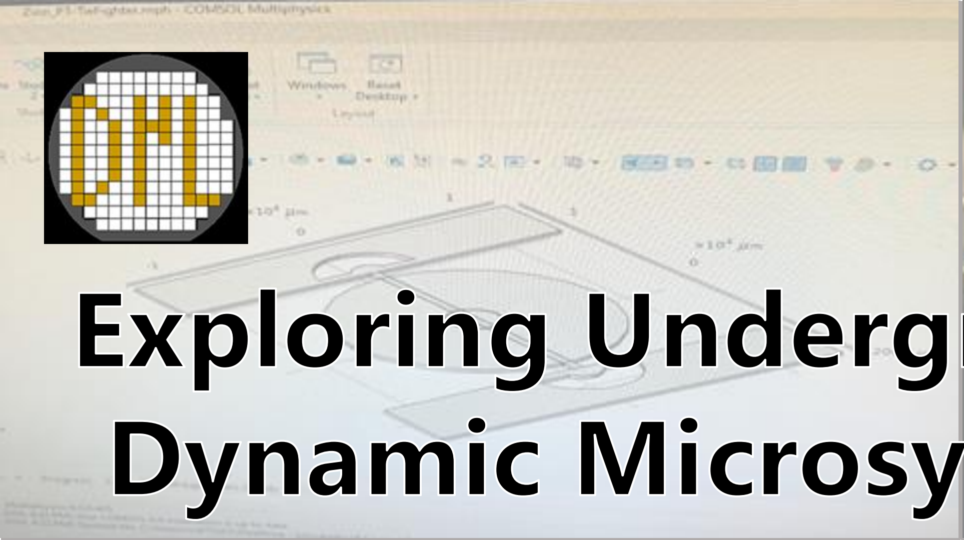
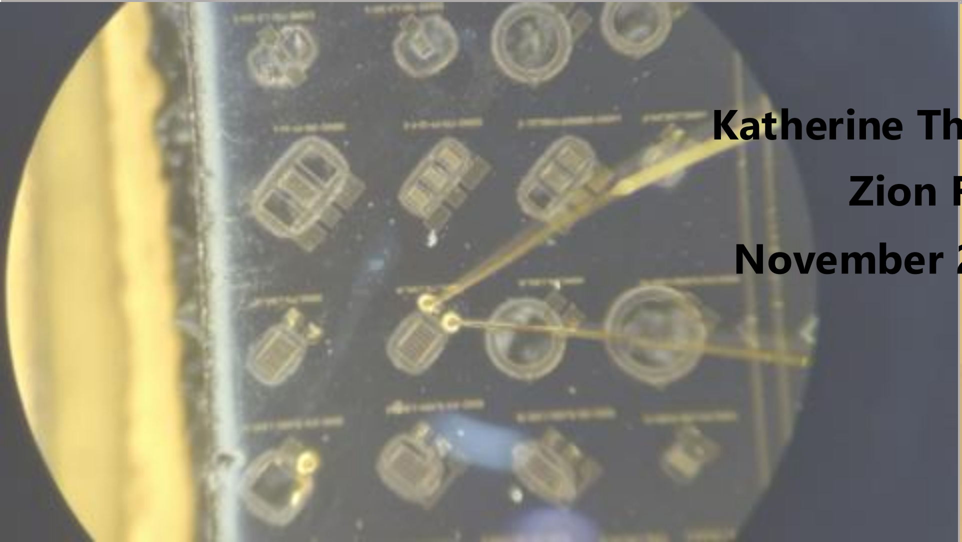
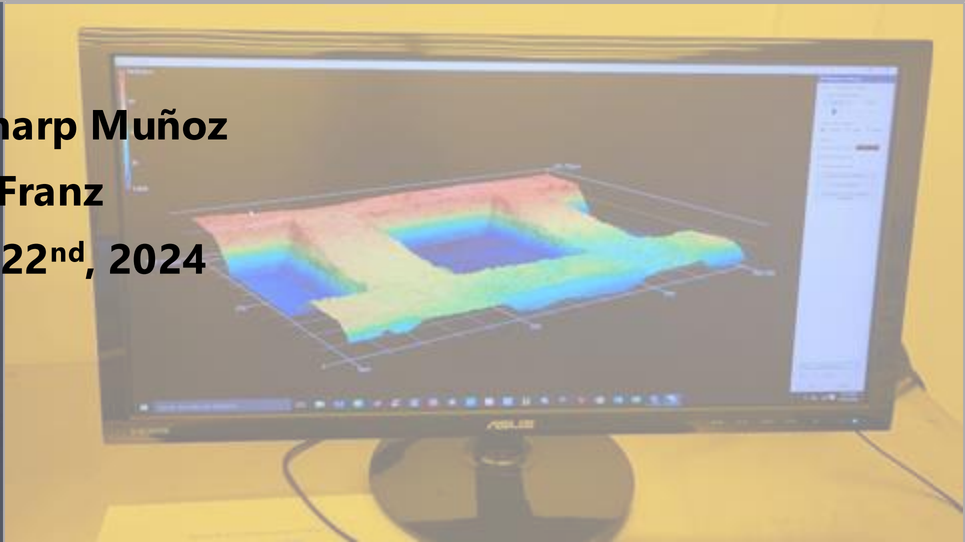


