Design and Fabrication of a Three-Axis Capacitive Accelerometer

R·I·T KATE GLEASON College of ENGINEERING

Eddie Huang, Advisor: Dr. Lynn Fuller

Rochester Institute of Technology, Department of Electrical and Microelectronic Engineering, Rochester NY 14623

MicroE Microelectronic Engineering

I. Project Objectives

Goal: Sense acceleration in the x, y, and z direction.

- Measure up to ±10G of acceleration.

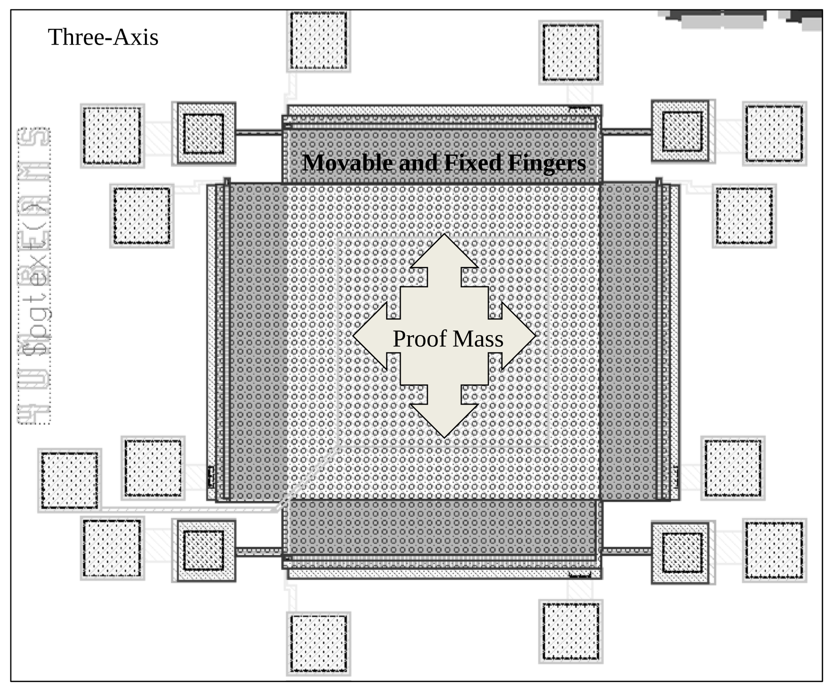
▪Demonstrate a working 3-Axis device fabricated in the SMFL.

▪Fabricate working Comb-Drives.

▪Releasing of the device from the sacrificial layer.

II. Motivation

- To fabricate a working 3-Axis Accelerometer with comb-drives, which hasn't been done in the SMFL.
- By choosing appropriate sacrificial material, sacrificial distance, beam thickness, electrode thickness, and finger gaps, the capacitance can be used to measure acceleration.



Parameter	Measurement & Units
Proof Mass Size	1500μm x 1500μm
Proof Mass Thickness	2μm
Proof Mass Weight	9.04μg
Comb Finger Gap	1μm
Comb Finger Length	200μm
Beam Length	250μm x 250μm
Beam Width	4μm

Figure 1: Design of Device and Parameters.

III. Process Flow

All MEMS process was done in the SMFL.

