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Design and Simulation of RF Capacitive MEMS Switch for Wide Band Applications with Different Dielectric Materials- A Step to Fast Switching Switches

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***Abstract**: This Paper principally manages Analytical Design, Simulation parts of MEMS for satellite correspondence. The Switching is principally required in numerous applications. GaAs based PIN Diode and CMOS based FET are reasonable for exchanging in low recurrence applications, yet for good detachment and inclusion based exchanging in Ku-band, these switches are not appropriate. Ku-Band Micro Electro Mechanical Switches are giving answer for this issue. This Proposal includes Modeling and reenactment of MEMS Switches by utilizing distinctive Finite Element Analysis (FEM) devices for best small scale incitation structure and material analysis with different dielectric's analysis and mechanical stability with different load analysis are simulated using Finite element modelling. The Switching speed of the device in 12-26 GHz was achieved higher switching speeds and less actuation voltage.*

***Key words**: RF MEMS, Switch, Dielectric materials, wide band.*

I. INTRODUCTION

MEMS include multidisciplinary innovation from various fields of material and manufacture, gadget building, microwave designing, mechanical designing and so forth. For innovative work, MEMS switches and different parts is being intriguing zone of concern. Contrasted and different kinds of switches like PIN diode switches, GaAs based FET, pHEMT, MEMS switches are favourable for low addition misfortune, higher separation, zero influence utilisation, little size, lesser weight and low inter modulation distortion[1-2]. In spite of the fact that burdens like low exchanging velocity and high activation voltage persevere yet can be endured in numerous media transmission utilizations of low misfortune high segregation RF switches Switching is significant necessity in the correspondence, and giving the Switching in satellite correspondence is the genuine test, in light of the fact that ku-band of recurrence in the range 12GHz to 18GHz is utilised in satellite correspondence. At this radio recurrence run the CMOS innovation based FET and GaAs based PIN diodes exchanging execution isn't great, elective is production of exchanging in transmission lines utilising Micro Electro Mechanical Systems (MEMS) innovation.

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Contrasted with different switches RF MEMS Switches execution is great as far as unwavering quality, addition misfortunes, disconnection misfortunes, influence utilisation, and influence taking care of. In Space and satellite correspondence the required changes need to give exchanging of high recurrence flags and need to deal with the high power for this RF MEMS Switches are best.For Radio Frequency (RF) signals are utilised, the scope of RF signals is gigantic that is from 9 KHz to 300 MHz[3-5], As RF signals shows electromagnetic field for this reason micro-machined gadgets, for example, channels, oscillators and switches required. For remote correspondence applications RF switches are structured at high recurrence (1MHz to 60 GHz).RF MEMS circuits leaves tremendous effect on correspondence applications, for example, handset (cell phones) on account of their little in size, low power utilisation, less addition misfortune and isolation being high. So there are a few inconveniences of MEMS switches, for example, low time of switching and higher actuation voltage. Normally arrangement or parallel associated circuit setups are utilized. The most utilized RF MEMS structures are the cantilever's & beams along with the bridge structures.

II. CANTILEVER BASE SWITCHES

In this one end of the shaft is settled and other is free. The voltage is connected at the free end. Working rule is, when voltage is connected over the cathode, the charge created on the bar causes the electrostatic power on the pillar which pulls down. Results the worry in the pillar as hole goes on reductions the pressure increments. At the point when this connected voltage is evacuated the equivalent and inverse power called reestablishing power creates, supportive to convey the shaft to its unique position[6-10].

A. Capacitive base switch

These switches utilize metal-cover metal sort contact. Capacitive switches are created by utilizing surface micromaching process. In view of its simplicity of plan and manufacture process these switches are utilized in reconfigurable bandstop channel improvement[11]. The inclusion loss of the capacitive switch is lower than 1.2 dB up to 40 GHz, the extricated up-state capacitance is 30 PF and confinement is 1.3dB, 26dB, and 27dB at 1GHz, 20GHz, and 40GHz individually. As one end is free it requires lower activation voltage contrasted with Air Bridge MEMS switch [2]. The capacitive MEMS switch is as appeared in Fig.2.

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B. Resistive contact switches

These changes utilize metal to metal contact for ohmic contact between flag line and contact pillar. Manufacture process utilized for such switches is either mass micromachining or surface micromachining process. The dc inclination is connected among ground and the cantilever bar, electrostatic power pushes the cantilever pillar to move along the side and contact the flag line. Such kind of switch utilized for a Ku-band reconfigurable impedance tuner advancement [3].

