DESIGN AND ANALYSIS OF VARIOUS MEMBRANE RF SHUNT CAPACITIVE SWITCH FOR LOW VOLTAGE APPLICATIONS

B.V.S. Sailaja¹, K.V. Vineetha¹, P. Ashok Kumar¹, B. Sujatha¹, K. Girija Sravani¹,² and K. Srinivasa Rao¹*
¹Microelectronics Research Group, Department of ECE, K L UNIVERSITY, Vaddeswaram, Andhra Pradesh, India
²National MEMD Design Center, Department of ECE, National Institute of Technology, Silchar, Assam, India
srinivasakarumuri@gmail.com

ABSTRACT: Micro Electro Mechanical System Switches play major role in electronic industry. This paper provides the study of RF MEMS capacitive shunt switch Membranes. Different structures of membranes are presented. Low pull in voltage was obtained for flexure type membrane. Effect of materials plays key role and design was done with different types of materials. Performance depends on materials utilized for the design. Considering the material properties also important for good performance of switch. Membranes are designed with different types of materials and Comparison has noticed low pull in voltage of 9v for flexure type membrane. High isolation of -38 dB was observed at 22GHZ frequency and insertion loss was below -0.07 dB for flexure membrane, by varying gap performance of switch has been observed.

Keywords: Shunt capacitive switch, actuation voltage, scattering parameters, COMSOL, Intellisuite software, ANSYS HFSS

1. Introduction

PIN diode and Mechanical switches are potentially replaced by the MEMS switches [1] MEMS technology presents miniaturization than other technologies like CMOS and GaAs technology. They present good electrical performance with low Consumption of power and good linearity. [4] RF MEMS is promising technology, because of superior performance; they are spread widely in wireless communications. RF switches enable switching in transmission line they use mechanical switching Classification of MEMS switches is done in two ways i.e. metal to metal. Capacitive contact switches. They support for high frequency applications; resistive switches are suits for low frequency application. [5] Configuration is of two types’ series and shunt. Switch with shunt configuration produce improved performance. In actuated state capacitive contact was achieved by fixed –fixed switch that use metal membrane. Capacitive contact switches have capability of power handling. The capacitive contact switch provides excellent isolation when the switch is in actuated state. It shorts the RF signal to the ground. MEMS technology is the integration of mechanical and electrical components on single platform i.e. substrate [3].

In this paper three membranes-1, 2 have been proposed. Both the membranes are of Fixed-Fixed type. First membrane is simple and effective one with no perforations and meanders presents low pull in voltage. Next consists of serpentine meanders along with perforations. Membrane with serpentine meanders provides lower actuation voltage compared with others. Materials consideration is also important for the design of membrane to show better performance [12]. Membranes are designed with different materials. A gap of 2and 2.5µm maintained between the electrodes performance of membranes has noticed. Similarly membranes were designed Intellisuite software. High performance mainly drawn by evaluating scattering parameters

2. Description of shunt switches

In this paper, capacitive shunt switch is designed by using new techniques like flexure type structure and perforations. Capacitive shunt switches are suitable for high frequency applications.

![Switch Diagram](image)

During on state of the switch RF signal flows from input to output, i.e. switch is in unsaturated state. Silicon is the best material rather than other materials because they provide high resistivity switch has been given in the above
figures. 1(a) and (b) denotes cross section view of both states of the shunt switch. Actuation of switch is done only when appropriate voltage is applied.

A. Design and analysis of Membranes

Membrane-1 was given below with desired dimensions and materials like Gold, Aluminum, and Titanium. Platinum material properties varies from material to material. Membranes are designed using gold and analysis is observed. Then materials are changed one by one. Comparisons of materials are observed through graphs.

Membrane-2 with serpentine meanders and holes is designed it reduces buckling effect and stiction problem. A gap height of 2µm and 2.5µm are maintained between membrane and electrode. Anchors are provided with a thickness of 4µm on ground plane of cpw. It is necessary to reduce pull down voltage to attain reliability. So gaps are varied and compared Lower the gap lower the voltage is obtained.

