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Review Article

ELECTROMECHANICAL AND RF PERFORMANCE ANALYSIS OF SERIES CONFIGURATION BASED MEMS SWITCH

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Abstract

The paper presents a RF MEMS (Radio-Frequency-Micro-Electro-Mechanical-System) of cantilever series switch which is developed with low actuation voltage which depends upon the beam characteristics and the gap between the plane and metal beam. The MEMS series switch that designed is operating with a frequency range (0-60GHz) and it provides control of the other devices. The RF MEMS switching component consists of a electrode with tuning fork shaped which is fixed using anchor points on coplanar waveguide lines to decrease the actuation voltage and the insertion loss of the switch. The Air gap in between the tuning fork shaped electrode and actuation electrode of RF MEMS series switch is designed to boost the isolation attributes of the switch with less actuation voltage. The switching voltage for designing the switch is 18 V. The designed RF MEMS series switch can be used for sub-system level for broadband applications and communication devices.

Keywords: RF MEMS, Broadband applications, Switching voltage, Isolation Attribute.

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INTRODUCTION

The RF MEMS switch (Radio-Frequency-Micro-Electro-Mechanical) cantilever switch is constructed with low actuation voltage [1] and it controls the signals by opening and closing with high isolation and zero power consumption smaller size and low cost. For high performance components and delay lines this RF MEMS switches are used. The designed switch is used in different applications like telecommunication as well as in mobiles handsets, cellular based station, tuneable filters signal routing phased array antenna [2]. RF MEMS switches have become the most important part of any RF SYSTEMS [3] .The unit contains of two types of RF MEMS switches, they are the series and the shunt switch. The series switch has a metal cantilever is fixed at one end over the center of a coplanar wave guide (CPW), it can be integrated on polished ceramic substrates [4] . The actuation voltage can be reduced by the increase in the actuation area, then it will increase the size of the switch. Hence the increase in the size is not recommended because of the miniaturization limits. But we can decrease the actuation voltage by decreasing the spring constant. Mechanical switches like push buttons and semiconductor switches are mostly used in switching systems. The most commonly used mechanical switches are coaxial switches, PIN diodes MOSFET and BJT transistors are used for semiconductor switches. BJT can switch faster due to less capacitance the capacitive RF MEMS switches run on frequencies of 4 GHz due to low dielectric constants[5]. Many of the RF MEMS switches are configured in an unpackaged model, but for reconfigurable circuit implementations, the packaged RF MEMS switches are used.

STRUCTURAL DESIGN

The designed RF MEMS switch contains of a Coplanar Wave Guide (CPW), tuning fork shaped electrode, an actuation electrode and two anchors (contact points).Switch that consists of substrate, oxide layer, two ground lines with one signal line and contact layer is used for electroplating. Electroplating was used form contacts under electrode of RF MEMS switch. Polycrystalline silicon is used as the substrate material for the switch and silicon oxide is used as the oxide layer which is deposited on the substrate layer. A tuning fork shaped electrode which is a movable structure in MEMS switch is placed on CPW line with two anchor points on signal line and contact point with gold(Au) material is placed in between the signal line below tuning fork shaped electrode for making contacts and signal flow. Width is indicated with W. Length is indicated with l.

The design of the switch starts with bottom layer that is substrate and Sio2 is deposited on the substrate layer. For the signal flow we have to design one signal line and two ground lines. These two ground lines are separated with certain space as fig follows. The tuning fork shaped electrode is designed on the signal line. To design tuning fork shaped electrode we need anchors, dielectric and air gap. Anchors are used as contact points between signal line and tuning-fork shaped electrode. Dielectric layer in RF MEMS switch is used to produce the high quality in advanced semiconductor equipment. In this paper, HFO2 (solid, polycrystalline) is used as dielectric layer. Air gap is given with minimum height to get the low actuation voltage. In this switch anchor point is fixed at one end and the other end is allowed to move freely and there are no contact points at another end and another end where there is no anchor is provided with dielectric layer. This switch is implemented to obtain less actuation voltage,low insertion loss with more isolation loss.

