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고주파에서 높은 신호 격리도를 갖는 접촉식 RF MEMS 스위치의 설계

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Design of Ohmic Contact RF MEMS Silicon Switch with High Isolation at High Frequencies

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Abstract - This paper presents the design and simulation results of ohmic contact RF MEMS silicon switch with a high isolation at high frequencies along with the position of a contact part, initial off-state and intermediate off-state including the state where a contact part is placed right over a signal line of coplanar waveguide (CPW). The ohmic contact part is connected with comb drives made of high resistivity single crystalline silicon. The released contact part is 30 μm apart from the edge of signal line on the glass substrate along the lateral direction (x-direction) at initial off-state. The electrostatic force of the comb electrode creates the x-directional movement thus initial state is converted to the intermediate off-state. The initial off-state of the switch results in isolations of -31 dB, -24 dB and reflections of -0.45 dB, -0.67 dB at 50 GHz and 110 GHz, respectively. It shows the isolation degradation when the contact part moves right over the signal line of CPW like an initial off-state of a conventional MEMS switch. The isolations and reflections are -31 dB, -24 dB and -0.50 dB, -1.31 dB at 50 GHz and 110 GHz, respectively at the intermediate off-state.

1. Introduction

Radio-frequency (RF) microelectromechanical systems (MEMS) switches have been actively developed for their superior performances to conventional solid-state switching devices such as p-i-n diode or FETs in high frequencies since MEMS switches offer low insertion loss, high isolation, low series resistance and high linearity due to low intermodulation [1].

Isolation is a critical parameter of the MEMS switch since the parameter represents a separation between on-state and off-state, determining the signal loss at the off-state. High isolation is required to separate effectively off-state from on-state and to reduce the power consumption. Typically there are two kinds of switches, namely, shunt capacitive switches and series contact switches. The isolation of each device depends on different mechanism. Shunt capacitive switches operate by controlling the gap between the switch and transmission lines. Normally RF signal transmits through transmission lines (T-lines) in off-state, but the signal sinks to the ground electrodes when the gap of the switch is reduced. Series contact switches are initially in off state. The contact metals connect signal lines by moving contact parts if a driving voltage is applied to switch actuators.

A lot of efforts have been paid to achieve the high isolation in MEMS switches to improve their performance [2-5]. Series contact switches are widely used in several GHz range, however it is not suitable over 50 GHz because of a large coupling capacitor between a top contact electrode and signal lines leading to poor isolation. A capacitive shunt switches for high isolation have been researched over 50 GHz using high-k material [2]. The isolation was improved but the larger gap and higher driving voltage were drawbacks of this approach.

In this paper, we propose the RF MEMS contact switch which has high isolation from 50 GHz to 110 GHz. MEMS switch has three state, initial-off, intermediate-off, and contact on-state and a high-isolation is achieved by departing the top contact electrode from the bottom at the intial off-state.

2. Design

The proposed high-isolation MEMS switch largely consists of two parts, namely, a top silicon substrate and a bottom glass substrate, as shown in Fig. 1-(a). The top silicon substrate of high resistivity silicon includes a comb actuator for the lateral movement, a switch contact metal for the switching operation. The bottom glass substrate of 300 μm thickness has 0.42 μm thick gold CPW and 0.3 μm thick aluminum electrodes to be used as a counter electrode of the switch. The designed initial gap between the contact metal and CPW line is 2 μm.

Proposed MEMS contact switch has three state, initial off-state, intermediate off-state, and contact on-state in order to realize the high-isolation over 50 GHz (Fig. 1-(a)). Intermediate off-state and contact on-state is achieved using lateral and vertical movement respectively. At the initial state, the top contact electrode is 30 μm distant from the bottom signal line along to the x-direction and it has 2 μm gap from the bottom signal line. Thus the switch configuration has high isolation than conventional MEMS contact switch whose top contact electrode is right above the signal line at off-state. The lateral movement of the top electrode is achieved by the electrostatic force of the comb drives and it changes the initial off-state to intermediate off-state. (Fig. 1-(b)).

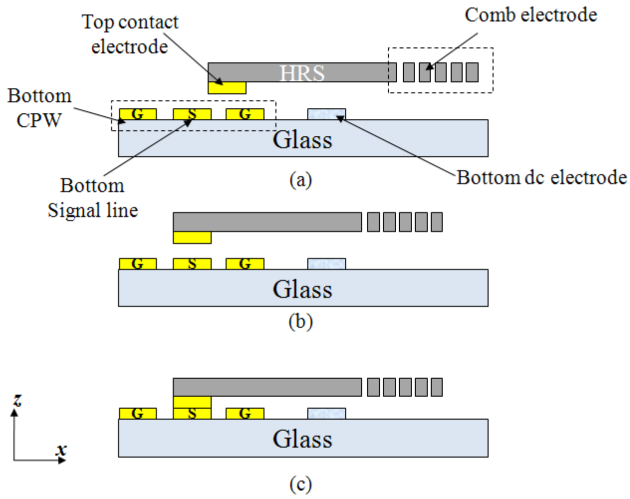

Fig. 1 Schematic view of the high-isolation MEMS contact switch; (a) initial off-state without applying voltage, (b) intermediate off-state when the voltage is applied to the comb electrode, (c) On-state when voltage is applied to the comb electrode and bottom dc electrode.

