Low Loss High Isolation NEMS Switch (0-80GHz) for RADAR Application

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Abstract

NEMS switches are advantageous in terms of low power consumption, switching times, high isolation, low insertion loss and many more. This paper proposes a NEMS switch with reasonably high isolation and low insertion loss. The model used is a cantilever series switch built on a CPW with a silicon substrate. The switch parameters are optimized for the lowest insertion loss and return loss. An insertion loss values of -0.1305 *dB in the down state with return loss of -38 dB and -75dB of isolation have been observed up to 80GHz.*

Keywords: NEMS switch, Low Loss, High Isolation, RADAR

I Introduction

Nano-Electro-Mechanical Systems (NEMS) is the future electronics. Two different electrostatic actuation models exist namely the capacitive switch and the metal-metal contact switch. High isolation in the switch OFF position and low insertion- loss in the ON position is expected. The cut-off frequencies obtained may reach a value of 40THz [1]. The actuation voltage is the main feature of the switch.

Micro-Electro-Mechanical Systems (MEMS) technology has grown rapidly and entered into many communication and defense applications. At present, as the development in MEMS technology, Radio Frequency (RF) MEMS is one of the fastest growing areas in commercial MEMS technology. As a novel switch, RF MEMS switches have a myriad application in radar system and wireless communications. Comparing to semiconductor switches widely used in millimeter wave integrated circuits and microwave circuits, the novel device has a low insertion loss, good isolation, low return loss, high frequency, good Q-factor, and a low cost and power consumption.

The components and subsystems used in radar are based on RF MEMS switches, switched capacitors, and varactors. Limiters protect active microwave circuitry from damaging power levels. Anti-stiction treatments involve the application of a molecular film to the micro-machine surface. [2]

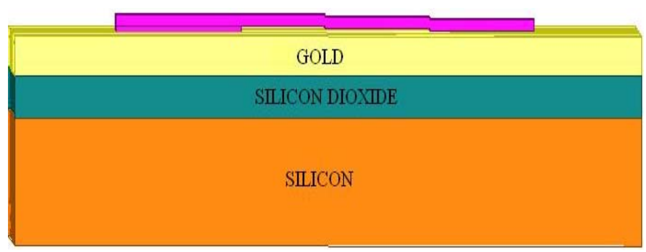
II RADAR APPLICATIONS

Radio Frequency Nano-Electro-Mechanical Systems have been proposed to replace the already existing components like the Active Electronically Steerable Antennas, Passive Electronically Scanned Arrays, phase shifters, radomes [3].A wide bandwidth can be obtained by using RF NEMS switch as phase shifters in RADAR [4-12]. Thou many switches are proposed but detailed study of NEMS switch is not available in the literature. This paper presents the detailed optimization of parameters of NEMS switch for the RF Characteristics.

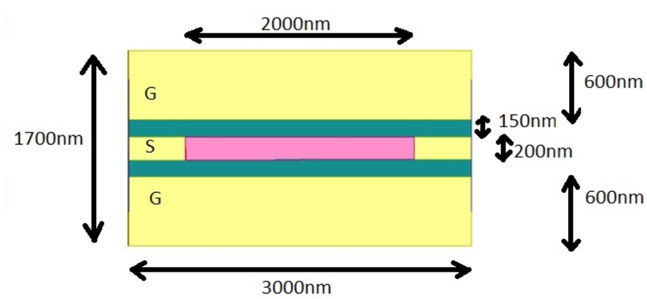
III DESIGN

A) Conventional NEMS switch

The proposed NEMS switch is a cantilever beam developed on a 50 Ω Co-planar Wave-guide (CPW) with G/S/G = 150/200/150 nm as shown in Fig. 1. The substrate used is a silicon substrate of thickness 450nm.The whole switch is fabricated on the silicon substrate with a silicon oxide layer on top of it [6]. A layer of SiO2 of about 150nm is layered for the isolation purpose. The anchor for the beam is made of Gold. A dielectric layer made of Silicon Nitride (SiN) is layered between the cantilever and CPW to avoid stiction in the down state.



a) Side View



b) Top View

Fig. 1: Structural representation of the switch.

B) Structural Variations

Various structures in the NEMS switch are altered to observe certain changes in the S-parameter Characteristics viz. Insertion loss and the return loss. As the down state is the important phase of a switch the isolation is ignored and is assumed to be constant. Although the dimensions of various structures are being changes it is taken care that the cantilever of the switch dimensions remains unaltered.

Substrate height change:

Substrate of the switch is varied from 250nm to 1000nm.As we are aware that as the substrate dimensions changes the CPW G/S/G changes hence altering the substrate and G/S/G to maintain 50Ω impedance[7] various combinations have been considered and tabulated.

Table 1: Substrate height variations.

