Material Optimization for Squeeze Film Damping in Fixed-Fixed Beam RF MEMS Switches

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Abstract-In this paper the effect of different materials on the squeeze film damping of fixed-fixed beam RF MEMS switch is analyzed. Squeeze film air damping analysis is done on the fixed-fixed beam membrane for different materials like Aluminium, Platinum, Copper, Titanium and Bismuth. The surface pressure distribution and damping force on the membrane is simulated. Membrane using Titanium and Aluminium is better compared to membrane using other materials. Modeling and simulation of damping force and surface pressure is done in COMSOL Multiphysics.

Index Terms- squeeze film damping; fixed-fixed membrane; damping force

1. INTRODUCTION

Squeeze film damping occurs in most of the dynamic MEMS devices like switches, resonators, accelerometers etc. An accurate estimation of squeeze film air damping is inevitable in predicting the real time performance of MEMS structures [1]. In RF MEMS switches, squeeze film air damping occurs during the electrostatic pull-down of the membrane. When membrane gets pulled down, thin film of air between the membrane and substrate get squeezed, thus the pressure builds up from the centre of coordinate to the membrane boundary. Fig. 1 shows the built-up pressure in the structure [2]. This built-up pressure creates damping forces on the membrane.

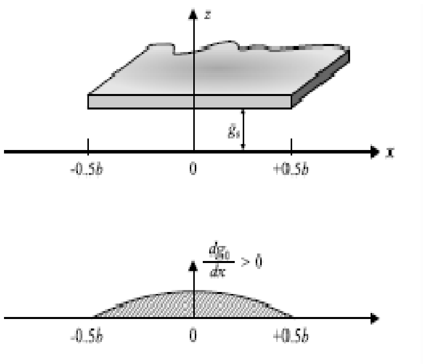

Fig. 1. Pressure built-up by squeeze-film motion of membrane

2. SIMULATION OF PRESSURE DISTRIBUTION

When membrane squeezes the gap, gas flows from the edges. The narrow path of gas flow causes the increase in gas pressure, which in turn decelerates the movement of membrane. Pressure distribution is simulated for a fixed-fixed membrane for some low and medium damping materials like Aluminium, Platinum, Copper, Titanium and Bismuth [3]. The pressure distribution in the narrow gap is modeled using the modified Reynold’s equation [4]. Fig. 2 shows the simuated 3D structure of fixed-fixed membrane in COMSOL Multiphysics. Fig. 3 to Fig. 7 shows the pressure distribution in membrane using materials like Aluminium, Platinum, Copper, Titanium and Bismuth for an ambient pressure (pA) of 1000Pa.