Exploring Undergraduate Research: Dynamic Microsystems Lab (DML)



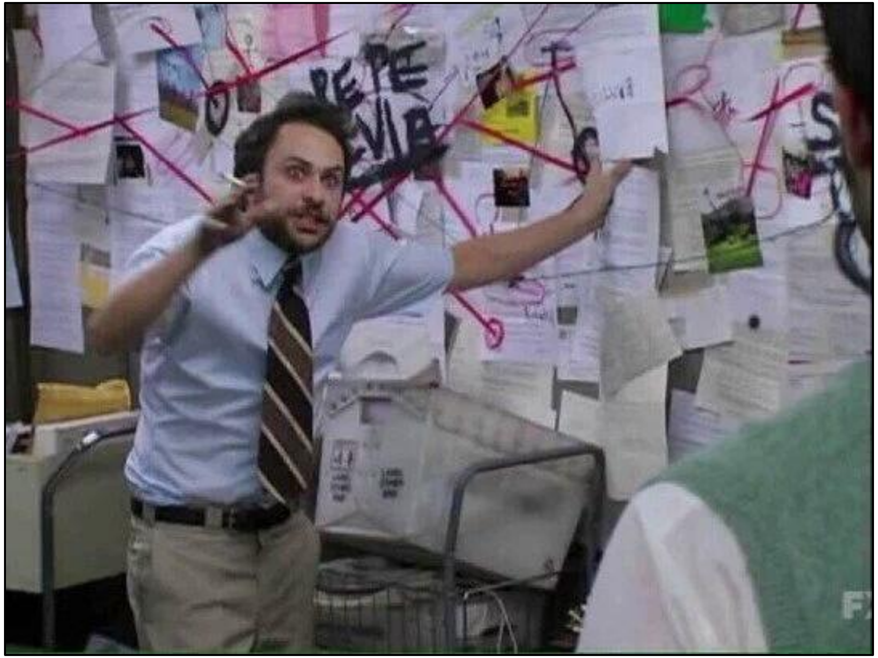


Katherine Tharp Muñoz

Zion Franz

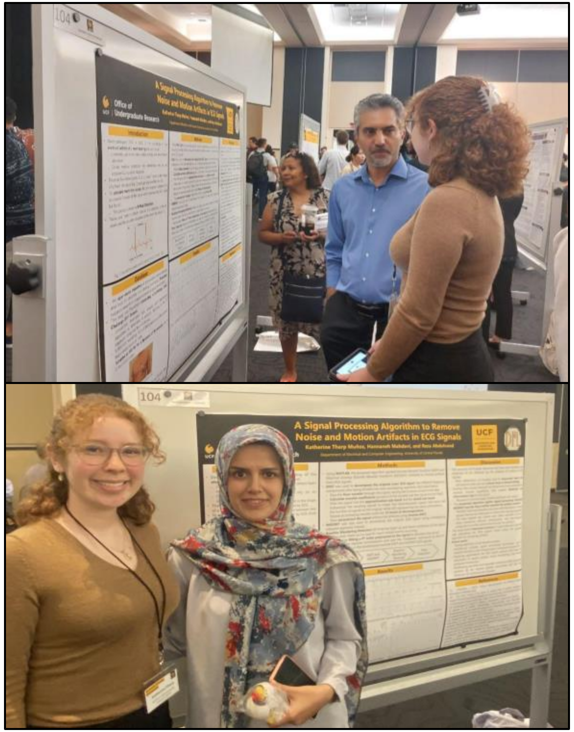
November 22nd, 2024

Why Undergraduate Research?



- Work with a team of experts in their fields to <u>expand your knowledge</u>.
- Opportunity to <u>apply what you learn</u> in your courses (through projects).
- Publish/present your work!
- Attend <u>research conferences</u> (travel!)
- Get paid (potentially).
- Helps you decide if you want to pursue <u>higher education</u> (Master’s, PhD, etc).

Office of Undergraduate Research: SURF



- ~$2,000 scholarship for summer courses
- Attend workshops for professional development, poster presentation, creating a research portfolio, and conference preparation.
- Present at the UCF Summer Research Showcase and then at the Student Scholar Symposium in the Spring.

