

The Consortium for Enabling Technologies and Innovation

# *Virtual Summer Meeting for Young Researchers*

## **Carbon Nanotubes as an Ionizing Radiation Sensor**

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# Bio



**Arith Rajapakse** is a 3<sup>rd</sup> year PhD student researching the use of nanomaterials for radiation detection under Dr. Anna Erickson.

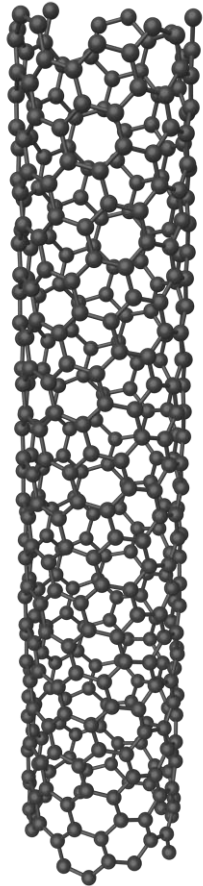
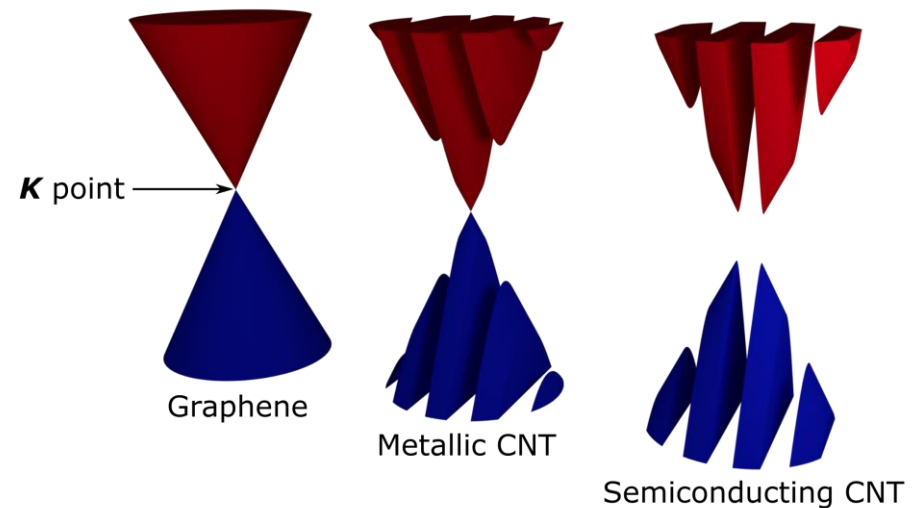
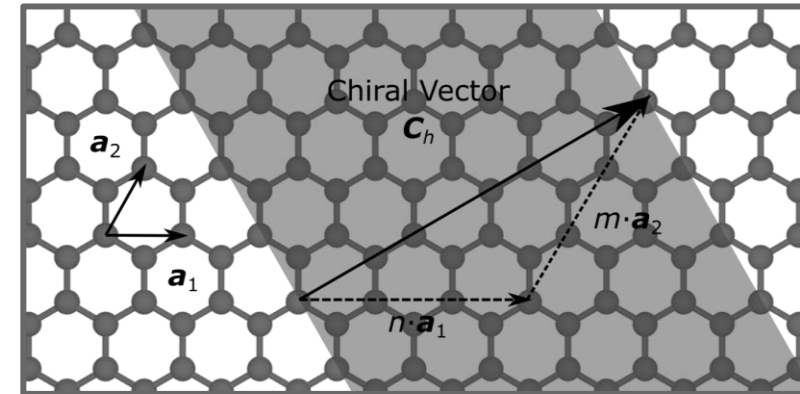
Before coming to Georgia Tech, he earned his B.S in physics from UC Irvine and his M.S. in physics from Cal State Long Beach. His previous research focused on the synthesis of carbon nanotubes (CNTs) and the fabrication of CNT based transistors.

# Outline

- Motivation and Background
- Device Features
- Fabrication
- Operation
- Current Work
- Future Work

