Electrostatically Actuated MEMS Resonator

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I. Project Objectives

Goal: To fabricate electrostatically actuated MEMS resonator.

· Develop and improve RIT's MEMS fabrication process.

· Analyze the effects of different resonator structures and dimension on fabrication and performance.

· Observe the operation of the MEMS resonators in a multiplexed signal filtering circuit.

II. Motivation

- MEMS resonators have improved reliability and performance over traditional LC filters or quartz resonators
  - Smaller in size
  - Lower power consumption
  - High q factor
- Ideal for timing or signal filtering circuits
  - Can be integrated into the CMOS process
- Help make a more robust MEMS fabrication process
  - Fabricate a MEMS resonator and report
  - Report any new considerations of the process

III. Resonator Operation

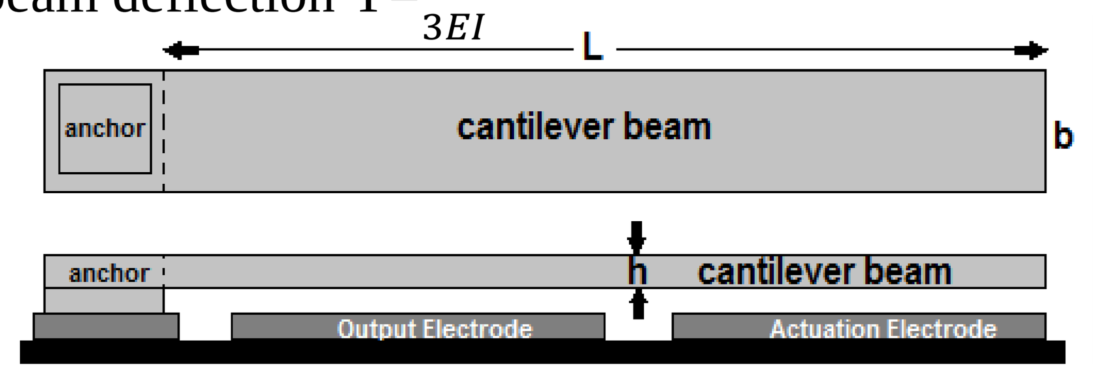
- Fixed-Free cantilever beam actuation using electrostatic force

Resonate Frequency $f_o = \frac{1}{2\pi}\frac{3.5}{L^2}\sqrt{\frac{EI}{\rho}}$

Electrostatic Force $F = \frac{\varepsilon_o \varepsilon r A V^2}{2d^2}$

Moment of Inertia $I = \frac{bh^3}{12}$

Max beam deflection $Y = \frac{FL^3}{3EI}$



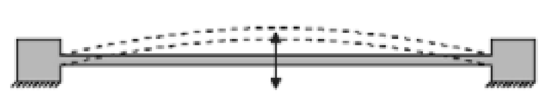
- Fixed-Fixed cantilever beam actuation using electrostatic force

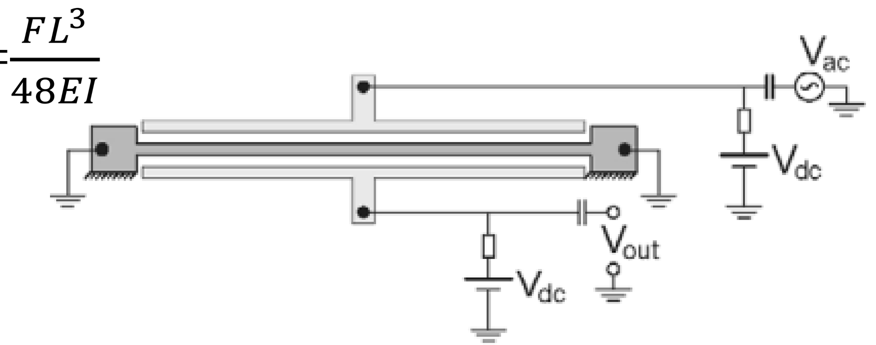
Resonate Frequency $f_o = \frac{1}{2\pi}\frac{22.373}{L^2}\sqrt{\frac{EI}{\rho}}$

