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Comparative Study of Perforated RF MEMS Switch

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Abstract

MEMS are the Micro Electronic mechanical system or in general terms it is also known as Micro electronic mechanical switch. MEMS have classified in two types of switch that is series switch and shunt switch .The cantilever is a series type switch whereas the fixed- fixed beam is shunt type switch. Fixed- Fixed beam is the element that is fixed at both anchor ends. The electrostatic actuation process occurs on the switch due to which switch deflects from its original position. The stiction problem occurs in MEMS switches which have been reduced by the proposed design. The perforation is used to reduce the squeeze film damping by decreasing the mass of the switch. As the voltage increases the switch moves to downward z-direction .The displacement is produced in the switch as direction of movement is towards negative z-axis. When the beam contacts with electrode, pull in voltage is achieved. This paper explores the perforation and meander concept with Fixed -fixed switch, which increases the flexibility, low actuation voltage and switching speed. The various types of perforations provide discrete displacement corresponding to voltage. In this paper we represent the design and simulation of Fixed-Fixed switch using perforation of size 2µm-5µm. The electrostatic actuation mechanism is applied on the Fixed-fixed switch which has a serpentine meanders and perforation at different voltages. The switch is designed and simulated by using COMSOL®MULTIPHYSICS 4.3b software.

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Keywords: Fixed-Fixed beam; Material; MEMS Switches; Low actuation voltage; Perforation

1. Introduction

MEMS (Micro-electro-mechanical-system) are the combination of electrical and mechanical function on the same substrate by the bulk micro machine and surface to fabricate, to design microstructures. These microstructures are used in applications such as biomedical , industrial sensors, telecommunication and optical communication [1].As MEMS switches are widely used in different actuation of electrostatic, electromagnetic ,electro thermal, and piezoelectric [1]. In MEMS switches, issues like stiction between metal and metal occurs which increases the ohmic resistance and provide losses. The charge injection due to a very high electric field at down state is the major problem of this type of MEMS switches [1]. The issue of the electrostatic MEMS

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switches is their high actuation voltage owing to a large capacitance ratio. These types of problems can be conquered by MEMS switches.In this technocratic era, the main motive is to develop the high performance MEMS switches which mainly focus on power transmission, low actuation voltage, wide band operational frequency, short switching time, good packaging, and high reliability [2]. In this paper we represent the design and simulate Fixed-Fixed switch with different shapes of perforation. Fixed-Fixed beams are the omnipresent structures in field of Micro electronic mechanical system. The perforation is a small hole in a thin material. Normally more than one perforation is a pattern used to design the switch. The role of perforation is to increase the flexibility of switch [3]. It is used to reduce the squeeze film damping and increase the switching speed of MEMS switch [3]. These switches are categorized as Capacitive and Ohmic contact and the signal flows in series and shunt configuration [4]. The holes release some of the residual stress in the beam and reduce the Young's modulus of the MEMS structure [5]. The perforation technique can be used in fixed- fixed beam or cantilever beam. The MEMS switches can be actuated by several methods such as electrostatic, electromagnetic, piezoelectric and thermal. The low power consumption (near to zero) and linearity is achieved by electrostatic actuation methods, so the reason of electrostatic actuation method is widely used for switching operation between fixed electrode and movable membrane.

This paper represents comparative study of perforated RF MEMS switch. The result of RF performance reduces the bucking effect and eliminates the problem of stiction. When electrostatic force is applied on the Fixed-Fixed beam, beam shifts to downward direction corresponding to z-axis and various displacements at various voltages is obtained. The perforation geometry used in MEMS switch, which is designed and simulated for cylindrical, rectangular and square. The Design structure uses serpentine Meanders for all perforated switch which also increases the flexibility. Here the calculation for the value of z-component displacement with respect to voltage for distinct perforation is carried out. During simulation graphical presentation between displacement and applied voltage is observed. The pull in voltage is a voltage where the beam gets complete contact with the electrode. The COMSOL MULTIPHYSICS 4.3b software is used to design and simulate MEMS switch.

Nomenclature

V_{PI}	Pull in voltage of beam
P_R	Rectangle Perforation
P_C	Cross section cylindrical Perforation
P_S	Square perforation
L	length of beam
W	width of beam
c_1	constant
c_2	constant
B	force
g_0	gap between beam and electrode
ϵ_0	permittivity
r	radius of cylindrical perforation
h	height of perforation
w	width of perforation

l	length of perforation

The aim and research of this paper is to design and simulate RF MEMS switch at low electrostatic actuation voltage, lower mass its effect on squeeze film damping. Fixed – Fixed beam with various geometry of perforation. The comparative analysis of perforated switches with serpentine meanders is done in this paper.