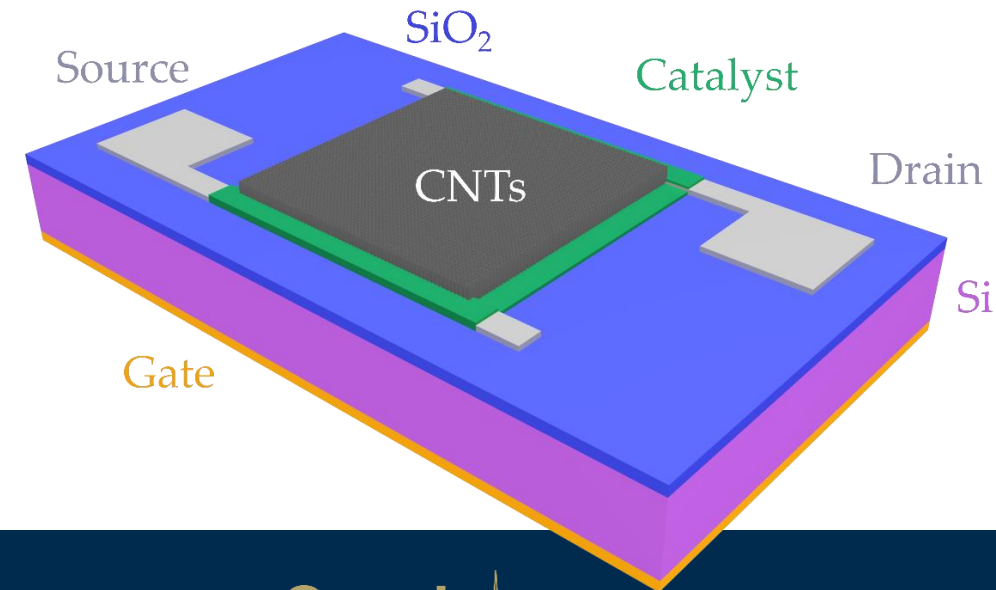
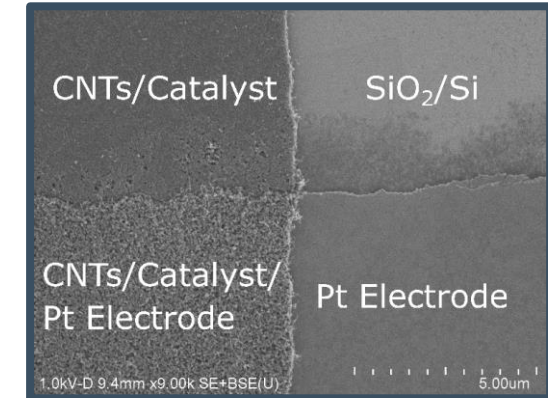
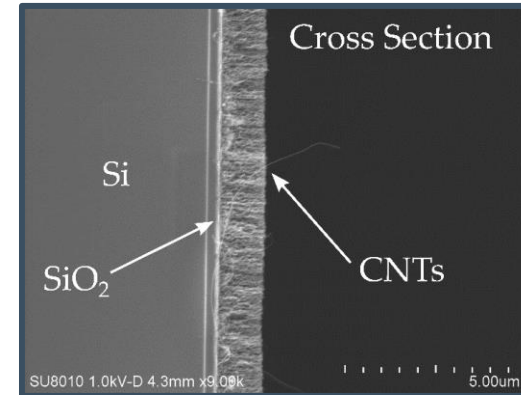
# Carbon Nanotubes

- “Possible successor to silicon”
- Nanostructured material
  - Sheet of graphene rolled into a cylinder
  - Semiconducting or metallic based diameter and chirality
    - $d = \frac{a_0}{\pi} \sqrt{n^2 + m^2 + nm}$ 
      - if  $n = m$ , then the CNT is metallic
      - if  $n - m$  is a multiple of 3 and  $n \neq m$  and  $nm \neq 0$ , then the CNT is quasi-metallic with a small band gap
      - otherwise the CNT is semiconducting
- Semiconducting CNTs are sensitive to external electric fields
  - Changes Fermi Energy  $E_F$  and therefore DOS
  - Also modifies Schottky barrier in FETs