Electrostatic Force $F = \frac{\varepsilon_o \varepsilon r A V^2}{2d^2}$

Moment of Inertia $I = \frac{bh^3}{12}$

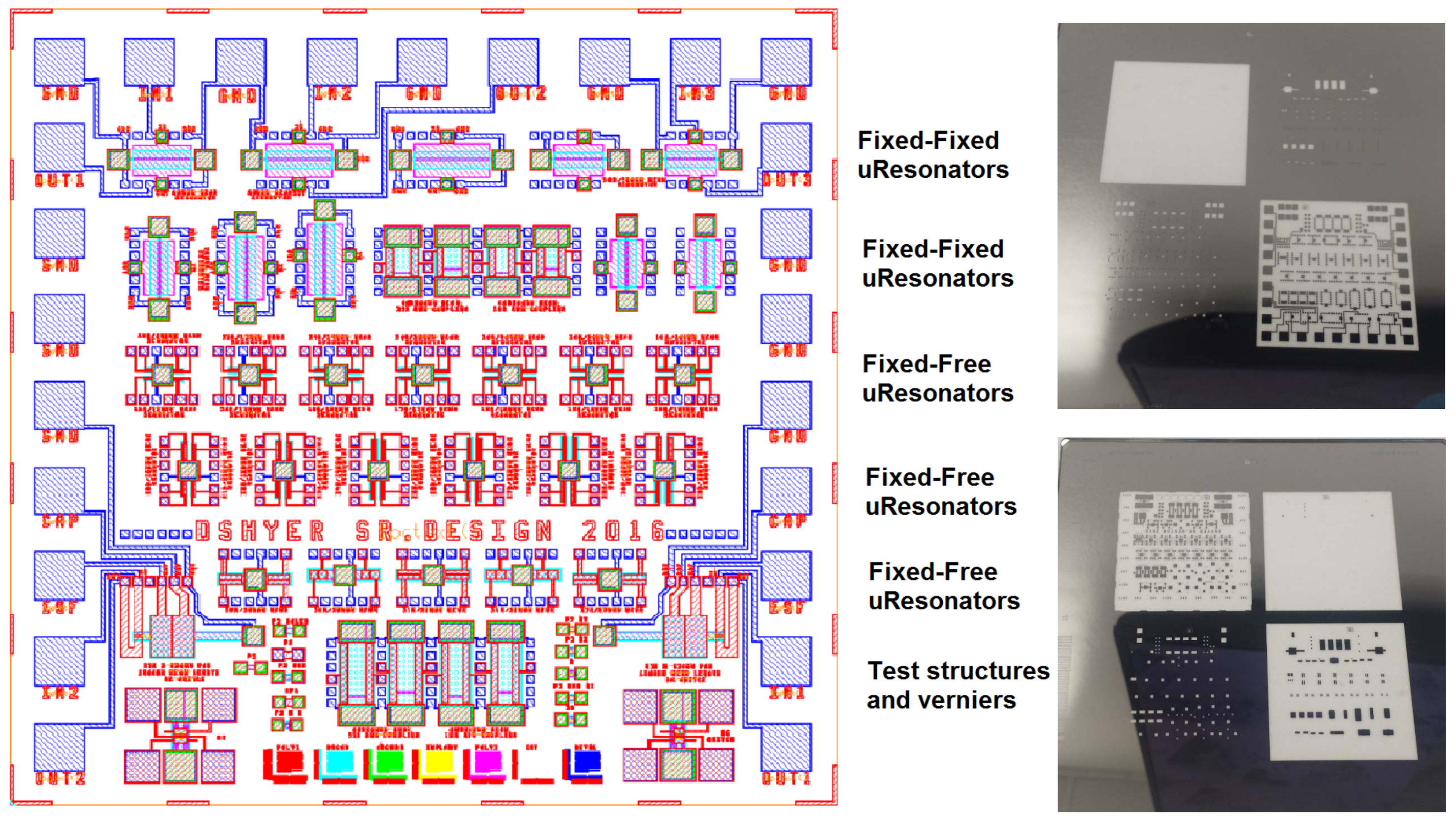
Max beam deflection $Y = \frac{FL^3}{48EI}$





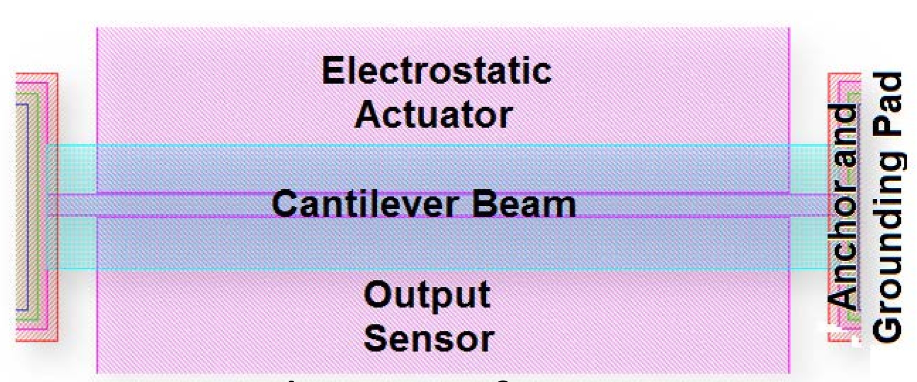
IV. Device Design

8 levels of mask design with an array of devices with varying dimensions to demonstrate the different device structures, operation and resonance.

