

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 10, October 2018

Design and Simulation of RF MEMS Switches

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ABSTRACT: Electromechanical and Electromagnetic modelling is used to improve the overall dynamic characteristics of the proposed geometry of switches and the number and size of holes in them. The objective of this paper is to design and simulate capacitive type Radio Frequency Micro-Electro-Mechanical Switches (RF MEMS) with improved electromechanical performances. Capacitive MEMS are preferred over the dc contact switches as these provide very low insertion loss and high isolation at very high frequencies exceeding 10GHz.

The modelling of the switches on Pyrex glass substrate (500 μ m) is using a low complexity four-mask surface machining process. This design of MEMS requires only 4.8-6.2V as pull-in voltage. The dynamic behaviour of these switches is investigated experimentally where the measured mechanical resonant frequency is found to be the range of 10.56-15.7 KHz. Measured switching time for all the design is 25-32 μ S at their respective pull-in voltages. At the respective frequency range of 20-45 GHz. two of the switch designs have an insertion loss of less than 0.01 and 0.5dB and isolation better than 30dB. Close agreement between experimentally measured and simulation result demonstrates successful realisation of fast switching capacitive switch at low voltage. Therefore, reduced bouncing during switching and fast settling upon release are other aspects of designing these switches.

KEYWORDS: low actuation voltage, low insertion loss, high isolation, low power consumption.

I. INTRODUCTION

In the past three decades, advances in microfabrication processes along with the design and modelling have shown that Radio Frequency Micro Electro Mechanical Systems (RF MEMS) switches have emerged as the sustainable alternative for the existing semiconductor switches. RF MEMS switches are promising basic building blocks of the present and future communication systems including mobile phones, satellite communications, the defence as well as in high-end applications such as automated measurement and test equipment.

MEMS are small integrated devices or systems that combine mechanical and electrical components. In the present work, we have proposed the designed model of RF MEMS switch with the analysis and simulation. The mere focus is to design the switch without compromising on RF performances and dynamic behaviour.

Previously RF switching has been implemented by using p-i-n diodes and GaAs MESFET's in the form of junction field-effect transistor (JFET) based semiconductor switches. However, these semiconductor switches show poor performance in the respect of signal loss and power consumption as the frequency increases. Recently, RF microelectromechanical switches have been introduced for low actuation voltage, low insertion loss, high isolation and low power consumption. MEMS, although this term first appeared in 1987, its history can be traced to the late 1960's. After the invention of the transistor at Bell Telephone Laboratories in 1947 and the production of the first integrated circuit (IC) at Texas Instruments in 1958 using Germanium (Ge) devices, a gold resonating MOS gate device was fabricated in 1967 [Nathan son 1967] which is generally accepted as the first MEMS device. The turning point for MEMS was the beginning of the 1990's with the development of integrated circuit (IC) fabrication processes where sensors, actuators and control functions were co-fabricated in silicon.

Normally MEMS has two types that are MEMS actuators and MEMS sensors. MEMS actuators are moving mechanism activated by an electrical signal like a micro-motor. Microsensors are the devices used to detect changes in the system's environment by measuring mechanical, thermal, magnetic, chemical or electromagnetic information or phenomena.

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II. RELATED WORK

From the literature survey we compared sacrificial layer, substrate, air gap, bridge material thickness, dielectric thickness, actuation voltage, insertion loss & isolation loss and these helped us for determining the range of various losses, various forces acting on the beam such as fringe field effect, restoring force, residual stresses, signal frequency along with the influence of voltage on the device performance parameters.

The literature survey was done for determining the range of various losses, various forces acting on the beam such as fringe field effect, restoring force, residual stresses, signal frequency along with the influence of voltage on the device performance parameters. Considering the vast scope of work involved, it was decided to limit ourselves in the present work for the mechanical and electromechanical analysis of the MEMS switches. Performance mainly depends on the dielectric material used, surface roughness, surface topology etc. However, the information which was made available from the literature review helped in the selection of design parameters, their ranges required for the present investigation of MEMS switches.

III. EXPERIMENTAL RESULTS & DISCUSSION

This chapter focuses on the simulation results of the deformable beam within MEMS. The obtained simulation results for different geometries and structures can be used to determine RF performances and dynamic behaviour.

