Design of Vertical Packaging Technology for RF MEMS Switch

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ABSTRACT

Wafer-level micro-encapsulation is an innovative, low-cost, wafer-level packaging method for encapsulating RF MEMS switches. This article presents an approach for design and processing steps related to encapsulation of individual RF components e.g. CPW, RF MEMS switches, in view of the variation in performance subsequent to packaging. Bottom contact vertical packaging is more prone to misalignment margin and easy to make connections. Cavity height of 30 µm is optimized for bottom contact vertical packaging.

RF MEMS, CPW, encapsulation.

1. INTRODUCTION

The expansion of wireless communication applications, and specific trend towards miniature energy-efficient devices have lead the development of RF-MEMS devices such as switches, antennas and filters etc. RF MEMS component in general offer small size, lower power consumption, lower losses, higher linearity and higher Q factors than conventional communication component. Over last two decades research work has been concentrated on MEMS switch design and fabrication. RF MEMS switches have been demonstrated successfully [1-3]. SEM image and 3-D view of RF MEMS switch developed at CEERI [2] are shown in fig 1 and 2 respectively. Reliable packaging of switch without degradation in performance is considered to be the last barrier in commercialization of RF MEMS. Packaging contributes to almost 80% of the total cost of the device. Device functioning and reliability strongly depend on its packaging. Therefore MEMS packaging tends to be customized to the specific application, with emphasis on the cost, performance and reliability [4-5].

