DEVELOPMENT OF NEW MEASUREMENT CAPABILITIES BASED ON PHOTOEMISSION ELECTRON MICROSCOPY AND ELECTRICAL MEASUREMENTS
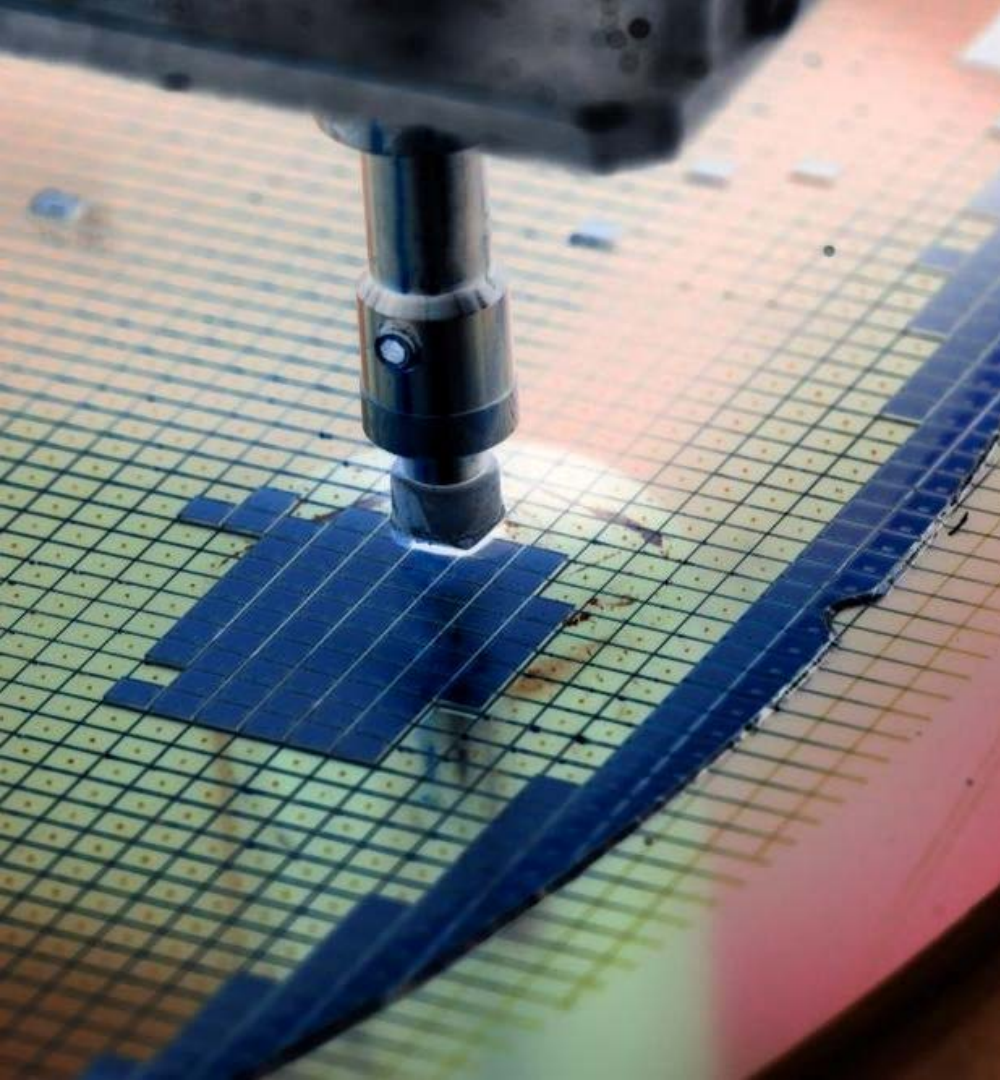
Div Chamria
Colgate University
Advisor: Dr. Sujitra Pookpanratana
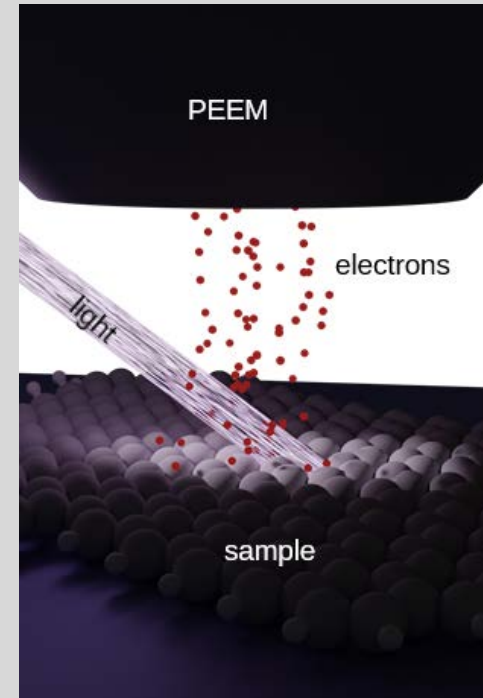Nanoscale Device Characterization Division, NIST