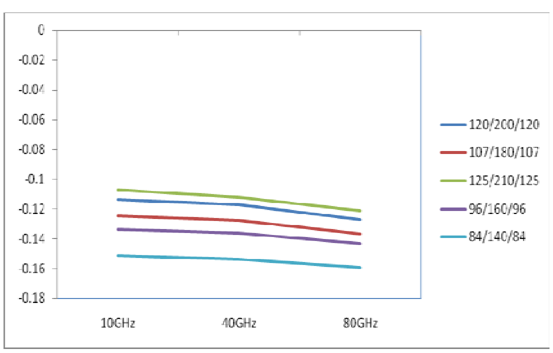
G/S/G	Height	INSERTION LOSS		
		10GHz	40GHz	80GHz
110/250/110	250nm	-0.094	-0.0987	-0.1105
100/150/100	470nm	-0.1474	-0.1496	-0.1545
180/250/180	650nm	-0.0883	-0.0911	-0.0989
80/130/80	800nm	-0.1684	-0.17	-0.1738
125/200/125	1000nm	-0.1091	-0.111	-0.1164

G/S/G	height	RETURN LOSS		
		10GHz	40GHz	80GHz
110/250/110	250nm	-30.2817	-29.7617	-28.9383
100/150/100	470nm	-27.9256	-27.734	-27.6013
180/250/180	650nm	-34.0348	-33.0942	-3.4035
80/130/80	800nm	-27.2323	-27.0357	-26.7489
125/200/125	1000nm	-37.4543	-38.2672	-37.0692

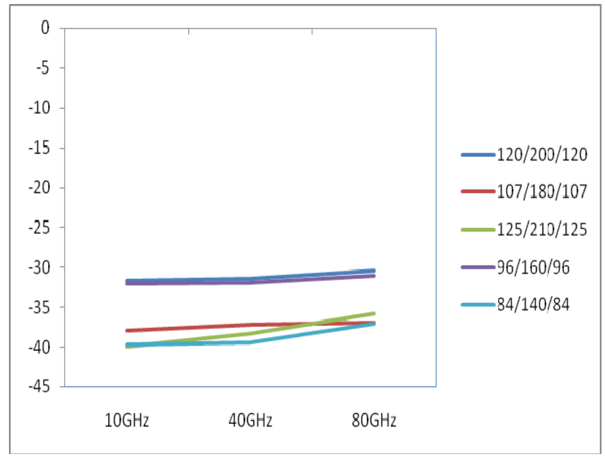
It is observed from the above table that 1000nm with G/S/G of 125/200/125 is the optimized value for the substrate variations. These values are considered keeping in mind that the overall impedance of the circuit is 50Ω. Although the G/S/G is determined, changing the CPW gap may alter the impedance hence keeping the impedance of 50 ohm in mind the gap is altered accordingly.

Variation in CPW G/S/G:

After varying the substrate thickness, CPW G/S/G is varied accordingly.



a) Insertion loss



b) Return Loss

Fig.2 CPW G/S/G variations a) Insertion loss b) Return loss of a RF NEMS Switch

From the graph it is evident that the values of the insertion loss and return loss are better for 125/210/125. Hence 125/210/125 is taken as the optimized value of G/S/G.

Effect of CPW length:

Keeping the G/S/G variations as derived earlier, the CPW length is altered to be tabulated as below.

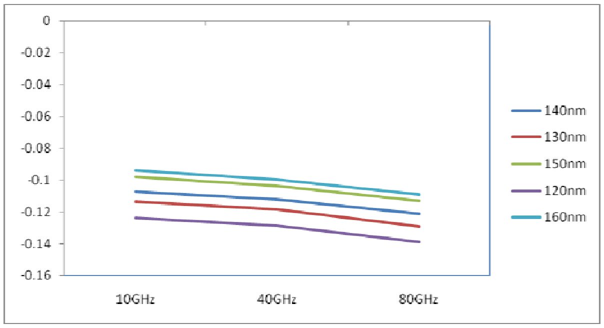
Table 2: Variation of CPW length.

CPW LENGTH	INSERTION LOSS		
	10GHz	40GHz	80GHz
3um	-0.093	-0.0977	-0.1097
4um	-0.1194	-0.1257	-0.1412
5um	-0.146	-0.1526	-0.1714
CPW LENGTH	RETURN LOSS		
	10GHz	40GHz	80GHz
3um	-55.2368	-43.4799	-37.7889
4um	-34.5904	-33.2651	-31.288
5um	-28.5954	-28.313	-27.1366

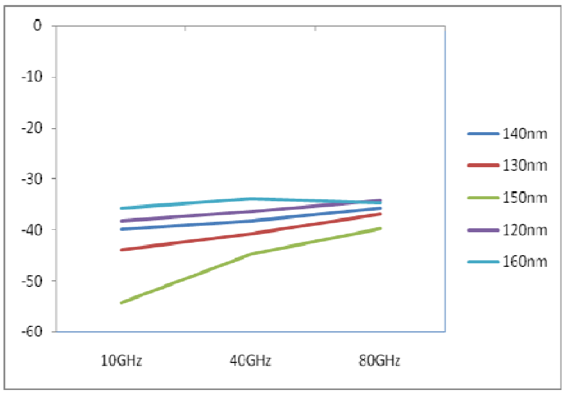
Based on the tabulated values it is observed that 3µm is the corrected length of CPW for the switch.

