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Characteristics of RF MEMS Switches for Communication Systems

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Abstract

Characteristics of capacitive radio-frequency (RF) microelectromechanical system (MEMS) switches have been investigated on the basis of the finite element method. The structures and the materials of the switches are the main factors for determination of switch performance. How the static and modal characteristics of the RF MEMS switches are affected by the structures and materials is investigated comprehensively.

1. Introduction

Microelectromechanical system (MEMS) technology has been proved to be a powerful tool for integration of mechanical and electronic systems. The MEMS technology can realize miniaturization of devices and systems such as actuators, sensors, transducers, and motors. The MEMS technology can also be applied to switching of radio-frequency (RF) signals to form a devices, so-called RF MEMS switches [1-4].

The RF MEMS switches are actuated by an applied electric voltage for signal switching. The operation of the RF MEMS switches relies on the structures and materials of the switches. The RF MEMS switches were mostly designed from an electromagnetic perspective. However, a successful design of the RF MEMS switches requires consideration from not only an electromagnetic standpoint but also a mechanical point of view.

In this paper, design and analysis of RF MEMS switches have been developed by the finite element method. The structures and materials of the switches are studied from a mechatronic standpoint.

2. Results and Discussion

The three-dimensional structure of a capacitive RF MEMS switch is shown in Fig. 1. The switch is built on a silicon (Si) substrate with a thickness of 525 μm and a relative permittivity of 11.9. A layer of silicon dioxide with a thickness of 1 μm is used as an isolation buffer between the substrate and the switch metal and grown on the silicon substrate. The MEMS switch consists of a coplanar waveguide (CPW) transmission line, a silicon nitride dielectric layer, and a metal membrane. The different structures and materials of the metal membranes are adopted. The connection beam widths (W) of the membranes range from 20 to 100 μm. Two kinds of metal materials, aluminum (Al) and gold (Au), are used for the MEMS switches. Aluminum has a Young's modulus of 70 GPa, a Poisson's ratio of 0.34, a density of 2700 kg/m3, and a yield strength of 170 MPa. Gold has a Young's modulus of 83 GPa, a Poisson's ratio of 0.44, a density of 19320 kg/m3, and a yield strength of 324 MPa.

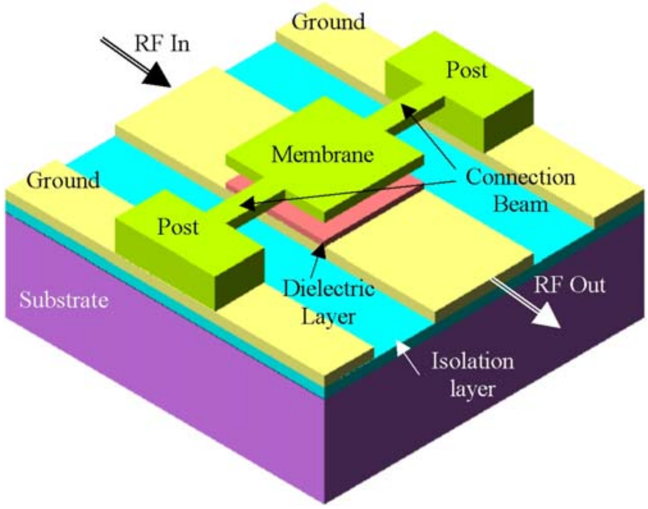
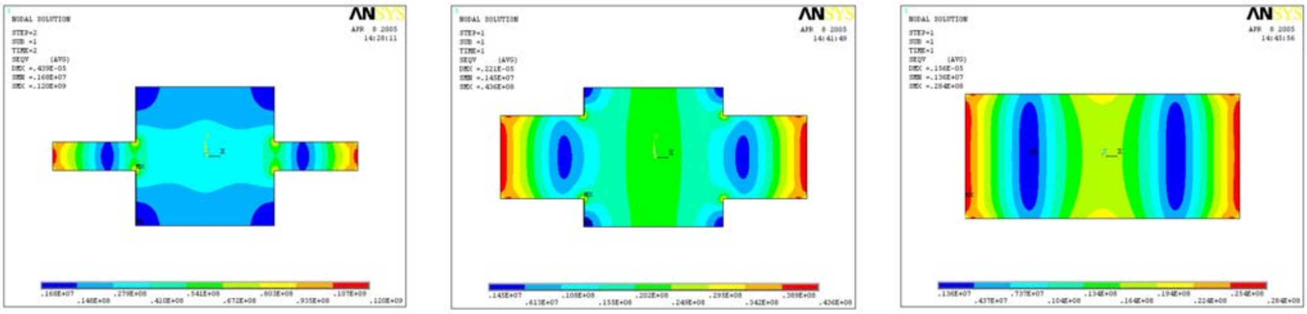


Fig. 1. Three-dimensional structure of RF MEMS shunt switch.

