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Design, Simulation and Analysis of MEMS Perforated RF Switch with Platinum

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Abstract

A new model of RF switch was designed using MEMS technology with a cantilever structure which is giving high sensitivity. The materials having low spring constant have been taken and will be examined in COMSOL by identifying the relation between Eigen frequency and displacement.The Proposed structure will be examined with different materials with different thickness(2µm,2.2µm,2.4µm,2.6µm,2.8µm,3µm).The maximum displacementand the minimum displacement for a Eigen frequency will be taken for the platinum materialwithanexamined beam thickness for which highest displacement occurs. And thebeam structure will be tested with perforations and without perforations. It should get a high sensitivity of 6.75*10-4 For the proposed thickness of 2µm The graph for Eigen frequency and displacement have been plotted and verified the values.

Keywords: *RF Switch, Eigen frequency, Displacement, thickness.*

RADIO FREQUENCY SWITCH

RF switch is also named as microwave switch. This device passes high frequency signals through transmission paths and used for signal routing. This routing will be in between instruments and devices.

MEMS

The microelectromechanical framework is a gadget innovation with a small-scale meter scale. MEMS is a combination of actuators, sensors, automatic items and physical sciences in a run of the mill substrate that utilizations CI process successions and these estimations are utilized in various applications, for example, show innovations, finder frameworks, for example sensor frameworks and systems Optical MEMS are frightfully appealing for distinct operations because of their estimate and weight. These MEMS measurements shift from micrometres to millimetres.

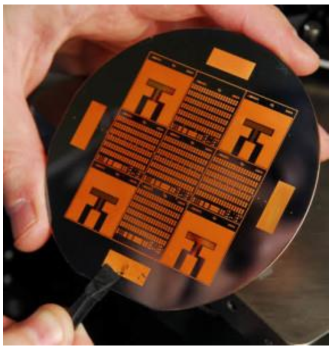

Fig 1:MEMS Device

They are frequently found in a few frameworks, from car, incorporated frameworks physical science, correspondence, to restorative applications. Popular MEMS gadgets incorporate projection screen chips, BP sensors, accelero meters in airbag sensors, versatile plate drive examining and composing heads, optical switches and microvalves. Every one of these items are made in the production line in enormous mechanical volumes. These MEMS frameworks can control and recognize taking things down a notch and cause results in the macroscale.

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Lately, the micro wave switch has gotten one of the fast increase innovations. This innovation tenders unbelievable gain over silicon exchanging gadgets and GaAs.

RF-MEMS SWITCH

Radio Frequency MEMS switches are micromechanical switches. These switches are intended to work in radio recurrence at mm wave recurrence, which implies that 0.1 to 100 GHz

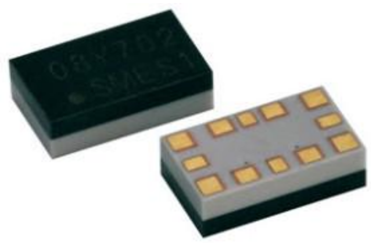

Fig:2 MEMS Switch

RF MEMS switches are frequently utilized in microwaves and recurrence specialized gadgets, for example, transmitters and recipients, radio wire switches, and so on. These switches are unambiguous microswitches that should work at Radio frequency to millimetre wave frequencies, which mean 0.1 to 100 GHz. Radio frequency MEMS has a few favourable circumstances than electrical switches. They devour little power and have properties, for example, low inclusion misfortune, linearity, moderateness, influence taking care of and high detachment rates. MEMS properties incorporate less weight, little size and addition misfortune, in any case, they rapidly need difficulties, for example, high working voltage, low speed, and so on.

Micro wave switches are miniaturized scale machine frameworks that utilisesthe mechanical group inside the recurrence transmission line to accomplish a short out or open electrical circuit. This switches are characterized by incitation method. There are two kinds of powers utilized for the enactment of RF MEMS switches; They are attractive fascination and electrostatic powers. The static power covers a high working voltage, notwithstanding, it has no present utilization. Then again, the attractive fascination power incorporates a high present utilization and a low working voltage. Static switches are the most ordinary switches and are of two kinds: arrangement and sidestep. Attractive fascination switches are utilized in the mm and microwave wave districts.

