# Demonstration and Characterization of High-Resolution 4H-SiC Schottky Diode Alpha Particle Detectors at High Temperature

Jarod Remy

The Ohio State University

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**Objective:** Demonstrate and characterize Schottky diode radiation detectors fabricated on 4H-SiC at high temperatures.

**Completed Tasks:**

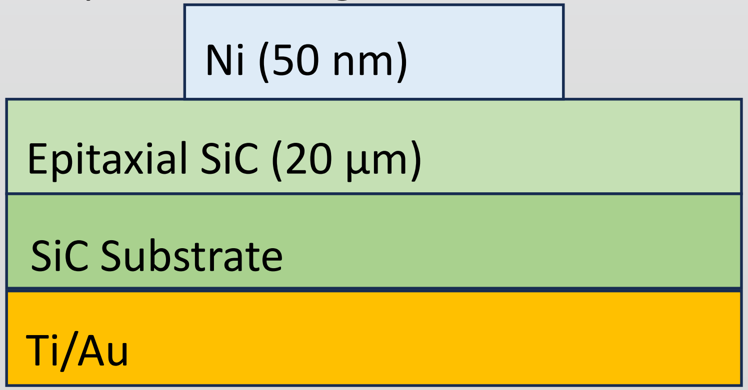
- Fabricated Schottky diodes on 4H-SiC
- Measured electronic performance up to 500 °C
- Determined detector characteristics up to 500 °C
- Demonstrated high-resolution alpha particle spectroscopy at room temperature
- Measured room temperature detector characteristics and spectroscopy capabilities prior to heating up to 400 °C

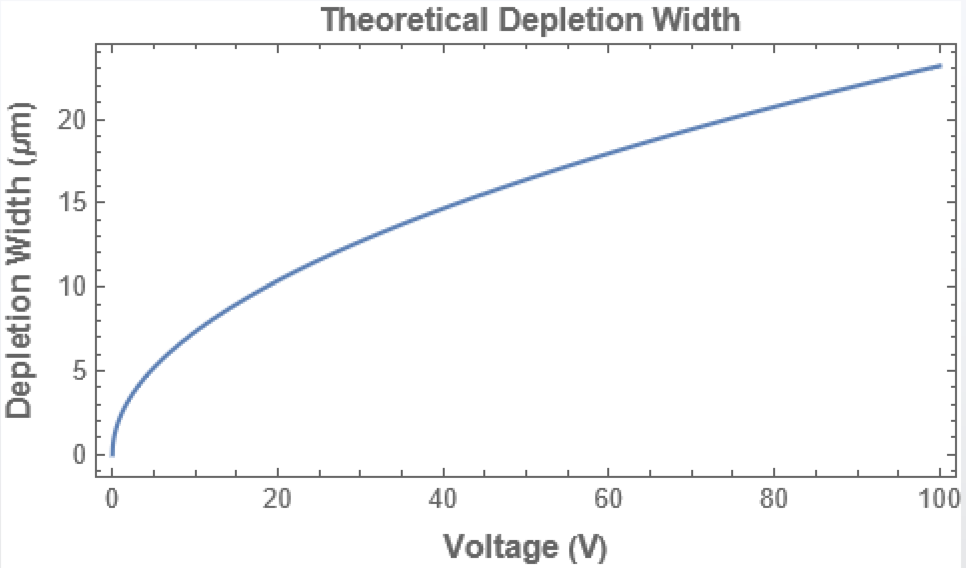
# Fabricated 4H-SiC Schottky Diodes

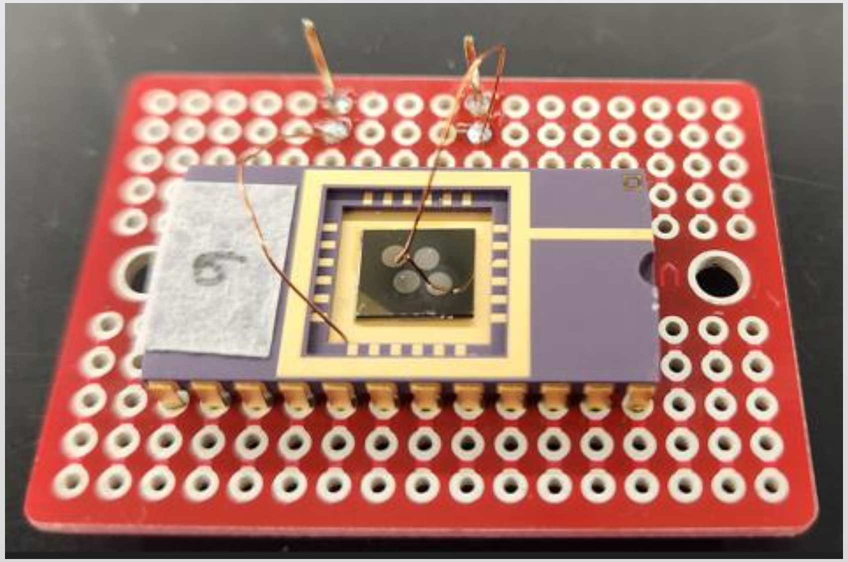
**Silicon Carbide Epitaxial Layer:**
- Thickness: 20 µm
- Doping Concentration: $2.4 \times 10^{14}$ $cm^{-3}$
- Dopant: Nitrogen