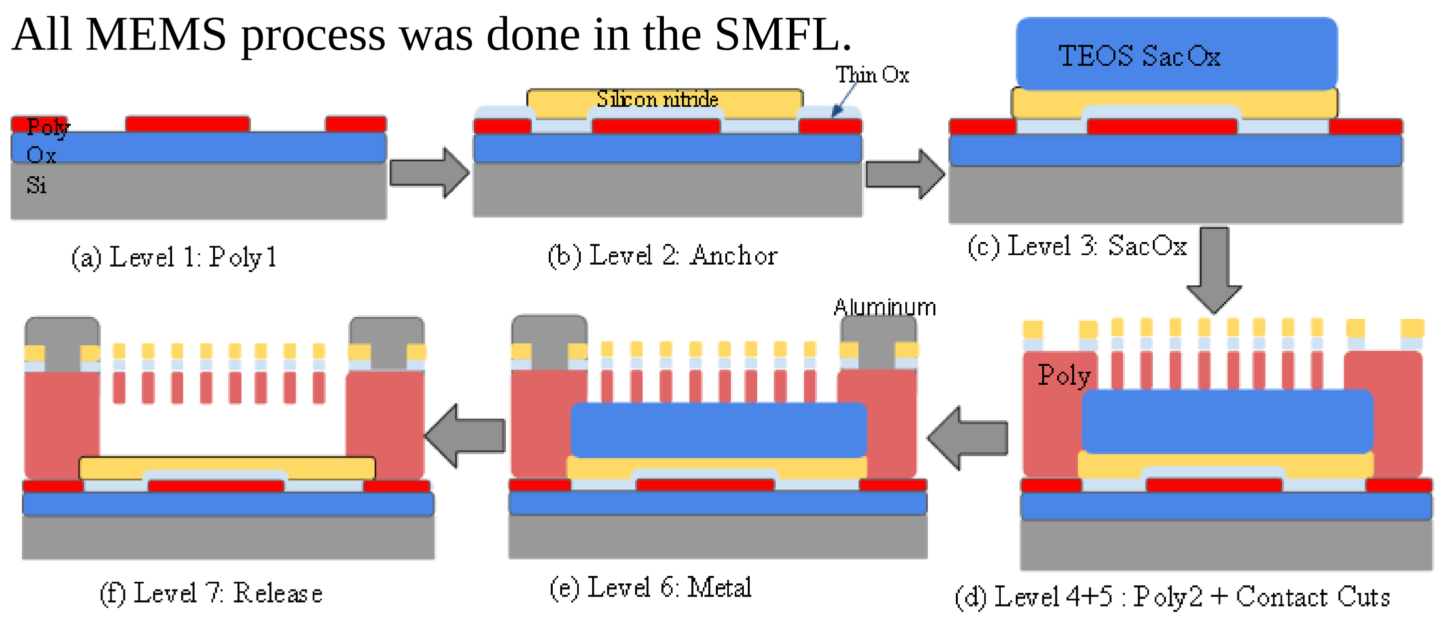
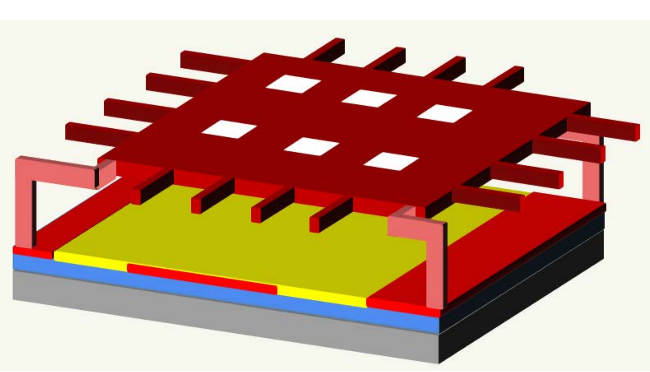


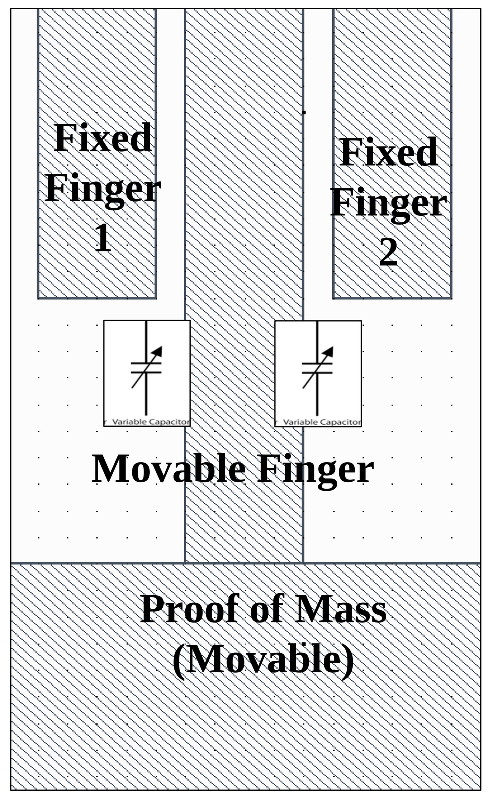
Figure 2: 7 Level Process Flow



- 4μm Beams for displacement sensitivity.
- SacOx layer should be at least 2μm
- Top Poly layer should be at least 2μm
- 4μm Holes in the proof mass for SacOx release.