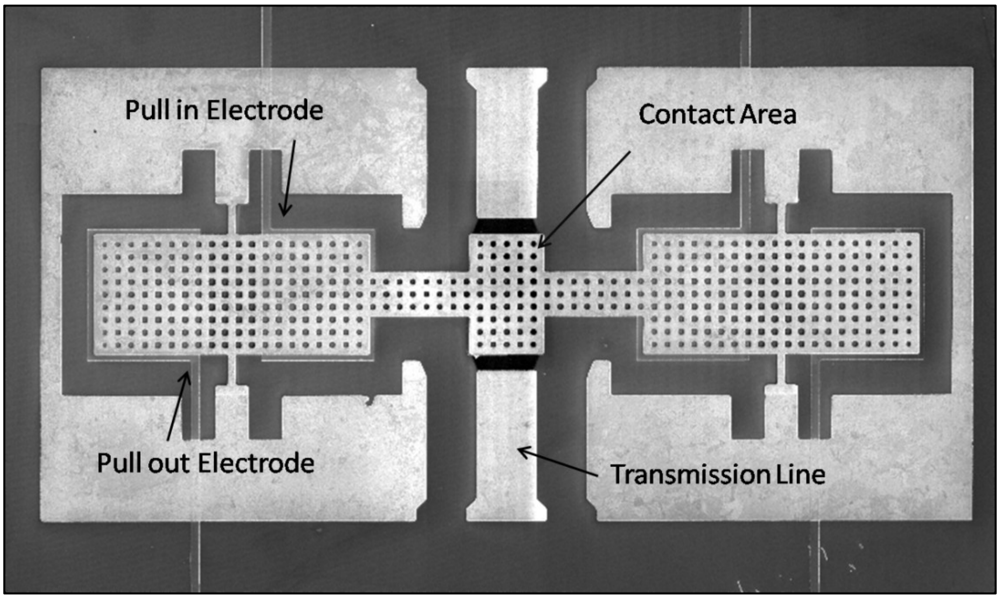

Figure 1. SEM image of capacitive type switch developed at CEERI

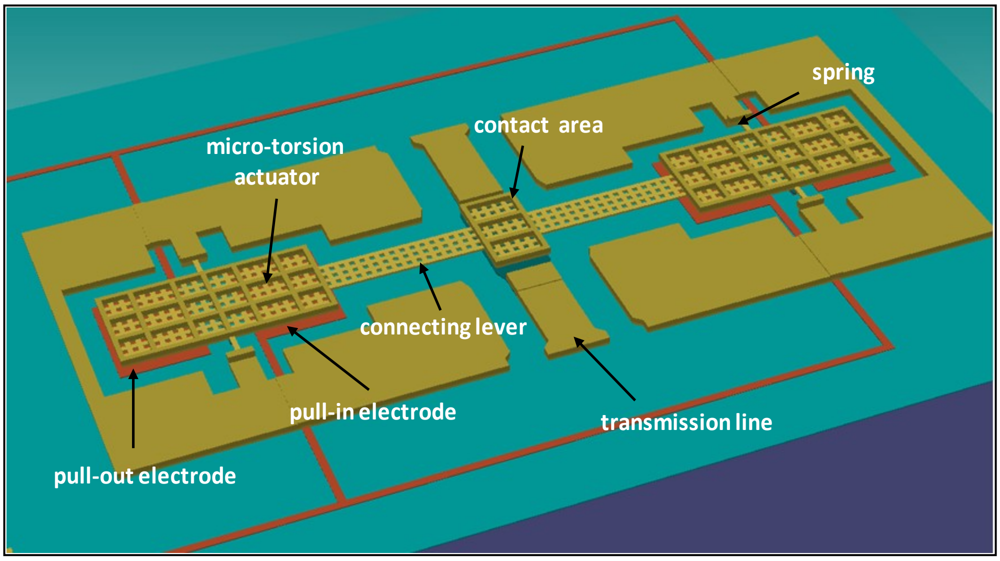

Figure 2. 3-D view of capacitive type switch

This paper presents design of packages for RF MEMS switches based on two different techniques: lateral packaging as shown in fig 3 and vertical packaging.

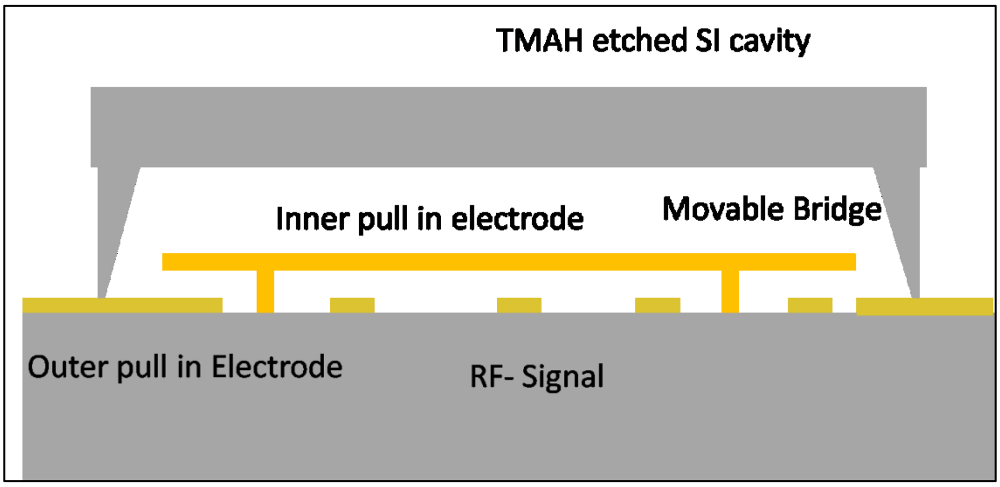

Figure 3. Cross sectional view of Lateral Packaged RF MEMS switch

The vertical packaging technique is more prominent as it occupies less wafer space and leads to lower cost. The two important variants of the vertical packaging are: the top contact (conventional approach) [6-9] as shown in fig 4 and bottom contact as shown in fig 5. In the conventional approach, chip and package alignment and connections to external environment are more complex than the bottom contact.