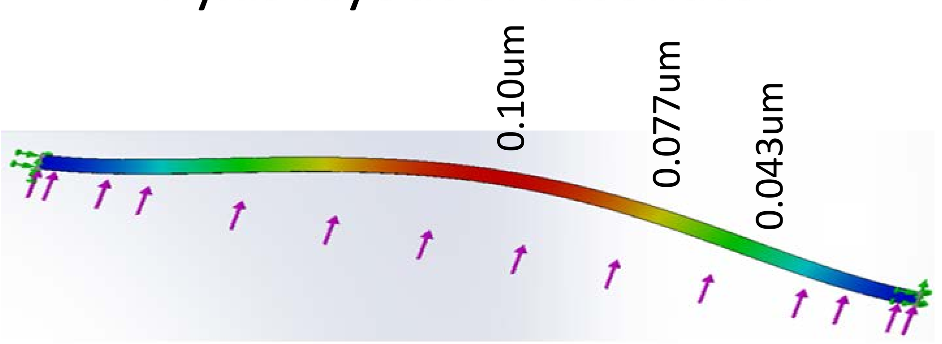


V. Characteristics

- Horizontal actuation using electrostatic force

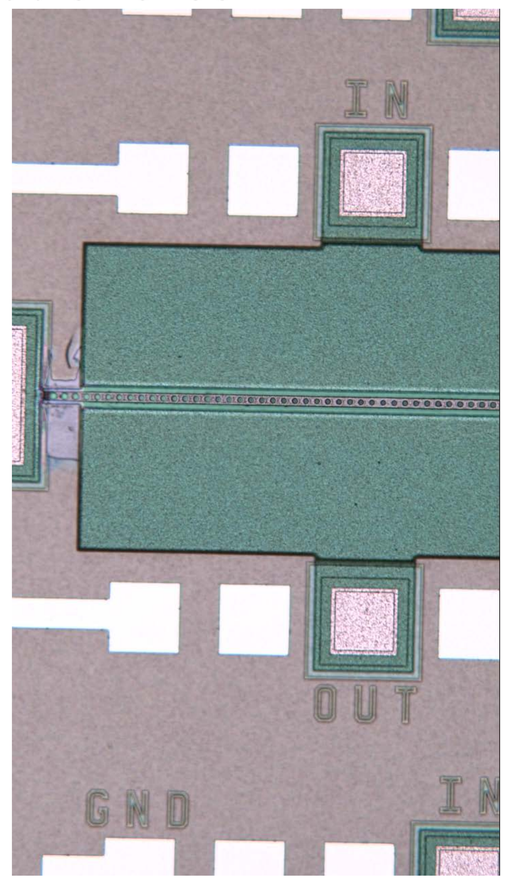


Pyxis layout of resonator

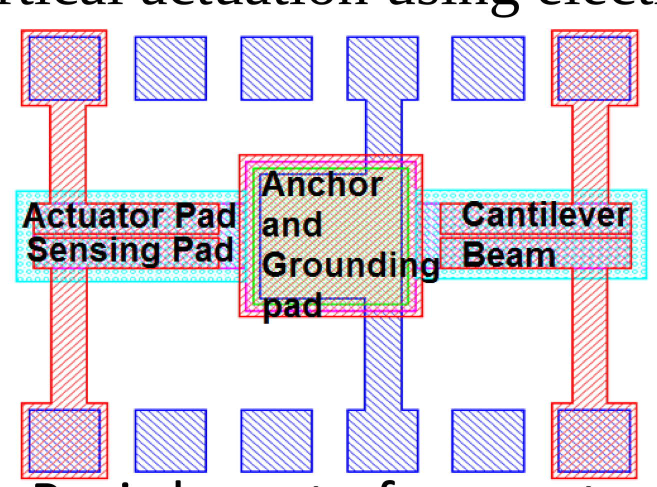


Finite Element Analysis using Solidworks