Apply to SURF in Spring 2025

A Signal Processing Algorithm to Remove Noise and Motion Artifacts in ECG Signals

Katherine Tharp Muñoz, Hannaneh Mahdavi, and Reza Abdolvand

Department of Computer and Electrical Engineering, University of Central Florida

UCF Office of Undergraduate Research

UCF College of Engineering & Computer Science

Introduction

- Electrocardiogram (ECG or EKG) is the recording of the **electrical activity of a heart beating** over an interval.
  - Commonly used to monitor cardiac activity and detect heart rate values.
  - Certain medical conditions like arrhythmias rely on an accurate ECG signal for diagnosis.
- There are five distinct peaks: R, Q, S, P, and T found in the shape of a heart rate signal (Fig. 1) and typically identified by ECG.
- To **calculate heart rate values**, the time elapsed between two successive R-waves of the signal wave produced by ECG must be found.
  - This process is known as **R-Peak Detection**.
- Noise and motion artifacts obstruct the detection of the R-peaks and the accurate calculation of the heart rate values.

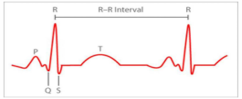


Fig. 1. Five distinct peaks on ECG signal: R, Q, S, P, and T [6].

Database

- An **open-source repository** of physiological signal datasets and tools for analyzing and sharing information, **PhysioNet** supports research in complex biomedical signals and systems.
- This study uses PhysioNet's **Computing in Cardiology (CinC) Challenge 2011 Dataset.**
  - Competitors developed ECG analysis and classification algorithms to determine if patients had one of the 12 diagnostic categories for arrhythmias.
  - 5,0000 ECG recordings from 3,3000 patients of either various heart-related issues or none.
  - **Sampled at 500 Hz for a duration of 10 seconds** using a 12-lead ECG system.

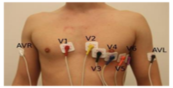


Fig. 2. 12-lead ECG system [2].

- **Application**:
  - The augmented vector right (aVR) electrode was the only lead tested and measures the right upper side of the heart.
  - Only **10 randomly selected, aVR obtained, ECG signals** were testing with the proposed algorithm of this study.

Methods

- Using **MATLAB**, the proposed algorithm applied Discrete Wavelet Transform (DWT) and Maximal Overlap Discrete Wavelet Transform (MODWT) methods to remove artifacts from ECG signals.
- **DWT** was used to **decompose the original (raw) ECG signal** into different frequency components after being divided into non-overlapping segments. Described below:
  - Pass the **Haar wavelet** through the signal, varying the location at each time step.
  - **Calculate wavelet coefficients** (product of the wavelet and the signal at time step).
  - Filter the signal into the **approximation sub-band** and the **detail sub-band.**
  - Subsample the resulting signals to create two downsampled signals that have half the number of signals as the original, while still representing the same information.
  - Repeat at increasing wavelet scales for **12 levels of decomposition**.
  - Then **reconstruct the signal** without the artifacts using **inverse DWT**.
- **MODWT** was also used to decompose the original ECG signal using overlapping adjacent segments instead.
- **Baseline Wandering Detection** finds the slight up and down variations of the signal baseline when there are no specific heart-related events occurring.
  - Removed by **fitting a 4th order polynomial to the signal** to decrease the trend**.**
- **Peak Detection** requires normalization and uses the 'findpeaks' command to find R-Peaks and S-Peaks in the randomized inverted DWT and MODWT ECG signals.

Raw Signal from CinC Challenge Dataset → DWT and MODWT → Baseline Wandering Removal → Peak Detection

Results

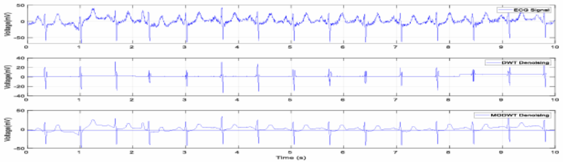


Fig. 3. (a) noisy ECG signal, and reconstructed signals after applying (b) DWT and (c) MODWT

