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Design and Fabrication of Low-actuation Voltage and Low- Insertion Loss RF Switch by CMOS-MEMS and EN/IG Processes

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ABSTRACT

This paper presents the design of DC-contact RF switch fabricated by 0.18μm CMOS-MEMS which has the advantages of small area、easy fabrication、low–voltage、low Insertion Loss and high RF performance. The switch is compatible with CMOS process. The switches are actuated by electrostatic force that drove the tail of the cantilever beam contact with the transmission line. The DC and RF signal are separated by SiO_2 that avoid RF signal loss. The simulation results show that SiO_2 could avoid the loss of RF signal.

In the MEMS post-process, the device is based on aluminum as the cantilevers and the scarified layer. The structure is released by wet-etching. Electroless Nickel immersion gold (EN/IG) is applied for better Insertion Loss. At last, supercritical CO_2 drying is used to release the structure.

Keywords: CMOS-MEMS、CO_2 drying、RF-Switch、Electroless Nickel immersion gold (EN/IG)

1. INTRODUCTION

In this work, in order to achieve the function of wireless sensor network, we hereby integrate bio-chips and wireless communication chips on one single chip (SOC). Low-consumption, high transmission efficiency and low noise are highly demanded for wireless sensors. Compared with the circuit of RF switch, the advantages of MEMS-Switch are low consumption, low insertion loss and high isolation that are essential in wireless sensor networks.

2. PRINCIPLE AND STRUCTURE

The principle of Switch is applying voltage bias between the bottom electrode and the cantilever. Therefore, the cantilever is driven toward the bottom electrode by electrostatic force. Furthermore, it causes the contact of the cantilever and CPW transmission line to achieve the purpose of signal transmissions. The factors which influence the driven voltage involve A (area), k (spring constant) and g_0 (the distance between upper and bottom electrodes). Formula .1 shows the relationship of these factors.

$$V_p = \sqrt{\frac{8Kg_0^3}{27\varepsilon A}} \qquad (1)$$

The design is using TSMC 0.18μm processes. Post-process is applied to etch the sacrificial layers for the structure release. The contact point of cantilever is constructed by dielectric layer (SiO_2) to isolate DC source. It can prohibit the signal loss at Ground resulted from that the signals at high frequencies pass through the cantilever.

Fig.1 shows the schematic diagram of 0.18μm RF MEMS Switch structure. The isolated block is designed to avoid "short" caused by the contact of cantilever and bottom electrodes. Furthermore, Metal_1 can be used to prove isolation.

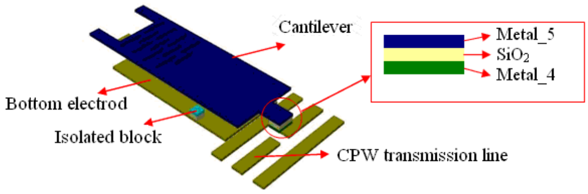
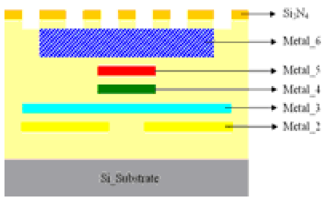


Fig.1 RF MEMS switch structure of 0.18μm.

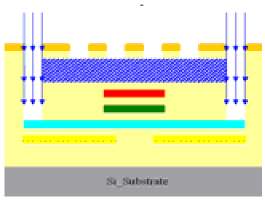
3. EXPERIMENTAL METHODS

The post process was to implement wet-etching to release the structure, manufactured by CIC. Fig. 2(a) showed the cross-section illustration of transmission lines and the contact point of the switch. Metal_6 and Metal_3 as sacrificial layers were used to release the structure. Metal_2 as a transmission line was etched by RLS, shown in Fig 2(b). Fig 2(c) showed the Aluminum etching.

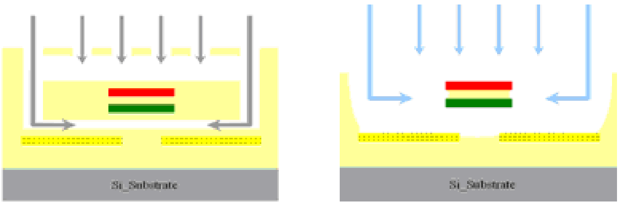
After etching Metal_6 and Metal_3, the SiO_2 etching was applied for the structure release. At last, we also used Supercritical CO_2 Drying to release the structure completely. Show in Fig 2. (d)



(a)



(b)