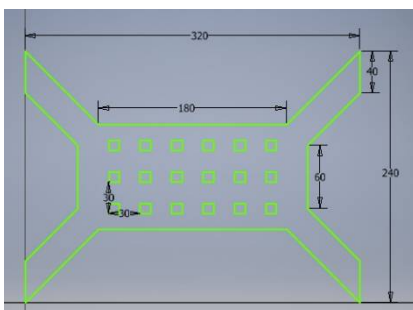


Fig 1 Structure 1

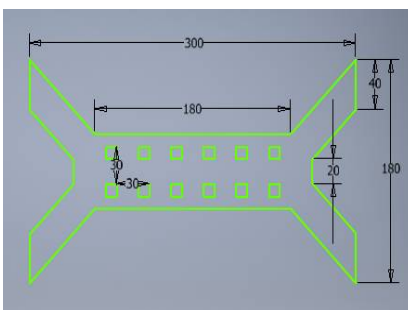


Fig 2 Structure 2

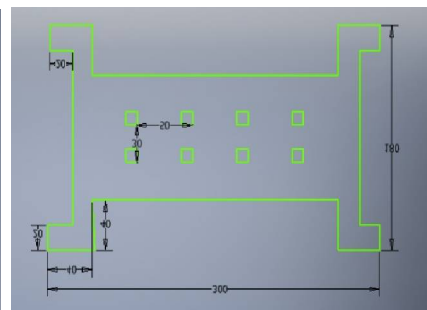
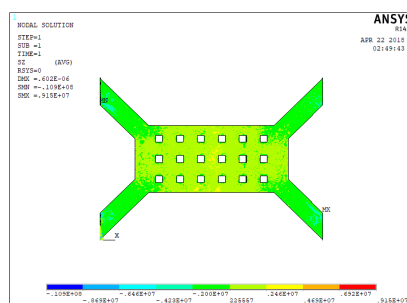


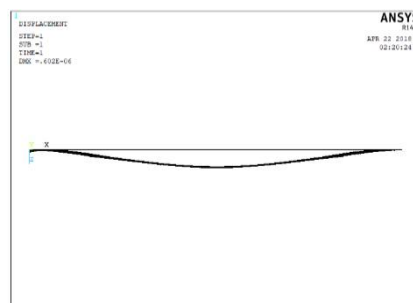
Fig 3 structure 3

SIMULATION USING ANSYS SOFTWARE

Figures show the Ansys 14.5 Simulation results of the deformable beams within MEMS. Figs. (1), (2), (3), (4) shows structure 1. Figs (5), (6), (7), (8) shows structure 2 and Figs (9), (10), (11), (12) shows structure 3.



(1)



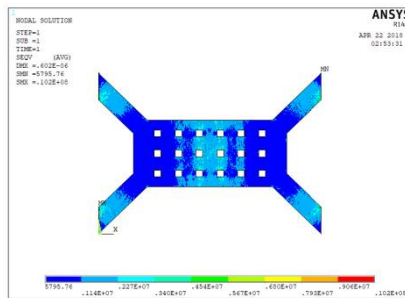
(2)

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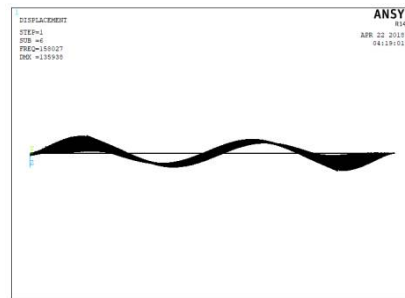
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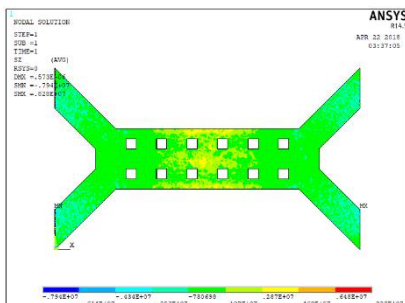


(3)

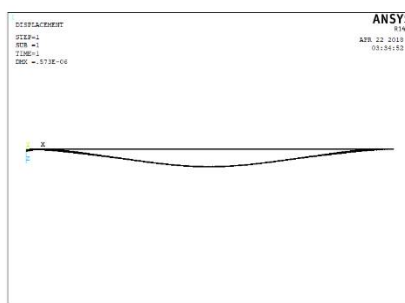


(4)