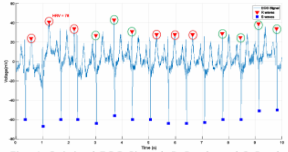


Fig. 4. Original ECG Signal: R-Peak and S-Peak

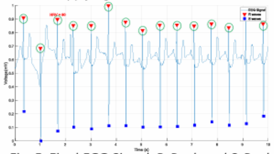


Fig. 5. Final ECG Signal: R-Peak and S-Peak

Discussion

- The accuracy of R-peak detection and heart rate calculation was observed to be affected by the presence of artifacts in ECG signals.
  - False detections of R-peaks lead to **inaccurate heart rate** calculations that can be a **critical issue in clinical settings**.
- Existing filter-based methods like Butterworth were examined but showed limited capabilities that created **distortion and information loss** for the signal.
  - Resulted in incorrect peak location and heart rate values.
- The **presented algorithm applies signal processing technique MODWT and the Haar mother wavelet for artifact removal**.
  - MODWT improved detection accuracy with the ability to handle signals that are non-stationary or have time-varying properties.
  - The Haar wavelet was chosen over other mother wavelets for its sharp transitions, efficient computation, and low-frequency component to swiftly detect and remove the artifacts.
- The study found **improved accuracy** in peak detection and heart rate calculation for ECG signals when using the proposed algorithm for removing artifacts.
- **Future works**:
  - Testing algorithm on all dataset samples.
  - Combining multiple signal processing techniques, such as wavelet transform with independent component analysis.
  - Exploring applications for ECG signal analysis and heart rate calculation in sports science, stress monitoring, and human-computer interaction.
  - Developing real-time and wearable continuous ECG monitoring systems for remote patient monitoring and the early detection of cardiovascular diseases.

References

[1] D'Aloia, M., Longo, A., & Rizzi, M. (2019). Noisy ECG signal analysis for automatic peak detection. Information, 10(2), 35.

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[3] Lilienthal, J. (2021). Tensor Decomposition for Motion Artifact Removal in Wireless ECG. A., & Rizzi, M. (2019).

[4] Madan, P., Singh, V., Singh, D. P., Diwakar, M., & Kishor, A. (2022). Denoising of ECG signals using weighted stationary wavelet total variation. Biomedical Signal Processing and Control, 73, 103478.

[5] Milanesi, M., Martini, N., Vanello, N., Positano, V., Santarelli, M. F., & Landini, L. (2008). Independent component analysis applied to the removal of motion artifacts from electrocardiographic signals. Medical & biological engineering & computing, 46(3), 251–261.

[6] *What is heart rate variability (HRV)? and how it can enhance your training*. Myithlete. (2021, February 8). https://www.myithlete.com/what-is-hrv/

Apply to O.U.R. Programs!

RAMP in Fall 2025

McNair in Fall 2025

Honors Undergraduate Thesis

Summer Research Academy

Undergraduate Research: DIY

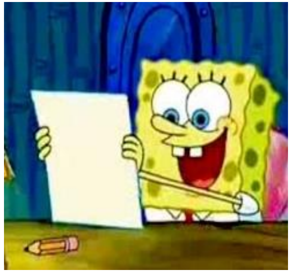
Read publications and learn about different fields and professors.

Email professors you are interested in learning from.

Schedule a meeting (it’s trial and error).

Ask as many questions as you can!

Show up and learn aka shadow grad students and post docs.



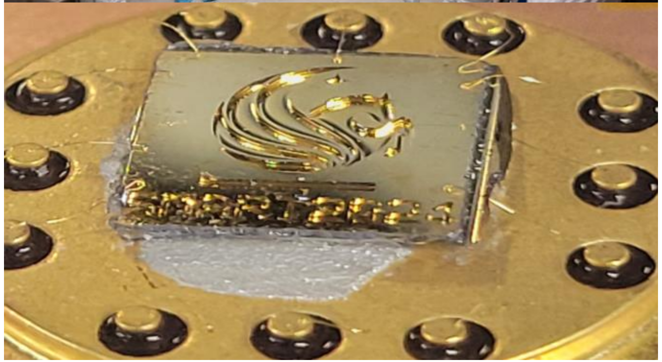
UCF

Co-Op Programs: Lab Technicians

- Senior Facility Manager: Ed Dein
- Lab Manager: Dr. Avra Kundu
- Maintain and operate equipment in EGN1 Cleanrooms,124 and 163.
- Facilitate cleanroom safety procedures and culture.
- Update SOPs for grad students and postdocs.

SMART Workshop

- Semiconductor Manufacturing and Advances in Recent Technology is a two-week summer program in collaboration with Texas Instruments (TI), Intel, and the ECE department.
- Hands-on training in microfabrication tools and processing through workshops.
- **End goal**: fabricate a p-n diode (pictured).



What is DML?

Mission:

Founded in the Fall of 2013, the Dynamic Microsystems Lab aims to extend the application of hybrid integrated micro-systems to areas of technology such as RF, biomedical, wireless sensing, and power electronics. We accomplish this through expertise in the design and fabrication of microelectromechanical (MEMS) systems.

Find our website through the QR Code.

Who is DML?

