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Design, Simulation, and Analysis of a High-Performance RF MEMS Switch for RF Applications

Abstract: - The capacitive RF MEMS shunt switch has been designed, simulated, and analyzed in this paper. We have performed a theoretical calculation to analyze the spring constant and pull-in voltage of the switch by varying the materials, thickness of beam and, air gap. It is highly important to select the appropriate material for the dielectric layer in capacitive shunt MEMS switches. This article evaluates a variety of performance indices in order to enhance the switch's lifetime and stability. Those performance indices are depends upon dielectric material indices. The switching time of the proposed RF MEMS switch is obtained as 4.75us for Gold Materials. The switching time of the proposed RF MEMS switch is 4.75us for Gold Materials. Gold's pull-in voltage is 7.17V, and its displacement is 0.17 µm. COMSOL Multiphysics is employed to evaluate the upstate and downstate capacitances at pull-in voltage. The capacitances are 2.14x10-14pF and 5.25x10-14fF, respectively, and a stress of 3.31 MPa is observed. In electromagnetic analysis, the return loss (S_{11}) and insertion loss (S_{12}) are evaluated by varying the air gap between beam and signal line, and electromagnetic analysis of the proposed switch is carried out by varying the dielectric thickness. For the proposed RF MEMS switch the return and insertion losses are 33.5dB and 0.0608dB. and isolation is 15.005dB. All these values are observed at 3 GHz.

Keywords: *Materials, Pull-in Voltage, Return loss, Isolation, Insertion loss, RF MEMS Switch, dielectric layer, beam.*

I. INTRODUCTION

In the past two decades, a variety of RF MEMS switches have been created for communication systems by utilizing the most advanced CMOS fabrication process [2]. Presently, the RF MEMS switch has the potential to replace the solid state switch and conventional electromechanical relay. This is due to its superior RF performance, which includes high isolation, low insertion loss, high linearity, negligible DC power consumption, and low intermodulation products in comparison to its counterparts [1], [2], [3], [4]. DC-series and capacitive-shunt switches are the two primary classifications of RF MEMS switches, which are determined by their contact. The DC-series switch is capable of being implemented in both fixed-fixed beams and cantilever configurations, both of which employ metal-to-metal contact [5]. In the up-state, these switches function as an electrically open circuit, while in the down-state position, an electrical connection is established to facilitate the transfer of RF power [1]. On the other hand, shunt capacitive switches are typically configured in a fixed-fixed configuration, in which RF power flows from one port to another in the upstate and the total input RF power flows to ground through the upper metal beam/bridge electrode in the downstate [6]. The top and bottom electrodes of RF MEMS capacitive shunt switches are typically separated by a thin dielectric layer of silicon nitride (Si3N4, εr = 7.5) [6], which serves as an isolation layer. Other dielectric materials with a high dielectric constant, such as hafnium dioxide (HfO2, εr = 25) [6], aluminum nitride (AIN, εr = 9.8) [7], piezoelectric lead zirconate titanate (PZT, εr = 190) [8], and strontium titanate oxide (εr = 120) [9], may also be substituted for the silicon nitride layer if desired by the application. A capacitive shunt switch functions as a two-state digital capacitor, displaying a small capacitance Cup (fF) in the up position and a large capacitance Cd (pF) in the down state of the switch. The figure of merit (FOM) for these devices is the ratio of Cd/Cup [1].

The reliability issues associated with the movable mechanical structure of the RF MEMS switches are the primary limitations of their performance, which is a significant concern for long-term applications. Stiction is a common issue with metal-to-metal contact switches. Stiction is induced when the surface adhesion forces exceed the resorting force of the structure [10,11]. It can be enhanced by maximizing the beam restoring force, maintaining an actuation voltage below 60V, and applying an anti-stiction coating of siloxane self-assembled monolayers to the oxide [12,13]. In the case of capacitive switches, the primary constraint on reliability is dielectric charging. The C-V characteristics of the devices are influenced by the trapping of charges across a narrow dielectric layer at

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a high electric field. Dielectric charging can be reduced through the use of a variety of dielectric materials and bipolar actuation [[14], [15], [16], [17], [18].

Nevertheless, the most significant obstacle in the development of RF-MEMS switches is the selection of an appropriate dielectric material for the application of pattern reconfigurable antennas [5-7]. Although numerous material selection strategies have been implemented in the past, the methodology for selecting the dielectric material for RF-MEMS switches, particularly for reconfigurable antennas, has not been implemented [1]. Ashby offers a comprehensive material selection strategy that requires minimal computation. Therefore, the Ashby approach is implemented in the study to determine the most suitable dielectric material for the RF-MEMS switch [8]. The potential dielectric materials have been examined in this research are: SiO2, SiN, Al2O3, AlN, ZrO2, HfO2, TiO2, BST, and Ta2O5 are the dielectric materials that are commonly used in fixed-fixed beam capacitive shunt switches [3-6].The dielectric constant, Young's modulus, electrical resistivity, thermal conductivity, and thermal expansion coefficient are the fundamental dielectric material indices explored in this study for MEMS capacitive switches.