On-state is realized by applying the voltage to the bottom dc electrode, which leads to the vertical movement and contact between the top electrode and the bottom signal line (Fig. 1-(c)).

3. Simulation Results

Electromagnetic simulation was carried out using FEM method (HFSS) to validate the isolation of the MEMS switch in the frequency range from 50 GHz to 110 GHz. The simulation was performed with respect to the x-directional displacements of 0 μm, 10 μm, 20 μm, 30 μm, respectively, to identify the effect of the coupling capacitance between the top contact electrode and bottom signal line.

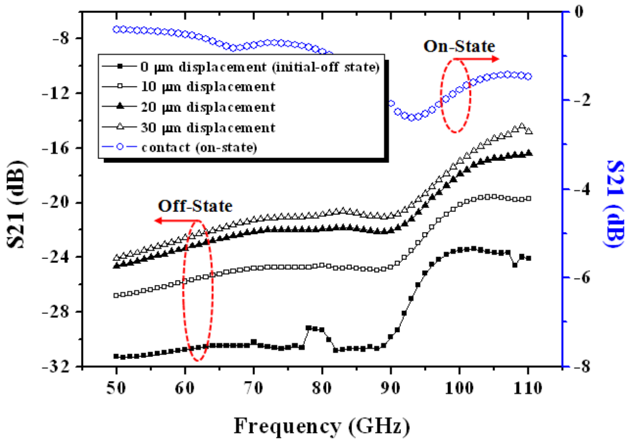

Fig. 2. Simulated S21-parameter of the switch with respect to the x-directional displacement.

As shown in Fig. 2, the isolation decreases as the top electrode approaches to the bottom signal line since the coupling capacitor between signal line and top contact electrode is increased. At the initial off-state, the MEMS switch has an isolation of -31 dB and -24 dB at 50 GHz and 110 GHz respectively. On the other hand, at the intermediate off-state -24 dB and -14 dB isolation was obtained at 50 GHz and 110 GHz respectively. Thus we could get the 10 dB better isolation in the initial off-state than intermediate off-state at 110 GHz. At the on-state the insertion loss was obtained -0.4 dB and -1.5 dB at 50 GHz and 110 GHz respectively, where the CPW line was 2 mm long.

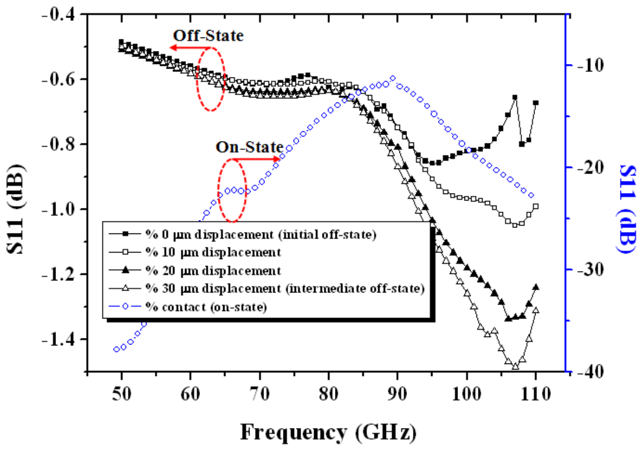

Fig. 3. Simulated S11-parameter of the switch with respect to the x-directional movement.

The reflection coefficient was -0.45 dB and -0.67 dB at 50 GHz and 110 GHz, respectively in the off-state. The return loss was obtained as -37 dB and -22 dB at 50 GHz and 110 GHz at the on-state (Fig. 3).

4. Conclusion

We demonstrated the high-isolation MEMS contact switch in the frequency range from 50 GHz to 110 GHz. In order to have a high-isolation than conventional MEMS contact switch, the proposed contact switch has the three states and the top contact electrode is to be apart from the bottom signal line along to the x-direction at the initial off-state. Simulated isolation was -24 dB at the initial state which has 10 dB better isolation than the intermediate off-state. We expect that the proposed MEMS contact switch will be used over 50 GHz frequency range applications.

[Reference]

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