RF SWITCH CIRCUIT:

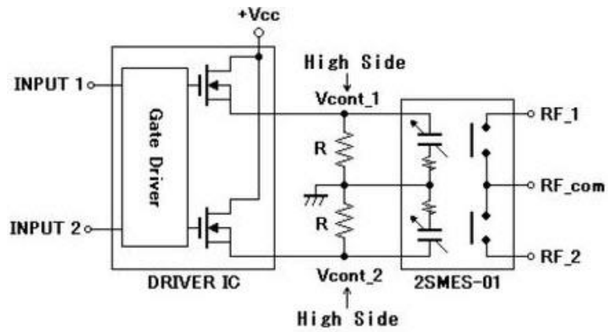

Fig:3 RF MEMS Switch Circuit

This RF MEMS exchanging circuit utilizes an incorporated structure for stick 9 of DC ground in the info viewpoint and RF ground in the yield angle. A hand-off transmission circuit utilizes the high-side switches Vcont_1 and Vcont_2 to show the working voltage on and off. To kill the switch in the principal viewpoint, the gathered burden must be released. Design a release circuit inside the electrical switch drive circuit to kill the switch. On the off chance that there is no release circuit, at that point the switch won't kill. This MEMS switch is structured so that the actuator works at fast. Along these lines, the time consistent of the drive wave could affect the existence execution of the switch, so the operational info pins (V_cont1 and V_cont2) are under 10us and more prominent than 0.5us, individually. The working voltage must be held inside the scope of 34V + 5% or 34V-5%, just as the wave.

In the principal viewpoint, the collected burden must be emptied. Arrange a release circuit inside the electrical switch drive circuit to kill the switch. In the event that there is no release circuit, at that point the switch won't kill. This MEMS switch is expected

RF MEMSSWITCHES:

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For remote correspondence Radio Frequency signals are utilized, the assortment of Radio Frequency signals is enormous, that is, from 9 kiloHz to 300 MegaHz, since Radio Frequency signals are shown in the field of attractive power for this reason, they are required Micromachined gadgets, for example, channels, oscillators and switches. In remote correspondence functions, Radio Frequency switches are structured at highest recurrence (roughly 1MHz to 60GHz). Radio Frequency MEMS circuits leave a high effect on correspondence applications, for example, the phone (cell phones) because of their low power utilization, little size, lower addition misfortune and highest detachment. With this, there are a few downsides of Micro Electonic Mechanical System switches, for example, less exchanging time and more incitation voltage. Ordinarily, arrangement or parallel associated circuit setups are utilized. The most usually utilized RF MEMS mechanical structures are the cantilever bar and, in this manner, airborne extension structures.

1)Canti-lever based Micro Electro Mechanical System Switch:

During this procedure, one finish of the shaft is fixed and the other is free. The voltage is applied at free front end. The guideline of activity is that, when the voltage is applied over the cathode, the charge created in the bar causes the electrostatic power in the bar that is sent. Things being what they are, the strain inside the shaft as space advances diminishes the pressure will increment. At the point when this applied voltage is expelled, the equivalent and inverse power known as the re-establishing power is created, valuable for carrying the shaft to its single position. The canti-lever model switch is as in Fig. 4a,4b.

The Canti-lever type switches are two types:

Capacitive contact switches:

Capacitive contact switches utilize a kind of metal protecting metal contact. Capacitive switches are made utilizing the smaller scale surface machining technique. Because of their simple plan and assembling technique, these switches are utilized in the improvement of reconfigurable band stop channels [1]. The figure of legitimacy of the Radio Frequency MEMS capacitive switch is determined as demonstrated as follows.

$$FOM = \frac{Down\ State\ Capacitance\ (C_d)}{Up\ State\ Capacitance\ (C_u)}$$

The figure of legitimacy depends moreover on the Q factor of the plane switch. The presentation of the switch is straightforwardly relative to the estimation of the Q factor, that is, if the issue Q is more noteworthy, the exhibition of the switch is great and on the off chance that the estimation of the issue Q is little, at that point the presentation of the switch is as poor as the factor Q.

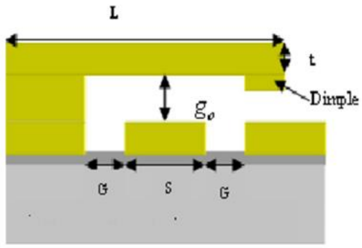

Fig 4(a) Canti-lever MEMS switch

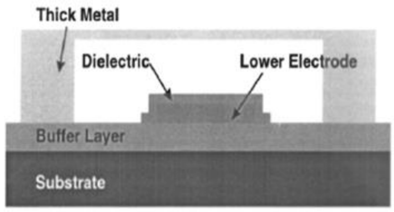

Fig 4(b) Air bridge MEMS switch.

The addition loss of the capacitive switch is beneath 1.2 dB up to 40 GegaHz, the upward capacitance extricated is 30 PikoFarade and the detachment is 1.3dB, 26dB and 27dB at 1GHz, 20GHz and 40GHz as needs be. As one end is free, it needs a lower incitation voltage that matches the Airbridge Micro Electonic Mechanical System switch [2]. The

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capacitive Micro Electro Mechanical System switch is as appeared in Fig. 5 underneath.