MEMS devices are fabricated by using the silicon, polymers, metals and ceramics. The steps involved in the fabrication are deposition, patterning, etching. One of the most significant technologies utilized in a variety of wireless applications is RF MEMS. RF MEMS technology has been extensively employed in reconfigurable antenna systems in recent years [5-7]. The electrical length and frequency characteristics are modified by RF MEMS switches, resulting in the antenna operating in various modes depending on the state of the switch. Selection of material for dielectric plays an prominent role in RF MEMS switches. Proper selection of material is important in order to avoid dielectric breakdown, which is an significant parameter in performance aspect of the switch. Because of its advantages, such as high isolation and low power consumption, the RF MEMS switch is the primary component in reconfigurable antenna systems, as opposed to solid-state devices. The primary obstacle in the development of the RF MEMS switch for reconfigurable antennas is the selection of the dielectric material. [8-13]. It has been observed that the literature survey reveals a variety of material selection approaches for the dielectric layer, which necessitates a longer execution time for material selection. Ashby approach is the best method to selecting the materials with the less computation. The proposed methods are used to select the appropriate materials for beam and dielectric used in the reconfigure antennas applications [14-18]. This work presents suitable dielectric material which can be used for the oxide layer in RF-MEMS fixed-fixed type switches are Si3N4, AlN, ZrO2, SiO2, HfO2, BST, TiO2, Ta2O5, and Al2O3. The Ashby's methodology is employed to select the appropriate dielectric materials based on indices such as Young's module, electrical resistivity, and thermal expansion coefficient. Switches, phase shifters, antennas, and switches are among the various kinds of RF-MEMS. The most frequently employed RF-MEMS device during this period is among these switches. The main advantage of using the RF-MEMS device over the conventional devices is the RF-MEMS have low power dissipation, improved in isolation, small in size and weight, low cost while producing in bulk. An RF-MEMS switch with a capacitive contact shunt for low Pull-In voltage is proposed in this paper.

II. ASHBY MATERIAL SELECTION APPROACH

The Ashby material selection strategy recommends that the appropriate material be characterized based on its mechanical, electrical, and thermodynamic properties in order to achieve the desired performance. A specific profile of these attributes is required for a design. Screening and classification will be employed to identify and prioritize these attribute profiles [8]. The Ashby material selection approach employs five stages, as illustrated in Figure 1. The initial phase of the design process involves the derivation of the structural component's requirements by considering its function, objectives, and constraints. The Ashby methodology's subsequent step demonstrates that the vast selection is initially reduced by imposing property limits that eliminate materials that do not satisfy the design specifications. By ranking the candidate according to their capacity to deliver the highest level of performance, additional narrowing is accomplished. Subsequently, the final selection of material is determined by the detailed supporting information for each shortlisted candidate [18]. Material indices are a combination of material properties that optimize the performance of a component for a specific requirement. These material indices are obtained by analyzing the function, objectives, and constraints of a component in order to determine the design requirement. A performance index is a collection of material properties that regulate a specific aspect of a component's performance. The most effective method of selecting materials using performance indices is to plot one material property on each axis of the material selection chart [10]. Three parameters are used to specify the design of a component: geometrical properties, functional requirements, and material properties.

P = f [(F G M)] describes the element's performance.... (1)

In this context, P denotes the functionality of an element, while f denotes the geometrical properties (G), material properties (M), and functional requirement (F).

P = f1(F), f2(G), f3(M),... (2)

The performance of the element is delineated by the individual functions of F, G, and M. Therefore, the optimal subset of material can be determined by a singular functional requirement. By optimizing the appropriate material indices, the efficacy of all F and G can be enhanced. This optimization was traditionally conducted using graphs with axes that corresponded to various material properties or material indices [10].

A. The Proposed structure of RF MEMS Switch

The switch is initially fabricated on the silicon layer, which is the fundamental structure of an RF-MEMS switch. Subsequently, the oxide layer is situated above the substrate layer. The CPW, or co-planar wave guide, is a term that refers to the signal layer that is situated between the two grounds and is above the oxide layer. The dielectric layer is accessible above the sign layer [5]. It will operate in opposition to the additional absence of the sign. The RF signal is communicated and the electric stream is regulated during this cycle. To ensure that an anticipated amount of air space exists between the pillar and the dielectric, the shaft and wanders are affixed to the anchors above the CPW layer. The switch in this paper is composed of silicon as the substrate, silicon dioxide as the oxide layer, and silicon nitride as the dielectric. Five distinct metal varieties were selected for analysis to determine which exhibits superior functionality. Gold, silver, aluminum, copper, and ferrous are the five metals that are being examined. Figure 1 illustrates the schematic representation of the proposed RF MEMS switch.

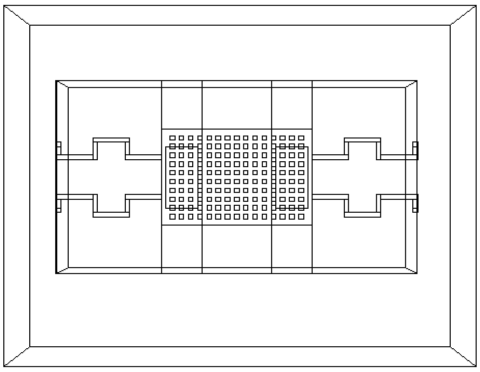

Fig. 1: The Schematic view of the proposed RF MEMS capacitive contact Switch

The meandering technique is being considered for the proposed RF MEMS Switch in order to decrease the Pull-in Voltage. The switch's meander is illustrated in Figure 2.