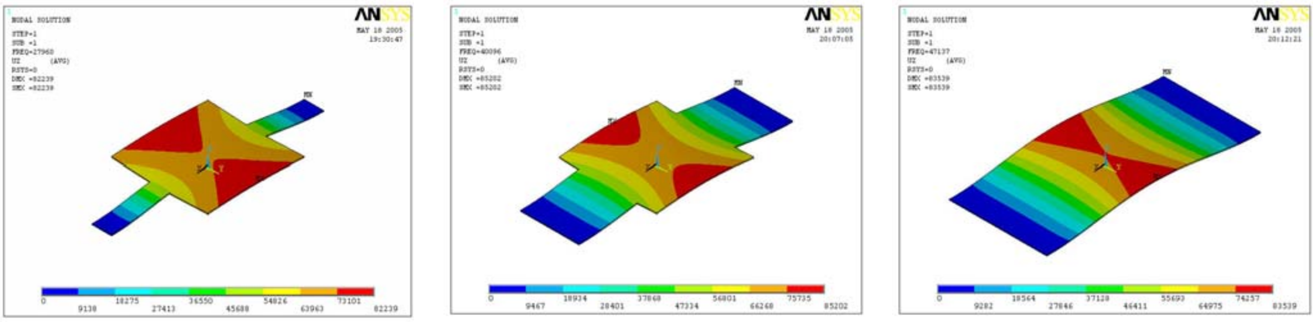
The von Mises stress characteristics of the connection beams of the RF MEMS switches are studied. For the stress analysis, the applied uniform distributed force on the membrane of a switch is 10 μN. Fig. 2 shows the stress characteristics of the aluminum RF MEMS switches as a function of the connection beam width. The stress characteristics of the gold RF MEMS switches are also dependent on the switch structures. The maximum stress occurs at the junction between the connection beam and the ground post. Either an aluminum switch or a gold switch with the 20-μm connection beams suffers the highest stress in comparison with the switches with other beam structures. The maximum stress values of the aluminum and gold switches are 120 MPa and 123 MPa, respectively. They are less than their corresponding yield strength values. The smaller the width of the connection beam is, the larger the stress is. This is because the stress undertaken by the connection beam with the smaller area is larger.

In addition to the stress characteristics, the modal performance of the switches with different switch structures and materials are also studied. Fig. 3 shows the first-mode natural frequency characteristics of the gold RF MEMS switches. The first three modes of the natural frequency characteristics of the aluminum RF MEMS switches with a connection beam width of 40 μm are shown in Fig. 4. The switch with the 100-μm connection beams has the highest



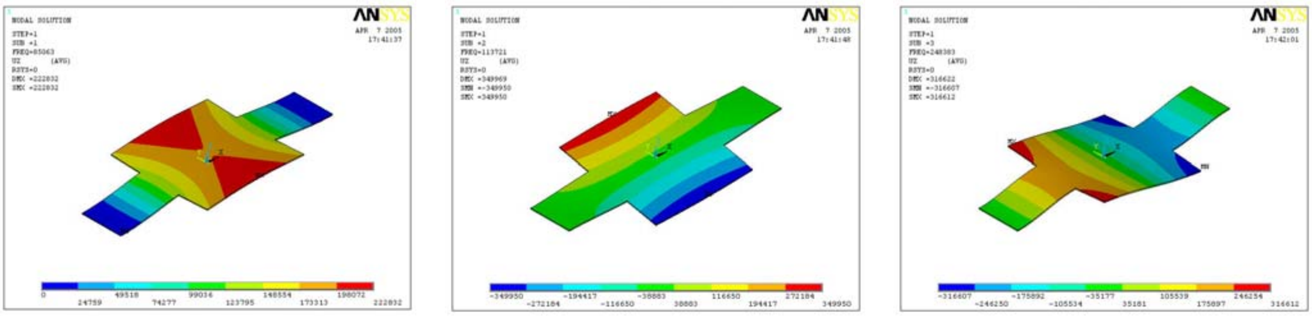
(a) $W = 20$ μm (b) $W = 60$ μm (c) $W = 100$ μm

Fig. 2. Stress characteristics of aluminum RF MEMS switches with different structures.



(a) $W = 20$ μm (b) $W = 60$ μm (c) $W = 100$ μm

Fig. 3. First-mold natural frequency characteristics of gold RF MEMS switches with different structures.



(a) 1st mode (b) 2nd mode (c) 3rd mode

Fig. 4. First three modes of natural frequency characteristics of aluminum RF MEMS switches with $W = 40$ μm.

natural frequency and the lowest switching time for either an aluminum switch or a gold switch. The switches made by aluminum have higher natural frequency and faster switching speed than those with gold.

3. Conclusions

The characteristics of the RF MEMS switches with the different structures and materials have been studied using the finite element method. The comprehensive investigation of the RF MEMS switches provides optimum switch performance for communication systems.

Acknowledgement

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