**Contacts:**
- Schottky Contact: 50 nm Nickel
- Contact Area: 2 $mm^2$
- Ohmic Contact – 50 nm Titanium/Gold Stack

**Device Characteristics:**
- Theoretical Schottky barrier height: 1.91 eV
- Theoretical Full Depletion Voltage: 75 V



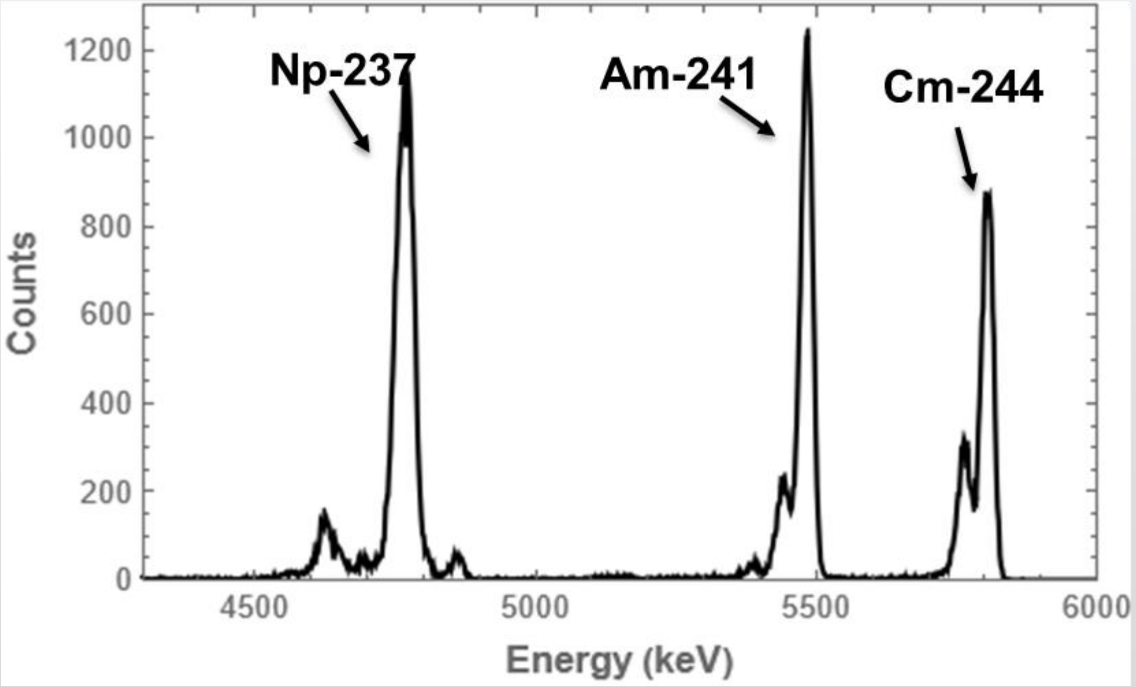



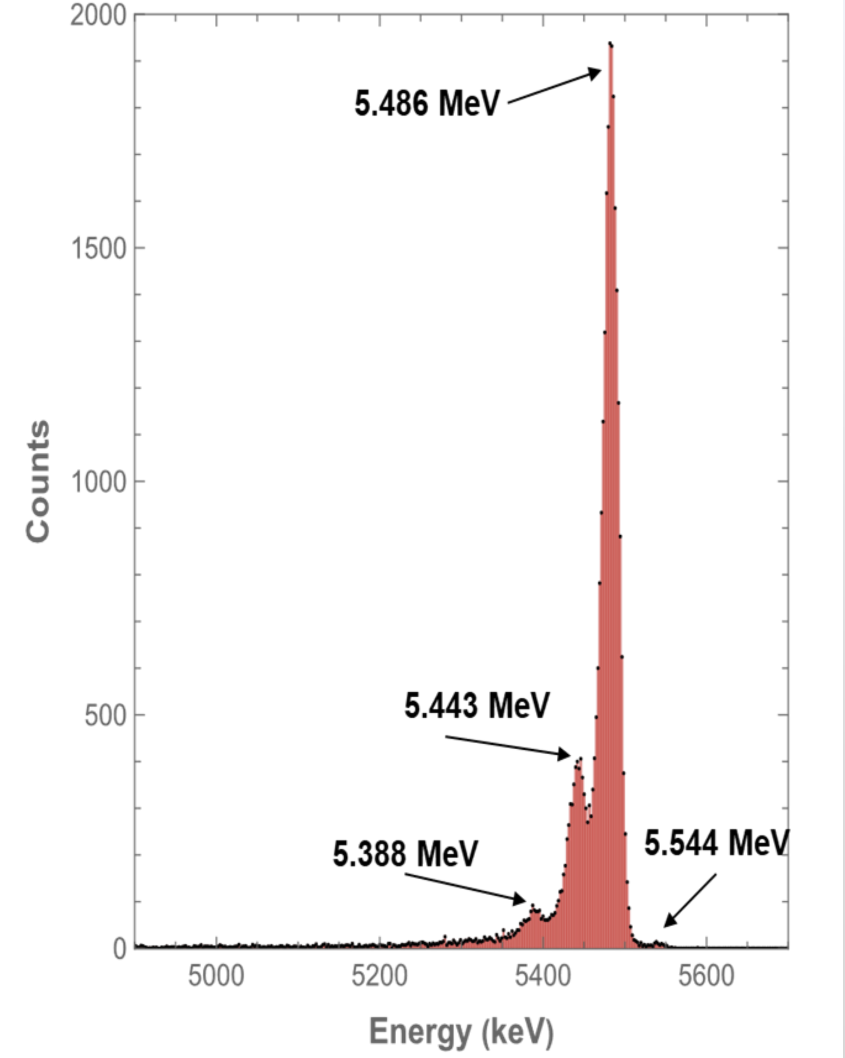
# Spectroscopy Capabilities:

- We have fabricated high resolution 4H-SiC Schottky diode radiation detectors:
  - Am-241 – 5.486 MeV peak FWHM: 21 keV (0.38%)