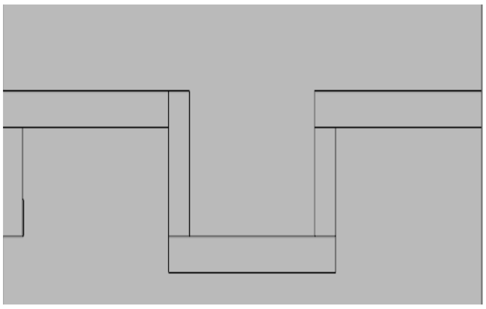

Fig. 2: The Schematic view of Meanders of the switch

Dielectric layer is a substance which is used to transmit the electric force without conduction. If the actuation voltage applied is too high for the RF MEMS switch, there is an occurrence of dielectric breakdown, which leads to the failure of the switch. Therefore, it is imperative to select an appropriate material for the dielectric layer that was affixed to the transmission line in order to reduce the likelihood of losses [7].

B. Material Selection Process

The Ashby's system is utilized to choose the particular material for the dielectric layer with least number of executions by considering a few ascribes to work on the presentation of the gadget like (warm conductivity, warm development, mechanical and electrical properties of the material). The means that are in Ashby material methodology are depicted and choice of materials by execution records is most ideal way by plotting one property of material on every hub of material determination outline as displayed in Fig.3. The components in the plan is indicated by three boundaries in particular mathematical properties, useful necessities and material properties.

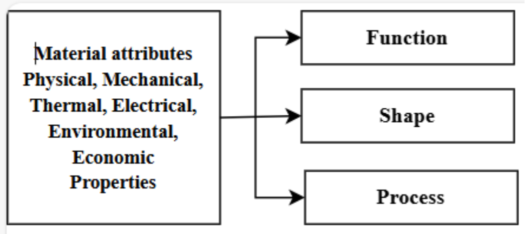

Fig.3: The Material selection process flow chart

The presentation of the gadget is brought through certain properties like mathematical properties, practical necessity, and material files. The components in the Performance can be communicated in the

$$P = f[(F, G, M)] \tag{1}$$

Here the exhibition of the component depicts with P and f shows the capacity of the mathematical prerequisite (G), material records (M), and useful necessity (F).

$$P = f_1(F)\, f_2(G)\, f_3(M) \tag{2}$$

Execution of the components can be conveyed by a few individual capacities like M, G, and F. So, Optimum sub-set of material can be recognized by single functional requirement. By optimizing the appropriate material indices, the performance can be optimized for F and G. This ministration is traditionally performed using graphs with axis comparable to multiple material properties (or) material indices [9]

Device performance can be explained by the given formula

$$P = f_1(F)\, f_2(M) \tag{3}$$

From the give study the following aspects can be assigning for the oxide layer material.

Functional requirement $f_1(F)$: pull- in voltage dielectric stability and dielectric charging.

Material indices $f_2(M)$: relative permittivity, young's modulus, electrical resistivity, thermal conductivity and thermal expansion coefficient.

C. Theoretical parameters

Electromechanics is a combination or interaction of electrical and mechanical system as a whole system. Electromechanical device consists of both electric and mechanical processes. The dimensions of different meanders and different parameters of the RF MEMS switch as shown in Table 2. & Table 3.

$$V_P = \sqrt{\frac{8Kg_0^{\,3}}{27\varepsilon_0 A}} \tag{4}$$

The proposed RF MEMS switch's up-state and down-state capacitances are determined using Eq.5 and Eq.6.

These capacitances are calculated while the switch is on and off state position.

$$C_u = \frac{\varepsilon_0 A}{g_0 + \frac{t_d}{\varepsilon_r}} \tag{5}$$

The calculation of down state capacitance C_d,

$$C_d = \frac{\varepsilon_0 \varepsilon_r A}{t_d} \tag{6}$$

Here, A= cross section area, g= gap between the beam and signal line, ε_o= relative permittivity of free space, ε_r = relative permittivity of dielectric, td= thickness of dielectric respectively.

The investigation of stress assists with understanding the superfluous distortion in the beam.

$$\sigma_{cr} = \frac{\pi^2 \mathrm{E} t^2}{3 l^2 (1 - v)} \tag{7}$$

Table 1. The proposed dimensions of different Meanders in the switch. All dimensions are referenced in µm.

Meander	Length	Width	Thickness
K1	40	5	1.1
K2	15	5	1.1
K3	20	5	1.1

Table 2. The proposed dimensions of different parameters in the switch. All dimensions are referenced in µm.

Parameters	**Materials**	**Width**	**Depth**	**Height**
Substrate	Polycrystalline Silicon	393	220	280
Oxide	Silicon dioxide	393	220	1
Ground	Gold	115	220	1
Signal	Gold	75	220	1
Dielectric	Silicon Nitride	75	110	1
Electrode	Gold	35	70	1
Beam	Gold	163	110	1.1

III. RESULTS AND DISCUSSIONS

The relationship between thermal conductivity and Young's module for various dielectric materials is illustrated in Fig. 4. Dielectric materials with a low thermal expansion coefficient and high electric resistivity exhibit a high degree of hardness and are capable of resisting the dielectric charge. In comparison to other materials, the dielectric materials Si3N4 and Al2O3 demonstrate a low thermal expansion coefficient and a high electrical resistivity (>>1014). Based on the findings, it appears that the most effective material combination for the development of a dependable RF MEMS switch is Si3N4 followed by Al2O3.