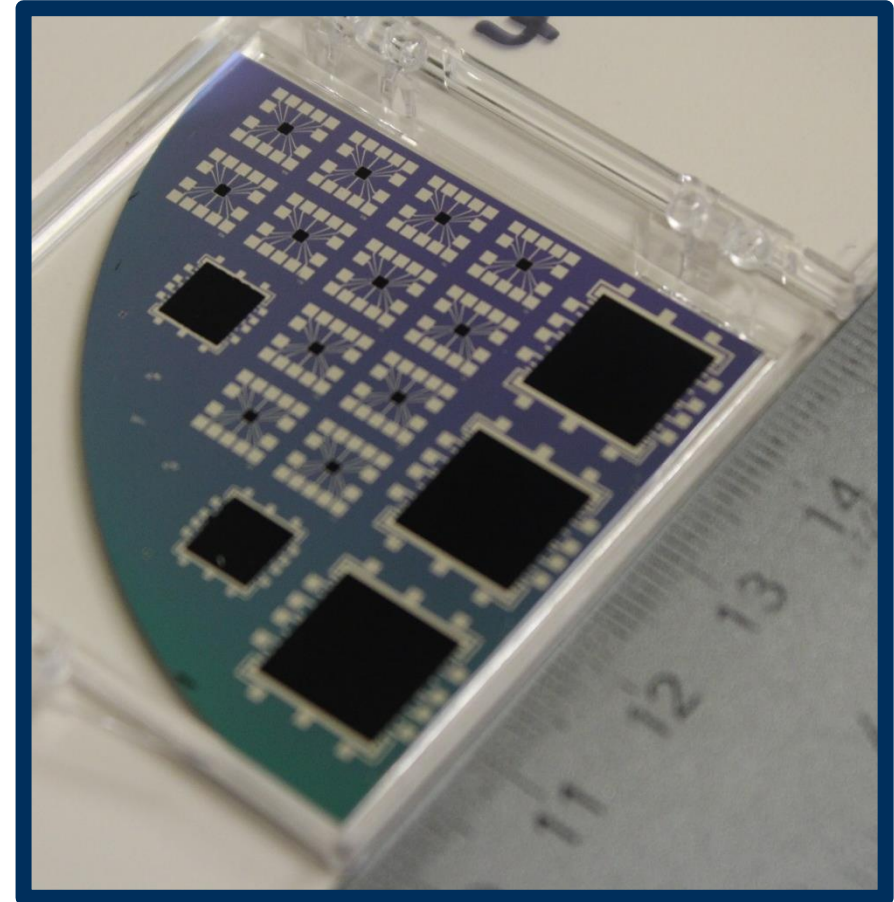
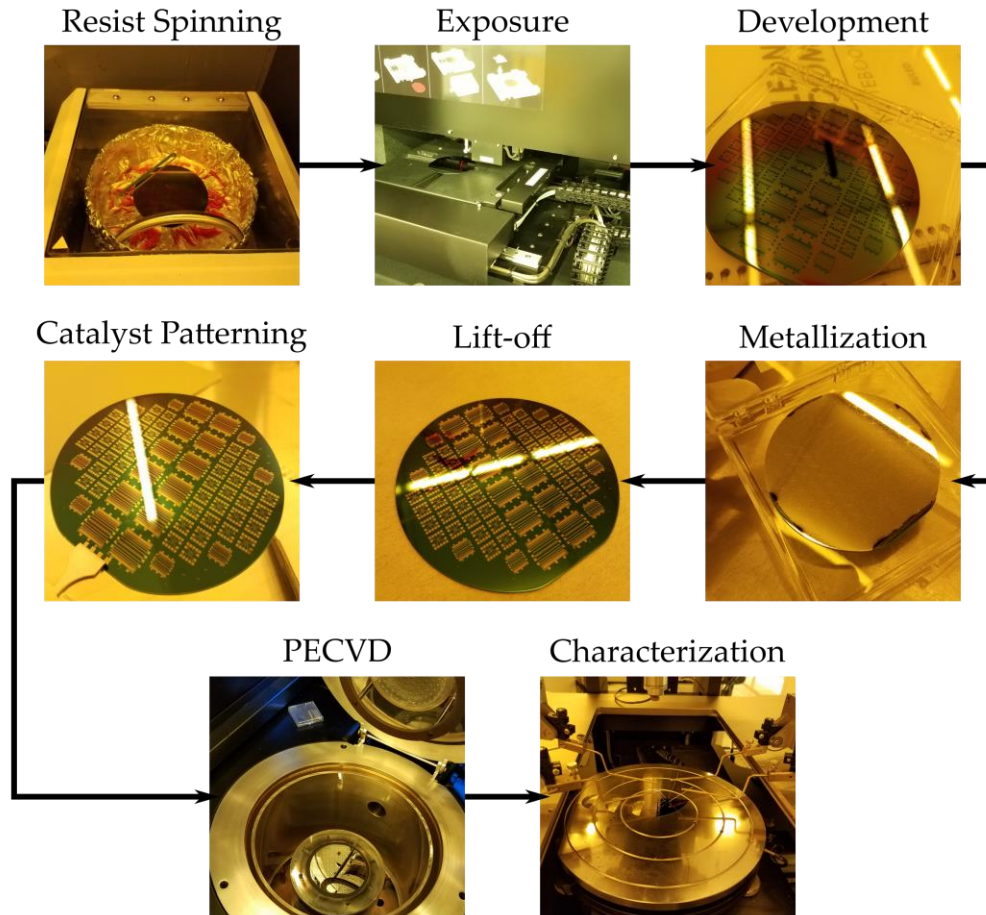


# VACNT-based detector features:

- Vertically aligned CNTs as the device channel
- Allows for 3D device geometries
- Grown using Aixtron Black Magic PECVD
- CNTs contacted by source and drain electrodes
  - Platinum
- Gate electrode separated from CNTs by thermal oxide
  - Platinum + 500 micron thick Si + 250 nm oxide
- Charge carriers generated in substrate and sensed by CNTs
- Standard back-gated FET geometry (for now)