Motivation

- Semiconductors
- Measuring and standardizing electronic properties
- Enhancing capabilities of instruments

Methods of Sample Characterization

Camera

Micropositioner

Probe Tips

Credit: Niefind Falk

PEEM

light

electrons

sample
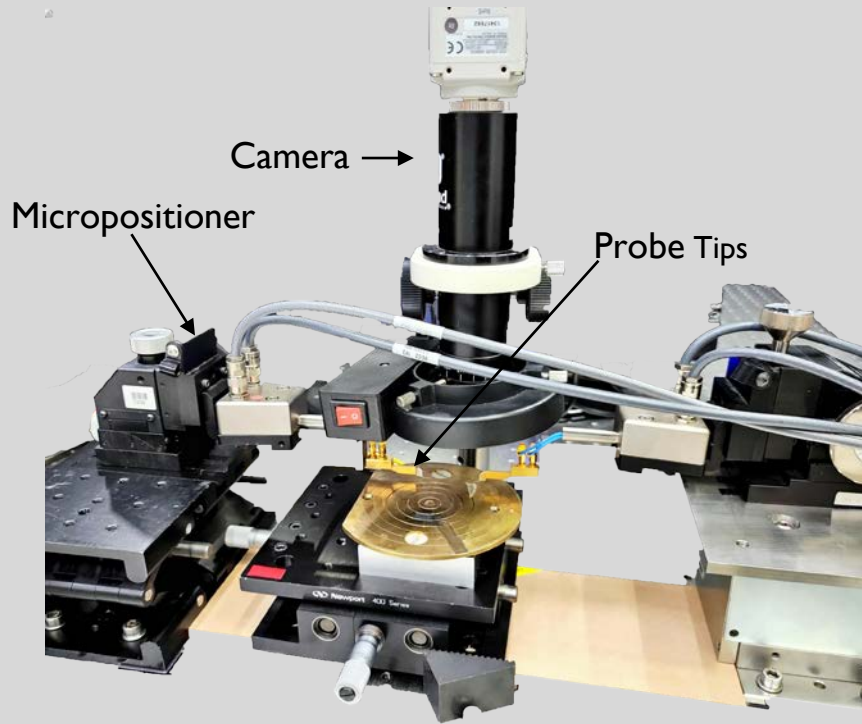
Electrical Measurements

Photoemission Electron Microscopy

The Instruments

Yokogawa 7651

DC Power Source – Outputs **voltage** or **current**

Keithley 6514

System Electrometer – Measures **current**, **voltage** and **resistance**

Agilent E4980

Precision LCR Meter – Sweeps through voltage/frequency while measuring **impedance**
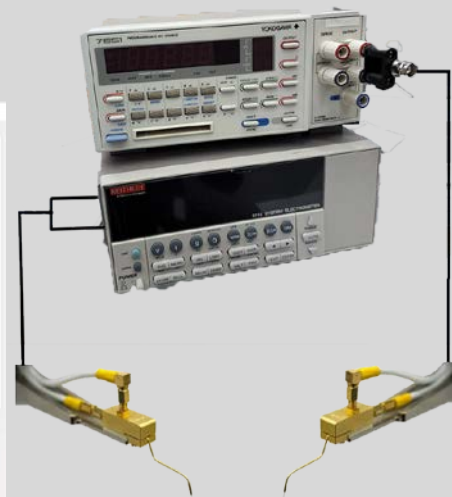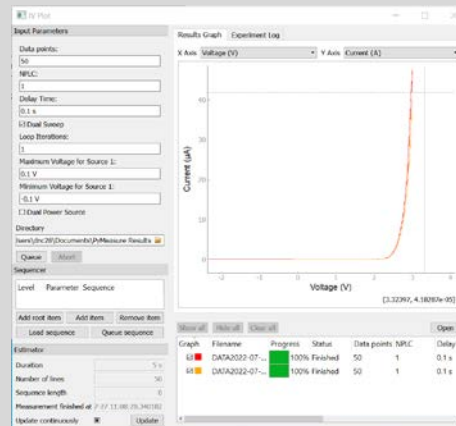
Source Measurement Unit

The work done

Adding instruments to Pymeasure
The instrument API is controlled using SCPI commands.

Adding functionality
The existing libraries were modified to add necessary functionality and controls to each instrument.