Triple Alpha Spectra Acquired by SiC at 60 V




High Resolution Alpha Spectra Acquired by SiC

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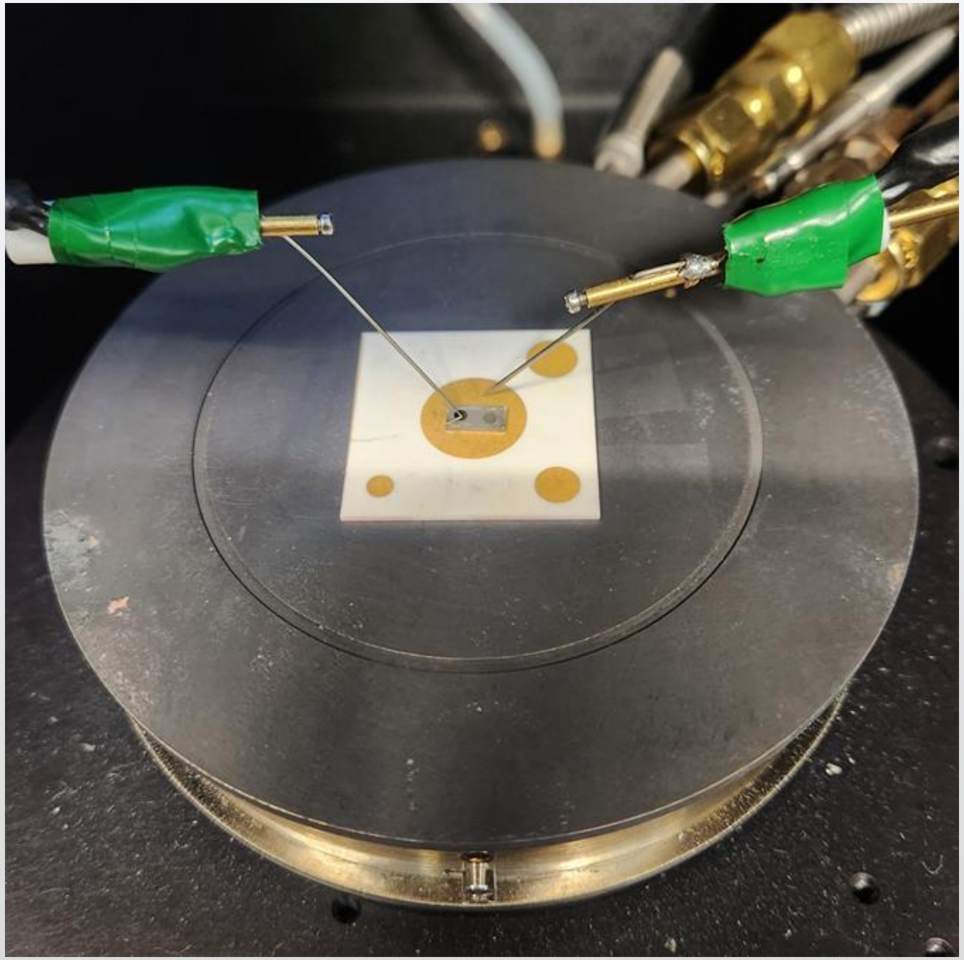
# High Temperature Electronic Characterization

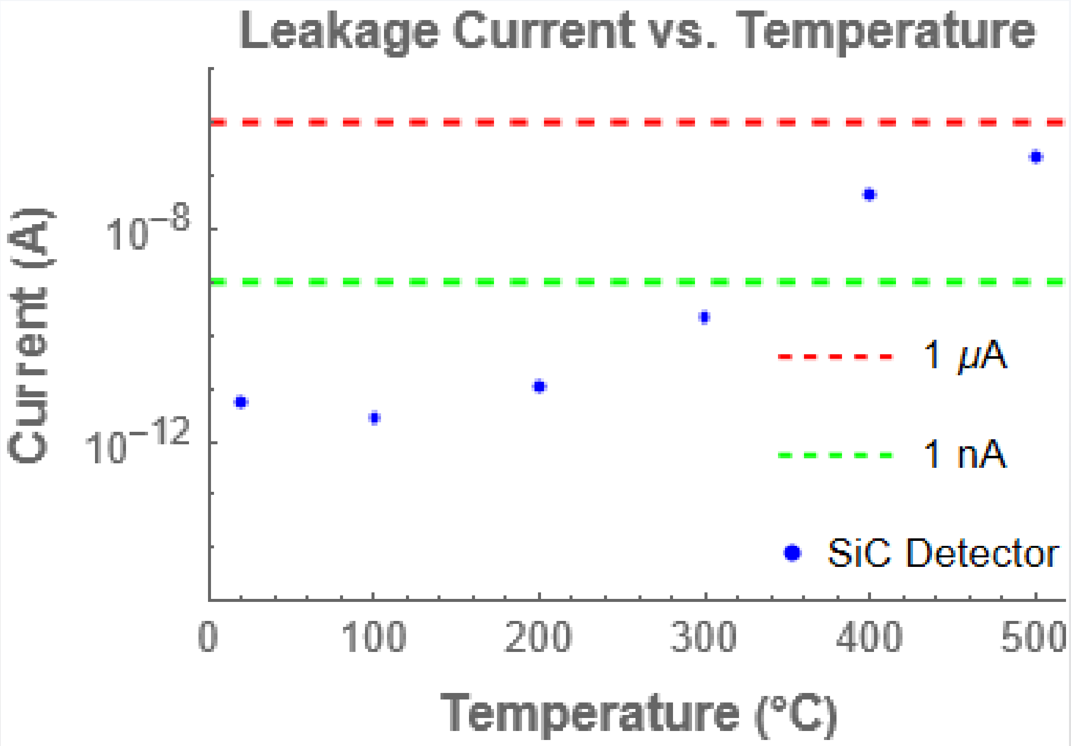


- Signatone High Temperature hot chuck in dark box electronic probe station
- Heating capability up to 500 °C