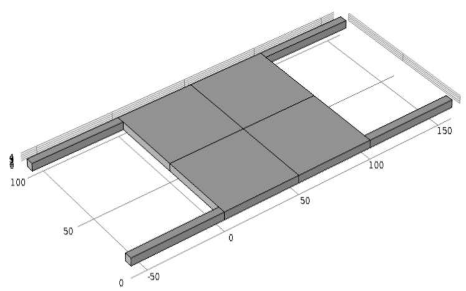

Fig. 2. Modeled 3D structure of fixed-fixed membrane in COMSOL Multiphysics

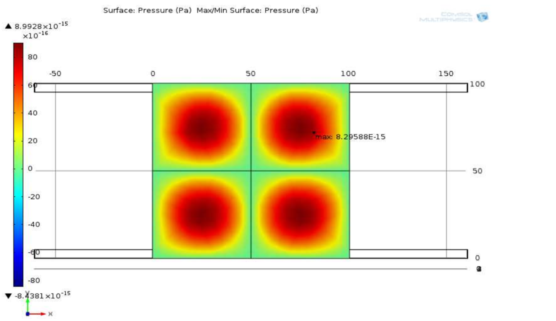

Fig. 3. Distribution of pressure on the surface of Aluminium membrane

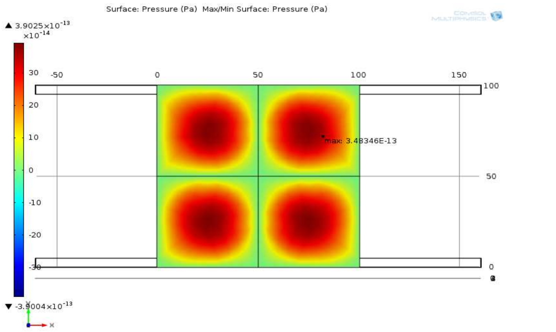

Fig. 4. Distribution of pressure on the surface of Platinum membrane

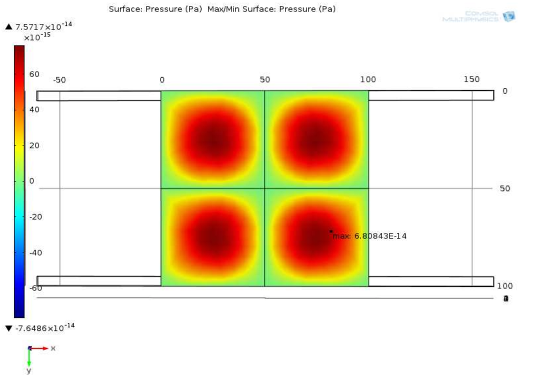

Fig. 5. Distribution of pressure on the surface of Copper membrane

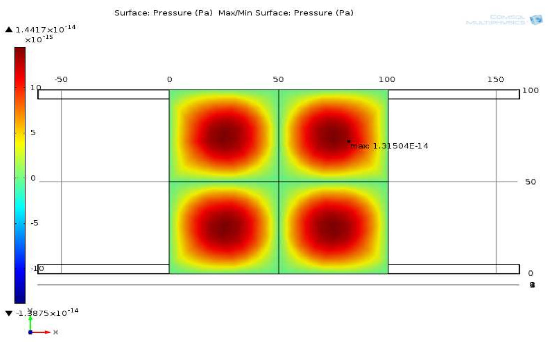

Fig. 6. Distribution of pressure on the surface of Titanium membrane

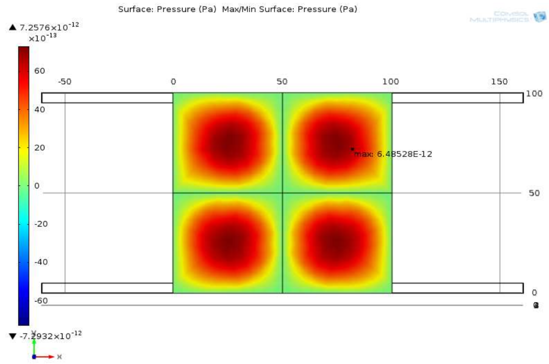

Fig. 7. Distribution of pressure on the surface of Bismuth membrane

Minimum surface pressure was obtained for membrane using Aluminium and maximum surface pressure was obtained for membrane using Bismuth.

3. DAMPING FORCE ANALYSIS

Damping force of fixed-fixed membrane is computed for some low and medium damping materials like Aluminium, Platinum, Copper, Titanium and Bismuth. The damping force F [2] on the membrane is given by Eq(1).

$$F = \int_{-0.5b}^{0.5b} P(x) l dx \qquad (1)$$

P(x) is the damping pressure build up under the membrane and l is the length of the membrane. Simulation of damping force is done for different ambient pressures (pA) of 50Pa, 300Pa and 1000Pa [5, 6]. Fig. 8 to Fig. 12 shows the damping force obtained for fixed-fixed membrane using materials like Aluminium, Platinum, Copper, Titanium and Bismuth for different ambient pressures (pA).

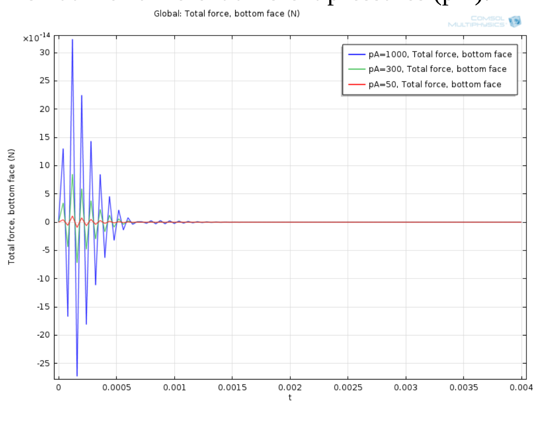

Fig. 8. Damping force obtained for fixed-fixed beam membrane using Aluminum as the material.

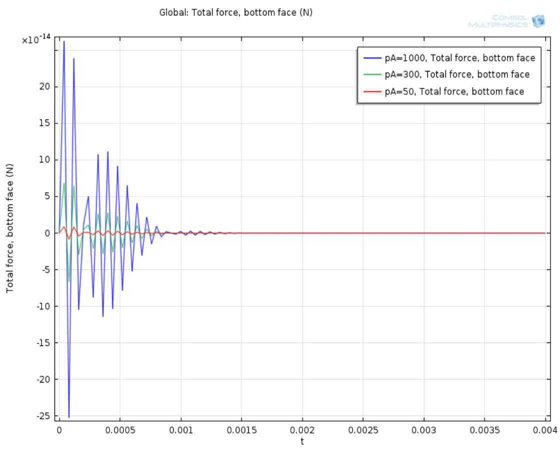

Fig. 9. Damping force obtained for fixed-fixed beam membrane using Platinum as the material.