Adding a user interface
Python code was used to control instruments and add a graphical user interface.
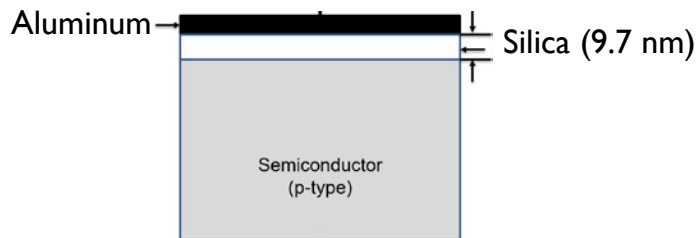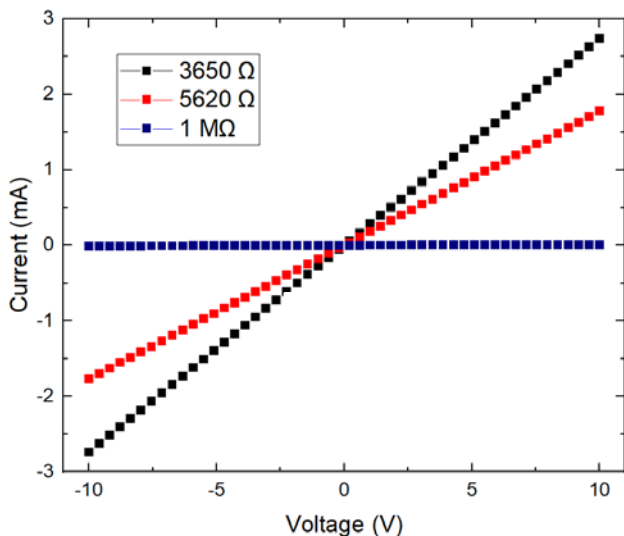
Testing!
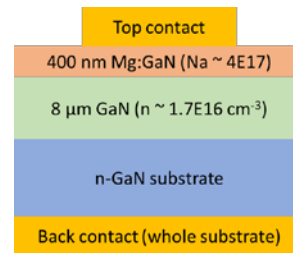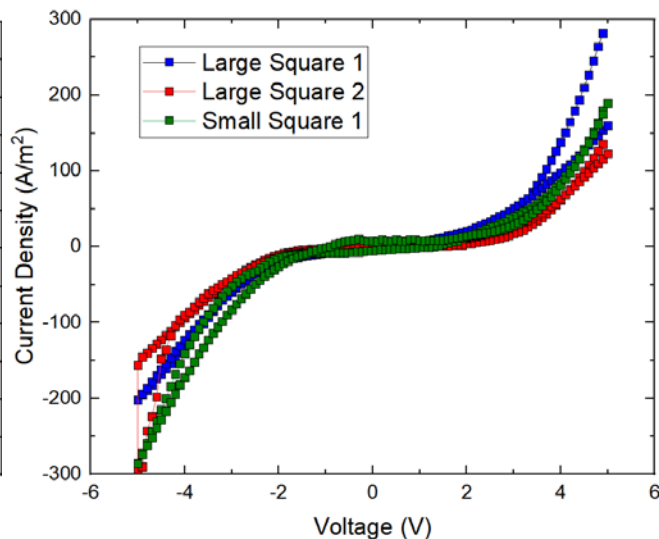The instruments were connected and tested with various devices to ensure reliability.

Source Measurement Unit Calibration

Commercial Resistors
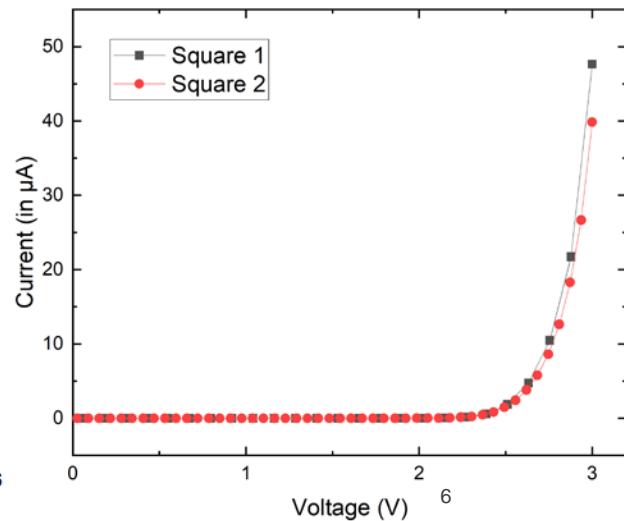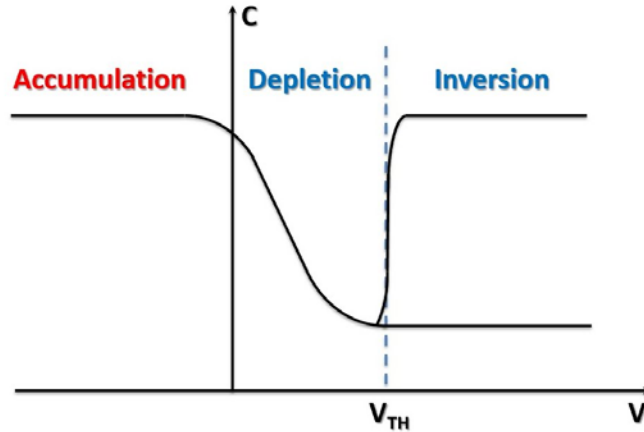