C. Methodology

The structure of capacitive base switch is based on the cantilever structure, where structural aspects are considered as vital in design the RF MEMS switch, to operate in Ku band frequencies. Where the widh-2 and thickness- t and length-l are considered for the cantilever having the E-Youngs modulus.

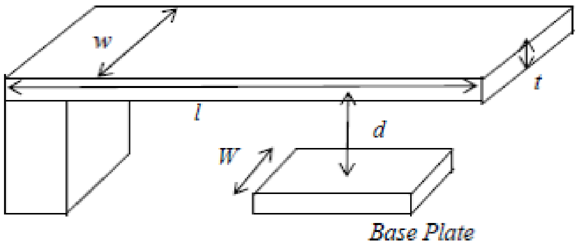

Fig. Structure of a cantilever for capacitive base RF MEMS switch

The calculation of moment of inertia is calibrated by the formula

$$I = \frac{wt^3}{12} \dots\dots\dots\dots. equ(1)$$

Where the spring constant of the cantilever structure is considered to be

$$k = \frac{2Ewt^3}{3l^3} \dots\dots\dots\dots. equ(2)$$

The most important factor in cantilever structure is damping ratio which is considered as

$$\zeta = \frac{b}{2\sqrt{mk}} \dots\dots\dots\dots. equ(3)$$

The resonant frequency of a such cantilever is given by the equation

$$w = 2\pi f = \sqrt{\frac{k}{m}} \dots\dots\dots\dots. equ(4)$$

Where k is spring constant and m- mass of the unloaded cantilever.

Quality factor which coined as the ratio of energy stored to dissipated for a given resonant frequency which implicates that higher the Q less energy lost.

$$Q = \frac{k}{b\omega_0} \dots\dots\dots\dots. equ(5)$$

The actuation of the sensor is through capacitive base actuation where the concept of parallel plates, one is fixed and another one is moving is adopted to find the excitation of the sensor. This was explained by using up state and down state capacitance which is explained with

Upstate Capacitance- Cu = CP + CPP + Cf .... equ(6)

Down State Capacitance-Cd = CP + 1.5 CPP + Cf

CPP=

$$\frac{S_0 Ww}{d} \dots\dots\dots\dots equ(9)$$

This parameter is considered to be important parameter of the MEMS devices

III. FABRICATION PROCESS

The basic fabrication process involves the surface micro machining are bulk micro machining, when the layer of materials are stacked on surface of another, a surface micro-machining approach is followed. The in most of the RF MEMS design the substrate being the silicon or flex glass and with the our paper we have considered the silicon as the primary substrate material, where the gold is considered as the coplanar wave guide material[12-15]. The dielectric materials can chosen to consider having low permittivity, where silicon Nitride is chose as content material for dielectric, but future scope can be with polymers like PTFE, PAE and grated fibres bas polymers are having good scope in the design. The deposition of the $YBa_2Cu_3O_7$Material which superconducting in nature is carried out by using Pulse laser Deposition technique (PLD) at 760 degrees to achieve 300nm and then its stacked with the Si_3N_4layer. At 700 degrees which is 500nm with around 500m Torr of pressure of oxygen with Nd-YAG pulsed laser. For the pattering the film a layer of AZ5214 is spun on the top of this using spin coater by considering the mask of CPW. And the etched off with 0.1 Mol HF solution to remove the excess nitride layer and later etch with acetic acid of 3% concentration to remove $YBa_2Cu_3O_7$ and the cleaned with DI water[16]. To remove excess photoresist the acetone solution is used and later the silicon nitride cantilever. The remaining part of the resist is removed using acetone, later silicon nitride is patterned using mask of dielectric type which dipped in a 10% HF around 6 minutes, which all the process considered as sacrificial layer for supporting the bridge of Au material. And later a 3 micron layer of resist was coated by spin and then lift process of the gold is done. The initial characterisation was done under microscopic observation in order to ensure complete sacrificial layer was removed or not and second if any sacrificial layer defects are found, one can ensure to peel of the layer and create a fresh layer of PMGI using a developer solution[17-20].

IV. SIMULATIONS OF RF CAPACITIVE

The capacitive switch base RF design was shown in below fig where the beam acting as like bridge with 2 micron thickness is considered , which is mechanically actuated for the ON/OFF condition. The width and length of the switch are maintained to 66 micron * 30 micron, which is mounted on a substrate state made up of silicon having the dimensions of length 100 micron width being 30 micron, & depth being 35 micron.