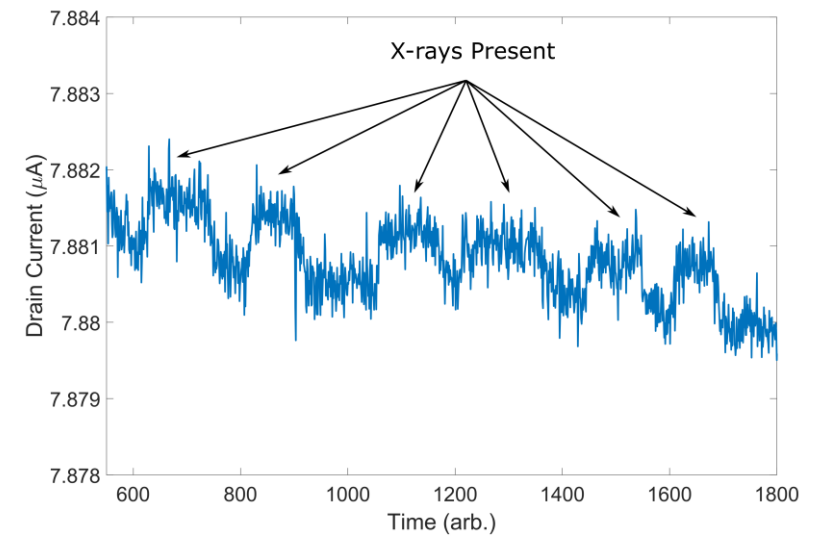
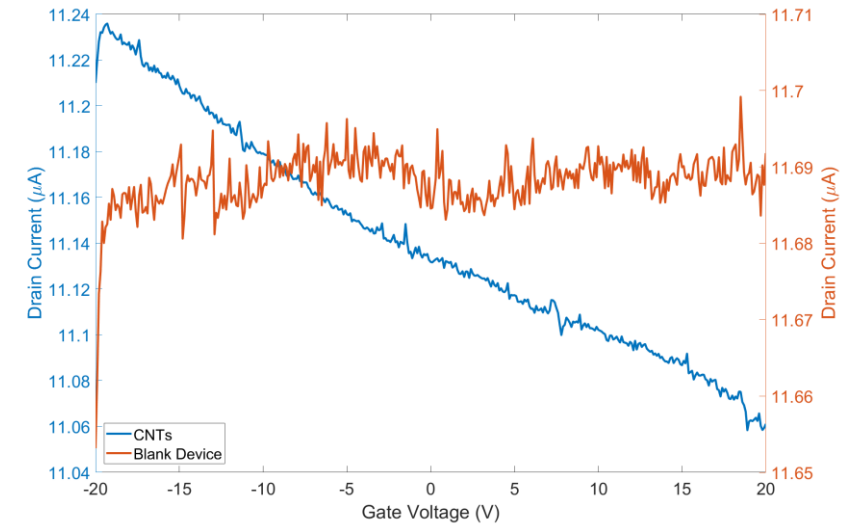
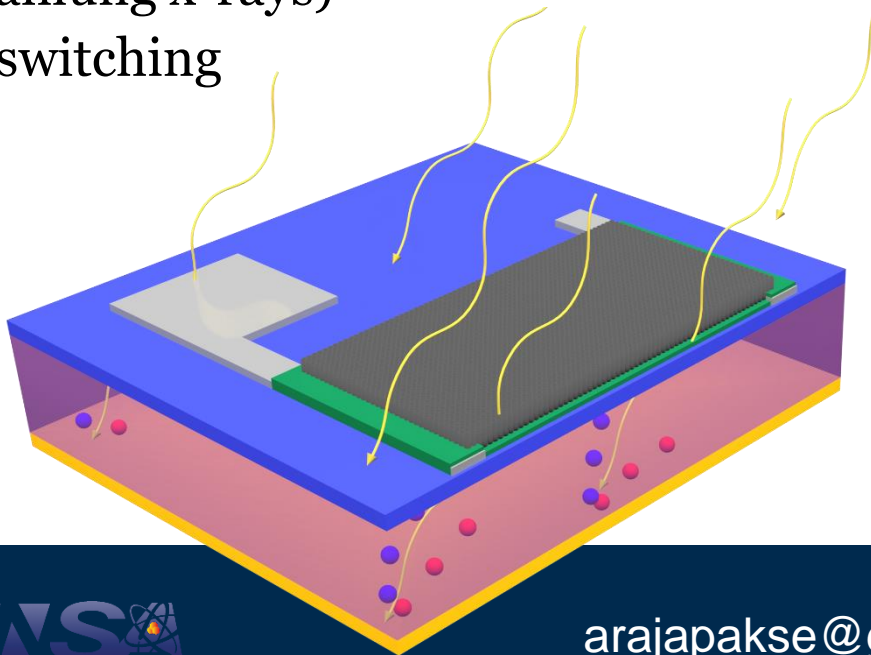