Resistive contact switches:

These switches uses the metal-to-metal contact for the obstruction unit contact between the sign line and the contact shaft. The assembling strategy used for such switches is a technique for mass small scale machining or surface miniaturized scale machining. The polarization Dc is applied between the ground and furthermore the cantilever pillar, the electrostatic power pushes the cantilever shaft to move along the side and contact the sign line. This sort of switch is utilized for Associate in the advancement of the X-band reconfigurable resistivity tuner [3]. The resistive Micro Electro Mechanical System switch is as in Fig. 6.

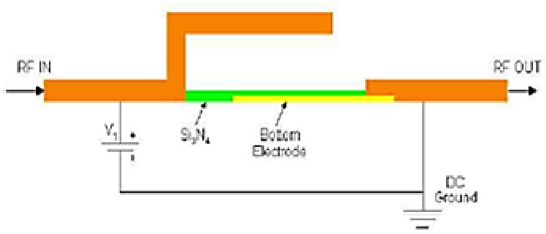

Fig. 5 The switch cross section canti-lever beam capacitive Micro Electro Mechanical System switch

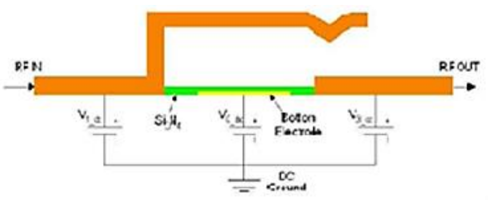

Fig. 6 The cross section of resistive Micro Electro Mechanical System

Contingent up on how MEMS activity is performed on Micro Electro Mechanical System switches, Radio Frequency circuits are ordered into the accompanying three classes

a) Radio Frequency Extrinsic: Micro Electro Mechanical System structure is out of the circuit however controls various gadgets in the circuit

b) Intrinsic Radio Frequency:The Micro Electro Mechanical System structure is inside the circuit and plays out a two folded capacity in the circuit, however, it is decoupled with the activity.

c) Radio Frequency Receptive:0 Inside the circuit and is coupled to the incitation work.

2) Air Bridge Type MEMS Switch:

The beam which we have taken now, it is fixed at the two finishes and weight or voltage is applied in the beam and the relocation of the beam towards the substrate is noted. The relocation is most extreme in the focal locale when we keep on expanding the applied voltage. The air connect Micro Electro Mechanical System switch is appeared in Fig. 4 (b)

TYPES OF RF MEMS SWITCHES:

There are two types of sorts in Radio Frequency Micro Electro Mechanical System switches:

one is the arrangement Micro Electro Mechanical System switch, and the other one is the Shunt MEMS switch.

Shunt switch:

The MEMS sidestep switch (appeared in Fig. 7) is demonstrated by two short segments of cloned clr and a transmission line model as appeared in Fig: 8 (a). The capacitance esteem changes all over with the condition of the scaffold since Copper is the rising state capacitance and Cd is the sliding state capacitance. The segments of the transmission line are of length (w/2) + l where l is the good ways from the reference plane to the edge of the MEMS connect (Fig. 8 (b)).

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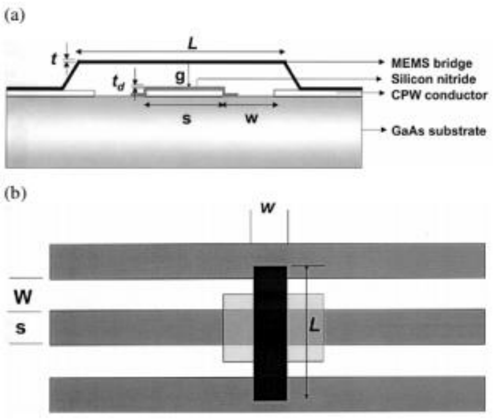

Fig. 7-Diagram of the MEMS sidestep switch in the upward express (a) cross segment and (b) top view

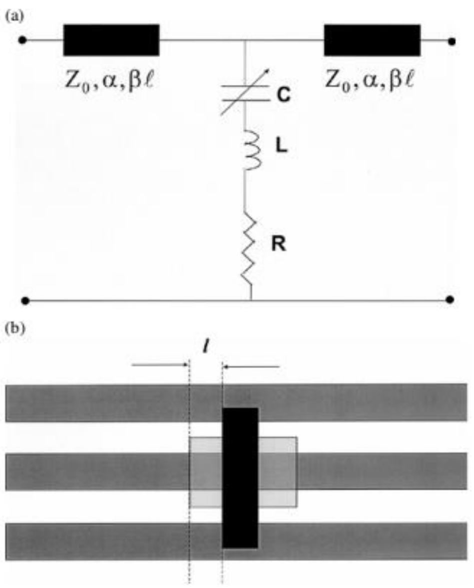

Fig. 8-(a) Equivalent circuit model and (b) schematic defining l

The switch shunt impedance is:

$$Z_s = R_s + j\omega L + \frac{1}{j\omega C}$$ →(1)