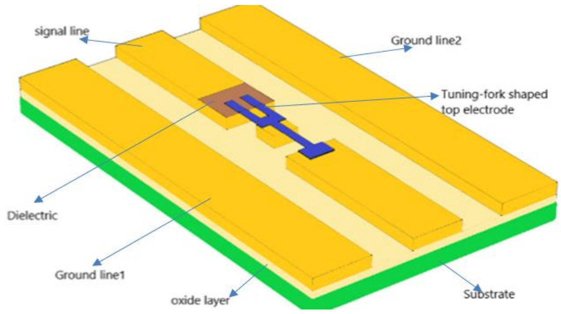

Fig.1 RF MEMS switch with tuning fork shaped electrode

$$V_{pull-down} =_{V} \left(\frac{2}{3} g_0\right) = \sqrt{\frac{8k}{27\varepsilon_0 A} g_0^3}$$

$$K = \frac{1}{2} EW \left(\frac{t}{l}\right)^3$$

SIMULATION

In RF MEMS switch performance analysis is determined using, the lumped equivalent parameters are essential. The insertion loss (IL) of the given RF MEMS switch is obtained by the following expression.

$$\mathrm{IL} = 20\lg\left|\frac{1}{1 + R_c/2Z_0}\right|$$

Where, resistance of the tuning fork shaped electrode and anchors is denoted with R_c ; characteristic impedance of the coplanar wave guide(CPW) signal is denoted with Z_0 The isolation expression of the RF MEMS switch can be obtained by following expression.

$$ISOLATION = 20\lg\left|\frac{2jwC_uZ_0}{1 + 2jwC_uZ_0}\right|$$

Where Cu is the capacitance of the tuning fork shaped electrode, characteristic impedance of the coplanar wave guide signal is denoted by Z_0.

Insertion loss

Insertion loss of a signal when it is travelling in and out of a given RF MEMS switch. When contacts are closed and if loss of the signal is small then the insertion loss will be smaller. In any communication systems the signal having small insertion loss is more preferable

Table 1:

Component	value(µm)
Length of Tuning fork(L)	275
Width of Tuning fork(W)	145
Thickness of Tuning fork(t)	1-2
Beam length (l)	25-145
Beam width (w)	30
Gap between tuning fork type electrode and actuation voltage(g)	1-3

Actuation voltage

Actuation voltage can be explained as the minimum voltage needed to take down the RF MEMS switch's switch beam. The main role of RF MEMS devices is to implement with the reduced actuation voltage, depends on the structure of the switch. This will help to expand the process simulation utility to predict the voltage necessary for cantilever switches and the circuit structure needed to drive these switches.

Isolation loss

The isolation loss is defined as the signal leak between the open links of the two circuits. If the leakage is small means that refers to the high isolation value. In this paper we are discussing about the high isolation value. The properties of isolation are relevant to the (l) lengths, and (w) widths, of cantilever, (t) thickness of tuning-fork shaped electrode. And also between the (g) gap of the actuation electrode and the tuning-fork shaped electrode.

RESULTS AND DISCUSSION

RF MEMS switch is designed with tuning fork shaped electrode have to reduce insertion and actuation voltage and to increase isolation loss. Actuation voltage to this switch is 18V. Here, we have used the HFSS software to plot the graphs for the S11, S12 and S21. S11 indicate return loss of the switch, S12 indicates insertion loss and S21 indicates isolation loss. By using HFSS software, S11, S12, S21 graphs are plotted. Thickness (t) of the tuning fork is 30µm, length (l) is of 145µm and height (h) is of 1µm. Fig2.1, Fig2.2, Fig2.3, and Fig2.4 are the simulation results of RF MEMS switch with tuning fork shaped electrode in comsol software. Shows the results of Fig2.1 is for the different types of metals, Fig2.2 shows the graph of air gap, Fig 2.3 shows the graph of different dielectric materials, and Fig 2.4 shows the graph of different beam structures. Fig3.1, 3.2, and 3.3 are the graphs that are plotted using HFSS software. Fig 3.1 represents insertion loss, Fig3.2 represents return loss, and Fig3.3 represents the isolation loss of the tuning fork electrode. Hence we have attained the 18V of actuation voltage in the switch.

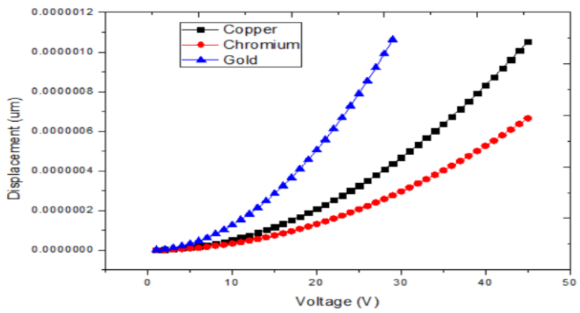

Fig2.1. Simulation results of different metals between displacement and voltage.