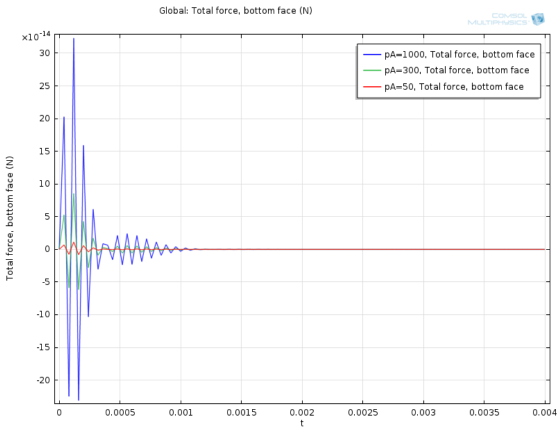

Fig. 10. Damping force obtained for fixed-fixed beam membrane using Copper as the material.

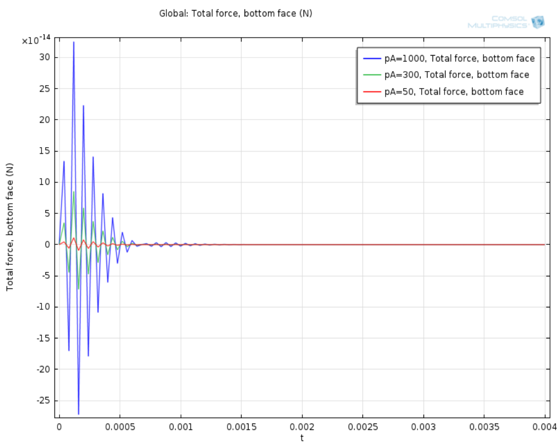

Fig. 11. Damping force obtained for fixed-fixed beam membrane using Titanium as the material.

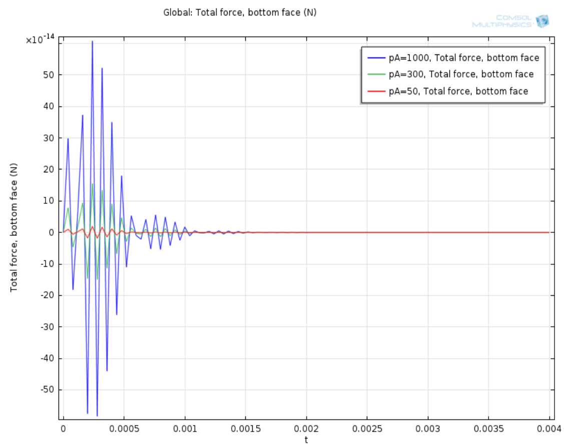

Fig. 12. Damping force obtained for fixed-fixed beam membrane using Bismuth as the material.

Table 1 shows the damping force obtained for different ambient pressure (pA) using different materials. For pA=1000Pa and pA=300Pa, the damping force obtained for Platinum membrane is minimum compared to damping force obtained from membrane using other materials. For pA=50Pa, the damping force obtained for membrane using Copper and Titanium is minimum compared to damping force obtained from membrane using other materials.

Table 1. Damping Force Obtained for Different Ambient Pressure (pA)

Material used	**Damping force(pN) for pA=1000Pa**	**Damping force(pN) for pA=300Pa**	**Damping force(pN) for pA=50Pa**
Aluminium	0.35	0.085	0.012
Platinum	0.27	0.07	0.009
Copper	0.35	0.09	0.001
Titanium	0.35	0.09	0.001
Bismuth	0.60	0.16	0.08

Table 2 shows the time of oscillation of damping force obtained for membrane using different materials. Longest time period of 1ms was obtained for membrane using Copper and Bismuth. Titanium membrane gives the shortest time of 0.5ms. When both damping force and time of oscillation of force are considered membrane using Titanium and Aluminium is better compared to membrane using other materials.

Table 2. Time Period

Material used	Time(ms)
Aluminium	0.65
Platinum	0.95
Copper	1
Titanium	0.5
Bismuth	1

4. CONCLUSION

The effect of different materials on the squeeze film damping of fixed-fixed beam RF MEMS switch is analyzed. Squeeze film air damping analysis is done on the fixed-fixed beam membrane for different materials like Aluminium, Platinum, Copper, Titanium and Bismuth. The surface pressure distribution on the surface of membrane is simulated. Variation in damping force is analyzed for different ambient pressures. Membrane using Titanium and Aluminium is better compared to membrane using other materials with respect to damping force, surface pressure and time period of force.

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