Aluminum → | Silica (9.7 nm)

Semiconductor (p-type)

MOS Device

Top contact
400 nm Mg:GaN (Na ~ 4E17)
8 µm GaN (n ~ 1.7E16 cm^{-3})
n-GaN substrate
Back contact (whole substrate)

GaN Diode

C-V Characteristics

Accumulation   Depletion   Inversion
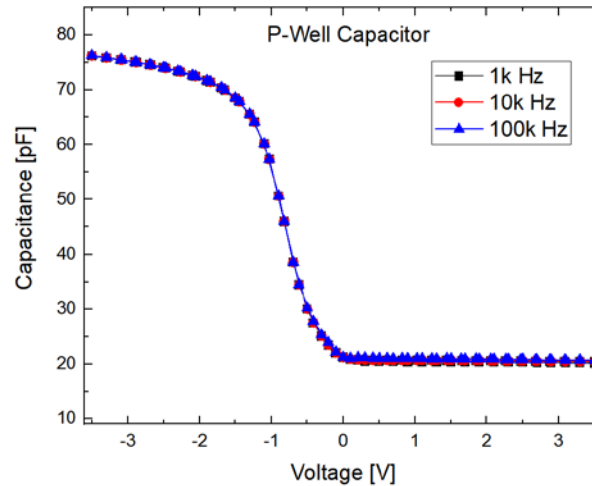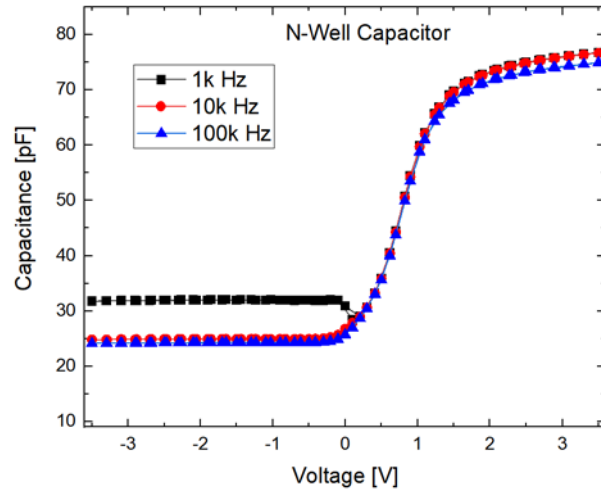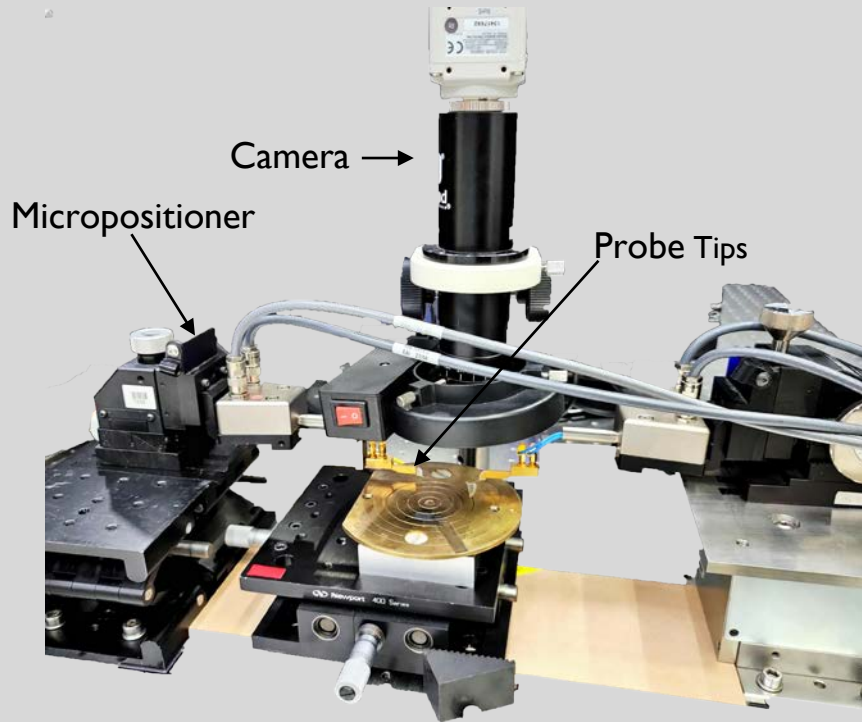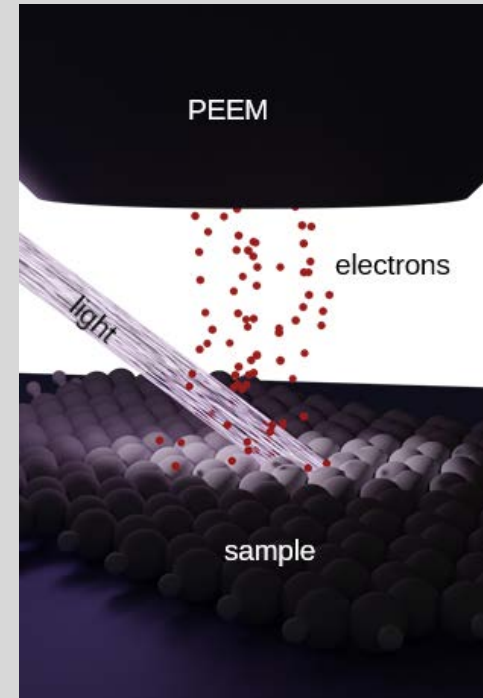
LCR Meter