Figure 3: 3D Diagram/Sketch of the device

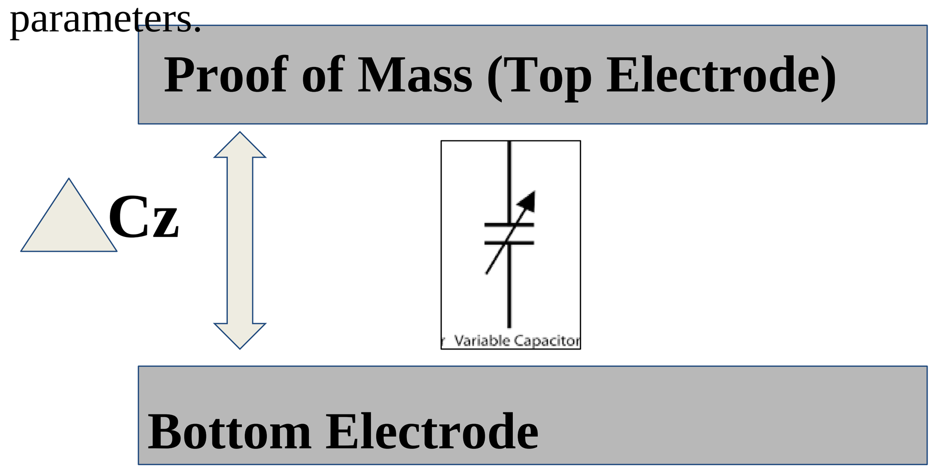
IV. Theory



$$C(fingers) = \left(\frac{\epsilon_o \epsilon_r N_s L_s H_s}{d_o}\right) * \left(\frac{1 + d_x}{d_o}\right)$$

Relative Permittivity	εo
Permittivity of Air	εr
Height of Fingers	Hs
Number of Fingers	Ns
Length of Fingers	Ls
Width of Fingers	Ws
Finger Gap	do
Displacement by Force	dx
Area	A

Figure 4: 7 Top-down view of the fingers, equation, and parameters.



$$C_Z = \frac{\epsilon_o \epsilon_r A}{d_o}$$

Figure 5: 7 Cross-section view of the top/bottom electrode and the capacitance equation.

V. Simulation

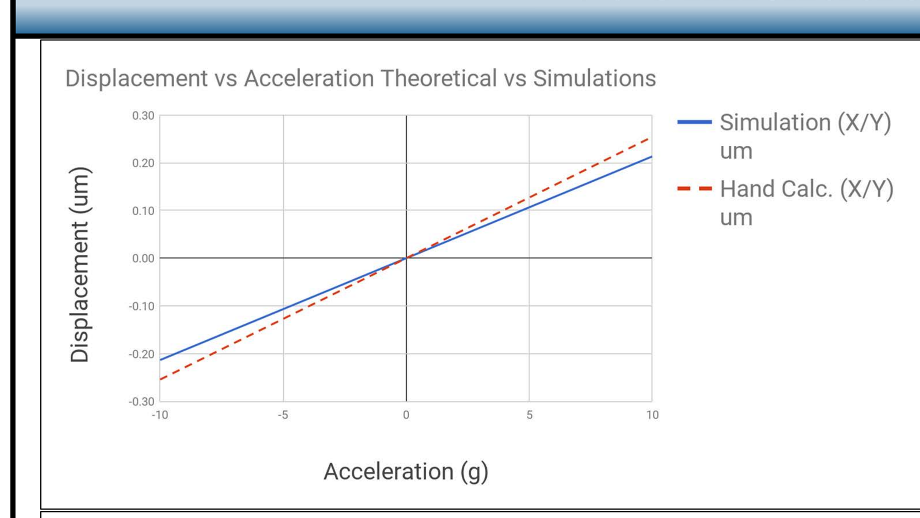


Figure 6: Displacement Simulations were extracted from a linear relation of Force and Displacement on ANSYS 18.1.

Simulation and Hand-Calc. differ 16%.

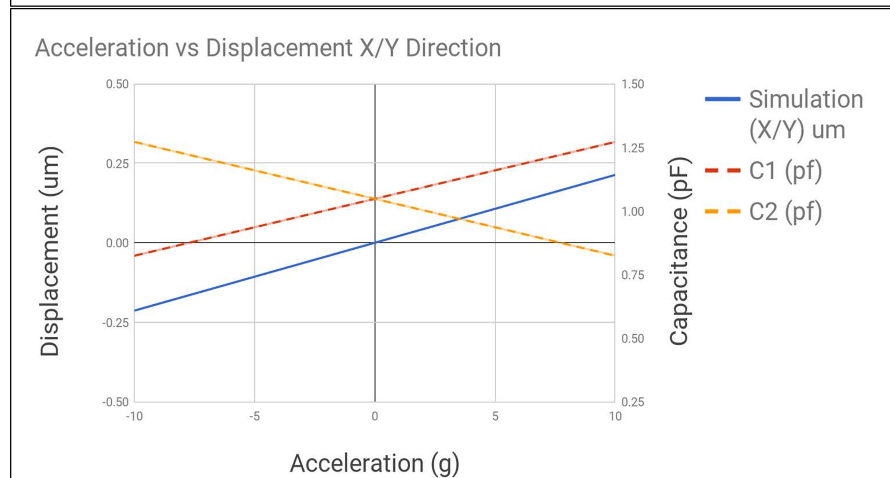


Figure 7: When there is no acceleration, the capacitance of the two fingers should be identical.