Dr. Reza Abdolvand

Dr. Hakhamanesh Mansoorzare

Dr. Hannaneh Mahdavi

Dr. Justin Phelps

Kevin Chan

Ankesh Todi

Jennyfer Vivas Gomez

Daniel Lopez Garcia

Maliha Sultana

Tanvir Hasan

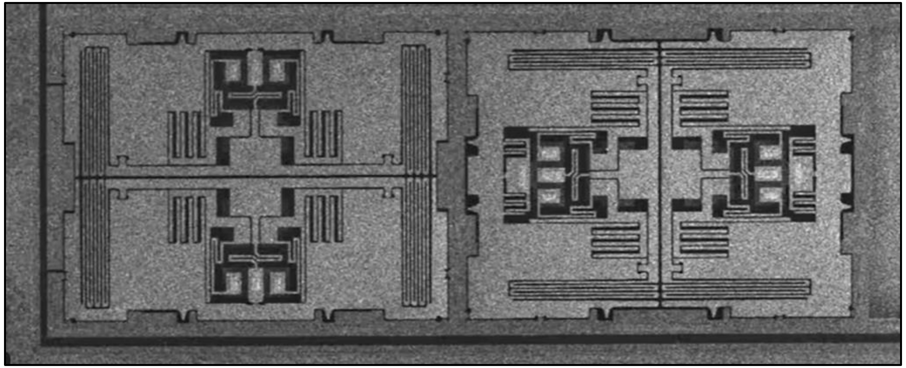
Hamed Atashbar

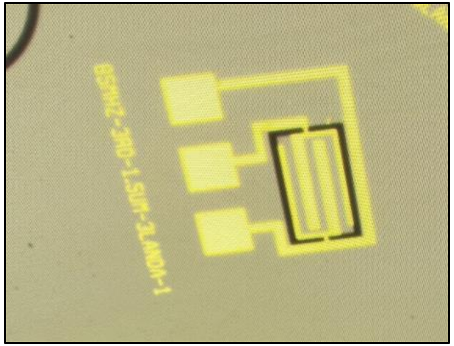
Zion Franz

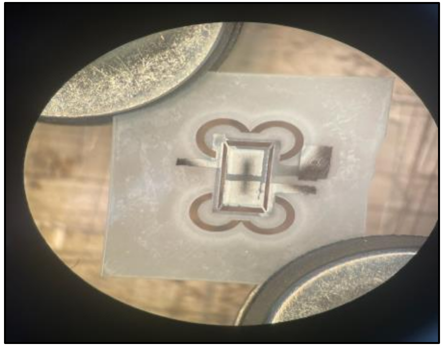
Katherine Tharp

Piezoelectric MEMS Systems

- Microscopic devices with <u>electronic and moving parts</u> used to detect and convert <u>changes in the environment</u> into electrical information.
  - Used in cell phones, hard drives, cameras, clocks, airbags, etc.
  - Actuators vs Sensors vs Transformers

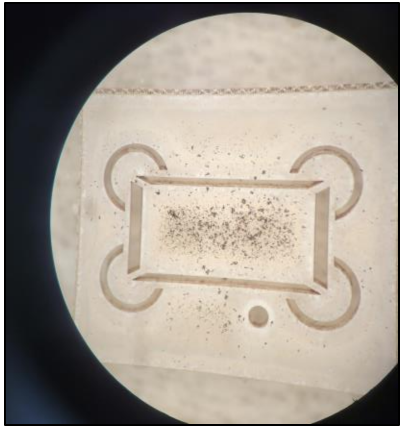


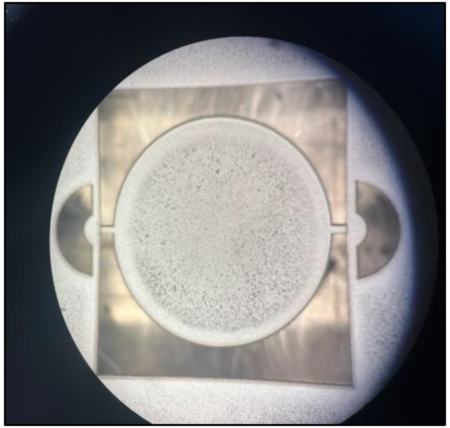


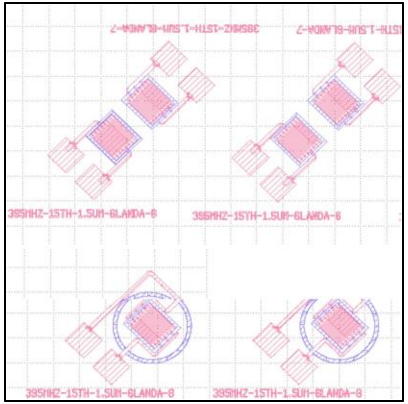


MEMS Applications: Current Projects

- Ring Dot Transformer aka ‘Tie-Fighter’
- MEMS Resonators under High Temperatures.
- Maintaining equipment/lab.