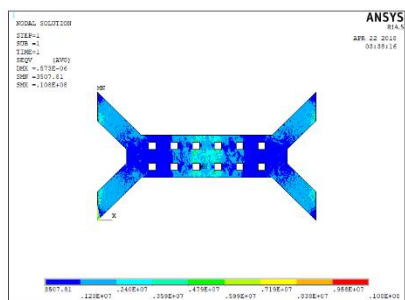
In structure 1 (i.e. fig 1,2,3,4) fig 1 shows stress in z- direction min stress is $0.109e8$ and max stress is $0.915e7$, fig 2 shows deflection of beam by $0.602\mu\text{m}$, fig 3 shows von mises stress min stress is 5795.76 and max stress is $0.102e8$, fig 4 shows modal analysis of structure 1.



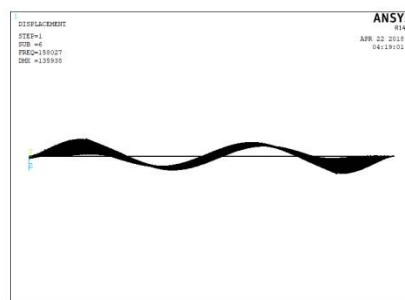
(5)



(6)



(7)



(8)

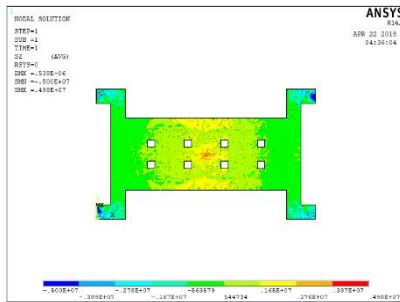
In structure 2 (i.e. fig 5,6,7,8) fig 5 shows stress in z-direction min stress is $0.794e7$ and max stress is $0.828e7$, fig 6 shows deflection of beam by $0.573\mu\text{m}$, fig 7 shows von mises stress min stress is 3507.81 and max stress is $0.108e8$, fig 8 shows modal analysis of structure 2.

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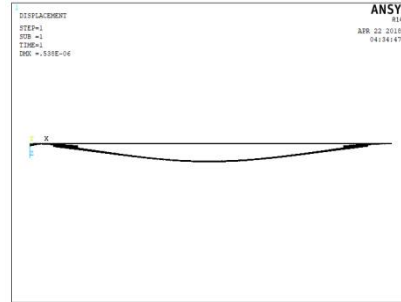
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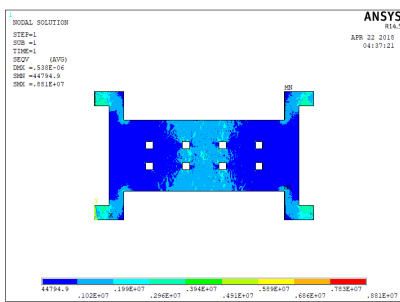
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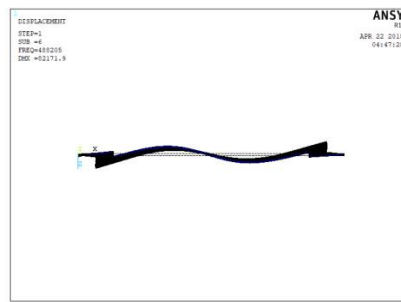
(9)



(10)



(11)



(12)

In structure 3 (i.e. fig 9,10,11,12) fig 9 shows stress in z-direction min stress is $0.5e7$ and max stress is $0.498e7$, fig 10 shows deflection of beam $0.538\mu m$, fig 11 shows von mises stress min stress is 44794.9 and max stress is $0.881e7$, fig 12 shows modal analysis of structure 3.

