

# Tunable MEMS Capacitor for RF Applications

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## Abstract

### Introduction:

Radio Frequency (RF) MEMS devices have emerged to overcome the problem of high losses associated with semiconductors at high frequencies. There are various RF MEMS devices available, including switches, resonators, tunable inductors, varactors and tunable capacitors. A tunable MEMS capacitor is a micrometre-scale electronic device whose capacitance is controlled through different actuation mechanisms which govern the moving parts. This work proposes an electrothermally actuated tunable MEMS capacitor (Figure 1) suitable for filters, oscillators, phase shifters and impedance matching networks. Asymmetric arm actuation (Figure 2) is commonly employed in electrothermal designs and has been used to evaluate the performance of the proposed design which utilizes bimetallic strip actuation.

### Use of COMSOL Multiphysics®:

MEMS fabrication imposes design constraints on the structure and composition of any micro device. This work has required trials with different materials and specification of material properties during simulation. The asymmetric arm model requires the full characterization of polysilicon used and the bimetallic strip model requires the pertinent parameters of aluminium and tungsten. The MEMS Module has been used with the COMSOL Multiphysics® tool to specify boundary conditions including fixed surfaces and voltages. The simulation has been able to provide surface deformation, temperature distribution, stress distribution and current density distribution results.

### Results:

The simulation results (Figure 3) have indicated that the proposed design requires a low operating voltage, in turn leading to reduced power consumption. The deflection of the upper plate of the capacitor has been observed to increase with increase in the actuation voltage, in accordance with theoretical calculations. A separate study has been made about the stability issues with the asymmetric arm structure (Figure 4) which indicates that the upper plate of the capacitor has an undesired curving and that, its deflection is difficult to control on a finer level. This has been overcome in the proposed bimetallic strip actuation structure.

### Conclusion:

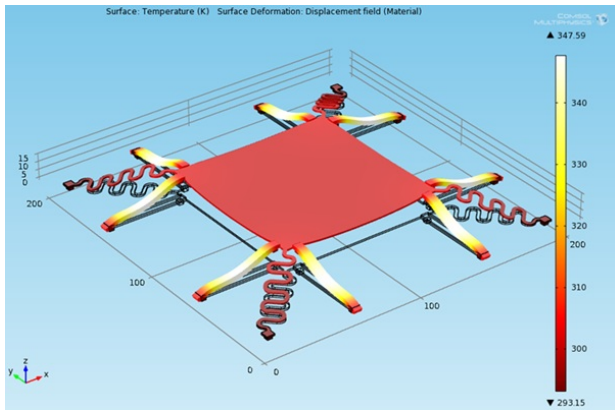
The electrothermally actuated tunable MEMS capacitor has been modelled with two separate mechanisms: the conventional asymmetric arm actuation (Figure 2) and the bimetallic strip actuation mechanism (Figure 1). The proposed bimetallic strip actuation model has been observed

to have a uniform upper plate profile with a stable deflection. The capacitance can be reduced to about a tenth of its initial value during operation. The device also has a low continuous DC power dissipation. This facilitates its use in a wide range of RF circuits for communication applications. The performance of the proposed model is intended to be tested for real-world applications after fabrication of the device.