With C = Cd or Cu relying upon the situation of the switch. The reverberation recurrence of the LC arrangement of the detour switch:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ → (2)

The impedance of the detour switch can be determined by

$$Z_s = \begin{cases} 1/j\omega C & f = f_0 \\ R_s & f = f_0 \\ j\omega L & f \; ? \; f_0 \end{cases}$$ →(3)

Government conditions during the ON state: capacitance and inductance are in the upper state position of the switch, the reflection coefficient is given by:

$$S_{11} = \frac{-j\omega C_u Z_0}{2 + j\omega C_u Z_0}$$ →(4)

$$S_{11}^2 = \frac{\omega^2 C_u^2 Z_0^2}{4}$$ →(5)

and for |S11|<-10 dB or ωCuZu<< 2

Cu is the climbing state capacitance that incorporates parallel plate capacitance and strip capacitance1. Typical up-state capacitance for shunt switches operating at microwave and millimetre-wave frequencies is ~ 35-160 fF whereas inductance is of the order of few nH. The LC-series resonance frequency :

$$f_0 = \frac{1}{2\pi\sqrt{LC_u}}$$ (6)

It very well may be seen that in the rising state position, the thunderous recurrence is basically chosen by the climbing state capacitance. The down-state capacitance of the switch is determined as Cd = ε0εrA/td. The resounding recurrence in the latent state is given as the condition. (2) Utilizing Cd rather than Cu.

Series switch:

The arrangement intelligent microwave switch is indicated diagrammatically in Figure (9). The state off at the pinnacle point and furthermore the state on

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at the base point. To change the microwaves, it must be conceivable to transmit microwave sign to and from the switch, in this manner; it is associated with the information and yield by transmission lines or wave guides. At the point of shut, the switch can be a transmission gadget with some reflection. Inside the open express,the switch is completely intelligent with a little undesirable transmission.

On account of off express, a sign lands at port 1 of the open switch is reflected with a voltage reflection consistent of +1 as indicated schematically inside the upper piece of Figure 9. A little piece of the wave is transmits through the change to port 2. in the figures, we will in general show the electrical sign as a short heartbeat, which accentuates the indication of the reflection coefficient that for the arrangement switch is +1 and for the detour switch is – 1 . we will in general select a heartbeat to underline the appallingly broadband nature of the switch that can be utilized in MEMS. As far as microwave scattering parameters, in the recurrence space, the reflected sign is S11 and furthermore the transmitted sign is S21, the immediate transmission is given by the accompanying conditions:

$$S_{11} = \frac{1}{1 + j\omega C_{\text{off}} 2Z_0},$$

$$S_{12} = \frac{j\omega C_{\text{off}} 2Z_0}{1 + j\omega C_{\text{off}} 2Z_0}.$$

The perfect interest is Coefficient = 0, aside from touchy conditions, if jω * Coeff<< 1 the denominators of every condition are around 1. This offers unitary reflection, while in the transmission the circuit is basically a differentiator. As a rule, forward transmission under the off state conditions is called switch separation. In the actuated express, the most minimal piece of Fig.(1), an image is for the most part transmitted through the switch with a little reflection and some assimilation. Inclusion misfortune is the connection between transmitted influence and the qualification among occurrence and reflected influence. In the event that the reflected power is low, at that point S21 is that the inclusion misfortune. The power reflected under these conditions is that the loss of return and inside the case sketched out is equivalent to S11. The state scattering parameters are estimations given by

$$S_{11} = \frac{R_{\text{on}}}{R_{\text{on}} + 2Z_0},$$

$$S_{21} = \frac{2Z_0}{R_{\text{on}} + 2Z_0}.$$

The perfect condition is Ron = 0, however obviously on the off chance that Ron << 2Z0, at that point S11≈ 0 and S21≈ 1