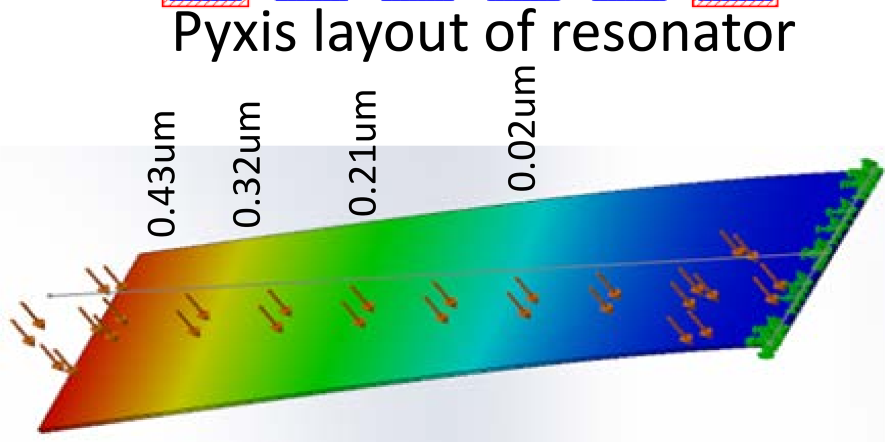
1e-6N (~8V) applied to electrostatic pad (800umx2um)



- Vertical actuation using electrostatic force

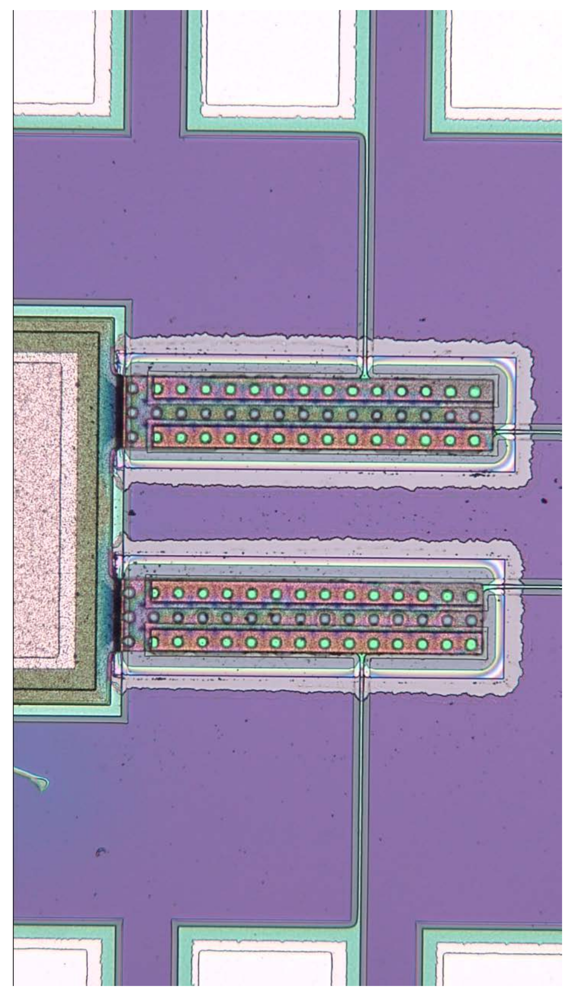


Pyxis layout of resonator



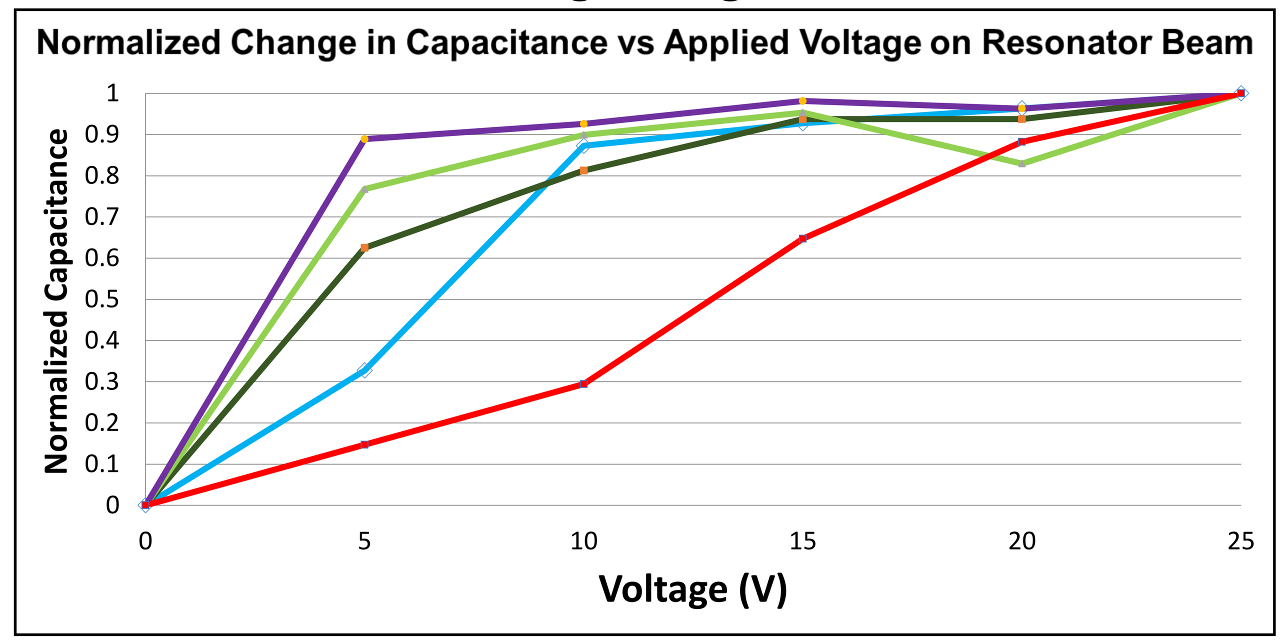
Finite Element Analysis using Solidworks