- 4H-SiC Schottky diodes are electronically characterized up to 500 °C at 100 °C increments
- Electronic characterization includes:
  - Current-Voltage sweeps
  - Capacitance-Voltage sweeps
  - Current vs Time at 60 V reverse bias

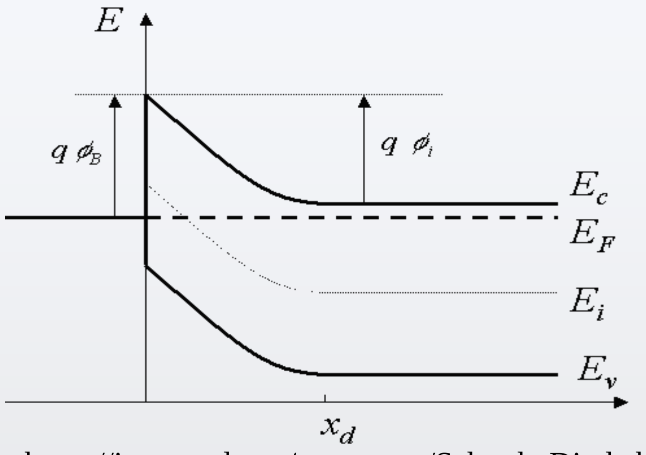
# High Temperature Electronic Characterization

- Leakage current should remain below 1 µA to obtain spectroscopy
- Leakage current should remain below 1 nA to obtain high-resolution spectroscopy

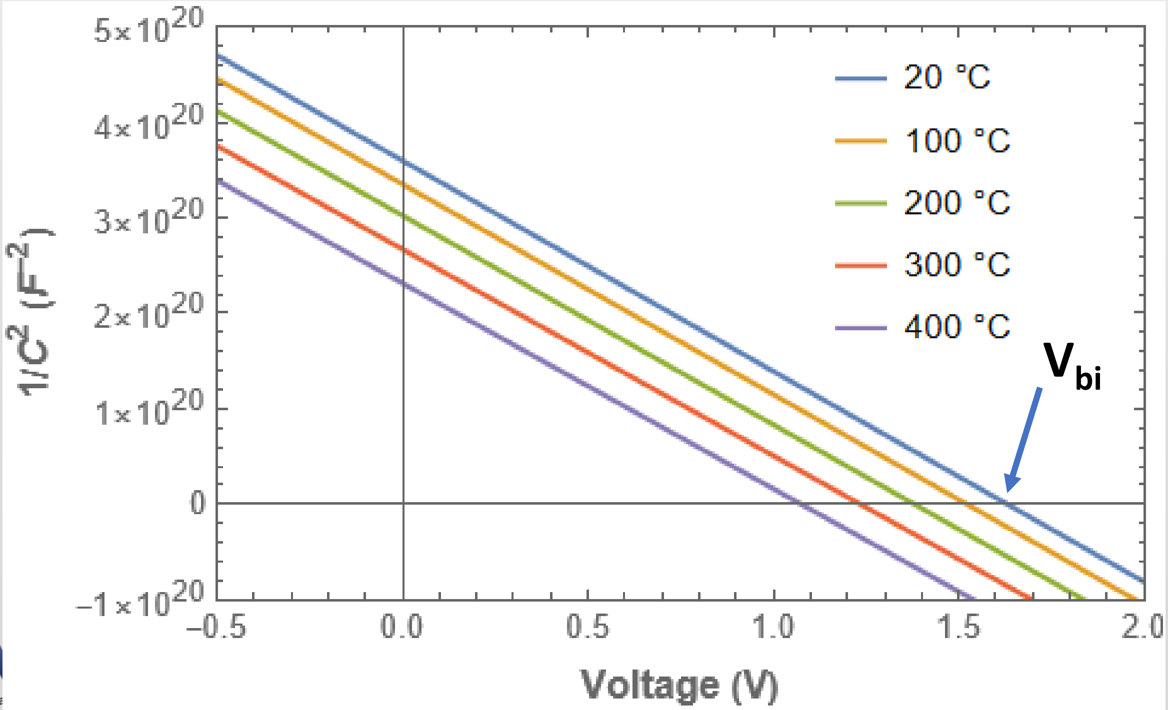


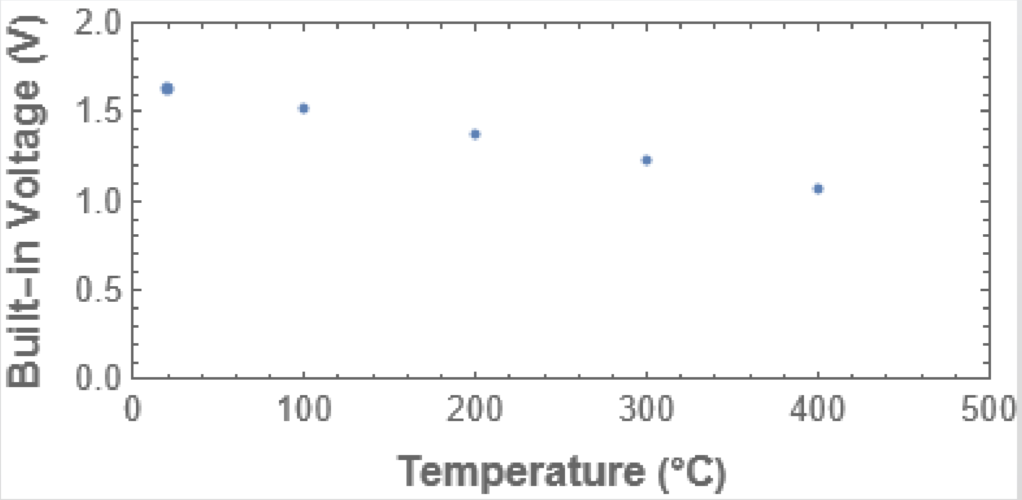
# High Temperature Electronic Characterization

