will be increases and squeeze film damping is reducing. The Fig.2 has shown the switch C_A simulation representation of z-component displacement at different applied voltage. The Fig.3 switch C_B simulation representation of z-component displacement at different applied voltage. The Fig.4 switch C_C simulation representation of z-component displacement at different applied voltage .The each geometry will be provide various displacement at pull in voltage. The all simulates results is shown in the figures.

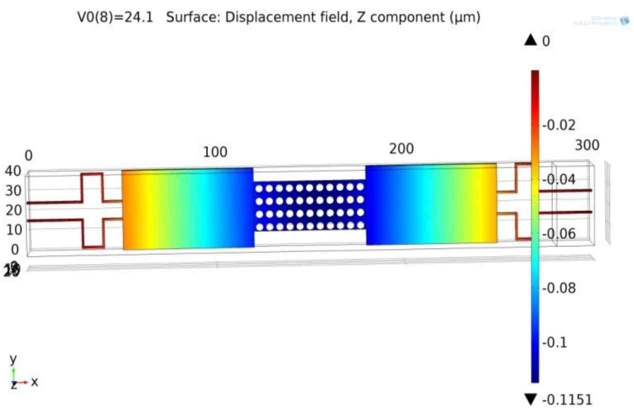

Fig.2 Simulated z- displacement component switch C_A at 24.1 volt

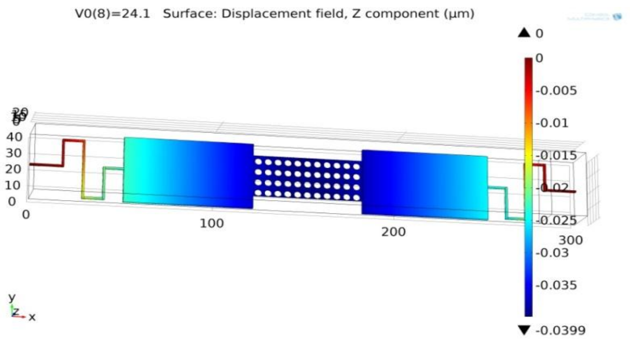

Fig.3. Simulated z- displacement component switch C_B at 24.1 volt

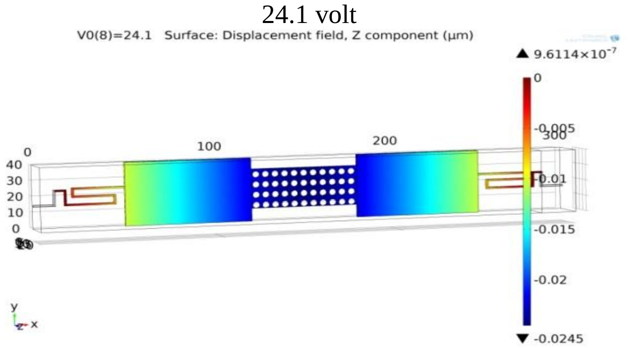

Fig.5. Simulated z- displacement component switch C_C at 24.1 volt

IV. GRAPHICAL PRESENTATION

The graphs of various switches are representing in the figures. All graphs are represents the variation in the z-component displacement at different voltages. Each voltage is differentiating with different colour .The switch C_A graphs is represent in Fig.5. The switch C_B graph is represented in Fig.6 and switch C_C graph is represented in Fig.7.

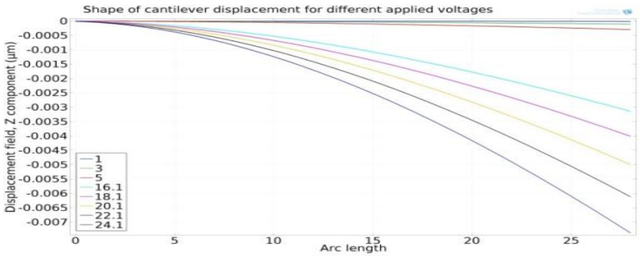

Fig.6 Graph between z- displacement component and arc length at different various voltages of switch C_A

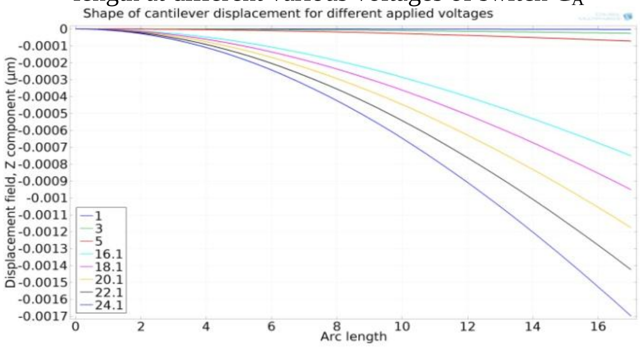

Fig.7 Graph between z- displacement component and arc length at different various voltages of switch C_B

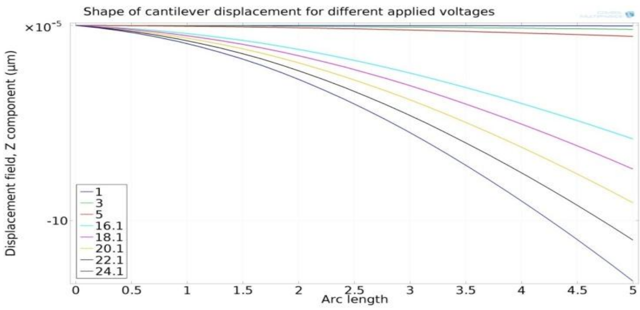

Fig.7 Graph between z- displacement component and arc length at different various voltages of switch C_C Results &

V. DISCUSSION

Fixed- Fixed shunt RF MEMS switch is design to decreasing actuation voltages, increasing the flexibility and reducing the switching time. The comparison study of various RF MEMS shunt switches at different applied voltages. The Table is shown the all comparison result with various types' voltages. In this we fixed the quantity of perforation geometry will be almost fixed and then compares the result. The use of meanders that stiction problem of switch is reduced. The perforation is providing reduced the fringing fields, air resistance and allowing the switching speed will be increased. The numerical and simulation result show that the shape for cylindrical will give high displacement at pull in voltage. These all values are negative displacement in z-direction .As the voltage increases the electrostatic forces induced due to effect of potential difference which reduces the gap between air and beam. The material is also play important that the HfO_2 having a high dielectric constant and high thermal stability in comparison of silicon dioxide, silicon and silicon nitride.

Displacement	***z-component displacement***		
Voltage	***Switch C_A***	***Switch C_B***	***Switch C***
1	-1.7942e-4	-6.7011 e-5	-4.1648e-5
3	-1.6168e-3	-6.0329e-4	-3.749e-4
5	-4.502e-3	-1.6769e-3	-1.0418e-3
16.1	-0.0485	-0.0176	-0.0109
18.1	-0.062	-0.0222	-0.0138
20.1	-0.0774	-0.0275	-0.017
22.1	-0.0951	-0.0334	-0.0206
24.1	-0.1151	-0.0399	-0.0245

Table 3 Results of different meanders with displacement at applied voltage

VI. CONCLUSION

The conclusion of this research paper that the perforated Fixed- Fixed RF MEMS switch C_A with cylindrical perforation is provided maximum displacement at pull in voltage .while the switch C_C very less displacement at the pull in voltage or maximum voltage. The Fixed-Fixed switch C_A is more flexible and increasing the switching speed. The material is also play important role that the value of young's modulus is very high of HfO_2 due to this thermal stability and switch speed of also high.

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