1e-6N (~8V) applied to electrostatic pad (300umx50um)

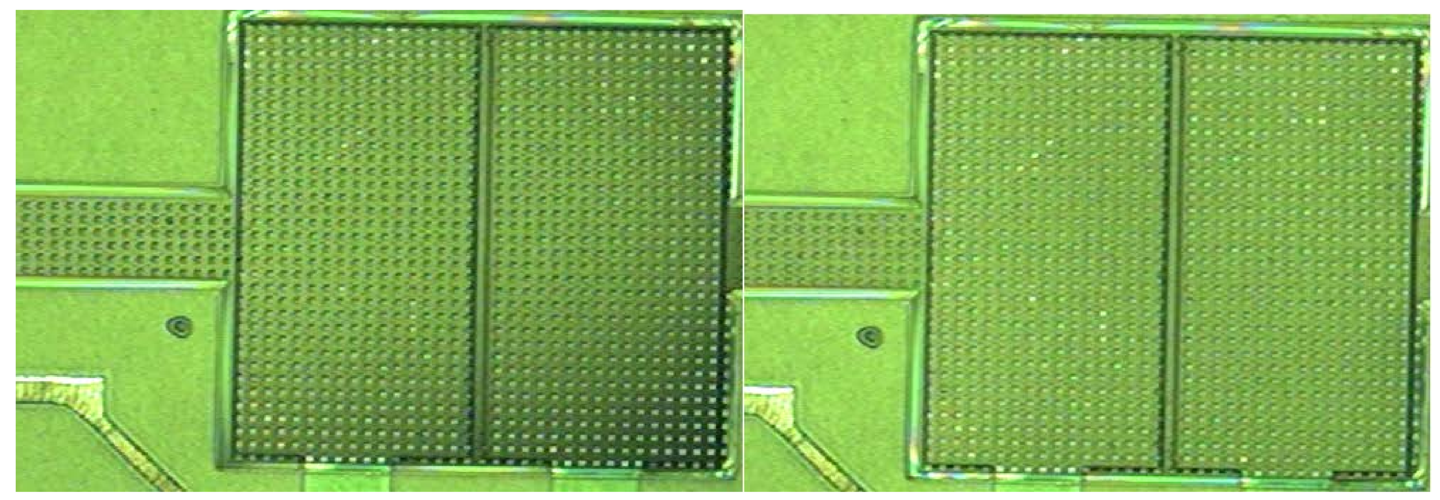


VI. Results

Demonstration of released beams with a measured change in capacitance versus increasing voltage. Visible deflection observed.



No cantilever deflection full cantilever deflection



V. Conclusions

New design rules and process considerations were proposed for the MEMS fabrication process. Additional process data was collected. The design, simulation, fabrication and testing of MEMS electrostatically actuated resonators was developed.

Future Work

The surface MEMS process is still being developed for the successful fabrication and higher yield of devices. Device testing setup of resonators or RF MEMS needs to be implemented before future devices are made.

References

[1] L. Fuller. (2015, MEMS Mechanical Fundamentals. Available https://people.rit.edu/lffeee/MEMS_Mechanical_Fundamentals.pdf

[2] C. Durand, et al., "Silicon on nothing MEMS electromechanical resonator," Microsystem Technologies-Micro-and Nanosystems-Information Storage and Processing Systems, vol. 14, pp. 1027-1033, Jul 2008.

[3] L. W. Lin, R. T. Howe, and A. P. Pisano, "Microelectromechanical filters for signal processing," Journal of Microelectromechanical Systems, vol. 7, pp. 286-294, Sep 1998.

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