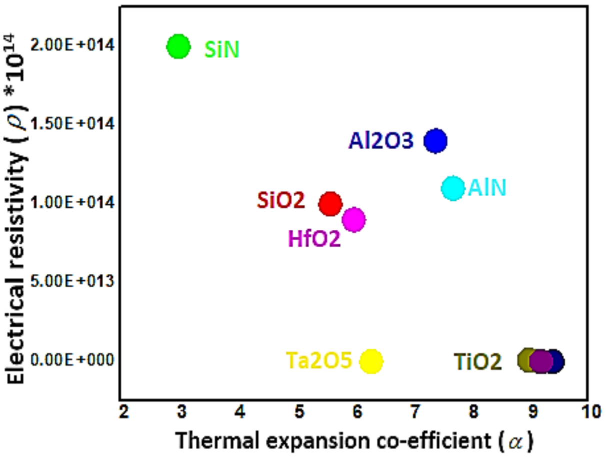

Fig.4 Thermal expansion coefficient (α) versus Electrical resistivity (ρ) for considered material.

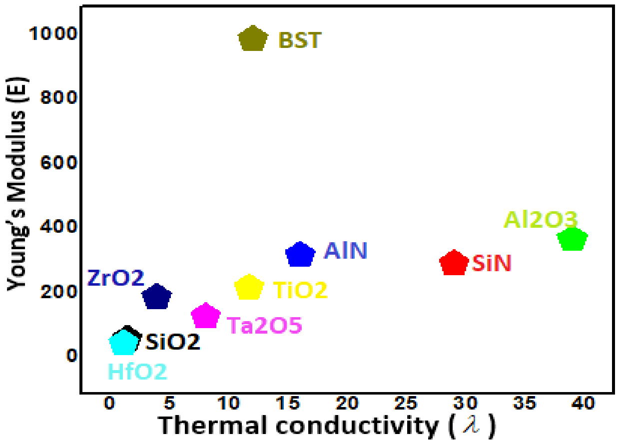

Fig.5 Thermal conductivity (λ) versus young's modulus (E) for considered material.

The relationship between the Young's module (E) and thermal conductivity (λ) for a variety of dielectric materials was shown in Fig. 5. In accordance with the aforementioned stability section, it is postulated that the dielectric stability and switch life are improved as the switching speed increases by a dielectric material with a high Young's modulus (E) and thermal conductivity (λ). Al2O3 is the material that is prioritized over BST and Si3N4, as is evident from the plot. Si3N4 is succeeded by Al2O3, which demonstrates a higher Young's modulus (E) and a lower thermal conductivity (λ) as a consequence of the material BST. The Al2O3 material is the most practical material for improving the switch's durability during this cycle.

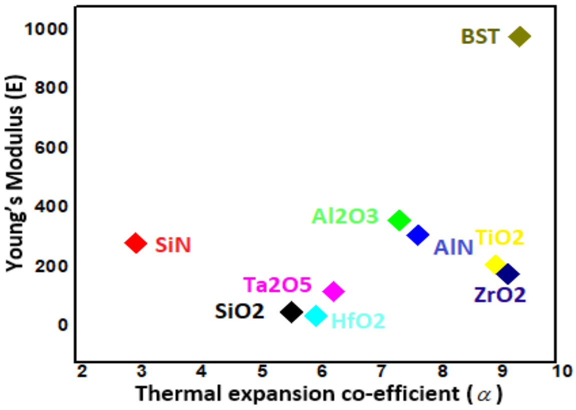

Fig.6 Thermal expansion coefficient (α) versus Young's modulus (E) for considered material.

Figure 6 illustrates the correlation between the thermal expansion coefficient and Young's modulus for a variety of dielectric materials, with the objective of improving dielectric stability. A comprehensive examination of the figure demonstrates that BST, which is closely followed by Al2O3, has a relatively low thermal expansion coefficient and a low Young's modulus. These materials are more preferable for sustaining dielectric stability due to their distinctive combination of properties.

Conversely, the remaining materials were deemed unsuitable due to their low Young's modulus values and large thermal expansion coefficients. These attributes may result in diminished dielectric stability, rendering them less suitable for applications that experience thermal and mechanical stresses. Consequently, BST and Al2O3 are the most promising dielectric materials, as they provide a well-balanced combination of mechanical and thermodynamic properties.

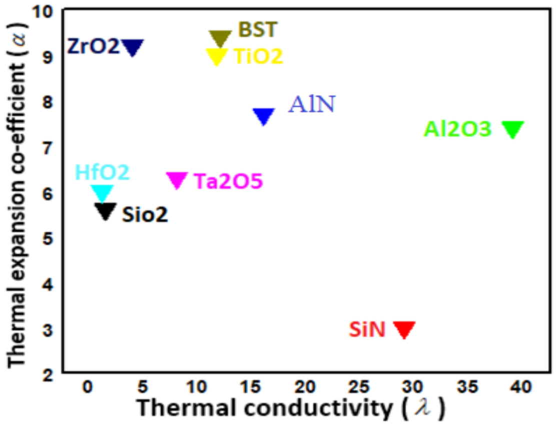

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Fig.7 Thermal expansion coefficient (α) versus for Thermal conductivity (λ) considered material.