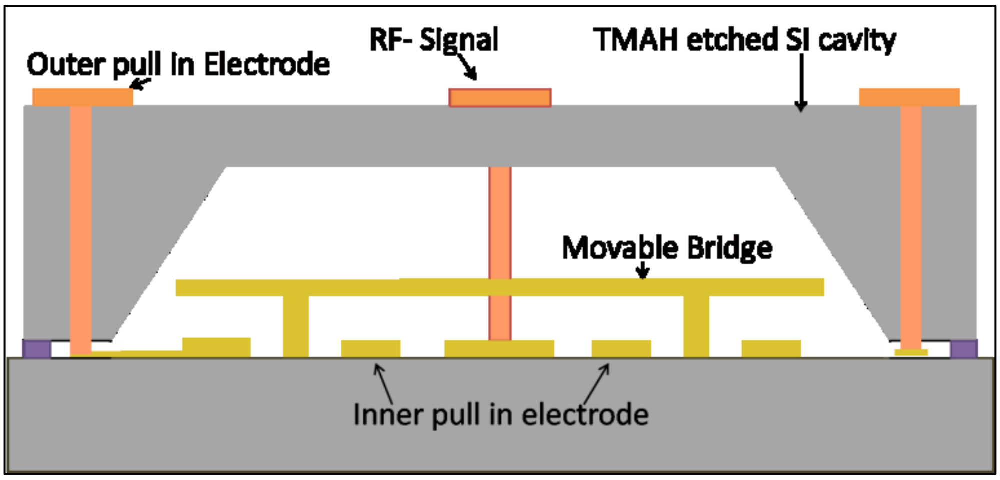

Figure 4. Cross sectional view of top contact packaged RF MEMS switch.

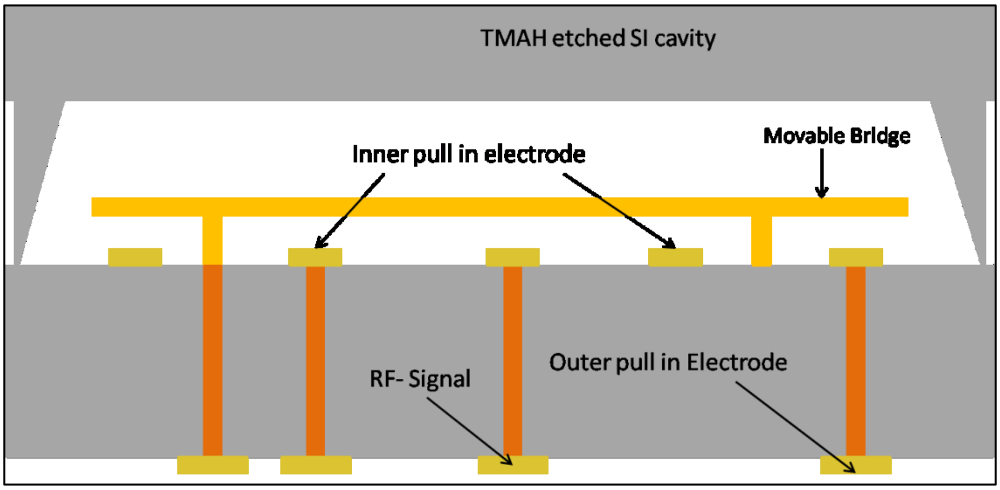

Figure 5. Cross sectional view of bottom contact packaged RF MEMS switch.

In this paper we present the design analyses based on top and bottom contact methods for RF MEMS switch packaging in view of the RF MEMS design and fabrication methodology developed at CEERI.

2. SIMULATION RESULTS & DISCUSSIONS

RF MEMS capacitive type switch developed at CEERI [2] are used as a reference for package designing. The design simulations were carried out using High Frequency Structure Simulator to optimize the cavity height for RF MEMS switch. Without packaging on state and off state result of RF MEMS switch are shown in fig 6. Insertion loss is around -0.05 at 8-10GHz, and isolation is better than -40dB.