Range for the X/Y Axis can measure up to **±10G.**

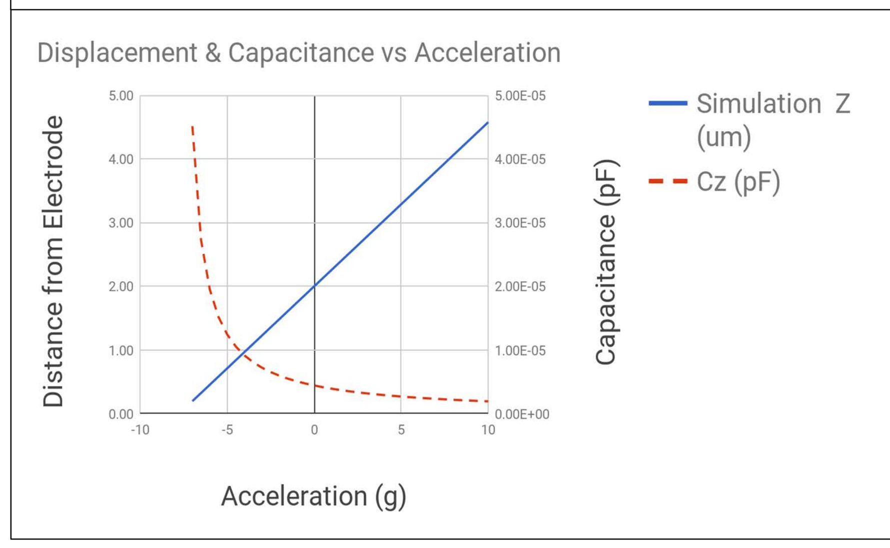


Figure 8: The maximum acceleration in the -Z direction only goes up to around -5g, before it hits the bottom electrode.

Therefore, the device will only be operational in the **±5G** range.