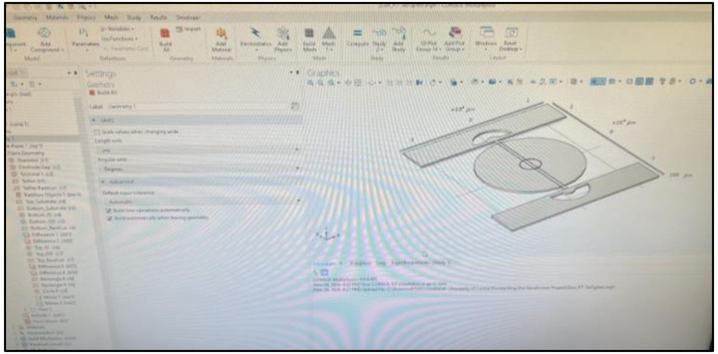


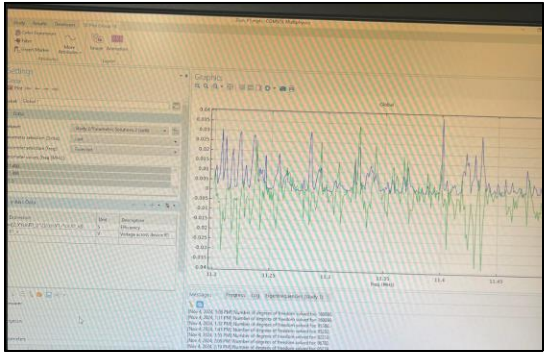


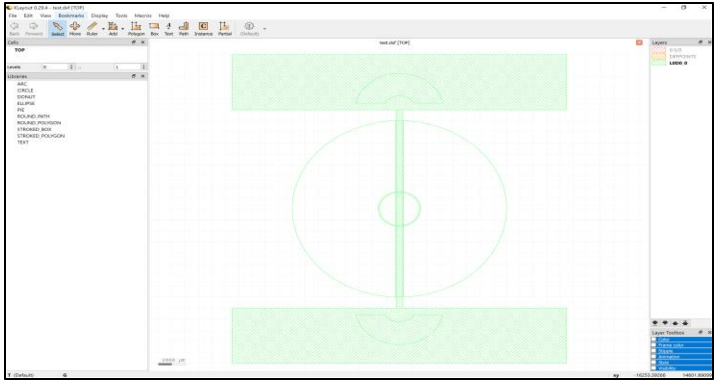


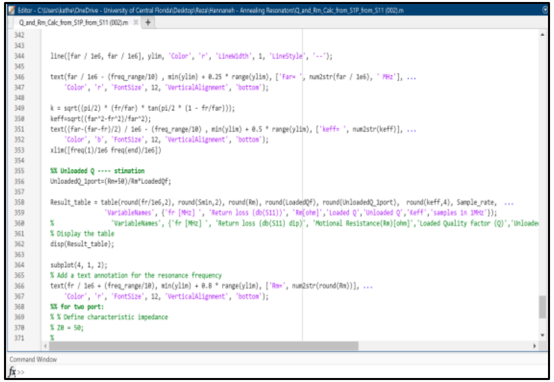
DML: Software

- Simulation:
  - COMSOL
- Fabrication:
  - K-layout
- Programming:
  - MATLAB
  - Python