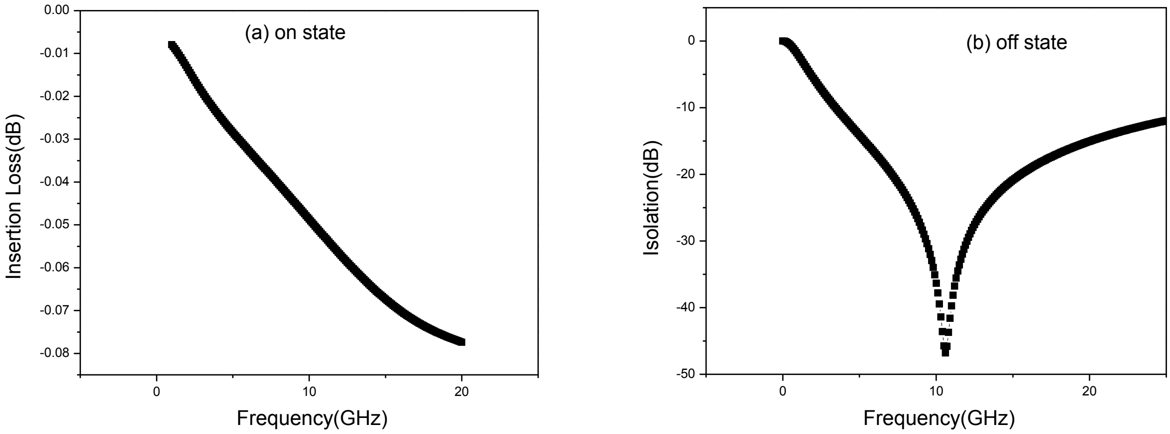

Figure 6. (a) On state and (b) off state response of RF MEMS switch without packaging.

As far as electrical responses are concerned, fig 7, 8 and 9 demonstrate the on and off state response of lateral, top contact and bottom contact packaging respectively. In off state, isolation is better than -40dB at 8-12 GHz in all types of packaging and independent from cavity height. Therefore isolation is not a big issue in packaging. But in case of on state, insertion loss is cavity height dependent. Lateral packaged switch has insertion loss of around -0.07 dB at 8-12GHz for cavity height 50μm. As can be compared from fig. 8 & 9 the insertion loss in the case of bottom contact stabilized around -0.8dB at 8-12GHz for cavity height 30μm onwards. In case of top contact, insertion loss is around -0.8dB at 8-12GHz for cavity height of 50μm.

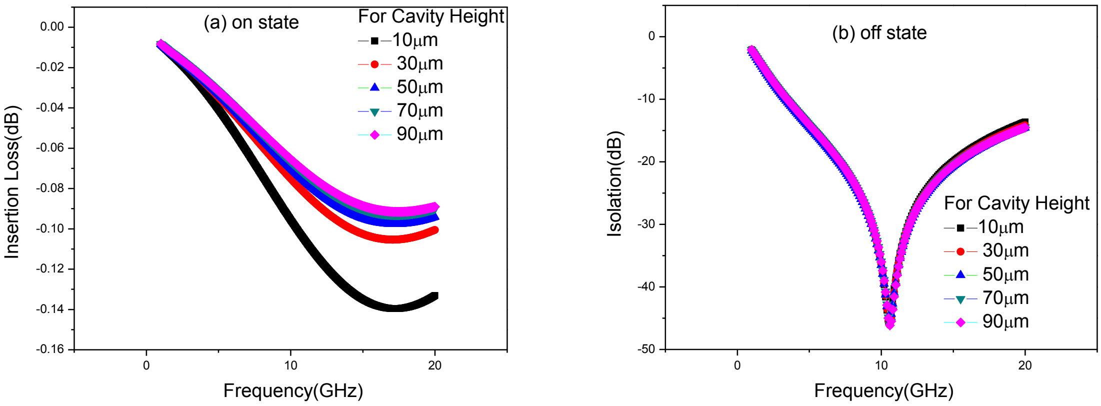

Figure 7. (a) On state and (b) off state response of lateral packaged RF MEMS switch.

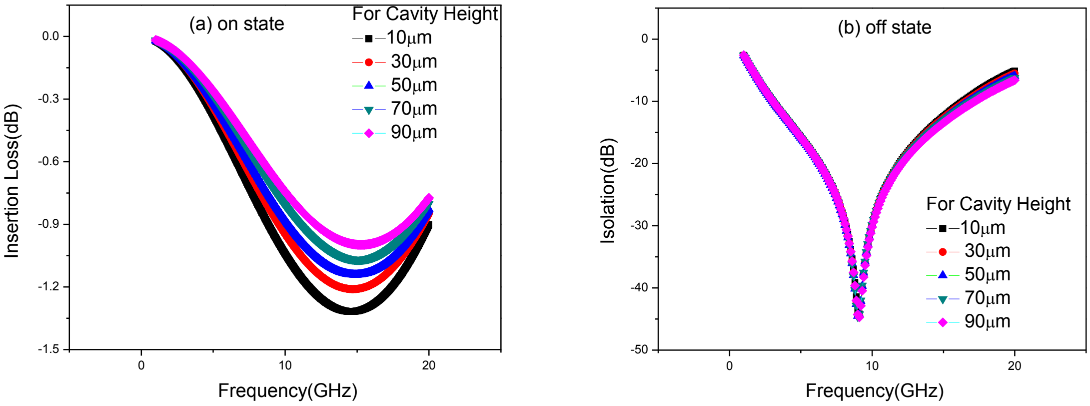

Figure 8. (a) On state and (b) off state response of top contact packaged RF MEMS switch.