To improve dielectric stability, Figure 6 shows the thermal expansion coefficient-Young's modulus connection for several dielectric materials. Reviewing the chart shows that BST, followed by Al2O3, has a low thermal expansion coefficient and Young's modulus. This particular mix of characteristics makes these materials better for dielectric stability. The remaining materials' high thermal expansion coefficients and low Young's modulus made them unsuitable. Their dielectric stability may be compromised, rendering them unsuitable for heat and mechanical loads. BST and Al2O3 are the top dielectric materials because to their attractive thermal and mechanical characteristics.

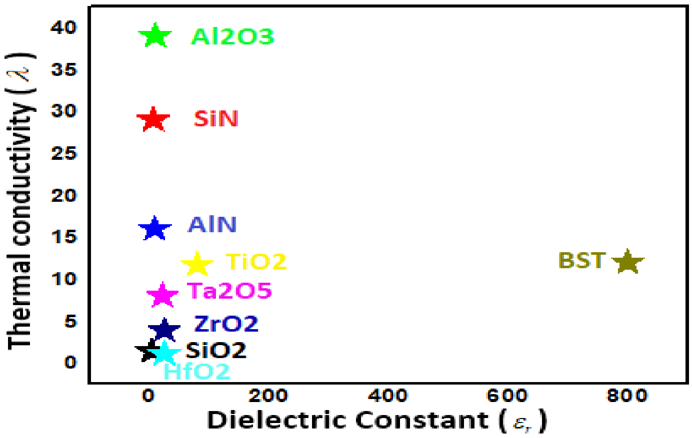

Fig.8 Dielectric constant (ε_r) versus Thermal conductivity (λ) considered material.

The relationship between the dielectric constant (εr) and thermal conductivity (λ) for a variety of dielectric materials is illustrated in Figure 8. BST and Al2O3 exhibit a trade-off. In particular, BST demonstrates a higher dielectric constant but a lower thermal conductivity, whereas Al2O3 demonstrates a higher thermal conductivity but a lower dielectric constant. Electromechanical and electromagnetic simulations were conducted using

COMSOL and High Frequency Structure Software (HFSS) to design and optimize the proposed RF MEMS switch. The high pull-in voltage necessary for operation is a significant constraint of RF-MEMS switches. In order to resolve this issue, a parametric study was implemented to examine the impact of geometric parameters and material properties on the pull-in voltage. The research entailed the modification of the distance (2, 1.7) and beam thickness (1.1, 1.5, 2, 2.5) as well as the variation of the metal used in the switch (gold, aluminum, silver, copper, and iron). The findings of this investigation offer valuable insights into the optimization of the design of RF-MEMS switches to attain reduced pull-in voltages.

Table 3. Theoretical Analysis of the different models.

Material	**Gap (um)**	**Thickness (um)**	**Voltage (V)**	**Material**	**Gap (um)**	**Thickness (um)**	**Voltage (V)**
Gold	2	1.1	8.14	Copper	2	1.1	10.37
		1.5	12.98			1.5	16.52
		2	19.98			2	25.48
		2.5	27.93			2.5	35.55
	1.7	1.1	6.38		1.7	1.1	87.13
		1.5	10.17			1.5	12.24
		2	15.66			2	19.93
		2.5	21.88			2.5	27.85
Al/Ag	2	1.1	7.68	Ferrous	2	1.1	13.122
		1.5	12.21			1.5	20.9
		2	18.75			2	32.19
		2.5	26.28			2.5	45
	1.7	1.1	6.02		1.7	1.1	10.28
		1.5	9.5			1.5	16.39
		2	14.71			2	25.22
		2.5	20.6			2.5	25.26

The analysis of pull-in voltages demonstrated that copper demonstrates higher values than gold and aluminum mixed with silver, while ferrous materials exhibit the highest pull-in voltages. The pull-in voltage for ferrous and copper-based materials is reduced by reducing the gap from 2 μm to 1.7 μm, while the pull-in voltage is generally increased by increasing the material's thickness. The gold metallic switch with a gap of 2 μm and a beam thickness of 1.1 μm was chosen as the optimal design based on these findings. Its performance, including its mechanical stress, capacitance, and voltage-displacement characteristics, was analyzed using COMSOL simulation.

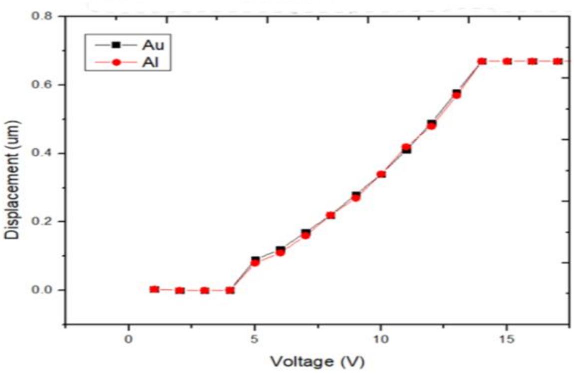

Fig 9. Voltage vs Displacement of two metals Gold and Aluminum.