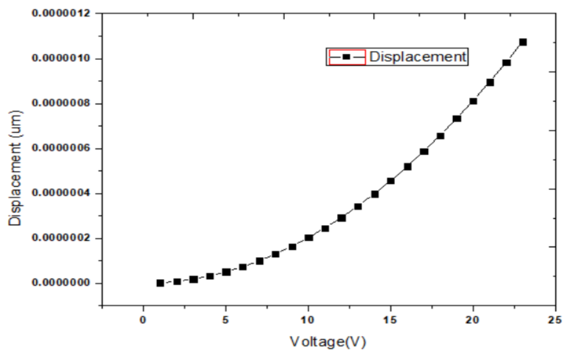

Fig2.2. graph between Displacement and Voltage of air gap.

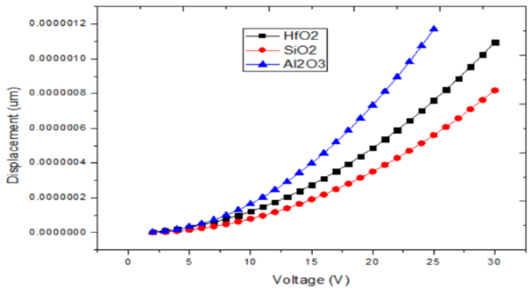

Fig2.3. simulation results of different dielctric materials between displacement and voltage

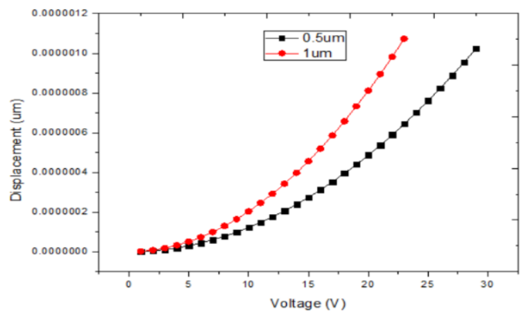

Fig2.4. Simulation results of different beam structures between displacement and voltage.

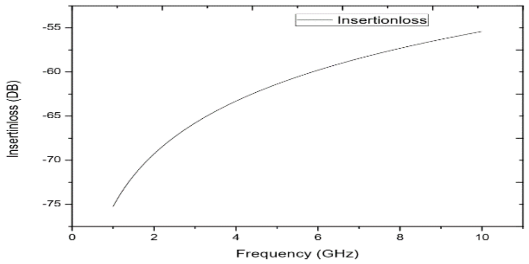

Fig3.1 shows the graph between frequency and insertion loss.

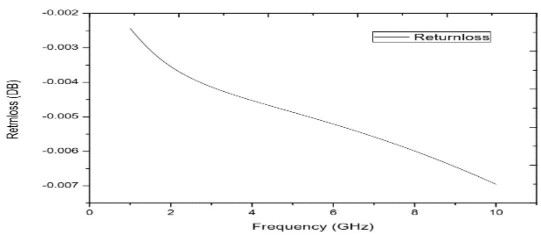

Fig3.2. shows the graph between frequency and return loss.

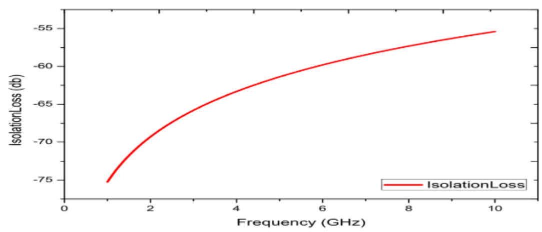

Fig3.3. shows the graph between the frequency and isolation loss.

CONCLUSION

In this paper, the RF MEMS series switch that is used for broadband applications and in some of the communication devices in the frequency range of 0-60 GHz. By using tuning fork shaped electrode and anchor points the RF MEMS switch is constructed in way that it can reduce the insertion loss as well as actuation voltage. By improving the Air gap between tuning fork shaped and actuation electrodes insertion loss is reduced and isolation loss is improved. Switch that designed is consists of low insertion losses and low actuation voltages and high isolation losses related to common switches.

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