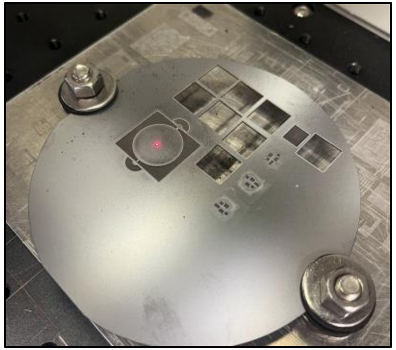




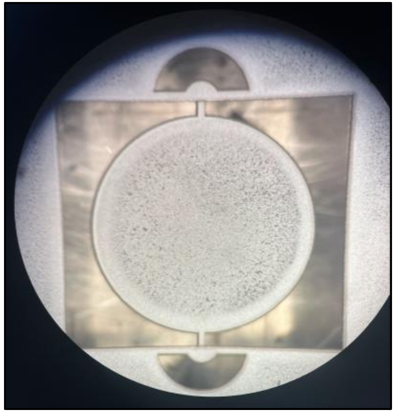


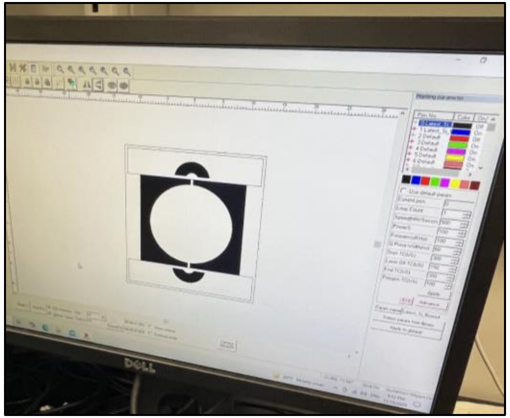


MEMS Fabrication: Laser Etching

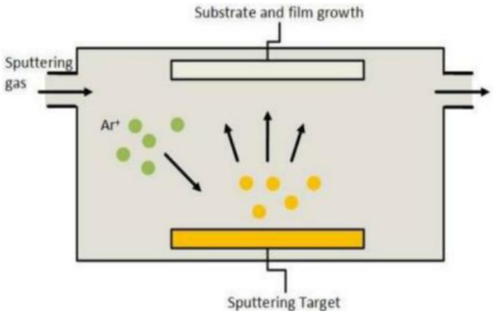


- Design masks to create intricate micro-scale structures.
- Focused laser beam with a specific recipe to precisely remove material from a wafer/surface.





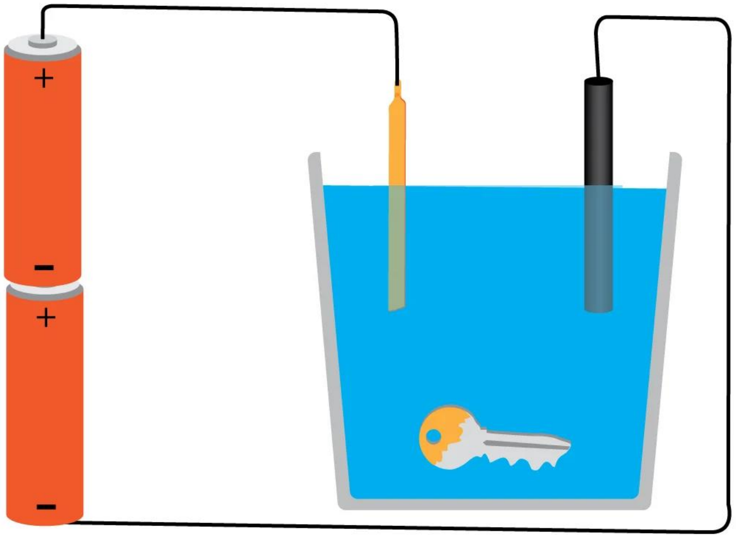
MEMS Fabri-geddon (Sputtering)



- RF Magnetron Sputtering System uses a vacuum chamber filled with a noble gas (argon) at a high voltage to accomplish deposition of a target material on to our substrate/device.

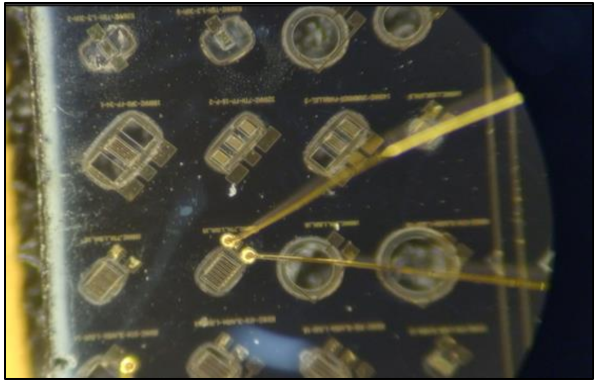
MEMS Fabrication: Electroplating

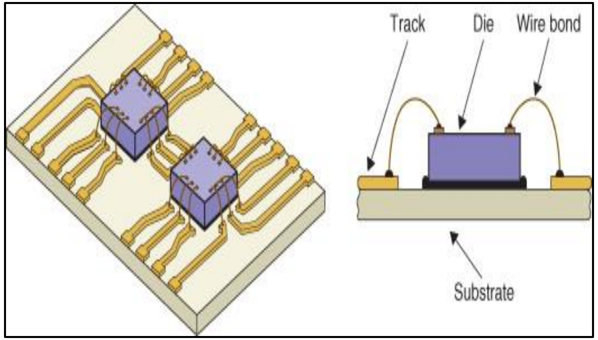
- We use an electrolyte solution (copper sulfate with water) that enables the transfer of copper ions to the surface of the MEMS device, as a solid metal coating, when an electric current is applied.