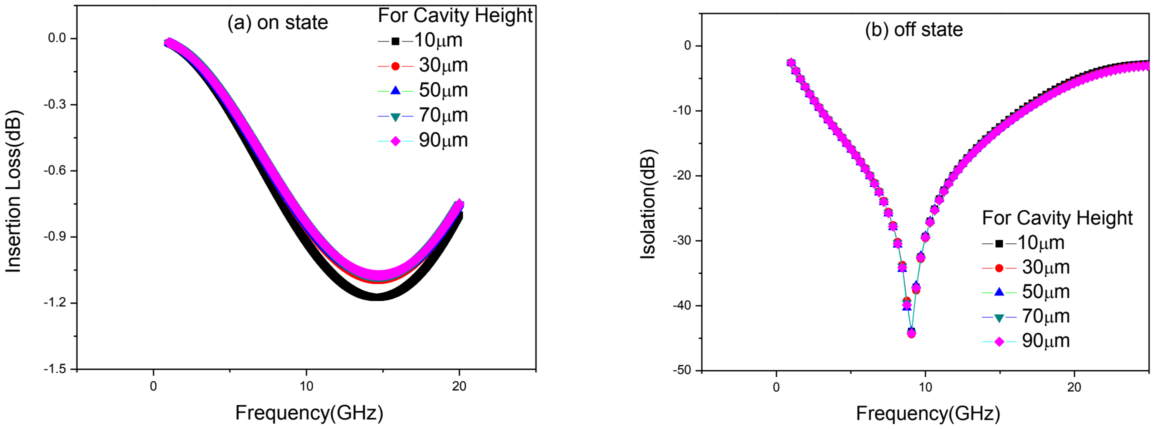

Figure 9. (a) On state and (b) off state response of bottom contact packaged RF MEMS switch.

3. FAB PROCESS

In conventional approach [6-9], a capping wafer with cavity inside it and metal seal rings is attached to the corresponding metal seal rings on the bottom wafer using thermo-compression or flip chip bonding. The local temperature using such an approach rises to 300ºC - 400ºC, which results in degradation of MEMS device performance. To obviate the problem, packaging should be done using epoxy or glue like BCB [5]. This is possible in case of either lateral packaging or bottom contact, vertical packaging. As in case of top contact, proper electrical connections are not feasible without high temperature. But lateral packaging result in large wafer area wastage. Therefore bottom contact packaging is proposed for MEMS devices.

In this approach, contact via holes are etched in the silicon substrate and then filled with appropriate metal prior to device fabrication. After via holes filling, the complete switch is fabricated on the substrate with the device contacts at the bottom side of the wafer as explained in [3]. After dicing, each die is covered with high-resistivity silicon cavity, which is fabricated in a separate process. The cavities and devices are to be sealed using non-conducting epoxy which is a room temperature process. Further the bottom contacts can be used directly for external connections or can be soldiered on circuit boards, where coaxial cables can be connected.

4. CONCLUSIONS

Vertical packaging is preferred over lateral packaging as wafer area wastage is more in lateral case. In vertical packaging, the decreased fabrication complexity of bottom contact packaging is found to be a better approach as compared to top contact packaging method. As via holes for external contacts are made at the initial stage in bottom contact, misalignment error is much smaller and no high temperature is required for proper connection.

In bottom package, insertion loss is -0.8dB for cavity height of 30µm at 8-10GHz and change in insertion loss is insignificant with further increase in cavity height. Whereas, in case of top contact, insertion loss is -0.8dB for cavity height of 50µm at 8-10GHz. Isolation, in both cases, are independent from cavity height and more than -40dB. Therefore bottom contact packaging with cavity height of 30µm is optimal for MEMS devices packaging.

5. REFERENCES

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