- The built in voltage can be extracted from the inverse capacitance squared by extrapolation
- As the temperature increases the Fermi level of the SiC increases resulting in a lowering of the barrier height




https://in.ncu.edu.tw/ncume_ee/SchottkyDiode.htm



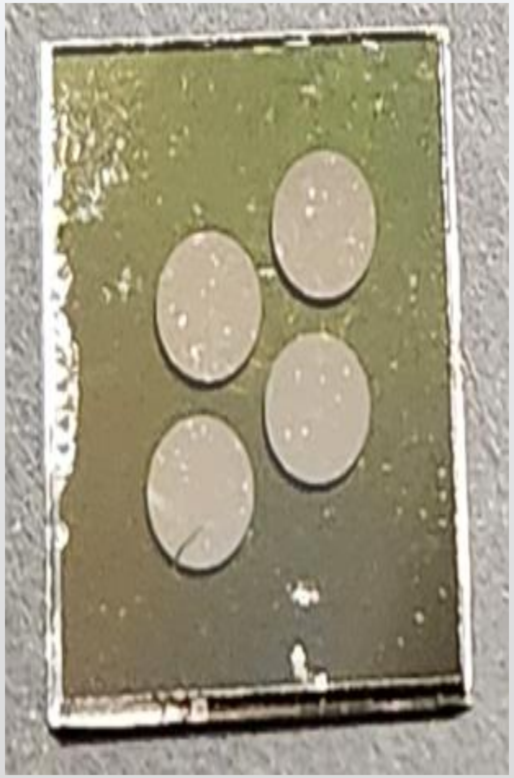



# Post-Heating:

Ti/Au Ohmic Contact:

Ni Schottky Contact:

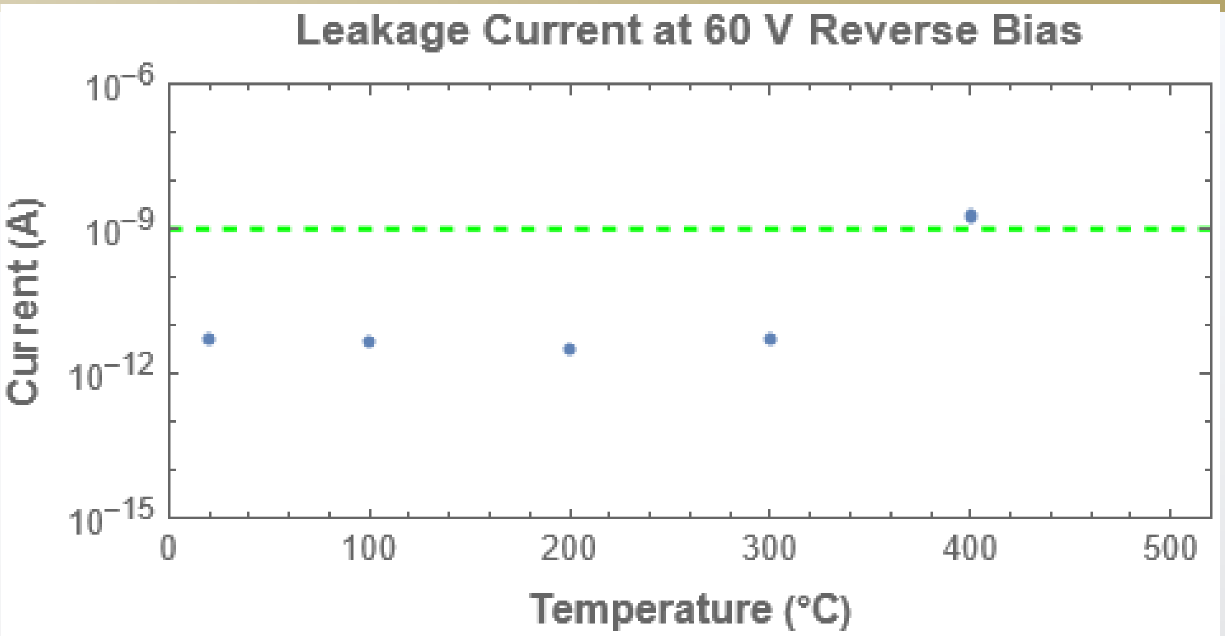
500 °C

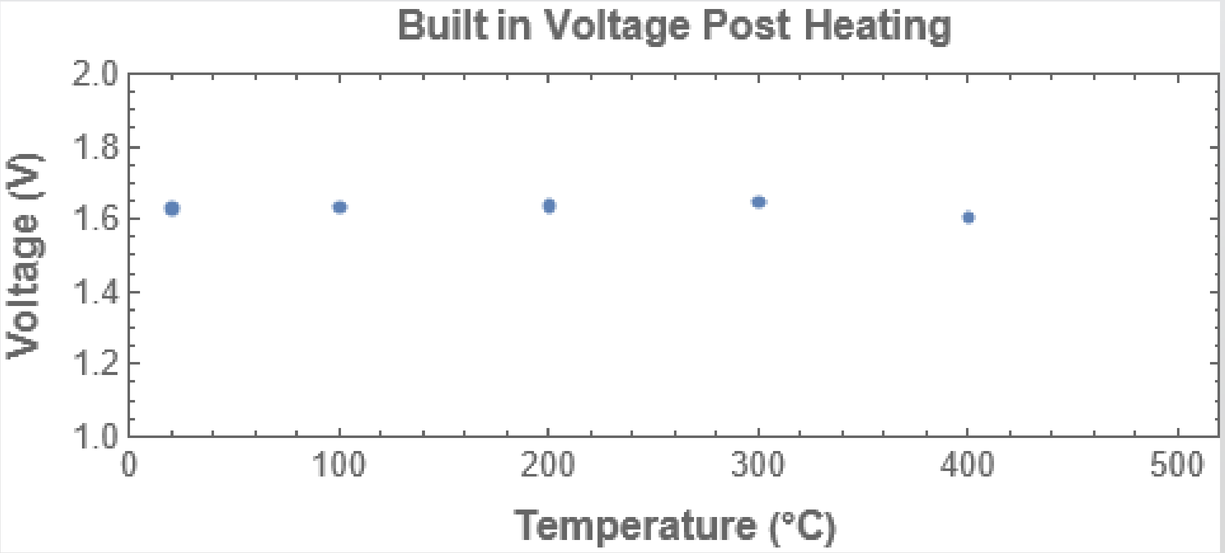


500 °C

# Electronic Characteristics Post-Heating

- Severe degradation of the nickel Schottky contact has occurred prior to heating at 500 °C
- Room temperature leakage current at 60 V reverse bias remains around 10 pA up to 300 °C heating and increases to 1 nA following 400 °C heating
- Built-in voltage at room temperature remains constant prior to heating up to 400 °C

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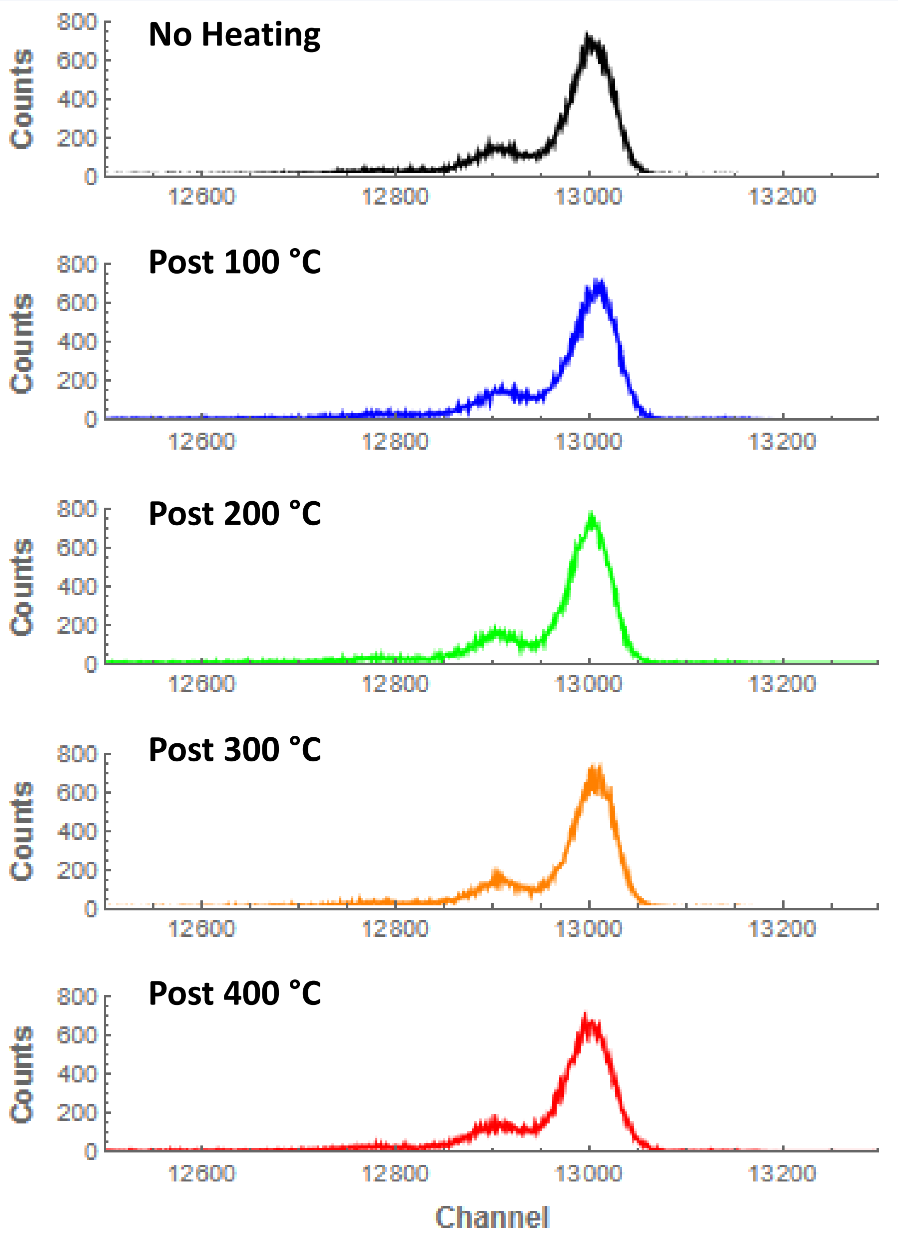
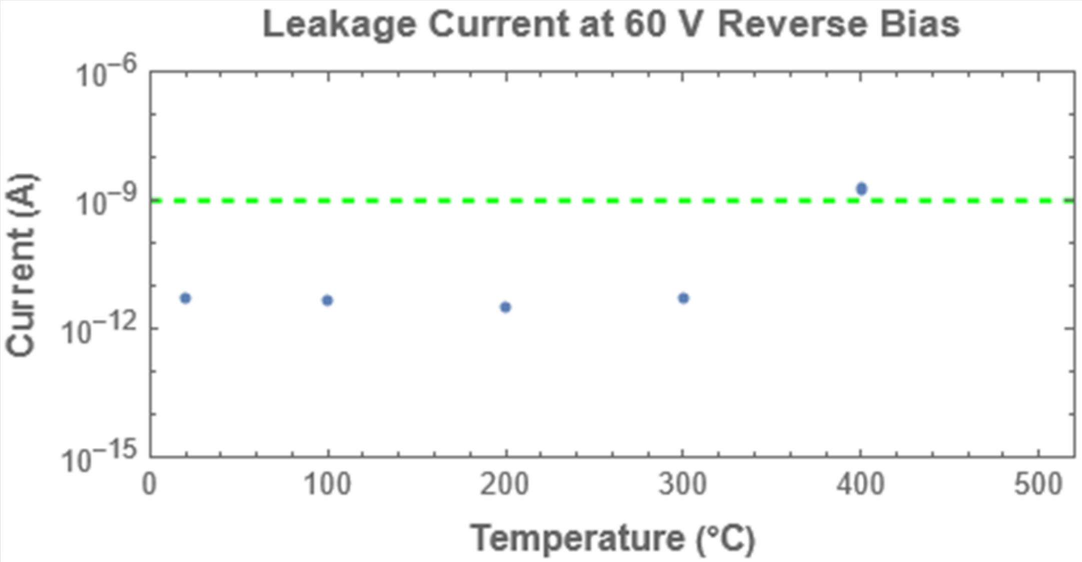
# Post-Heating Spectroscopy