VI. Results

Images of Devices

Pre-HF Etch Images **Post-HF Etch Images**

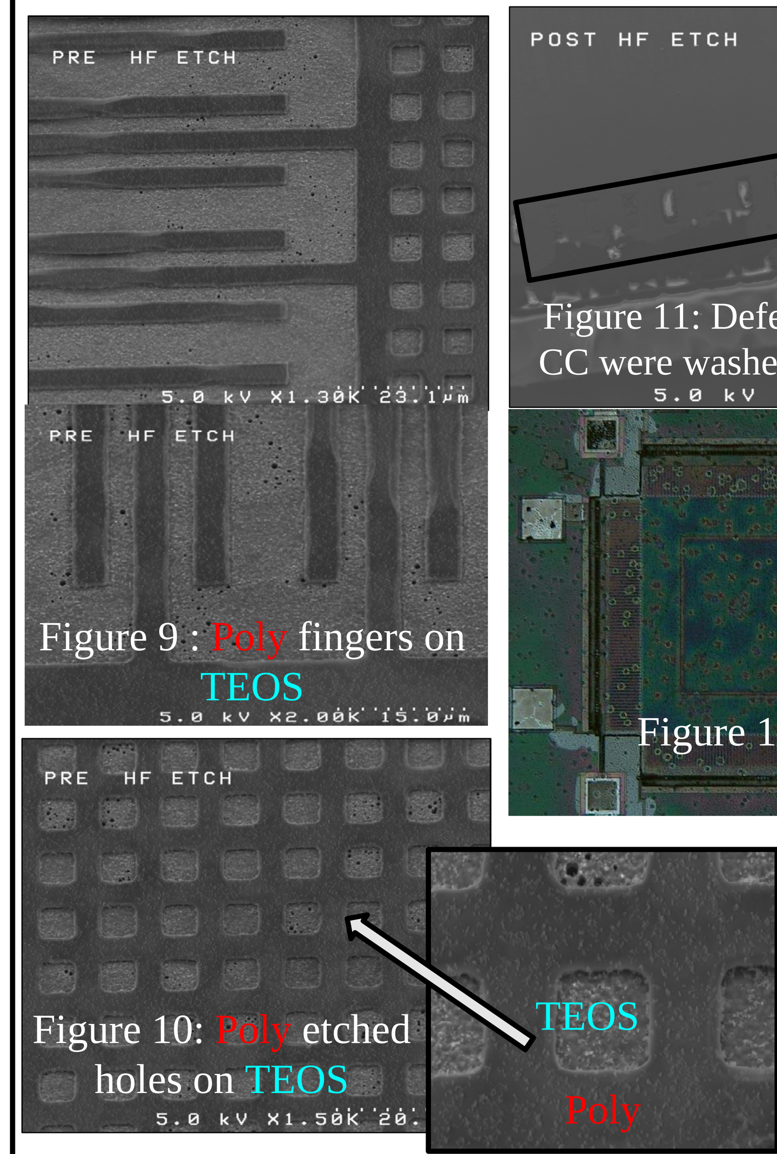


Figure 9 : Poly fingers on TEOS

Figure 10: Poly etched holes on TEOS

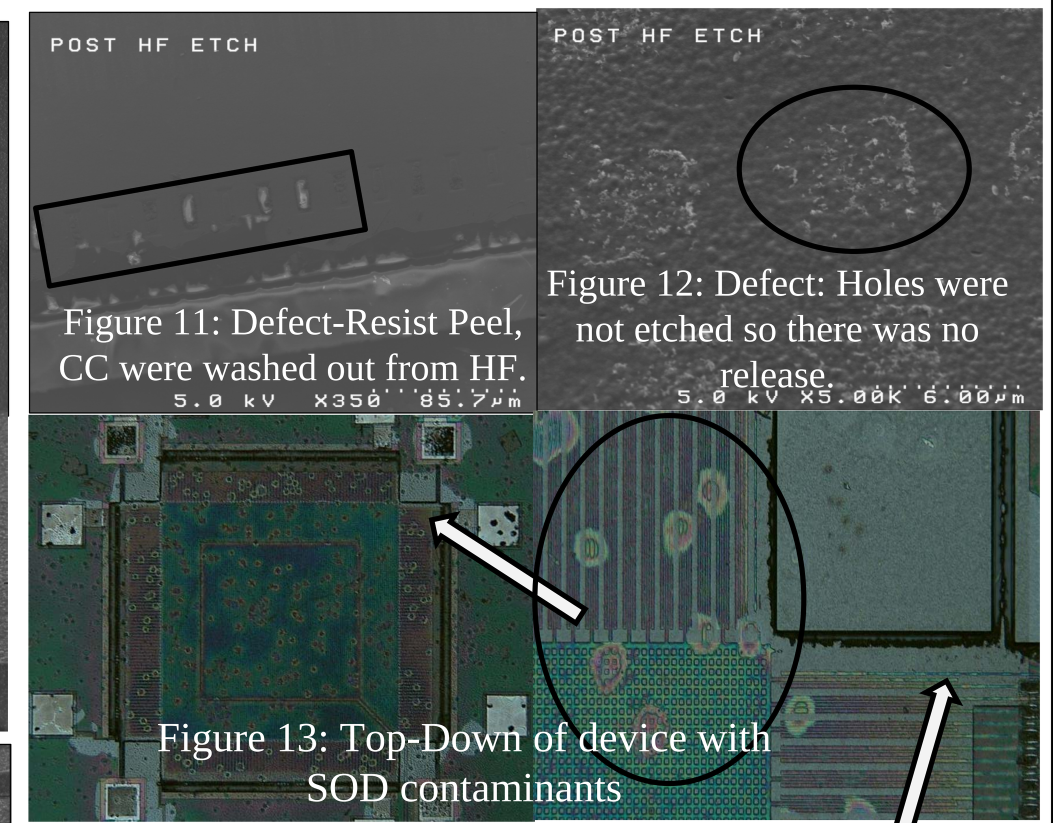


Figure 11: Defect-Resist Peel, CC were washed out from HF.

Figure 12: Defect: Holes were not etched so there was no release.

Figure 13: Top-Down of device with SOD contaminants

Spring Beams were not patterned on the poly.

VII. Conclusions

The devices fabricated using multiple tools in the SMFL. The spin-on-dopant used on top poly/electrode ruined a lot of patterning of the future layers and resulted in poor patterning of the fingers and beams. The release was an issue due to the photoresist peeling, which resulted in etching in unintended areas.

Future Work

- **Do not use Spin-on-Dopant. Too many particles from the solvent will remain on the poly and affect future patterning.**
- **Design areas that need to be released to be smaller so the HF etch process isn't too aggressive on the devices.**
- **Design wider beams since most of the feature was overetched and opened.**
- **Design multiple test areas on the mask for etch measurements.**

Acknowledgements

- Dr. Lynn Fuller
- Dr. Robert Pearson
- Dr. Dale Ewbank
- SMFL Staff
- MicroE Students of 2018

R·I·T Semiconductor & Microsystems Fabrication Laboratory