To determine the displacement efficacy of the beam, the displacement Vs Voltage curve is plotted. In figure 9, it is evident that the Au beam has demonstrated superior displacement at 7.1 V, as illustrated. This is due to the fact that gold (Au) has a higher ductility and a lower Young's modulus, which facilitates the demonstration of a greater displacement at lower actuation voltages. Consequently, it is an appropriate material for RF MEMS switch applications. The displacement performance of Au is evident in COMSOL multiphysics shown in figure 10. A porous Au beam of 163x110x1.1 um is hanged between the hinges on either sides to analyze its displacement properties by applying varying voltage. It has resulted ina highest displacement of 0.17 um at a stated potential of 7.1 V as plotted in figure 9.

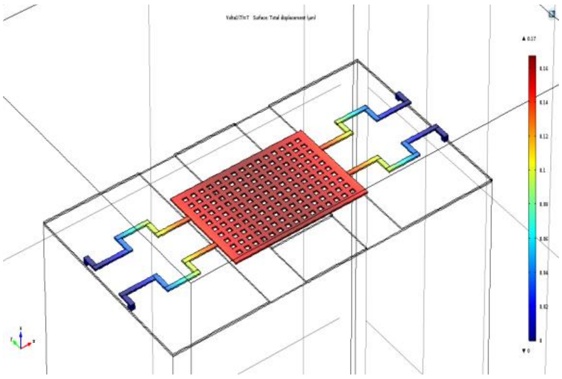

Fig 10 Gold Voltage vs Displacement at Pull-in Voltage 0.17 um.

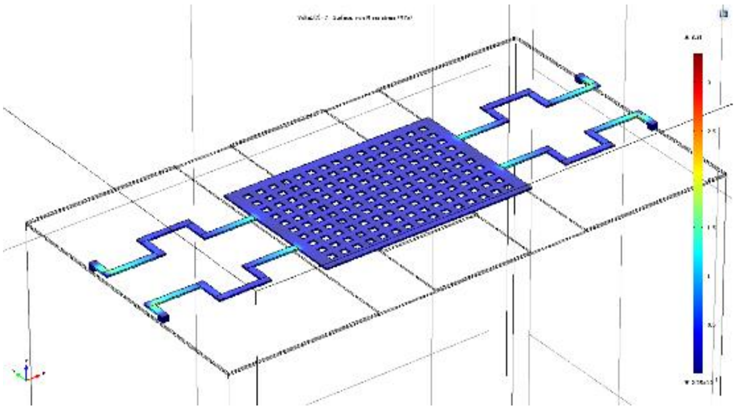

Fig 11.Stress analysis of proposed switch which is 3.31 MPa.

Similarly the stress analysis is carried out on the same Au beam analyze its deformation capacity. The stress analysis has shown a result of 3.31 MPa as shown in figure 11, which is suitable for a RF application of a MEMS device.

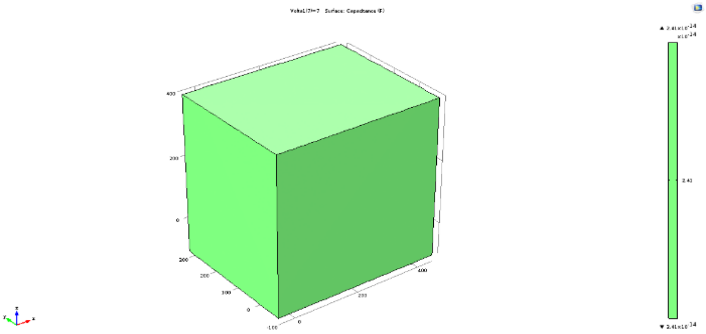

Fig 12 Upstate Capacitance of switch 2.14x10-14 F

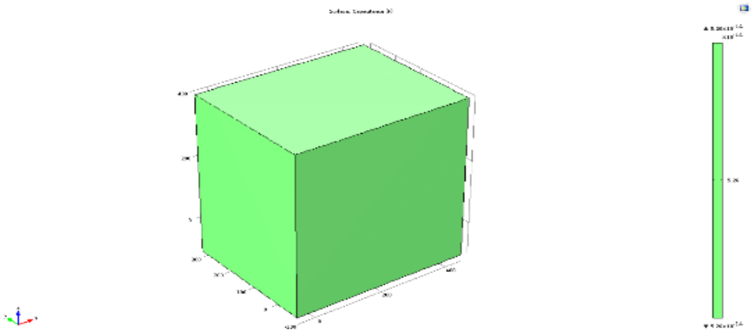

Fig 13 Downstate Capacitance of switch is 5.25x10-14 F.

The capacitance of the RF MEMS switch varies significantly between its upstate and downstate positions, with values of 2.14 x 10-14 F and 5.25 x 10-14 F, respectively. The capacitance ratio of approximately 2.45 suggests a substantial increase in capacitance as the switch transitions from the upland to the downstate position. This indicates that the switch is capable of modulating the capacitance in a manner that is suitable for RF applications. The electromagnetic efficacy of the proposed RF MEMS switch design was assessed using the High Frequency Structure Simulator (HFSS) 13.0 instrument in this research paper. The HFSS software is a widely used electromagnetic simulation instrument that facilitates the analysis of high-frequency structures, such as RF MEMS devices. The electromagnetic behavior of the RF MEMS switch was simulated using HFSS 13.0, and a variety of results were obtained, including the scattering parameters (S-parameters). These S-parameters are critical performance metrics that define the switch's behavior in terms of isolation, transmission, and reflection. The S-parameters that were obtained offer valuable insights into the switch's electromagnetic performance, enabling us to assess its suitability for RF applications. We performed the analysis on four different materials to check the performance in terms of return loss, insertion loss and isolation as shown in Fig 14,15,16. Further, the same material is subjected to the analysis in varying displacement conditions which were indicated in fig 17 and 18.