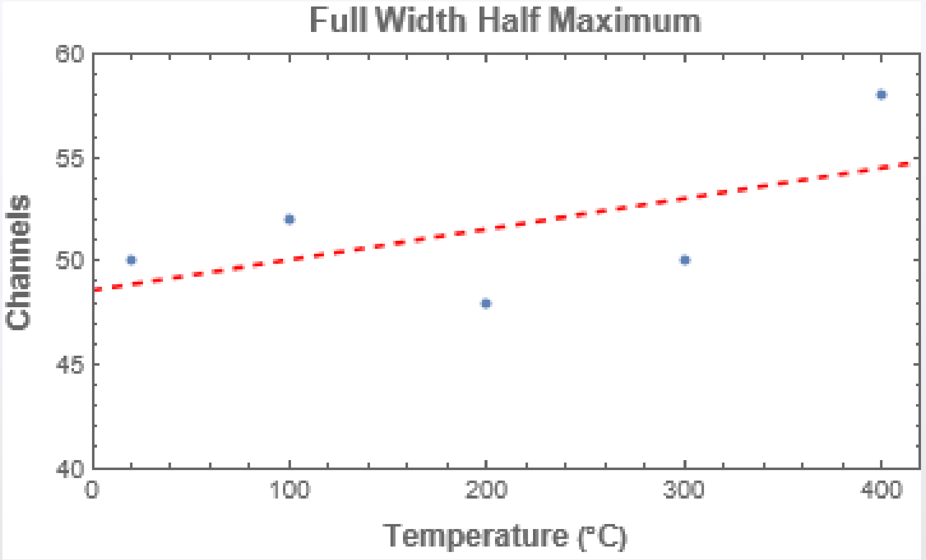


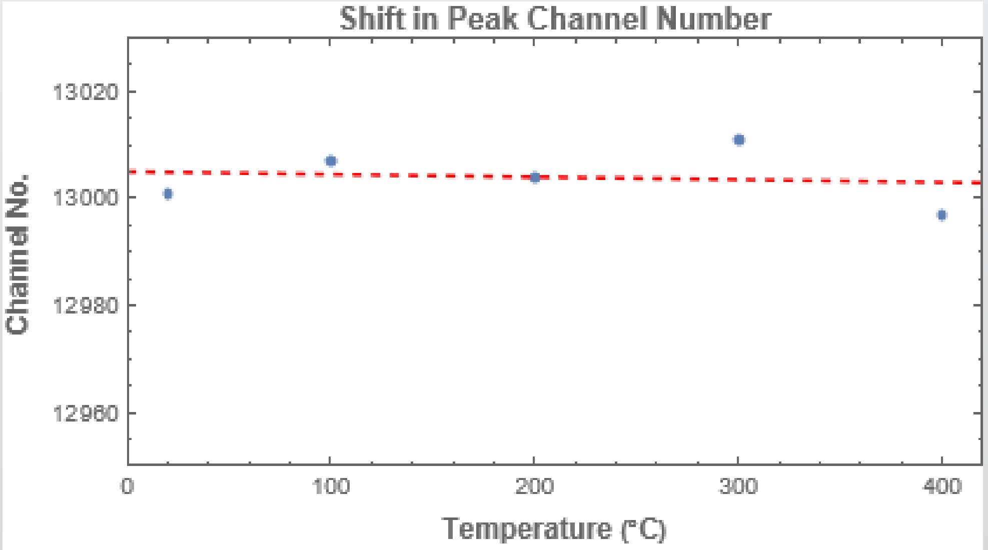

- Despite the increase in leakage current at 60 V after 400 °C heating, minimal loss in resolution has occurred