Effect of CPW thickness:

The thickness of the CPW also varies the overall impedance of the switch.Hence it is carefuly observed that 50Ω impedance is observed



a) Insertion Loss



b) Return Loss

Fig. 3 CPW thickness variations a) Insertion loss b) Return Loss of a RF NEMS Switch

From the above graph it can be estimated that 130nm give the optimizable outputs for the NEMS switch.As the CPW thickness is being varied the radiations being offered by the transmission is varied thereby producing a change in the parameters of the NEMS switch

Silicon dioxide layer thickness is further changed.

Silicon Dioxide thickness determination

The final dimesional aspect which may lead to a better switch characteristic is its isolation layer.Hence this isolation layer is varied in a few different dimesions to deduce the best optimized NEMS switch.

Table 3: Isolation layer variation characteristics

SiO_2 thickness	INSERTION LOSS		
	10GHz	40GHz	80GHz
140nm	-0.1152	-0.12	-0.1305
130nm	-0.1121	-0.1169	-0.1274
150nm	-0.1137	-0.1186	-0.127
120nm	-0.1129	0.1175	-0.1279
160nm	-0.114	-0.119	-0.1284

SiO_2 thickness	RETURN LOSS		
	10GHz	40GHz	80GHz
140nm	-51.5165	-43.8378	-38.0895
130nm	-38.4675	-37.5366	-35.759
150nm	-43.8837	-40.7257	-36.8914
120nm	-44.0879	-40.9167	-37.078
160nm	-36.5603	-37.2946	-32.856

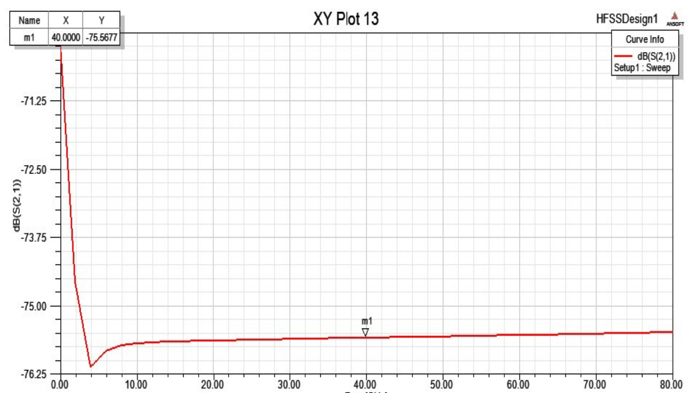
A few carefully selected values[8] of the isolated layer have been portrayed in the form of a table above to bring about the best of the characteritstics in an RF NEMS switch.

IV FINAL OPTIMIZED RF NEMS SWITCH

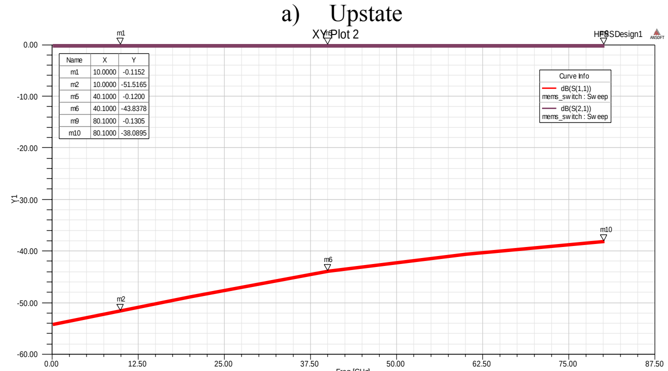
After analyzing various parameters and dimensions a final optimized result is simulated. The optimized dimensions are found out to be:

Substrate thickness: 1000nn
G/S/G: : 125/210/125
CPW length : 3µm
CPW thickness : 130nm
Isolation thickness : 140nm

Therefore the Insertion loss and the Return loss characteristics of the NEMS switch are as shown in Fig. 4



a) Upstate



b) Down state

Fig. 4 Final Optimized RF NEMS Switch Insertion loss and Return loss in down state

From the analysis performed for the optimized switch characteristics, a return loss of -75dB and an insertion loss of -0.1352dB is observed at 80GHz which is in the RADAR range.

CONCLUSION

A high isolation NEMS switch from 0-80GHz has been proposed. The effect of various parameters is studied and presented. The NEMS switch is optimized for the best performance. An insertion loss values of -0.1305 dB in the down state with return loss of -38 dB and -75dB of isolation has been observed upto 80GHz. The obtained range covers many applications of the radar.

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