# Fabrication



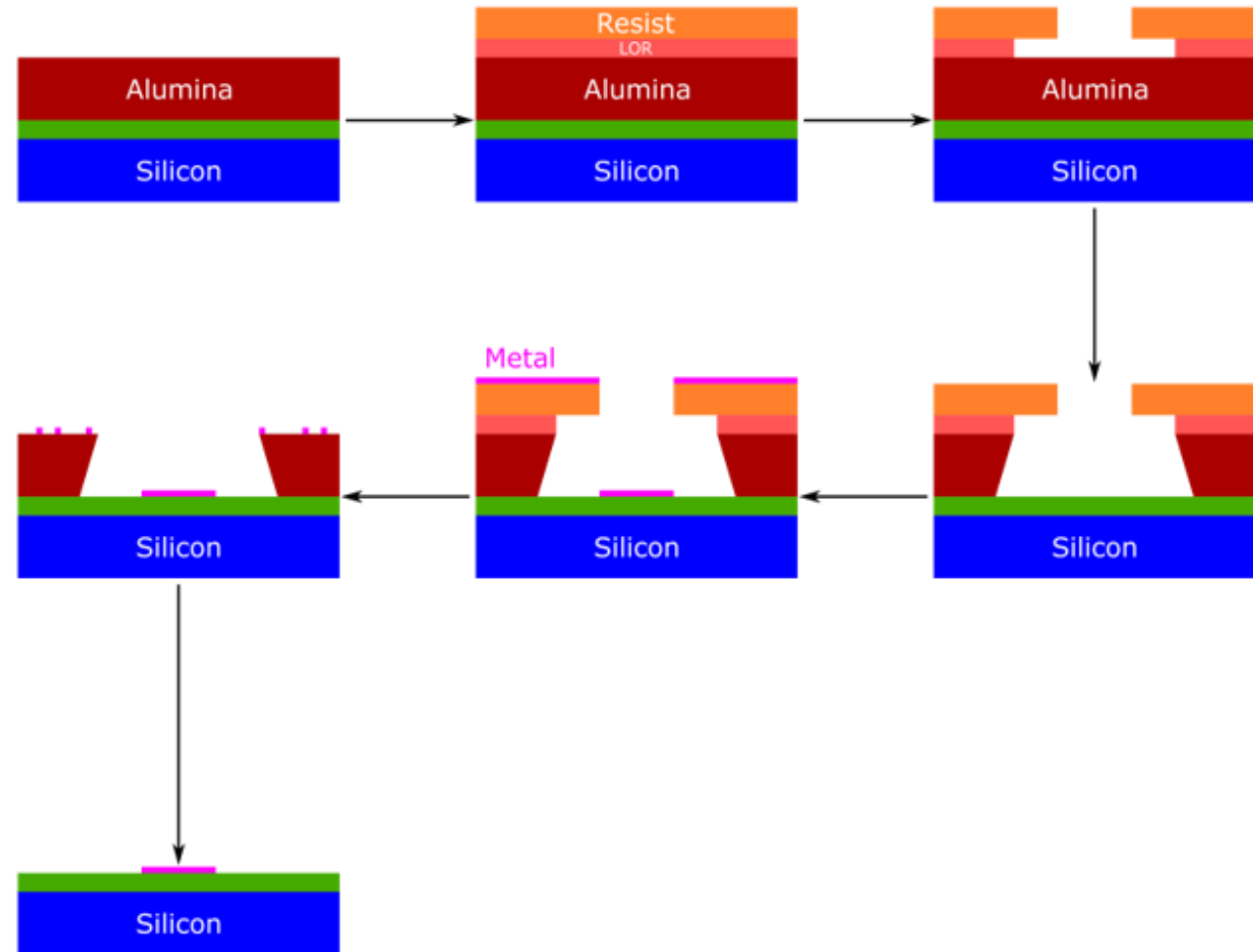
# Detector Operation

- Weak p-type FET behavior
  - Conductance increases at positive gate bias (increased tunneling probability of holes)
  - Metallic CNTs allow current flow while semiconducting CNTs are turned off
- Weak device response to ionizing radiation (108 kVp bremsstrahlung x-rays)
  - 1 nA switching