Table no. 1: comparison of frequency range for the structural membrane:

Load step	Frequency (Hz) Structure 1	Frequency (Hz) Structure 2	Frequency (Hz) Proposed model
1	19028	19028	72165
2	47055	47055	$0.19111e6$
3	57194	57194	$0.2282e6$
4	89085	89085	$0.31656e6$
5	$0.10743e6$	$0.10743e6$	$0.45199e6$
6	$0.158e6$	$0.158e6$	$0.4882e6$

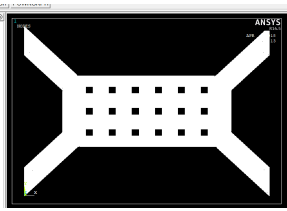
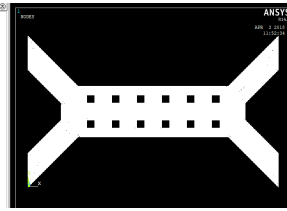
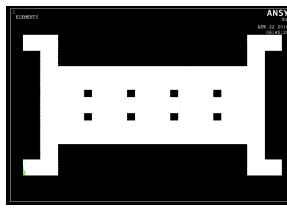
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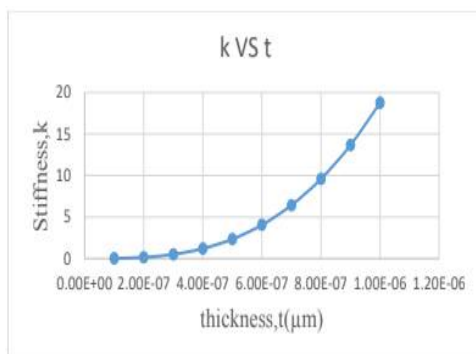
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Table no. 2: comparison of simulation results:

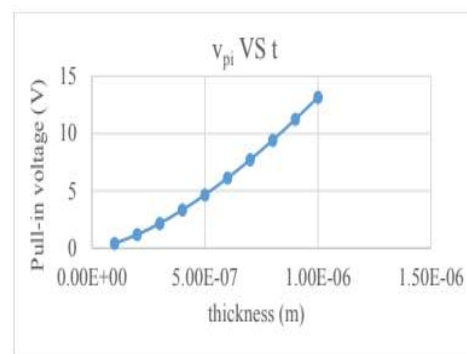
Structural and Modal analysis	Design 1 Planar	Design 2 Planar	Design 2 With Curved structure
Image			
Deflection of beam for 1 μN force	0.602 μm	0.573 μm	0.538 μm
Derived quantities from above K	2.34	2.13	2.13
Pull in voltage	4.652v	5.455v	4.684v
Von Mises stress Values (N/m ²)	SMN = 5795.76 SMX = 0.102e8	SMN = 3507.81 SMX = 0.108e8	SMN = 44794.9 SMX = 0.881e7
Stress in Z- Direction	SMN = 0.109e8 SMX = 0.915e7	SMN = 0.794e7 SMX = 0.828e7	SMN = 0.5e7 SMX = 0.498e7

Graphical results:

Fig 5 The graphs below show the relation between (1) Stiffness vs Thickness (2) Pull-in Voltage vs Thickness (3) Air Gap vs Critical voltage (4) Release Time vs Thickness (5) Air Gap vs Up-state Capacitance



(1)



(2)

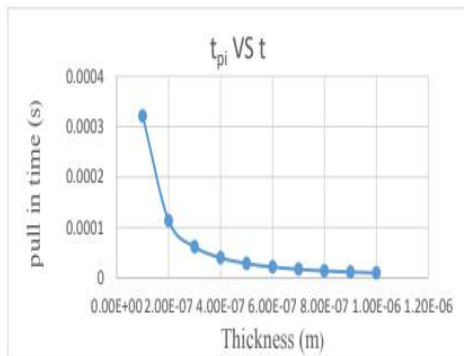
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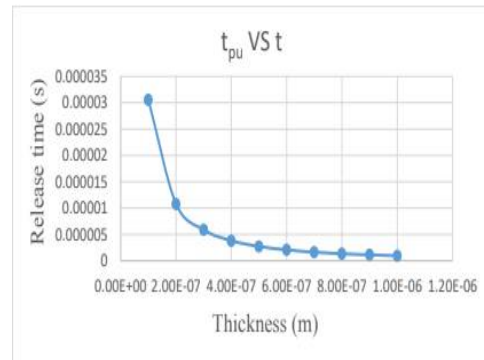
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It can be seen that from the graph no1 as the thickness increases stiffness also increases. i.e. They are directly proportional to each other. Fig No 2 shows that the dynamic behaviour of the beam makes sure that for thickness of 0.5 μm can achieved at low actuation voltage ($<5\text{V}$).