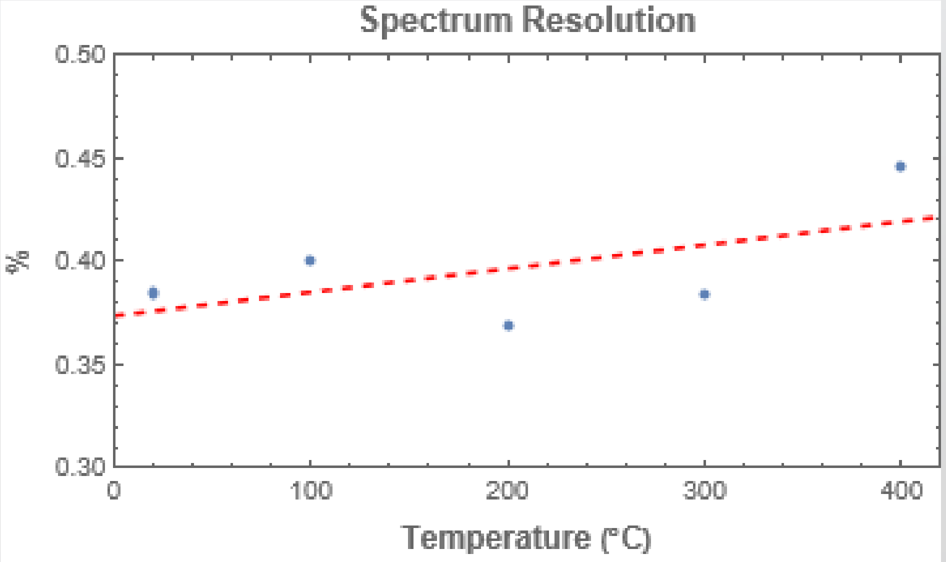


# Post-Heating Spectroscopy Data

- Centroid peak channel remains within 10 channels
- FWHM increase from 50 channels before heating to 58 channels post 400 °C heating
- Resolution increases from 0.385% to 0.446% post 400 °C heating

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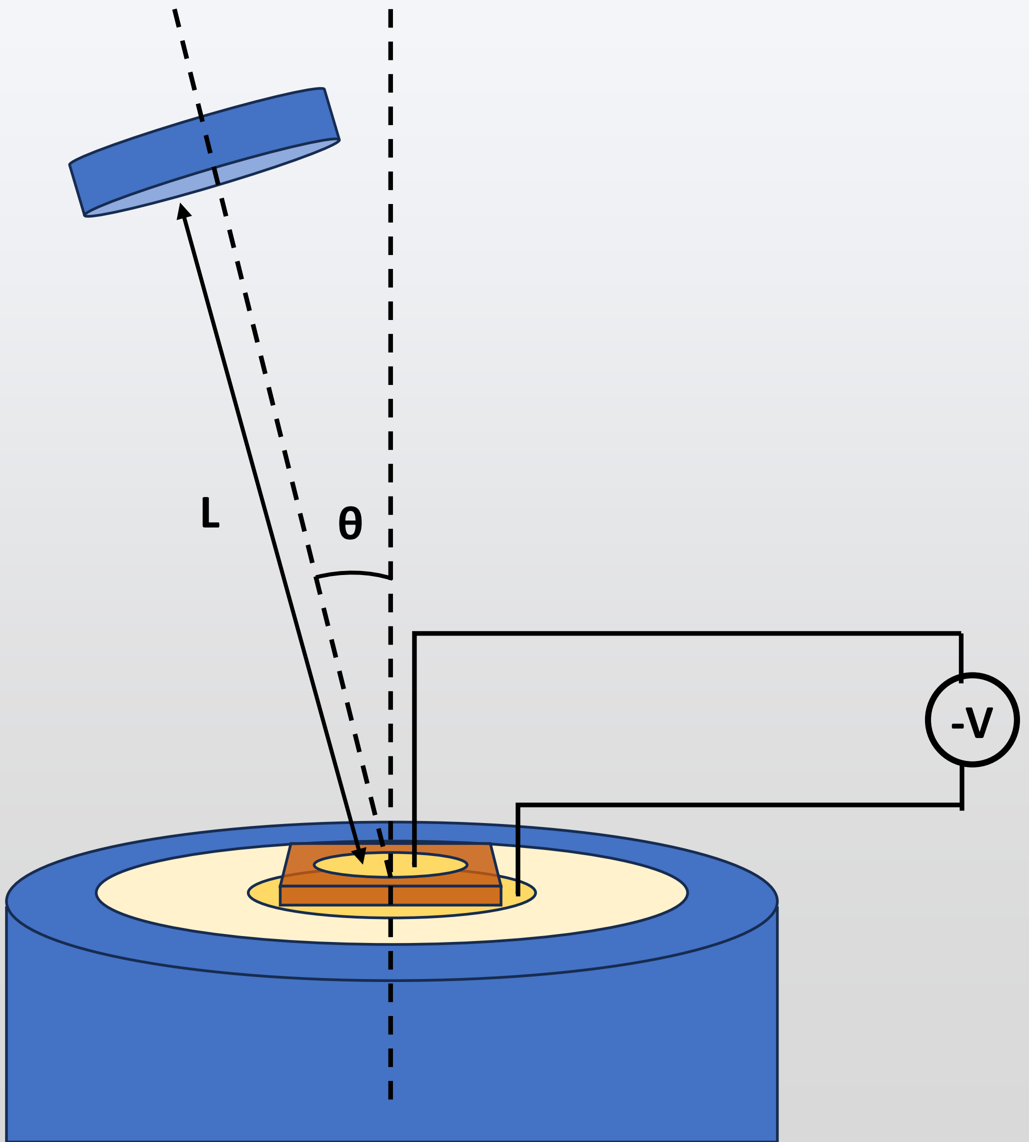
# Conclusions

- ❑Devices as fabricated show electronic stability up to 300 °C
- ❑Room temperature spectroscopy remains relatively unchanged post heating up to 400 °C
- ❑Contact degradation at 500 °C needs to be investigated
- ❑Leakage current at elevated temperatures need to be reduced
  - ❑Passivation layers, guard rings, etc.
- ❑A more robust Schottky contact will be necessary for operation at temperatures exceeding 500 °C

# High Temperature Spectroscopy Station

## Design Criteria:

- ❑ High temperature 1” sample heater
  Max Temp.: 800 – 1000 °C
- ❑ Isolated sample platform to minimize electronic noise
- ❑ Variable source mounting fixture
- ❑ Vacuum chamber environment
- ❑ Low noise high-voltage feed though to power and interface with detector

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# ACKNOWLEDGEMENTS

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