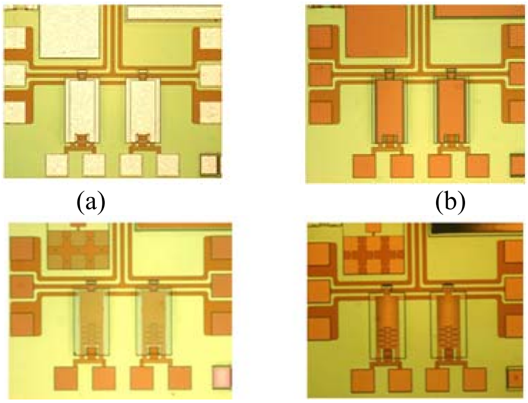


(c) (d)

Fig. 2 Flow chart of 0.18μm etching process

3.1. Wet Etching

Each etching steps of 0.18μm chip was shown in Fig 3. Fig. 3(a) showed the OM image after PR-stripping. Fig. 3(b) presented that the OM image after etching Aluminum by phosphoric acid at 50℃ Also, hydrogen peroxide at 50℃ was used to etch TiN, shown in Fig. 3(c). The SiO_2 around the cantilever was etched, shown in Fig. 3(d). At last, Supercritical CO_2 Drying was implemented to avoid the contact of the cantilever and substrate.



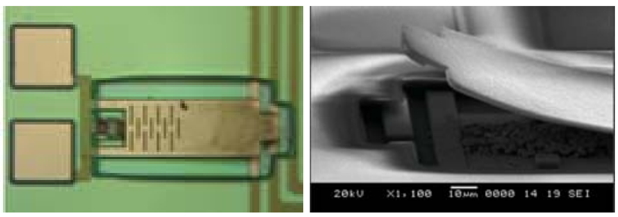
(a) (b)

(c) (d)

Fig.3 OM images of 0.18μm RF Switch wet etching

3.2. EN/IG and Supercritical CO_2 Drying

Electroless Nickel Immersion Gold (EN/IG) process and Supercritical CO_2 Drying was implemented at last in 0.18μm RF Switch, shown in the Fig. 4(a). The SEM inspection clearly magnifies shows the contact point of the cantilever, shown in the Fig. 4(b).



(a) (b)

Fig. 4 OM and SEM images of 0.18μm RF Switch with Supercritical CO_2 Drying and EN/IG

4. RESULTS AND DISCUSSION

At 2.4GHz and 0-28V, the 0.18μm CMOS-MEMS switch Isolation is -51.05dB, shown in the Fig. 5.

Fig. 6 shows the comparison of measurement and simulation of insertion loss, M1 indicates the insertion loss of simulation. In addition, M2 shows the insertion loss of measurement with EG/IG process and M3 points out the insertion loss of measurement without EG/IG process. M1 is -0.182dB, M2 is -1.652dB, M3 is -5.372dB, respectively.

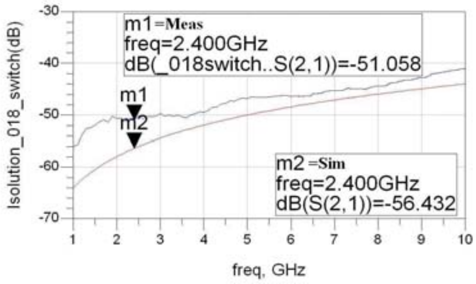


Fig. 5 The comparison of measurement and simulation of 0.18μm RF Switch Isolation

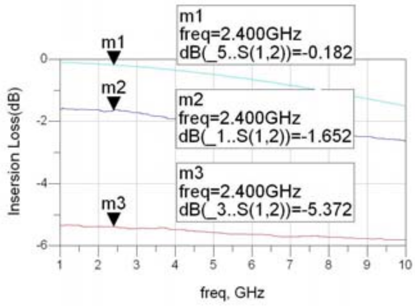


Fig. 6 The comparison of measurement and simulation of 0.18μm RF Switch insertion loss

5. CONCLUSION

1. The dielectric layers (SiO_2) between the contact point and the cantilever of the switch can isolate the RF signals and DC operation voltages. Thus, we can simplify the design of circuits to avoid the loss of RF signals.

2. The Metal_1 layer is designed as ground in 0.18μm fabrication, which could greatly improve isolation.

3. Electroless Nickel immersion gold process is implemented at last in 0.18μm RF MEMS Switch. Moreover, the measurement indicates that it could reduce Insertion loss.

6. REFERENCES

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