2. Design of Fixed-Fixed Switch using Perforation

The Fixed- Fixed beam or Fixed -Fixed MEMS switch at both ends are fixed above free gap. The Fixed - Fixed switch have all dimensions in micrometers. The materials HfO_2 is used in switch. The HfO_2 material possess a property of high dielectric constant value as compared to silicon, silicon dioxide (SiO_2), silicon nitride (Si_3N_4), aluminium oxide (Al_2O_3).

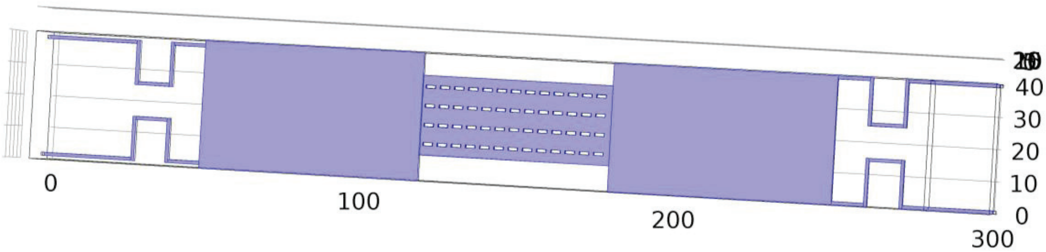

Fig.1. Schematic 3D of rectangle perforation on Fixed-fixed switch

In this design the perforation is done on the fixed area with different shapes. The Fig.1 shows the 3d structure of rectangular perforated switch. The dimension of beam is shown in Table 1. The dimension of meanders is shown in Table 2. The dimension of perforation is shown in Table 3. The serpentine meander which provides the greater flexibility and high switching speed which joints to beam. In electrostatic actuation process of, the electrostatic force induced by the potential difference between micro actuator and electrode. The electrostatic actuation process is popular actuation methods for micro actuators fabricated by MEMS technologies. 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. The applied voltage and displacement curve is plot for perforated switch. The switch is made of Hafnium oxide with a Young's modulus (E) of 280 GPa and a Poisson's ratio (v) of 0.24. The pull-in voltage is given such type [5]:

$$V_{PI} = \sqrt{\frac{4c1B}{\varepsilon_0 L^2 c^2 (1+\frac{c^3 g_0}{W})}}$$

Table 1 Dimension of Beam

Parameters	Block1	Block2	Block3
Length	70µm	90 µm	70µm

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

When the voltage is applied on the switch, value of voltage gradually increases due to this the displacement of MEMS switch in the negative z-direction is decreases. As pull in voltage is received the movable beam and electrode are contact to each other.

Table 2 Dimension of meanders of switch P_R

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 3 Dimension of various types of perforation

Perforation	Cylindrical	Rectangle	Square
Dimension	r = 2µm	w = 3µm	w = 3µm
	h = 2µm	d = 1µm	d = 3µm
		h = 2µm	h = 2µm