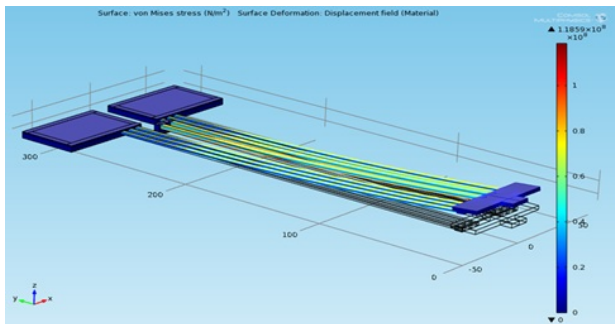
## Reference

1. Maxim V. Shakhrai, "Microelectromechanical (MEMS) Varactors for Mobile Communications", 4th siberian russian workshop and tutorials EDM 2003, tutorials, 1-4 July, ERLAGOL
2. A. Dec, K. Suyama, "Micromachined varactor with wide tuning range", *Electronics Letters* 33 (11) 1997. 922–924.
3. D. Young, B. Boser, "A micromachined variable capacitor for monolithic low-noise VCOS", *Solid-State Sensor and Actuator Workshop*, June 2–6, 1996, pp. 86–89.
4. Kevin F. Harsh, et al. "The realization and design considerations of a flip-chip integrated MEMS tunable capacitor", *Sensors and Actuators* 80 (2000) 108–118
5. Nino Zahirovic, et al. "A MEMS Variable Capacitor with Piezoresistive Position Sensing Fabricated in a Standard 0.35  $\mu\text{m}$  CMOS Process"
6. Yaping Liang, et al. "RF MEMS Extended Tuning Range Varactor and Varactor Based True Time Delay Line Design", *PIERS ONLINE*, VOL. 4, NO. 4, 2008
7. Zou, J., et al., "Development of a wide tuning range MEMS tunable capacitor for wireless communication system," *Technical Digest of International Electron Devices Meeting*, 403-406, 2000.
8. José Mireles Jr., et al. "Design and Analysis of a MEMS Variable Capacitor using Thermal Actuators"
9. Q.Huang and N.K.S.Lee. "Analysis and design of polysilicon thermal flexure actuator". *J. Micromech. Microeng.* 9 (1999) 64–70.
10. C. Goldsmith, et al. *Micromechanical membrane switches for microwave applications*, 1995 *IEEE MTT-S International Microwave Symposium Digest*, May 1995, pp. 91–94.
11. Thanh Nam Tran, Robert Waldingbrett, "Analyse and simulation of a thermal actuator for variable mems capacitor", *Analyse and Simulation of a thermal actuator for Variable MEMS Capacitor – Project SEN2MET autumn 2010*.
12. José Mireles, et al. *Design and Analysis of a MEMS Variable Capacitor using Thermal Actuators. Comp. y Sist. [Online]*, 2006, vol.10, n.1, pp. 3-14, ISSN 1405-5546

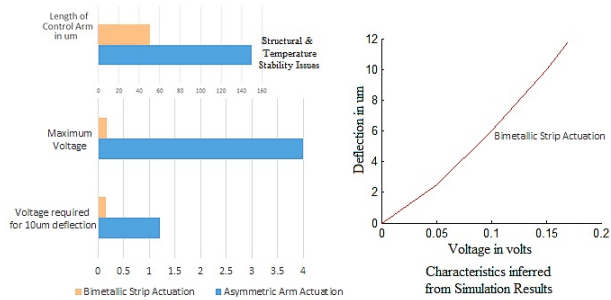
# Figures used in the abstract



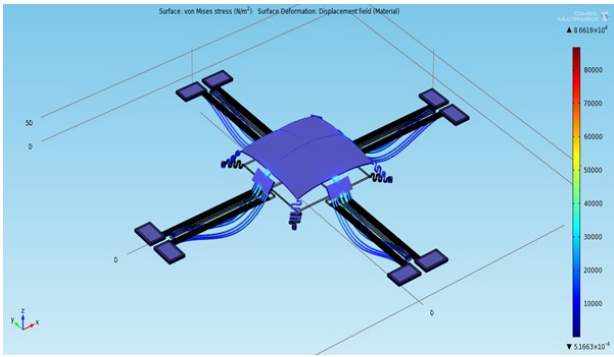
**Figure 1:** Proposed Tunable Capacitor Model



**Figure 2:** Asymmetric Arm Electrothermal Actuator



**Figure 3:** Results and Statistics



**Figure 4:** Stability Issues in Conventional Model