- Performing CV measurements

- Expected depletion behavior

- Testing and Results

Methods of Sample Characterization
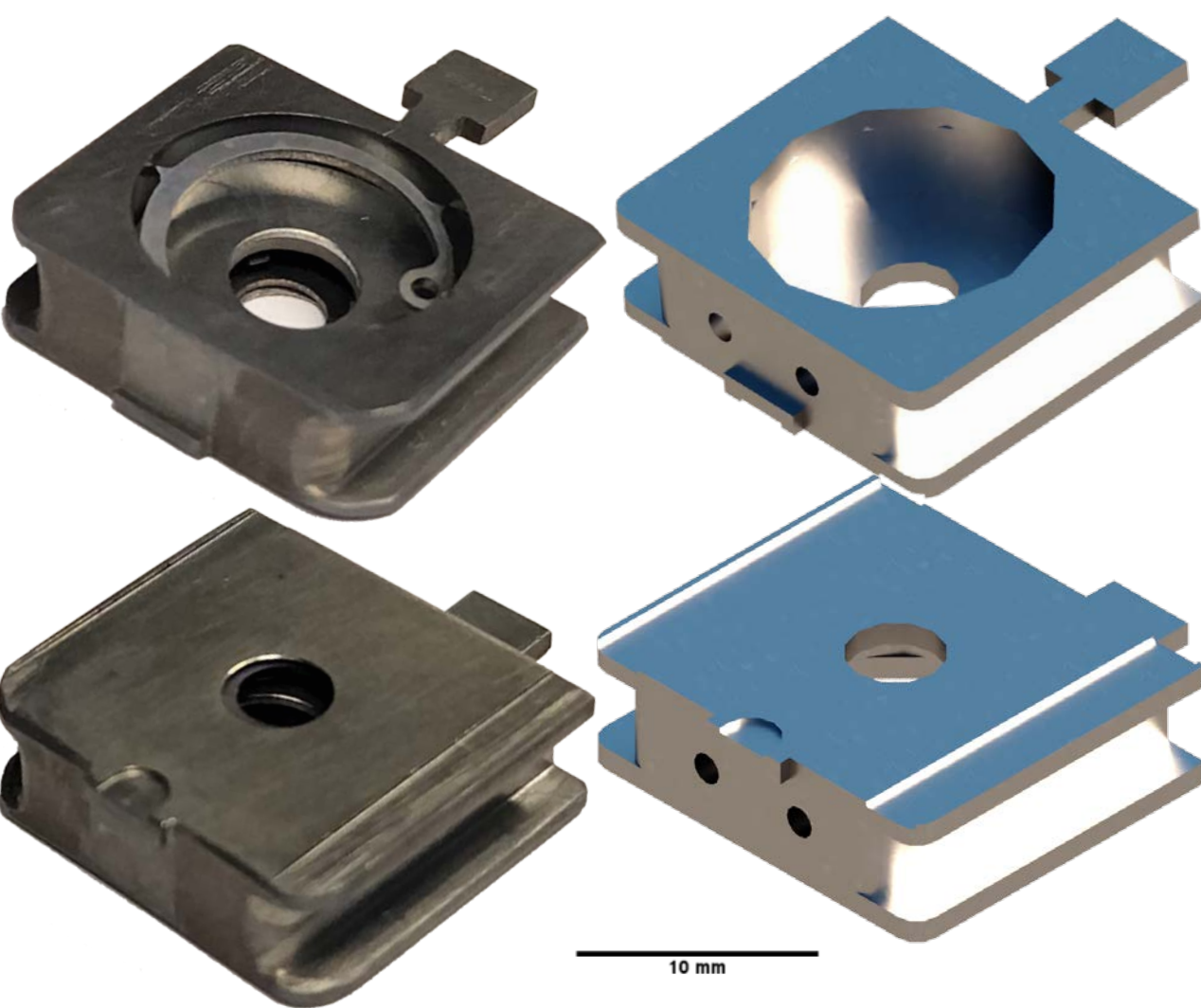

Camera

Micropositioner

Probe Tips

Credit: Niefind Falk

Electrical Measurements

Photoemission Electron Microscopy

PEEM – Sample Holder

- AutoCad

- 6 Separate Components

- PEEM Shuttle and Electrical Contact