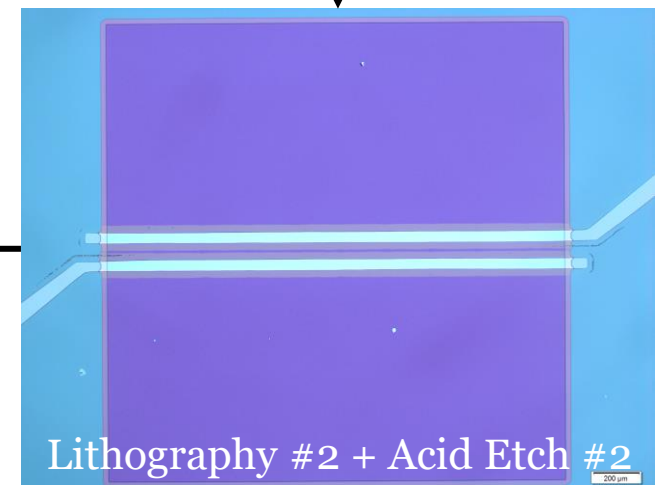
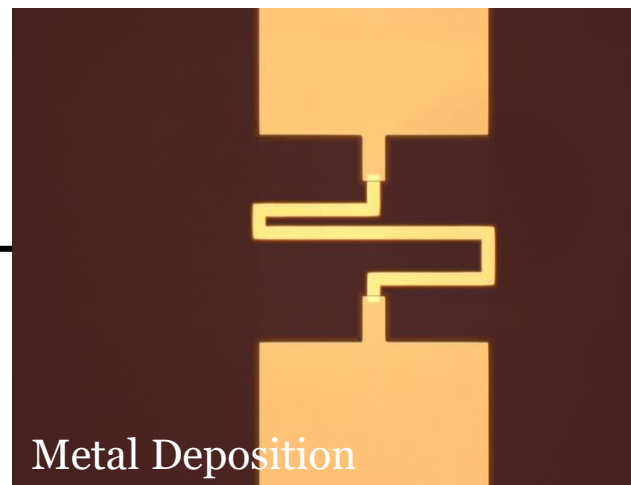
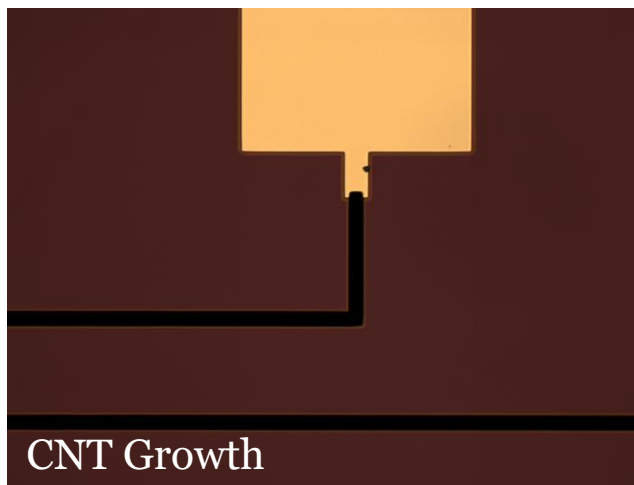
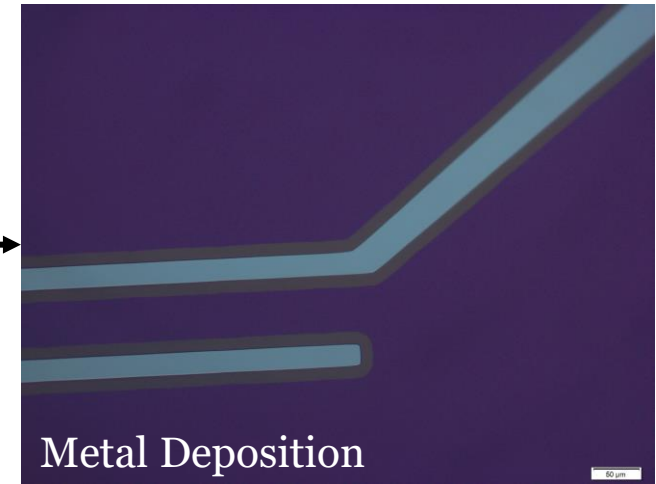
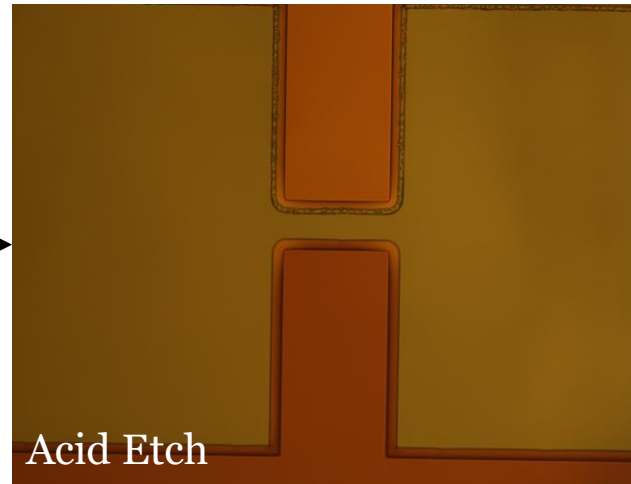
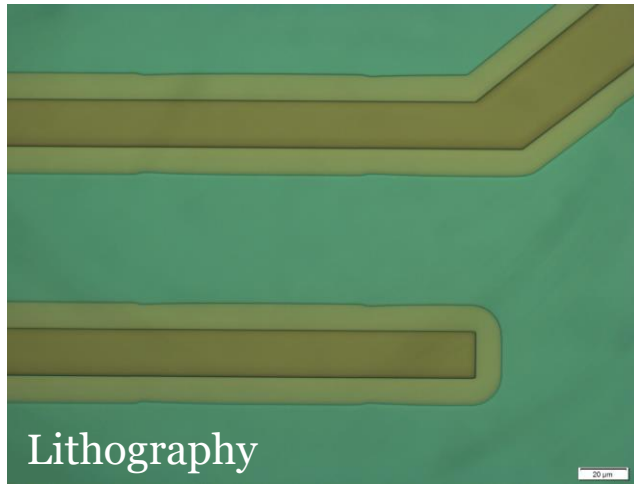
# Device Fabrication Overhaul

