Fabrication of a MEMS Comb Drive Actuator

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I. Project Objectives

Goal: To fabricate MEMS comb drive actuators

- Fabricate devices with the RIT Surface MEMS Process
- Optimizing the Surface MEMS Process for future fine geometry MEMS projects

II. Background Information

Comb drives are capacitive actuators that utilize electrostatic forces to **move combs**

- The actuator utilizes two combs: a movable comb and a fixed comb
- Comb drives are used in many other MEMS applications
  - Examples: gyroscopes, resonators, voltmeters
  - Used in applications of optical communication, wireless communication, and biomedical engineering

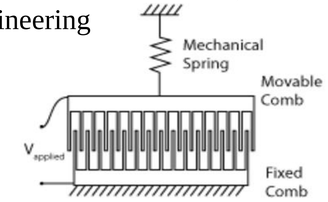
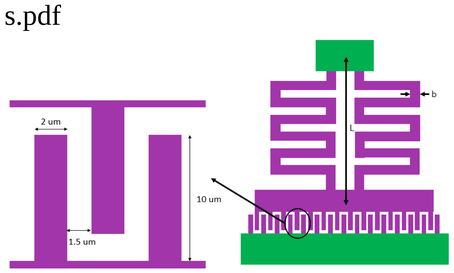


Figure 1: Simple Comb Drive Actuator [1]

III. Device Design

- The MEMS process has two phases:
  - Fall: Done with the MEMS fabrication class for proof of concept
  - Spring: Device parameter focus and design changes
- Surface MEMS process details can be found on Dr. Fuller's website (8 mask levels, 51 process steps): https://people.rit.edu/lffeee/SurfaceMEMsFabricationDetails.pdf



	Design A	Design B
# of fingers, n	47	41
Beam Length, L	280 um	200 um
Beam Width, b	5 um	5 um
Thickness, h	2 um	2 um
Finger Gap, g	1.5 um	2 um
Drive Voltage to Move 2um, V	52.2 V	92.7 V

Figure 2: Fall Semester Comb Drive Actuator Designs

IV. MEMS Comb Drive Operation

$$F_e = \frac{dE}{dx} = \frac{n\varepsilon_0 h}{2g}V^2$$ *Electrostatic Force Equation*

$$F_s = k_x \cdot x = \frac{2Ehb^3}{L^3} \cdot x$$ *Mechanical Spring Force Equation*

$$x = \frac{n\varepsilon_0 L^3}{4Egb^3}V^2$$ *Force Equilibrium Equation*

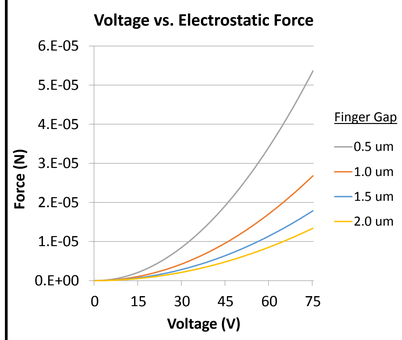


Figure 3: Voltage vs Electrostatic Force

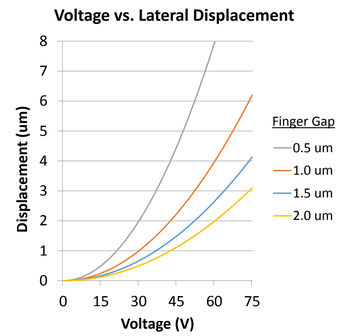


Figure 4: Voltage vs Displacement

- MEMS comb drives uses electrostatic force of the combs and the mechanical restoring force of the spring.
- The curves simulated above implements the design parameters in device Design A.

V. Experimental Results

- The aspect ratio of the fingers is 1:1 (thickness = 2µm & width = 2µm)
- The STS etcher or DRIE tool was needed for an anisotropic etch for the comb fingers
- The Bosch process used in the STS Etcher is not found in any other tool in the SMFL
- The back up plan was to use the Drytek or RIE tool to etch the mechanical poly but the results show that the etch was not very anisotropic.
- The STS etcher is now back up and became available last week but focus was on the completion of process.
- Future MEMS projects will use the STS etcher for the mechanical poly etch

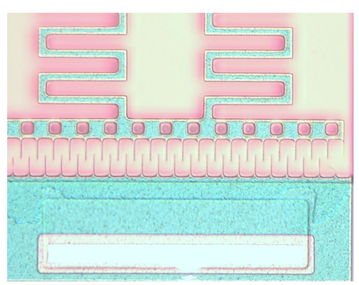


Figure 5: Spring devices at pre-release

Experimental Results (con't)

- Found a new design rule for future MEMS projects
  - Anchor over interconnect poly must be covered by mechanical poly or sacrificial oxide
- Both set of devices have not been completed:
  - Fall: At release layer (release layer work in progress)
  - Spring: At metal (problems with metal etch)

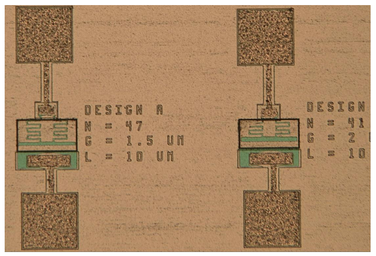


Figure 6: Fall device wafers at pre-release

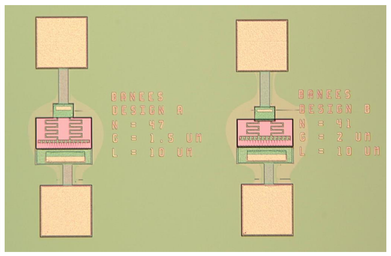


Figure 7: Spring device wafers at pre-release

VI. Conclusions

Comb drive actuators were designed and partially fabricated using the developing RIT Surface MEMS Process. It was found that the STS Etcher was necessary in creating the combs for the MEMS device.

Future Work

- Improve Surface MEMS process
- Incorporate more design rules for MEMS devices

References

[1]"Introduction to Microelectromechanical Systems (MEMS) | Compliant Mechanisms",*Compliantmechanisms.byu.edu*, 2016. [Online]. Available: https://compliantmechanisms.byu.edu/content/introduction-microelectromechanical-systems-mems. [Accessed: 04- May- 2016].
[2] MEMS Mechanical Fundamentals, L. Fuller
[3] Surface MEMS Fabrication Details,L. Fuller

Acknowledgements

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