Mechanical Model of RF MEMS Capacitor Structures

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Abstract

Introduction: MEMS structure is nowadays utilized in many aspects including in radio frequency field due to the fact that it enables the establishment of miniaturized and low power RF components. Tunable or variable capacitor is required in a variety of RF applications such as filter, matching network, phase shifter and others. An RF MEMS electrostatic tunable capacitor based on two parallel plates has been introduced for these last decades and since then the research to enhance its tunability driven by a moderate actuation voltage in its operation and with low cost and simple fabrication takes place in academia as well as in industries. In order to realize such MEMS structure, it is important to have information concerning how pre-stressed structural elements deform after removal of sacrificial layer takes place. By having this information, one can thoroughly calculate the initial distance between the two plates and furthermore estimate the capacitance exists, and also the actuation voltage applied necessarily on the plates to tune the capacitance. Moreover, the capacitance ratio can be analyzed whereas this would be an essential interest of particular RF application. Analysis and Simulation: Throughout this study the designed tunable capacitor consists of two aluminum plates as the conductors which are separated by insulator layers and air gap. The bottom plate is deposited on wafer and is followed by a sacrificial layer, which is etched afterward. Insulator layers are placed before a top plate membrane is grown. The cross section view of the structure is illustrated in Figure 1. The square top plate is 70 µm length size and held by suspensions. Several structures with different type of suspensions are presented and verified. As shown in Figure 2, the first structure consists of 2 simple meander suspensions; the second one is based on prolonged 2 meander suspensions; while the third structure is with 4 suspensions. Within this study, the gap distance between plates and effective area of the interacting plates are of high significance. Analysis is carried out and investigation is prepared by generating models and performing simulation with Solid Mechanics of COMSOL Multiphysics for particular internal forces related to the material being used and also the fabrication process. Result and Conclusion: The simulation result shown in Figure 3 provides distinguished information about the behavior of each structure. The second structure provides the highest initial gap among others. For instance, it is approximately 14 µm higher than the one of the first structure. On the other hand, the third structure provides more effective area while the effective area of the other two structures is less due to the effect of stress gradient. From the behavior it shows, the second structure among others would be a potential candidate for specific applications requiring less capacitance.

Reference

1. Mingxin Song et al., Design and Analysis of a Novel Low Actuation Voltage Capacitive RF MEMS Switches, Proceedings of the 3rd IEEE Int. Conf. on Nano/Micro Engineered and Molecular Systems (2008).
2. Dimitrios Peroulis et al., Electromechanical Considerations in Developing Low-Voltage RF MEMS Switches, IEEE Transactions on Microwave Theory and Techniques, Vol. 51 (2003).

Figures used in the abstract

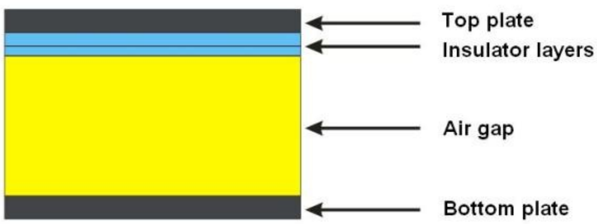

Figure 1: Cross section view of capacitor structure.

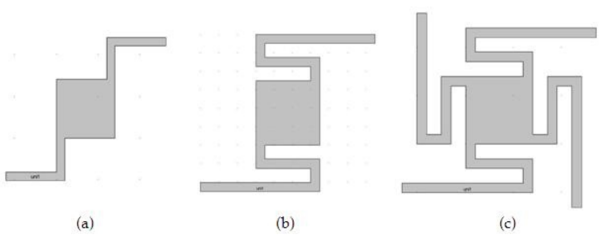

Figure 2: Top view of first structure (a), second structure (b), and third structure (c).

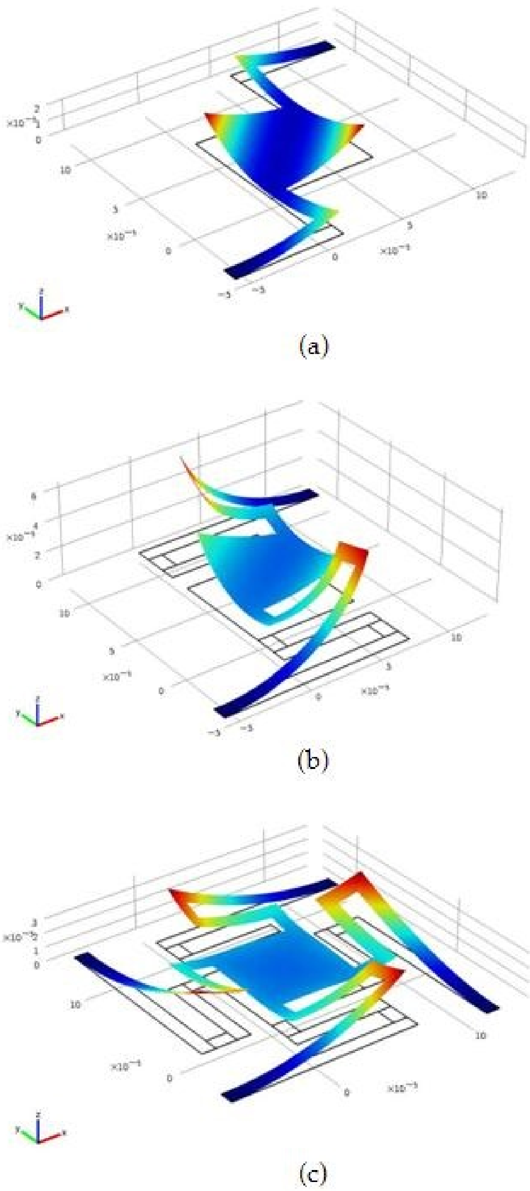

Figure 3: Simulation result for first structure (a), second structure (b), and third structure (c).