- Device Leakage
  - Metal redepositing from lift-off process
  - Compounded with high CVD temperature of 900°C
- Sacrificial oxide + bilayer resist to remove contaminants

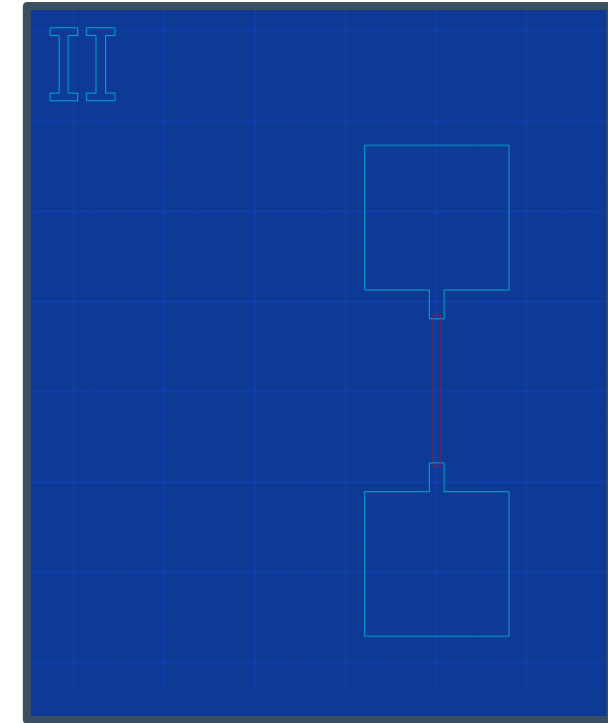
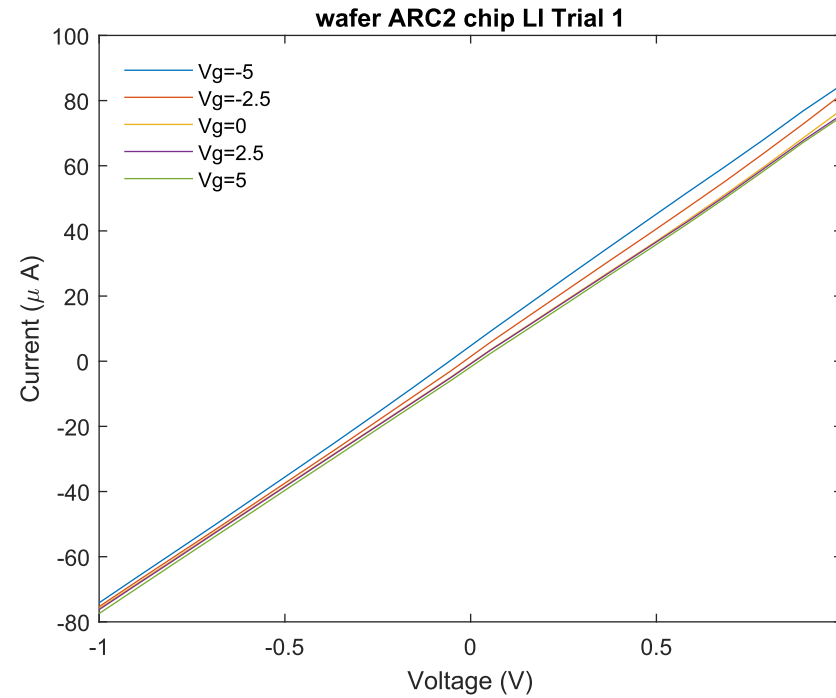
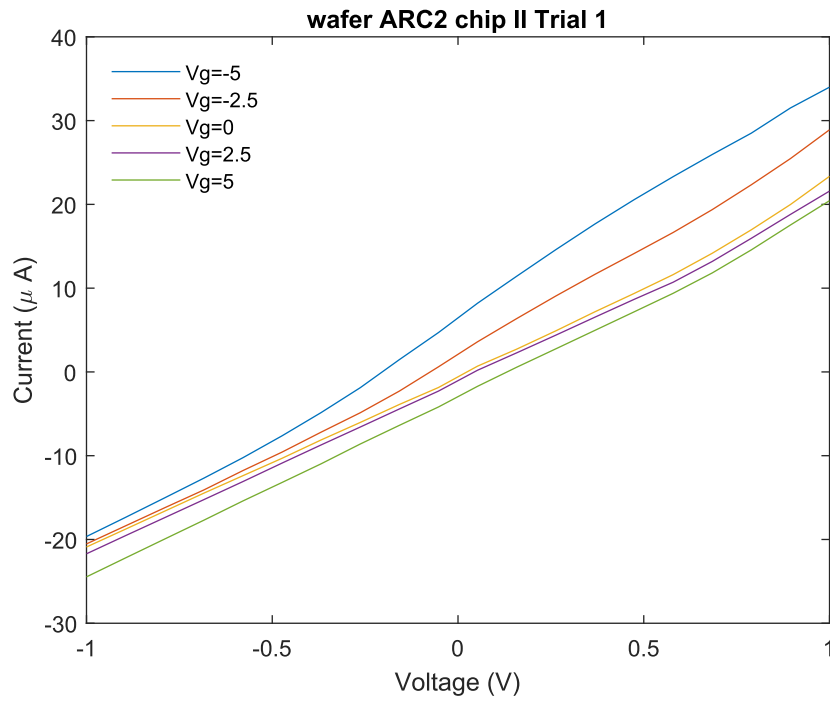