UCF

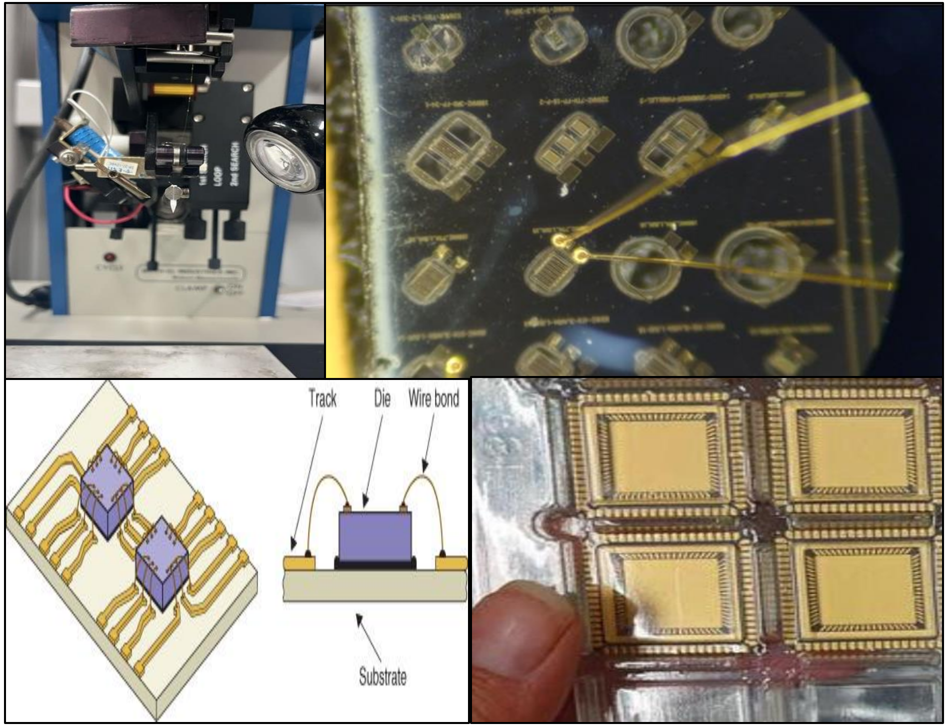
MEMS Wire Bonding





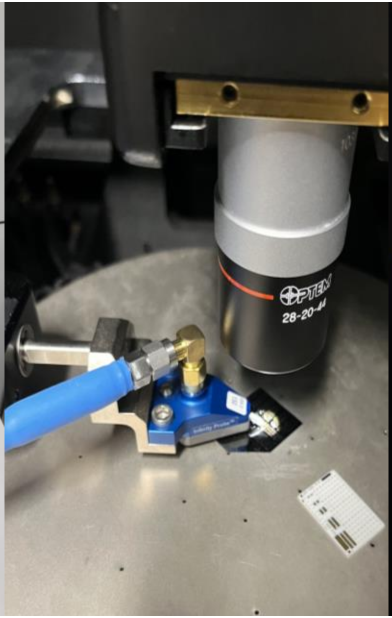
- Create physical and electrical connections between the pads of the MEMS die and the bonding pads on the substrate.
- Ensures device can communicate electrically with external circuits.

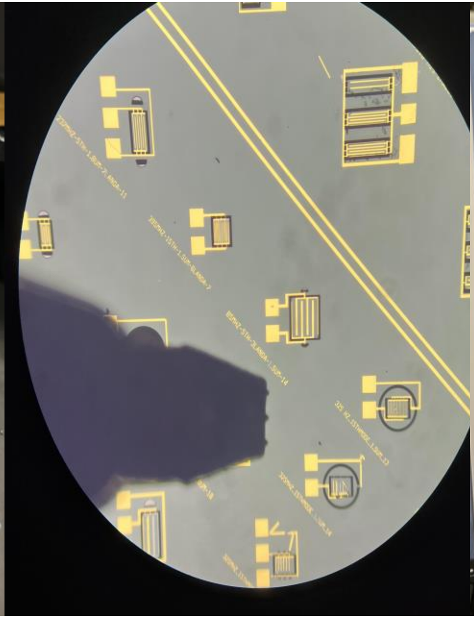
MEMS Wire Bonding & Packaging

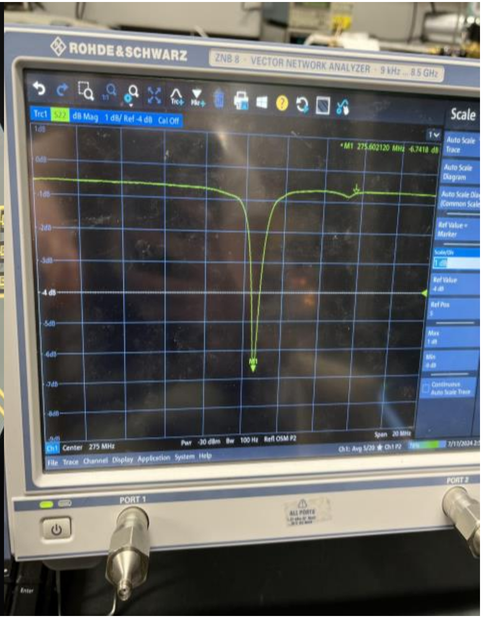


- Create physical and electrical connections between the pads of the MEMS die and the bonding pads on the substrate.
- Ensures device can communicate electrically with external circuits.

Characterization: Probing







Research Conferences

Questions?