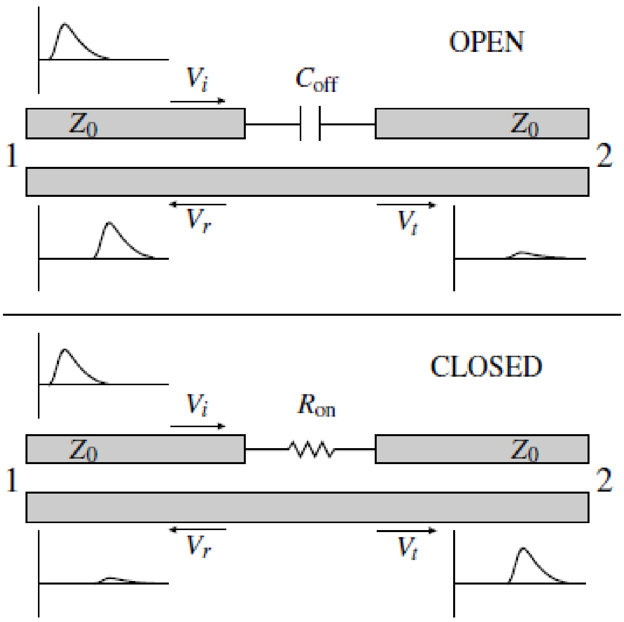

Fig: 9 An ideal series switch

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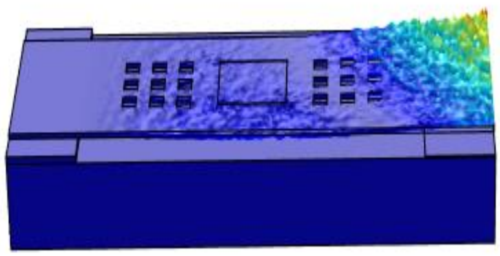
Cantilever beam switch Structure designed in comsol:



Values for different thickness of beam with different metals:

Material	Eigen Frequency	Total Displacement(µm)					
		2 µm	2.2 µm	2.4 µm	2.6 µm	2.8 µm	3 µm
Titanium	1666.6	$8.08*10^{-12}$	$1.76*10^{-12}$	$1.22*10^{-12}$	$1.06*10^{-12}$	$7*10^{-14}$	$7.4*10^{-13}$
	1775.6	$4.17*10^{-4}$	$1.11*10^{-5}$	$2.48*10^{-5}$	$1.77*10^{-6}$	$2.98*10^{-6}$	$3.13*10^{-6}$
	1777	$2.25*10^{-4}$	$1.85*10^{-5}$	$1.48*10^{-5}$	$3.99*10^{-6}$	$2.83*10^{-5}$	$2.28*10^{-6}$
	1791.9	$7.35*10^{-4}$	$5.13*10^{-6}$	$6.36*10^{-6}$	$3.25*10^{-6}$	$1.98*10^{-5}$	$2.99*10^{-5}$
	1838.3	$1.62*10^{-4}$	$2.06*10^{-5}$	$5.02*10^{-5}$	$2.65*10^{-4}$	$1.74*10^{-4}$	$4.05*10^{-5}$
	1888.7	0.06	$0.01*10^{-2}$	0.06	$7.79*10^{-3}$	$6.48*10^{-3}$	$0.03*10^{-2}$

Material	Eigen Frequency	Total Displacement(µm)					
		2 µm	2.2 µm	2.4 µm	2.6 µm	2.8 µm	3 µm
Platinum	1666.6	$5.91*10^{-11}$	$1.17*10^{-11}$	$1.79*10^{-11}$	$3.43*10^{-12}$	$4.59*10^{-13}$	$8.94*10^{-13}$
	1775.6	$1.07*10^{-3}$	$3*10^{-5}$	$6.21*10^{-5}$	$3.61*10^{-6}$	$9.59*10^{-6}$	$8.76*10^{-6}$
	1777	$5.78*10^{-4}$	$5.01*10^{-5}$	$3.7*10^{-5}$	$8.12*10^{-6}$	$9.12*10^{-5}$	$6.4*10^{-6}$
	1791.9	$1.89*10^{-3}$	$1.44*10^{-5}$	$1.6*10^{-5}$	$6.62*10^{-6}$	$6.39*10^{-5}$	$8.39*10^{-5}$
	1838.3	$4.16*10^{-4}$	$5.58*10^{-5}$	$1.26*10^{-4}$	$5.4*10^{-4}$	$5.62*10^{-4}$	$1.13*10^{-4}$
	1888.7	0.15	$0.04*10^{-2}$	0.14	$0.02*10^{-2}$	$0.02*10^{-2}$	0.07