B. Pull in voltage

Actuation voltage $V_p$ is the voltage required by the switch to activate with spring constant $k$ actuation voltage is given below. The principle of MEMS RF switch is some appropriate voltage need to be given to attain the displacement of membrane for switching usually rectangular based beams have the pull in voltage is given by the formula

$$V_p = \sqrt{\frac{8k}{\varepsilon_o A}}$$

(1)

$K$ is spring constant, go-Gap between electrode and membrane, $\varepsilon_o = 8.85 \times 10^{-12} \text{ F/m}$, $A$ -Area of contact.

Table-1: Membrane -1 comparison of materials with simulated and numerically calculated values with different gaps respectively.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Theoretical gap maintained [v]</th>
<th>Simulated gap maintained [v]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2µm</td>
<td>2.5µm</td>
</tr>
<tr>
<td>Gold</td>
<td>15 18</td>
<td>18.1 19</td>
</tr>
<tr>
<td>Aluminum</td>
<td>14 17</td>
<td>17 20</td>
</tr>
<tr>
<td>Titanium</td>
<td>18 22</td>
<td>21 23.5</td>
</tr>
<tr>
<td>Platinum</td>
<td>23 26</td>
<td>24 29.7</td>
</tr>
</tbody>
</table>

Table-2: Comparison of numerically simulated values of Membrane-2

<table>
<thead>
<tr>
<th>Materials</th>
<th>Theoretical gap maintained [v]</th>
<th>Simulated gap maintained [v]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2µm</td>
<td>2.5µm</td>
</tr>
<tr>
<td>Gold</td>
<td>10 13</td>
<td>11.2 13.5</td>
</tr>
<tr>
<td>Aluminum</td>
<td>9 11</td>
<td>10.2 12</td>
</tr>
<tr>
<td>Titanium</td>
<td>12 15</td>
<td>13 17.1</td>
</tr>
<tr>
<td>Platinum</td>
<td>17 20</td>
<td>17.6 22.3</td>
</tr>
</tbody>
</table>
3. Results and discussion

Pull in voltage varies for every structure are compared with different materials. Graph plotted for every structure by varying gap 2um and 2.5um. For the given actuation voltage displacement of the beam is observed considering the gold material shown below for the gap of 2.5um.

Figure 4. Displacement of membrane -1 in vertical direction.

Figure 5. Membrane-2 deflecting towards Z direction

A. Electromechanical analysis

Different pull in voltages are for different materials are noticed. On the contact area of Membrane action of force will be present. Residual stress is not present because of holes. Load distribution is done uniformly on both sides central contact it is forced to move in vertical direction i.e. towards Z direction. Contacting the signal line in this section.

Figure 6. Displacement analysis of Membrane-1 For a gap of 2um with different materials

Figure 7. Displacement analysis of Membrane-1 For a gap of 2.5um with different materials

Figure 8. Displacement analysis of Membrane-2 For a gap of 2um with different materials
Finite element method evaluates electrical and mechanical behavior of RF MEMS Switch with the help of Intellisuite software. Electro mechanical analysis is performed. It is apt tool for RF Mem Switches. Three membranes were designed maintained with the gap of 2.5um. Switch characteristics were governed by design of the structure.

**Figure.9.** Displacement analysis of Membrane-1 For a gap of 2.5um with different materials

**Figure.10.** Displacement analysis of Membrane-1 Maintained gap of 3um between mechanical membrane and dielectric layer

**Figure.11.** Displacement analysis of Membrane-2 Maintained gap of 3um between mechanical membrane and dielectric layer

**B. Performance analysis of scattering parameters**

RF performance is solved with the help of EM solver Ansys HFSS. Scattering parameters are evaluated for the frequency of 40 GHz for off state and on state of the switch. Proposed switch shows excellent isolation in off state for gap of 2.5um. It is the optimum distance to obtain the better performance

**Figure.12.** (a) RF response of Membrane-3 Insertion loss in onstate of the device, (b) Performance of isolation

**4. Conclusion**

RF MEMS switches replace solid state switches because of tremendous advantages. Capacitive shunt switch membranes designed and simulated. Membrane plays major role in MEMS switch designs. Performance mainly depends on the design, pull in voltage evaluated by the desired materials using FEM Tool. Electromechanical analysis are also analyzed using Intellisuite software. Serpentine meander structure shows excellent Isolation. Aluminum has better pull in voltage compared with other materials mentioned above. Membrane-3 gives low pull in voltage of 9v displacement of membranes observed through graphs.

**5. References**