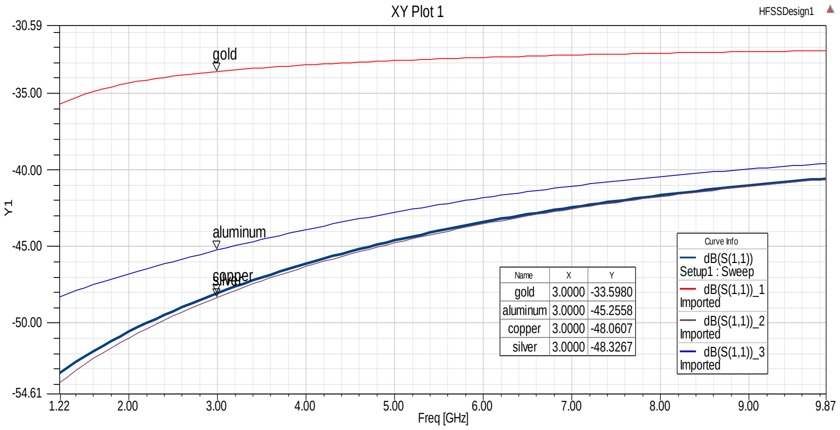

Fig 14. Return Loss of the proposed RF MEMS switch measured at 3 GHz for gold material

The return loss (S(1,1)) of various materials (gold, aluminum, copper, and silver) at a specific frequency (X = 3GHz) is compared in the table. The values range from -33.5980 dB (gold) to -48.3267 dB (silver). The materials can be ranked from highest to lowest return loss in the following order: silver, copper, aluminum, and gold. This information is useful for selecting materials for RF applications where minimizing return loss is a critical factor. Additionally, gold exhibits the lowest return loss, while silver exhibits the highest.

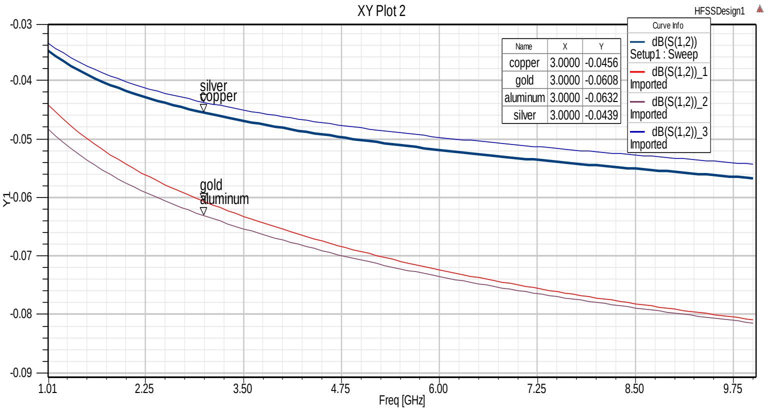

Fig 15.Insertion Loss measured at 3 GHz for gold material

The insertion loss (dB(S(1,2))) of various materials (copper, gold, aluminum, and silver) at a specific frequency (3 GHz) is compared in the table. The results indicate that silver has the lowest insertion loss (-0.0439 dB), followed by copper, gold, and aluminum, which has the maximum insertion loss (-0.0632 dB).

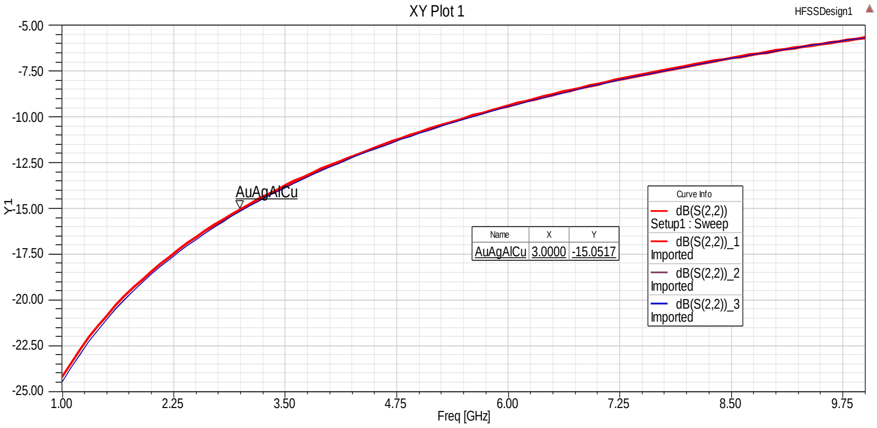

Fig 16. Isolation measured at 3 GHz for gold material

The isolation loss analysis of the four materials is indicating the similar behaveour at 3GHz. Return loss and instertion loss analysis performed by varying gap between beam and dielectric. This analysis has revealed the suitability of gold material for the RF MEMS Switch. From Figures 17,18, we have observed that by varying the metal in the switch does not affect very much in these S-parameters. Return and insertion loss analysis are study in upstate for gold material by altering the gap between signal line and the beam.