- Operando Electrical Measurements

10 mm

Retaining Ring

Molybdenum Washer

Ceramic Washer

Spring Plate

Distance Washer

Sample

Sample Holder

10 mm

PEEM – Sample Holder

- AutoCad

- 6 Separate Components

- PEEM Shuttle and Electrical Contact

- Operando Electrical Measurements

10 mm

Sample H ———— 10 mm

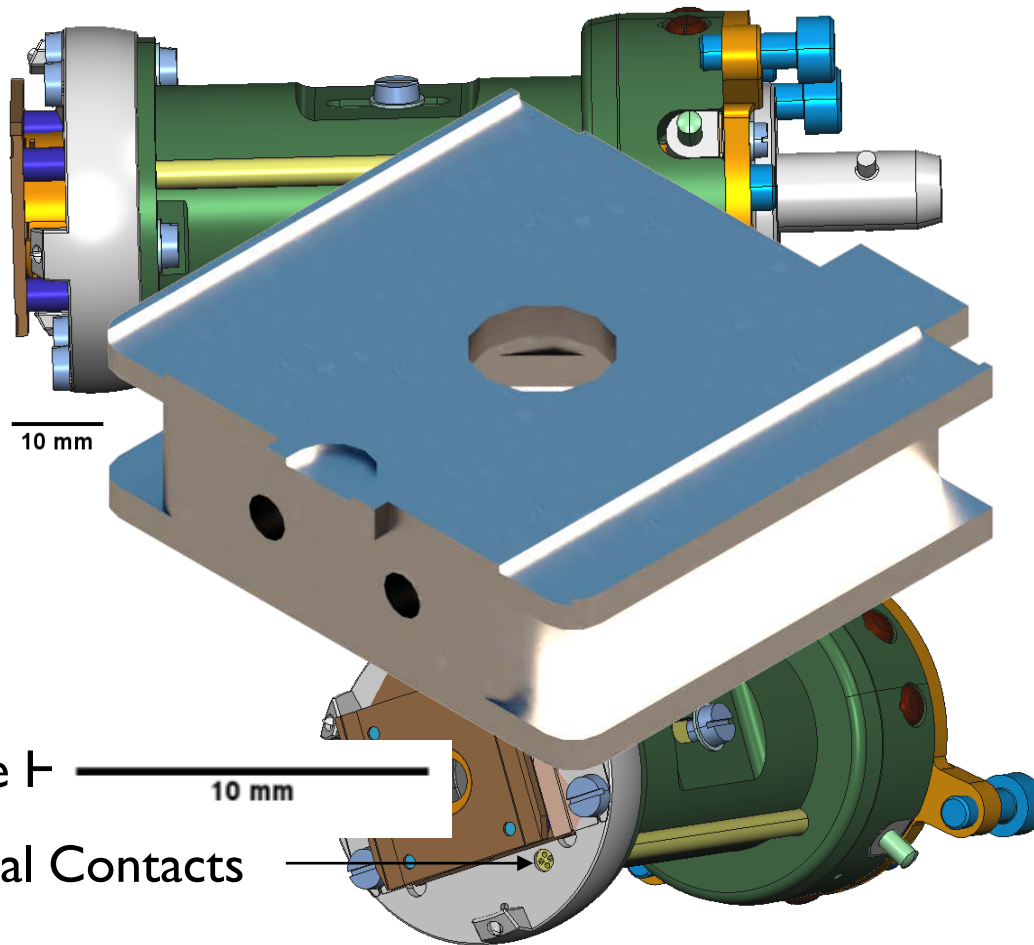Electrical Contacts ⟶