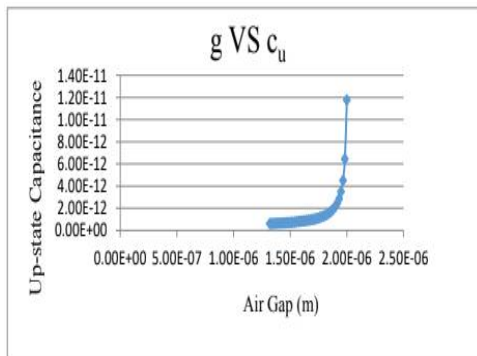


(3)

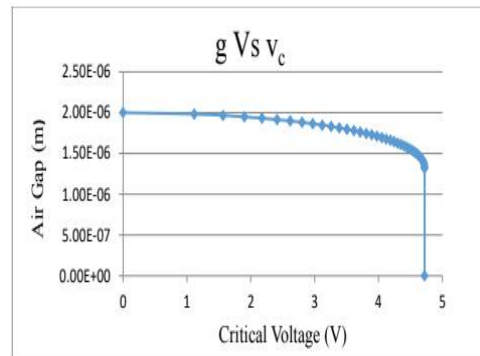


(4)

Graph 3 represents that as air gap decreases pull in voltage of the beam increases and at a certain point it attains its peak value and remains constant until the beam un-actuates and that voltage is called as critical voltage. Fig 4 shows as thickness increases time require to pull the electrode up to dielectric the layer decreases gradually but after certain point it becomes constant.



(5)



(6)

Above graph represents that as air gap decreases pull in voltage of the beam increases and at a certain point it attains its peak value and remains constant until the beam un-actuates and that voltage is called as critical voltage.

From the above graphs we conclude that by varying thickness, various parameters are achieved. Graphical result sums up the effective dimensions for given geometry. Using the above graph, we get maximum peak voltage, up-state capacitance, the stiffness of the beam, the range of frequencies, pull-in and pull-out time, etc.

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IV. CONCLUSION

A low voltage metal to metal contact shunt RF MEMS switch has been developed and tested. These devices have switching speed less than $30\mu\text{s}$. and good RF characteristics from DC to 40GHz with an actuation voltage of 4.65V. Optimizing the switch geometry has resulted in low actuation voltage, low insertion loss with 0.03dB, high isolation ($>30\text{dB}$) while incorporation of a bridge dimple has led to improving signal line contact. These switches are simulated using thin gold film, which indicates that these switches cannot qualify for high power application. But based on theoretical calculation the RF performance of a MEMS switch is significantly influenced by introducing holes in the structural layers. Therefore, in our proposed switch design, we introduced holes of $10*10\mu\text{m}^2$ in the switch membrane. The introduction force reduces the squeeze-film damping. However, the discrepancy of 0.641% in the pull-in voltages between calculated and experimental results for different switches topology. Consequently, the dynamic performance of switches is improved.

REFERENCES

- [1] A. Persano, A. Cola, G. De Angelis, A. Taurino, P. Siciliano, and F. Quaranta, "Capacitive RFMEMS switches with tantalum-based materials," *J. Microelectromech. Syst.*, vol. 20, no. 2, pp. 365–370, 2011.
- [2] J. Yang WS, Kang S, Choi CA, "Design and parameter extraction based small-signal modelling of a novel center anchor MEMS series switch". In proceeding of the 34th European microwave conference. Amsterdam, The Netherlands, pp1433-1436, 2004.
- [3] Singh T, Khaira N, Sengar J, "A novel capacitive RF MEMS switch design for low voltage application," Computing, Communications and Networking Technologies (ICCCNT), Fourth International Conference, Tiruchengode, pp 1–6, 2013.
- [4] Shekhar S, Vinoy KJ, AnanthasureshGK, "Design, fabrication and characterization of capacitive RF MEMS switches with low pull-in voltage", Microwave and RF Conference (IMaRC), IEEE International, pp 182–185, 2014.
- [5] Rebeiz GM, MuldavinJB, "RF MEMS switches and switch circuits". IEEE Microw Mag 2(4):59-71, 2001.
- [6] SiamakFouladi, Student Member, IEEE, and Raafat R. Mansour, Fellow, IEEE, "Capacitive RF MEMS Switches Fabricated in Standard 0.35- μm CMOS Technology", IEEE Transactions on Microwave Theory and Techniques, vol. 58, no. 2, pp 478-486 February 2010.