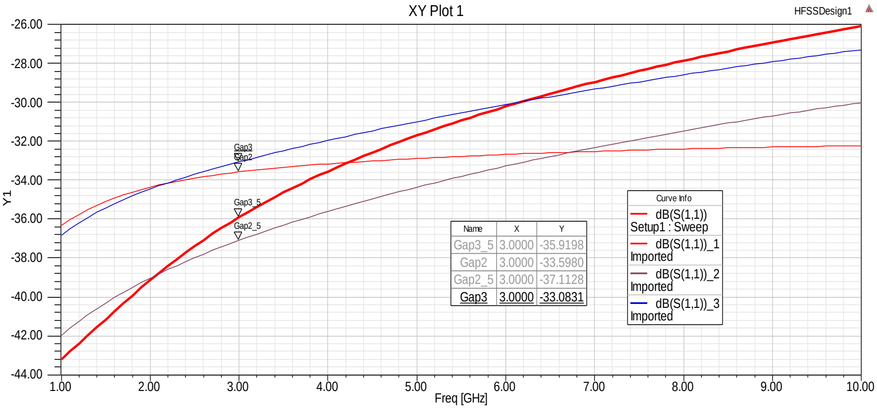

Fig 17. Return loss for a gold metal by varying the gap

The table displays the return loss for different gap widths (2 µm, 2.5 µm, 3 µm, and 3.5 µm) at a frequency of 3 GHz. The findings indicate that a gap size of 2 µm and 3 µm yields the optimal return loss (-33.5980 dB and -

33.0831 dB, respectively) and 2.5 µm return loss performance (-37.1128 dB), succeeded by 3.5 µm (-35.9198 dB).

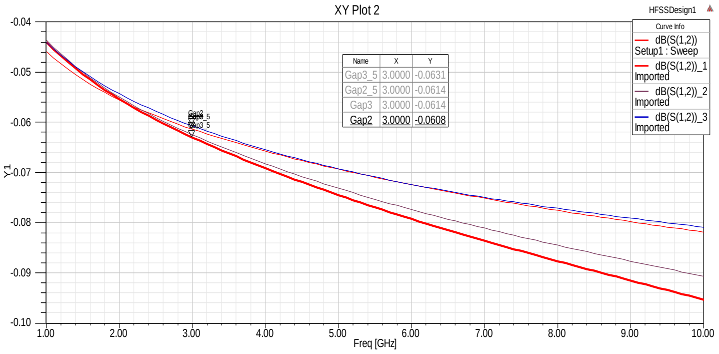

Fig 18 Insertion loss for a gold metal by varying the gap

The insertion loss for various spacing sizes at a frequency of 3 GHz is illustrated in the table. The results indicate that Gap 3.5 um has the maximum insertion loss (-0.0631 dB), while Gap 2 um has the lowest (-0.0608 dB). The insertion loss values of Gap 2.5 um and Gap 3 um are identical, at -0.0614 dB.

Table 4. The comparison of the proposed work with existing work

Parameter	**Ref [6]**	**Ref [3]**	**Ref [9]**	**Proposed Work**
Pull-in(Vp) Voltage	60v	16.9V	18.5V	7.17V
Stress Analysis	--	1.286MPa	4.19 MPa	3.31MPa
Switching Time(ts)	--	1.2µs	2.5 µs	4.75µs
Up state Capacitance	40fF	7.46 fF	5.12fF	2.14fF
Down state Capacitance	3.1pF	1.25pF	3.27pF	5.25pF
Return Loss(S11)	--	-41.55 dB	-38.60 dB	-33.5dbB
Insertion Loss(S12)	--	-0.0865dB	-0.1177 dB	-0.0608dB
Isolation Loss(S12)	-30dB	-47.70dB	-37.20dB	-15dB

The performance of the proposed RF MEMS switch design is compared (in table 4) to existing designs from references [3], [6], and [9] in the tables below. The pull-in voltage (7.17V), stress analysis (3.31MPa), and insertion loss (-0.0608dB) all demonstrate enhancements in the proposed design. Nevertheless, the proposed design has a higher transition time (4.75µs) and a reduced isolation loss (-15dB) than some of the existing designs. In general, the proposed design provides a satisfactory equilibrium of performance parameters, rendering it a viable alternative for RF MEMS switch applications.

IV. CONCLUSION

In this research paper, a thorough analysis and design of a proposed RF MEMS switch are presented. The switch's performance is evaluated in terms of pull-in voltage, stress analysis, insertion loss, and capacitance ratio. The results indicate that gold is a suitable material for the beam, as evidenced by a switching time of 4.75 ns, a pull-in voltage of 7.17V, and a displacement of 0.17 micrometers. The proposed design is a viable option for reconfigurable antenna applications due to its superior stability, extended longevity, and enhanced dielectric charging. Furthermore, the capacitance ratio and S-parameters of the design suggest that it is appropriate for RF applications. In general, the proposed RF MEMS switch design provides a better solution for RF MEMS switch applications due to its well-balanced performance parameters.

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