PEEM – Sample Holder

- AutoCad
- 6 Separate Components
- PEEM Shuttle and Electrical Contact
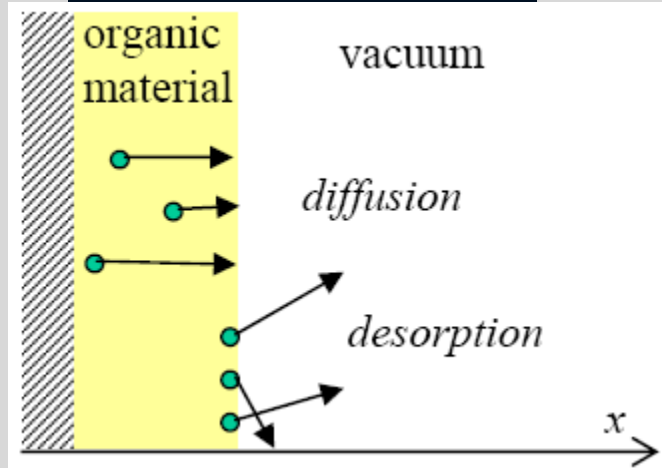- Operando Electrical Measurements
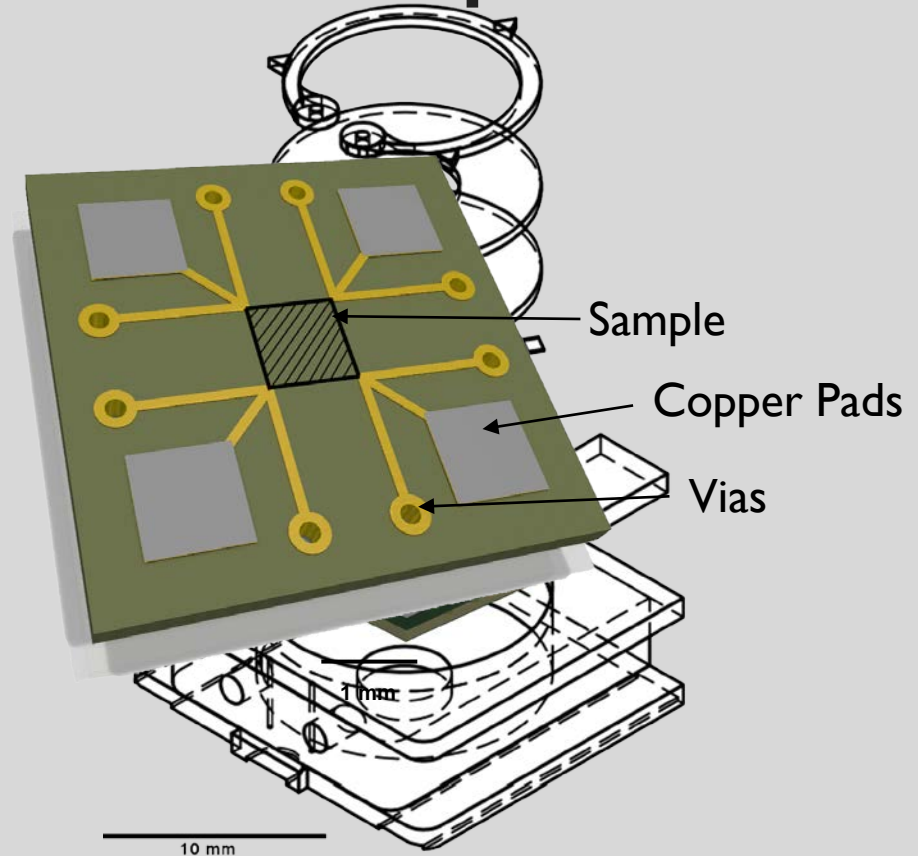
PEEM Shuttle designs provided by manufacturer
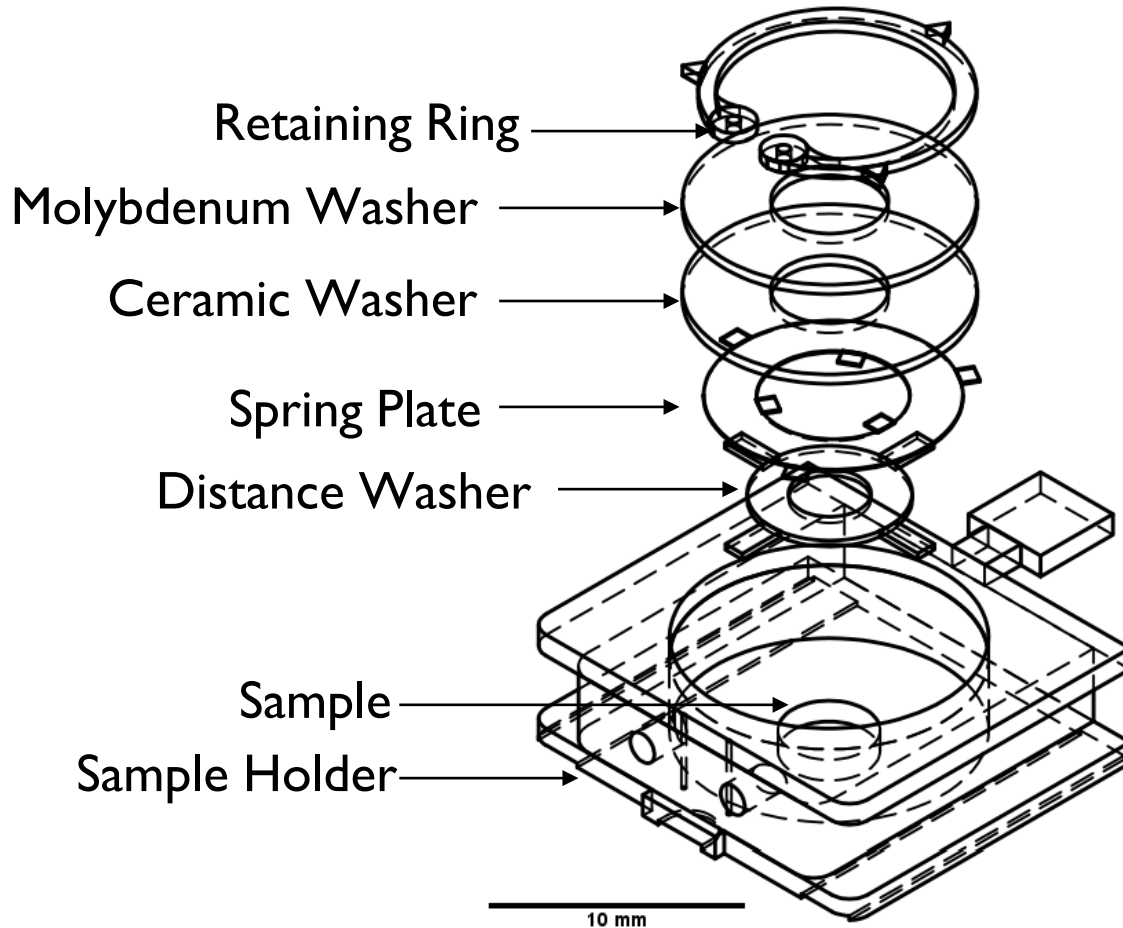
Printed Circuit Board for Sample Holder