3. Simulation of Fixed-Fixed Switch

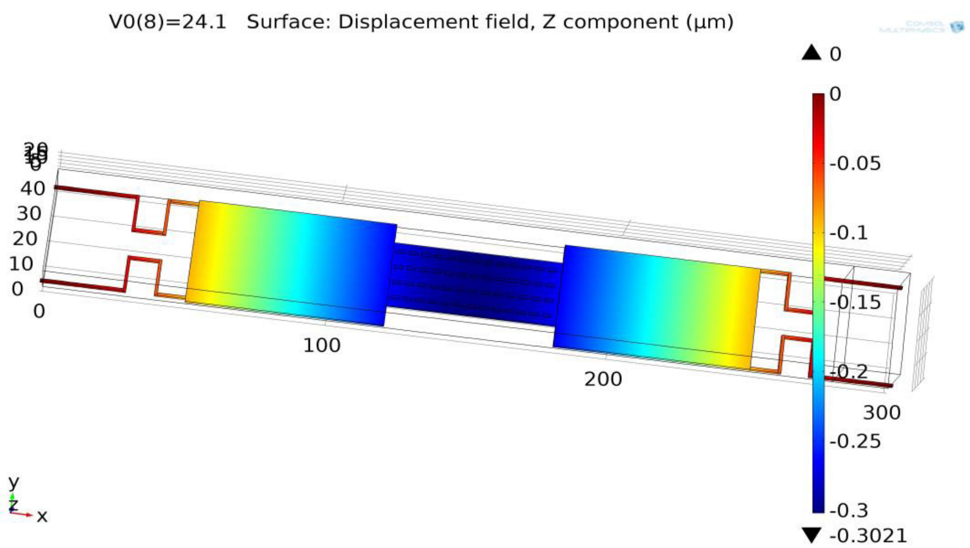

Fig.2 Simulated 3D structure of switch P_R at 24.1 volt

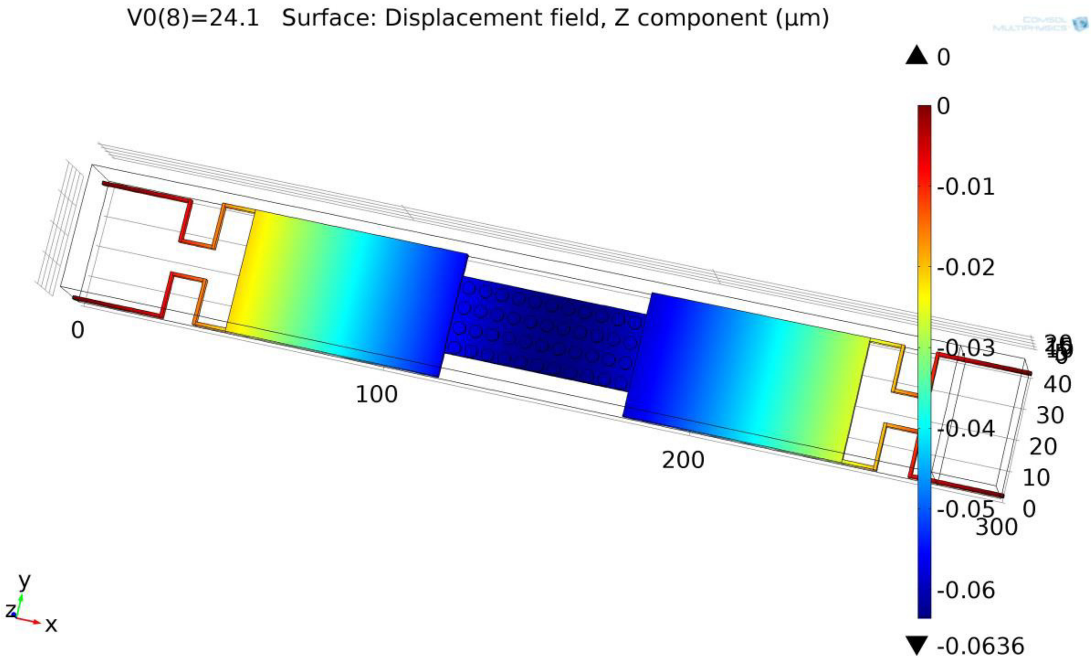

Fig.3 Simulated 3D structure of switch P_C at 24.1 volt.

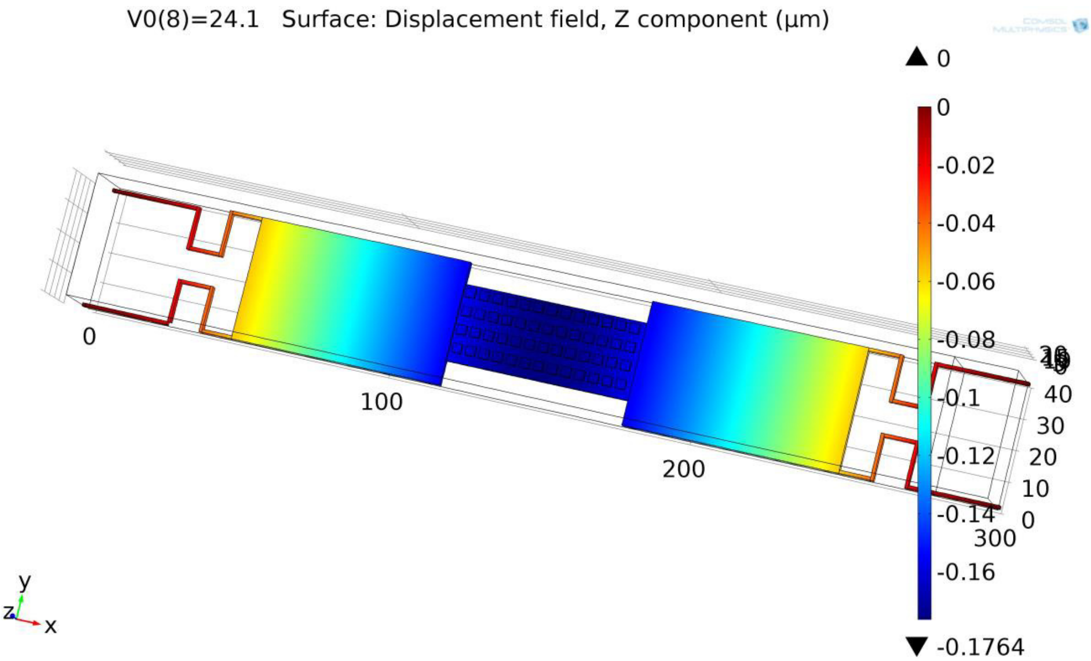

Fig.4 Simulated 3D structure of switch P_S at 24.1 volt.