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The dimension are chosen in such a way that switch operates in the wide band 18-40GHz, where the dielectric thickness 0.5 micron using Silicon oxide & Silicon Nitrite layer. The using of both the dielectric gives the comparison of the capacitance ratio Cp of the switch. The other materials being Aluminium for the bridge base circuit, and copper for contact pads. The fabrication process with different materials is explained in section II fabrication. Using Finite element modelling method(COMSOL Multiphysics) we have simulated the device to find out the electric potential, energy stored using the electrostatics an for identify the principle mode of the cantilever bridge, Eigen frequency analysis is done where the Principle of operation is to find the resonant frequency of the bridge and in our paper is around 3.5GHz. The stress induced on the cantilever bridge is more concentrated on the lateral part of the cantilever towards its fixed ends where the actual bending of the beam corresponds to take place.

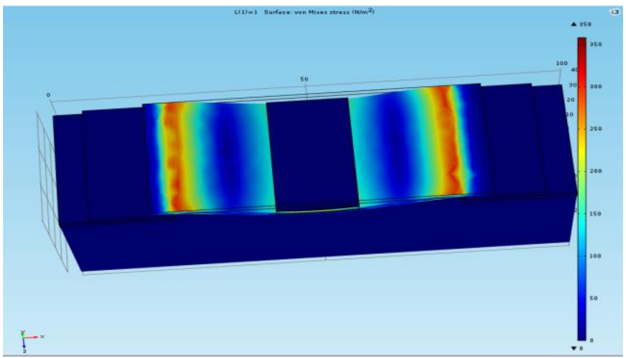
The simulation of capacitive MEMS switch was received,

V. Eigen Frequency Analysis

In this analysis resonant frequency analysis of the device is simulated, the Eigen frequency of the cantilever have the resonant frequency where there are 1,2,3,…n number of frequency modes. But the principle mode is important mode where the beam deflects maximum at that point in lateral movement gives the switching action clearly picture.

Fig principle mode of the Beam of the captive switch

The beam is analysed with load on the surface and deflection of the beam along the length of the beam is analysed and it can be observed that with increase in the load



the deflection of the at the centre is increasing which was depicted in the Figure.

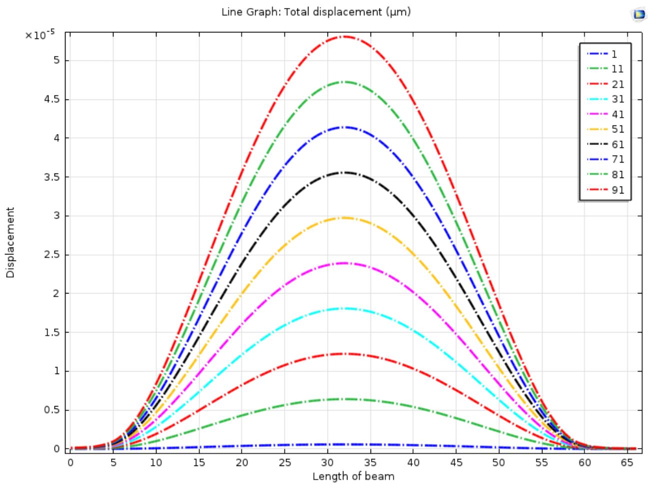


Fig. Deflection of the Beam along the length with load on surface of the beam.

The characterisation of electric properties of capacitive base switch where the charge is folded between the two parallel plates. So as the electric field distribution between the plates corresponded to the charge accumulated between the and that was shown in the below figure.

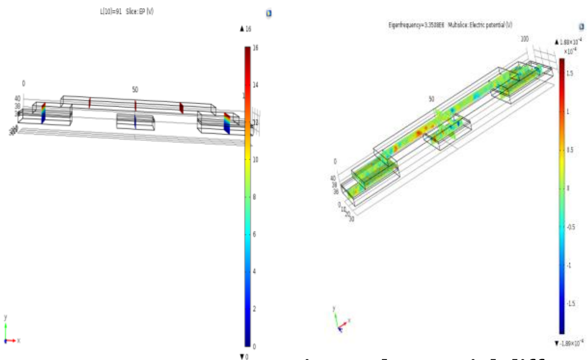


Fig Electric field distribution and Potential difference between the plates of the capacitive switch.