# Device Fabrication Overhaul

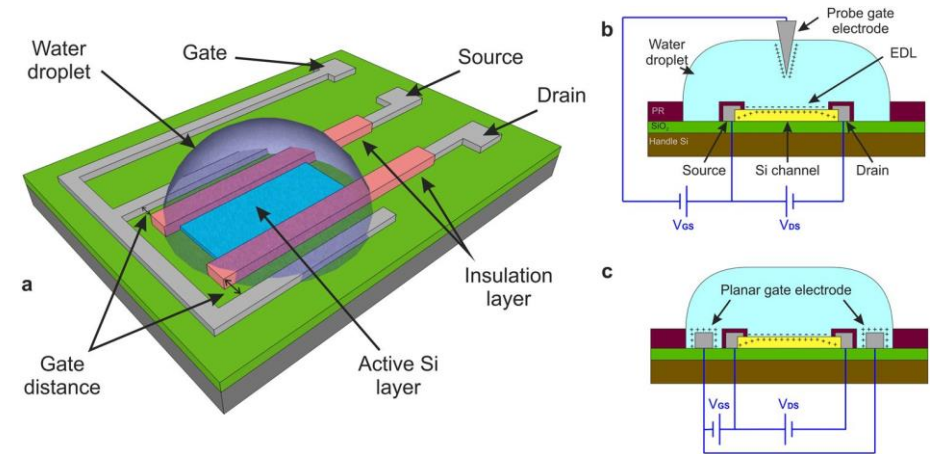
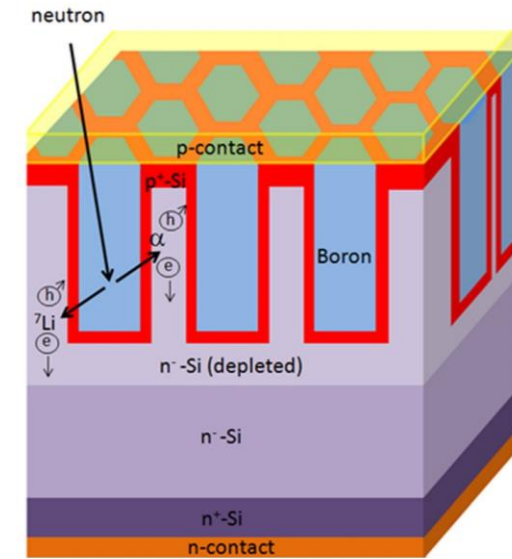


# New Device Design



# Future Work

- Optimize CNT growth
- Test fabrication process for 3D geometry
- Test device changes to allow for neutron detection (thermal and fast)
- Introduction of boron nitride into fabrication (thermal)





# Acknowledgement

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