The result of simulation of switch is shown in figures. This model shows the rectangular perforation at applied voltage .Here pull in voltage or maximum voltage is 24.1volt. The rectangular perforated MEMS switch increases flexibility, switching speed and reduces squeeze film damping. The Fig.2 shows the simulation representation of z-component displacement at applied voltages 24.1 of switch P_R. The maximum displacement of z-component is - 0.0636μm.Simalrly we represent simulated 3d structure of switch P_C in Fig.3. The Fig.4 represents the 3D structure of simulated switch P_S at 24.1 volt. The each geometry provides various displacements at applied voltage.

4. Results & Discussion

In Fixed- Fixed MEMS switch is designed to increase the flexibility and reduce the switching time. The comparative study of various types of perforated MEMS switches which provides different types of z-component displacement at pull in voltage. The comparison of perforated switch z-component displacement is shown in the Table 4. In this simulation constant density in fixed volume the density of perforation in a fixed volume and then results are compared. The use of meander is to reduce the problem of stiction by switch P_R. The perforation reduces fringing fields, air resistance and increases the switching speed. The numerical and simulation result shows the geometry for cross section cylindrical perforation which provides low displacement at pull in voltage. The material also plays a vital role i.e. HfO_2 having a high dielectric constant and high thermal stability in comparison of silicon dioxide, silicon and silicon nitride. The very less flexibility perforation is provided by cross section cylindrical perforation. Its gives -0.0636 μm at pull in voltage 24.1 due to this the beam is not in contact with the electrode completely. In Table 4 the z-component displacement of all three types of perforated switch is shown. The comparison of switches is found as voltage increases gradually the displacement also increases gradually.

Table 4.Comparison of various types perforated switches

Perforation	Cylindrical	Square	Rectangle
Voltage	Min.	Min.	Min.
1	-1.0295e-4	-2.5716 e-4	-3.8256 e-4
3	-9.2731e-4	-2.3188e-3	-3.4531 e-4
5	-2.58e-4	-6.46533 e-3	-9.6483 e-3
16.1	-0.0274	-0.0711	-0.1103
18.1	-0.0349	-0.0917	-0.1443
20.1	-0.0434	-0.1157	-0.1856
22.1	-0.0529	-0.1437	-0.2367
24.1	-0.0636	-0.1764	-0.3021

5. Conclusion

The conclusion of this research paper is that the design and simulation of perforated Fixed- Fixed switch of rectangular shape provides maximum displacement- 0.3021μm at pull in voltage 24.1. The cylindrical shape perforation provides very less displacement 0.0636μm at the pull in voltage or maximum voltage 24.1. As the result Fixed-Fixed switch is more flexible when it is perforated with rectangular geometry and increases the switching speed. The young's modulus of HfO_2 is very high due to this thermal stability and switch speed of switch increases. The perforated MEMS switches operate at lower actuation voltages than other capacitive switches and gives maximum displacement. This result of excellent RF MEMS switch can be used in low power and low loss application such wireless, satellite, mobile communication etc.

References

[1] Yasser Mafinejad,, Majid Zarghami and Abbas Z. Kouzani. *Design and Simulation of High Isolation RF MEMS Shunt Capacitor Switch for C-K Band* .

[2] Y. Mafinejad, A. Z. Kouzani , K. Mafinezhad H. Nabovatti .*Design and Simulation of a Low Voltage Wide Band RF MEMS Switch* .IEEE International Conference on Systems, Man, and Cybernetics San Antonio. TX, USA - October 2009.

[3] Tejinder Singh, Navjot K. Khaira, and Jitendra S ,Sengar .*Stress Analysis Using Finite Element Modeling of a Novel RF Microelectromechanical System Shunt Switch Designed on Quartz Substrate for Low-voltage Applications*. Transactions on electrical and electronic materials. Vol. 14, No. 5, pp. 225-230, October 25, 2013

[4] Poonam Verma, Surjeet Singh. *Design and Simulation of RF MEMS Capacitive type Shunt Switch & its Major Applications*. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) .e-ISSN: 2278-2834, p- ISSN: 2278-8735. Volume 4, Issue 5 (Jan. - Feb. 2013), PP 60-68.

[5] Gabriel.M.Rebeiz. *RF MEMS: Theory, Design, and Technology*. John Wiley & Sons, Inc. ISBN: 0-471-20169-3.