VI. Material & Discussions

The material for the dielectric will change the capacitance ratio Cp as the pull up and down voltages alter with the materials that are used for the dielectrics. Using finite element modelling a material sweep analysis of the captive switch is carried out by considering the material like Silicon oxide, Silicon Nitride, Silicon carbide and PTFE which is polymer base. These polymer base dielectric are new generation dielectric used in most of bio compatible antenna applications. In the capacitance that was calibrated for this these materials using Comsol Switch case analysis using stationary study and which reported in the below figure

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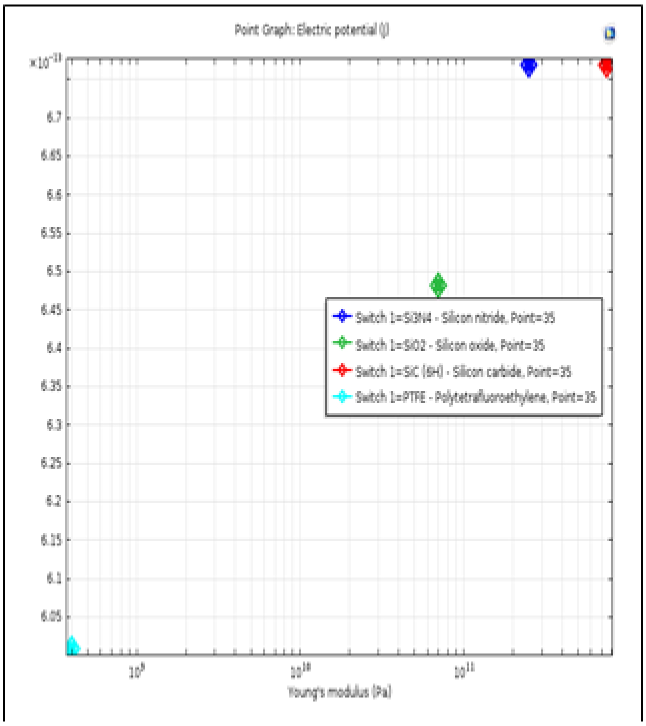

Fig. Total Electric Energy with respect to Material along the Device switching.

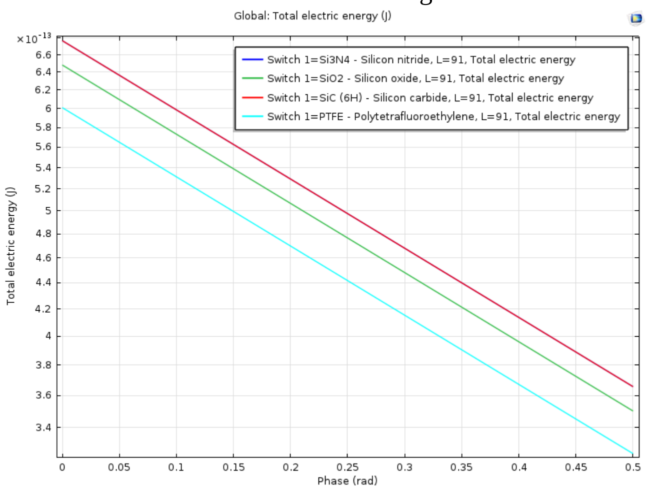

Fig. Total Electric Energy with respect to Material along the Device switching.

VII. CONCLUSION

Switching is the significant necessity in the correspondence and giving the switching in satellite correspondence is the genuine test, in light of the fact that ku-band of recurrence in the range 12GHz to 18GHz is utilized in satellite correspondence and even we have concentrated fr more wide band applications. At this RF extend the CMOS innovation based FET and GaAs based PIN diodes exchanging execution isn't great, elective is making of exchanging in transmission lines utilizing Micro Electro Mechanical Systems (MEMS) innovation. Contrasted with different switches RF MEMS Switches execution is great as far as dependability, addition misfortunes, separation misfortunes, influence utilization, and influence dealing with. In Space and satellite correspondence the required changes need to give exchanging of high recurrence flags and need to deal with the high power for this RF MEMS Switches are best. PC recreation and hypothetical outcomes will be analyzed for better investigation which will enhance the unwavering quality of the RF MEMS Switch after creation.The RF MEMS capacitive with wide band application that can actuate from 12-26 GHz, where the switching speed of the capacitive switch is improved when compared and material analysis was carried out to where the PTFE has minimum energy storage where the charge and discharge speeds are faster when compared with other material dielectric's[16]. The silicon carbide has more of ceramic type which involves complex fabrication process flows. So the device of fabrication was apt with the silicon nitride

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