○ Purpose

○ Symmetrical

○ Ultra High Vacuum compatible materials

○ Designed for sample holder

Sample

Copper Pads

Vias

1 mm

10 mm

Roussel et al., 2009 Schematic

Summary

- Got 3 instruments working with the probe station
- Added documentation to code to make it easier to use and modify as needed
- Modelled and modified PEEM sample holder
- Modelled and designed PCB for sample holder

Future Work

- Adding more functionality to instruments
- Using similar code to add support for more instruments
- Manufacturing the sample holder and PCB
- Testing the PEEM and the electrical contacts
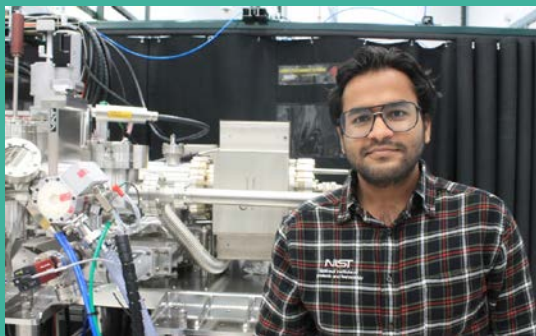
Citations

- Roussel, J-F, Faye, D., et al., "A new frontier for contamination: reaching the molecules", ISME, 2009.
- Using Nitrogen Gas in the Semiconductor Manufacturing Process | GENERON. (2020). Retrieved from https://www.generon.com/using-nitrogen-gas-in-semiconductor-manufacturing-process/.
- Pymeasure. *Pymeasure: Scientific Measurement Library for instruments, experiments, and live-plotting*. GitHub. from https://github.com/pymeasure/pymeasure

Acknowledgements

Contact Information

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Feel free to ask questions!