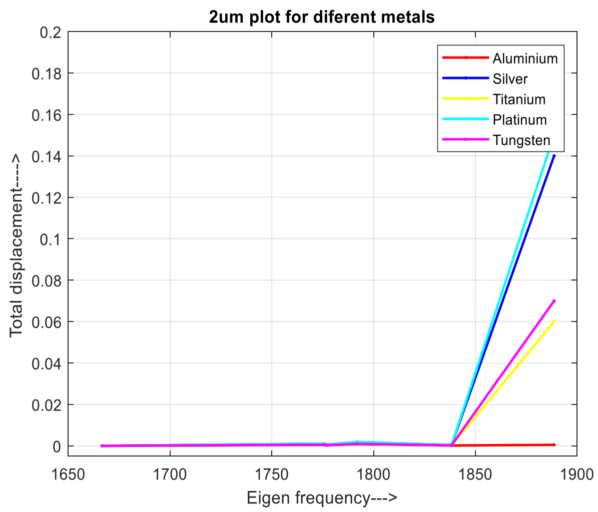
Material	Eigen Frequency	Total Displacement(µm)					
		2 µm	2.2 µm	2.4 µm	2.6 µm	2.8 µm	3 µm
Tungsten	1666.6	$6.3*10^{-12}$	$2.8*10^{-12}$	$3.92*10^{-12}$	$1.57*10^{-12}$	$3.76*10^{-13}$	$5.81*10^{-13}$
	1775.6	$5.24*10^{-4}$	$1.37*10^{-5}$	$2.93*10^{-5}$	$1.75*10^{-6}$	$3.93*10^{-6}$	$3.75*10^{-6}$
	1777	$2.83*10^{-4}$	$2.29*10^{-5}$	$1.74*10^{-5}$	$3.93*10^{-6}$	$3.74*10^{-5}$	$2.74*10^{-6}$
	1791.9	$9.23*10^{-4}$	$6.58*10^{-6}$	$7.53*10^{-6}$	$3.2*10^{-6}$	$2.62*10^{-5}$	$3.6*10^{-5}$
	1838.3	$2.03*10^{-4}$	$2.55*10^{-5}$	$5.94*10^{-5}$	$2.62*10^{-4}$	$2.3*10^{-4}$	$4.86*10^{-5}$
	1888.7	0.07	$0.02*10^{-2}$	0.07	$7.68*10^{-3}$	$8.55*10^{-3}$	$0.03*10^{-2}$

Material	Eigen Frequency	Total Displacement(µm)					
		2 µm	2.2 µm	2.4 µm	2.6 µm	2.8 µm	3 µm
Silver	1666.6	$9.15*10^{-11}$	$8.27*10^{-12}$	$1.78*10^{-11}$	$3.79*10^{-12}$	$8.91*10^{-13}$	$1.81*10^{-12}$
	1775.6	$1.03*10^{-3}$	$2.88*10^{-5}$	$5.82*10^{-5}$	$3.62*10^{-6}$	$9.04*10^{-6}$	$8.44*10^{-6}$
	1777	$5.56*10^{-4}$	$4.81*10^{-5}$	$3.47*10^{-5}$	$8.16*10^{-6}$	$8.6*10^{-5}$	$6.17*10^{-6}$
	1791.9	$1.81*10^{-3}$	$1.38*10^{-5}$	$1.5*10^{-5}$	$6.65*10^{-6}$	$6.02*10^{-5}$	$8.08*10^{-5}$
	1838.3	$4*10^{-4}$	$5.35*10^{-5}$	$1.18*10^{-4}$	$5.43*10^{-4}$	$5.3*10^{-4}$	$1.09*10^{-4}$
	1888.7	0.14	$0.04*10^{-2}$	0.13	$0.02*10^{-2}$	$0.02*10^{-2}$	0.07

Material	Eigen Frequency	Total Displacement(µm)					
		2 µm	2.2 µm	2.4 µm	2.6 µm	2.8 µm	3 µm
Aluminium	1666.6	$1.6*10^{-11}$	$2.69*10^{-12}$	$1.57*10^{-11}$	$2.32*10^{-12}$	$2.77*10^{-13}$	$3.99*10^{-13}$
	1775.6	$3.97*10^{-4}$	$1.06*10^{-5}$	$2.13*10^{-5}$	$1.76*10^{-6}$	$2.71*10^{-6}$	$2.99*10^{-6}$
	1777	$2.14*10^{-4}$	$1.77*10^{-5}$	$1.27*10^{-5}$	$3.96*10^{-6}$	$2.58*10^{-5}$	$2.19*10^{-6}$
	1791.9	$6.99*10^{-4}$	$5.09*10^{-6}$	$5.47*10^{-6}$	$3.22*10^{-6}$	$1.81*10^{-5}$	$2.87*10^{-5}$
	1838.3	$1.54*10^{-4}$	$1.98*10^{-5}$	$4.32*10^{-5}$	$2.63*10^{-4}$	$1.59*10^{-4}$	$3.87*10^{-5}$
	1888.7	$0.05*10^{-2}$	$0.01*10^{-2}$	$0.05*10^{-2}$	$7.73*10^{-3}$	$5.91*10^{-3}$	$0.03*10^{-2}$

GRAPHS:

2um plot for different metals:



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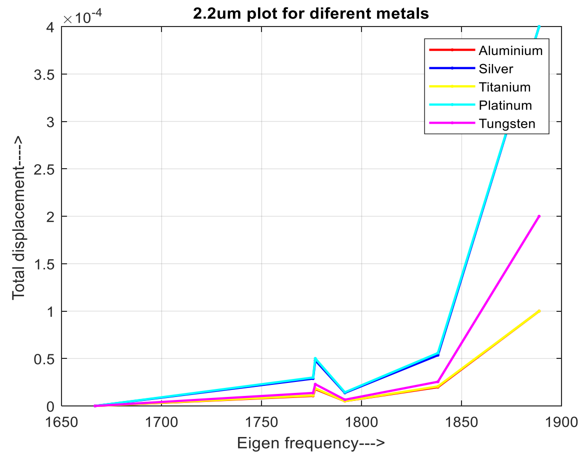
2.2um plot for different metals:



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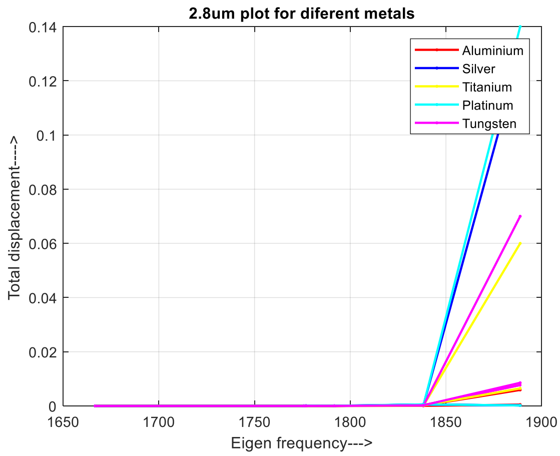

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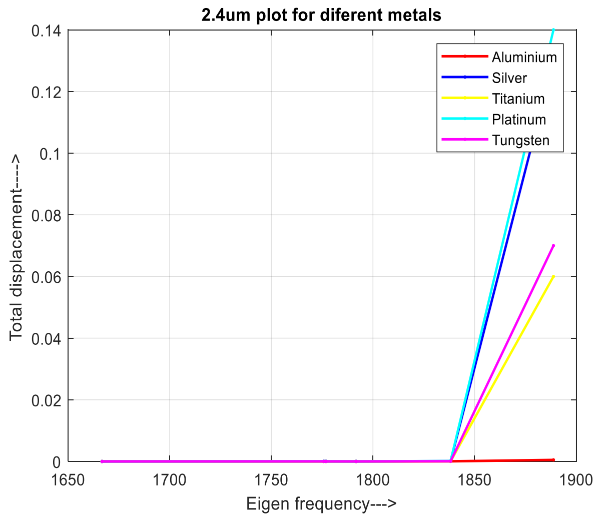
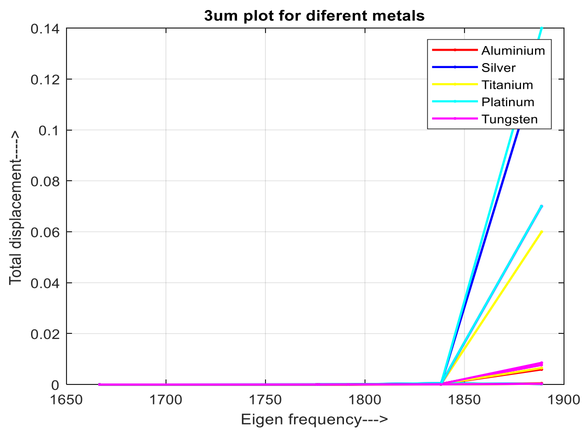
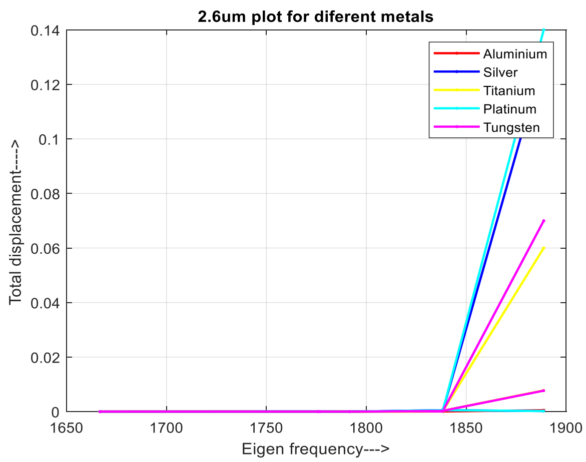


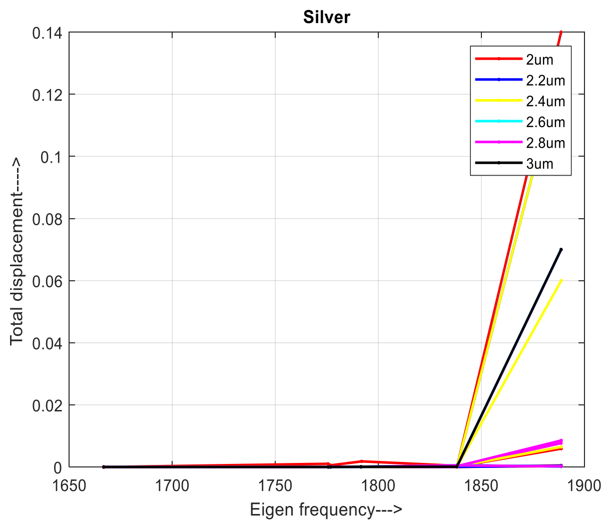
3.0 um plot for different metals:



2.6um plot for different metals:



Silver Metal for Different Thickness:



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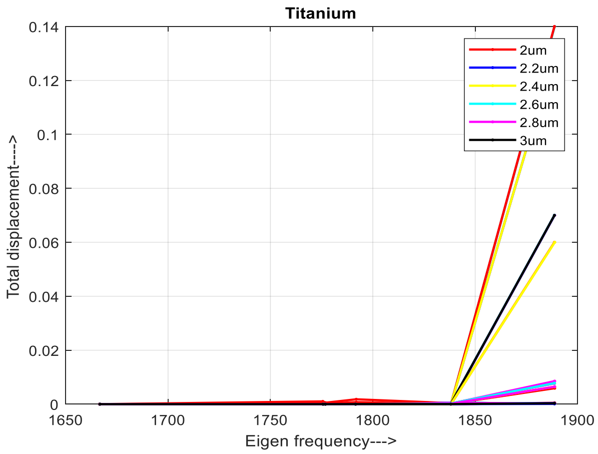
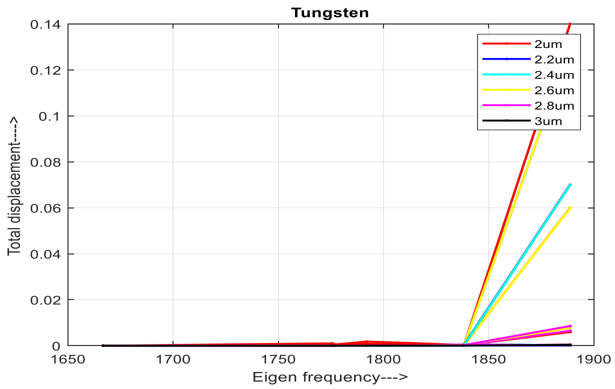
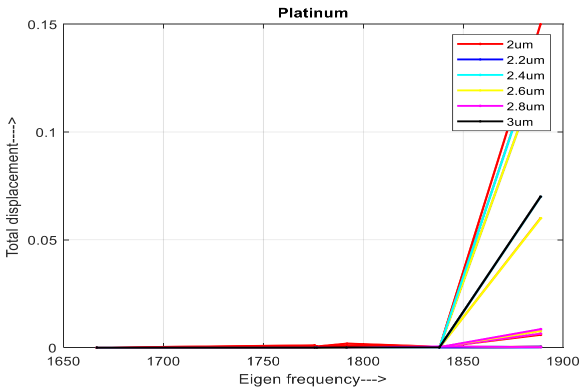
Titanium Metal for Different Thickness:



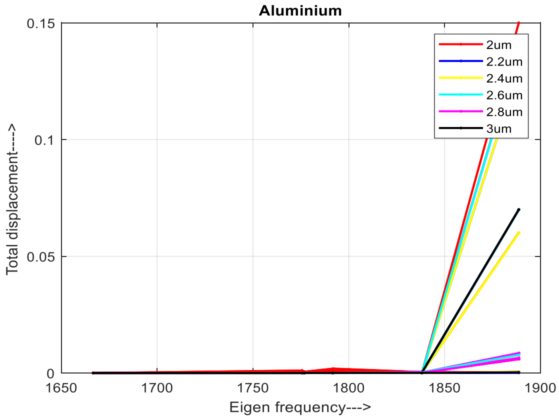
TungstenMetal for Different Thickness:



Platinum Metal for Different Thickness:



Aluminium Metal for Different Thickness:



CONCLUSION

A new model of RF switch is designed using MEMS technology with a cantilever structure which is giving high sensitivity. The materials having low spring constant have been taken and examined in Comsol by identifying the relation between Eigen frequency and displacement. The Proposed structure is examined with different materials with different thickness (2µm,2.2µm,2.4µm,2.6µm,2.8µm,3µm). The corresponding Eigen frequencies and displacements have been shown. The maximum displacement is 0.15µm for an Eigen frequency of 1888.7 and the minimum displacement is 5.91*10-11µm for a Eigen frequency of 1666.6, for a material of Platinum with a thickness of 2µm beam thickness. The beam structure is tested with perforations and without perforations. It is showing high sensitivity of 6.75*10-4,For the proposed thickness of 2µm The graph for Eigen frequency and displacement have been plotted and verified the values.

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