Dielectrophoretic Assembly, Integration, and Characterization of Nanostructures

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Presentation Outline

- Introduction to MEMS / Project Overview
- Wafer Design / Fabrication
- Experimental Setup / Assembly Parameters
- Results (Electrical Characterization)
- Conclusion / Future Outlook

Introduction to MEMS

MEMS (Micro-Electro-Mechanical Systems):

- Integrate sensing capabilities with processing power
- Manufactured using durable, reliable, and cost effective IC techniques

- Examples
  - Inkjet Print-Heads, Airbag Accelerometers, Drug Delivery Systems

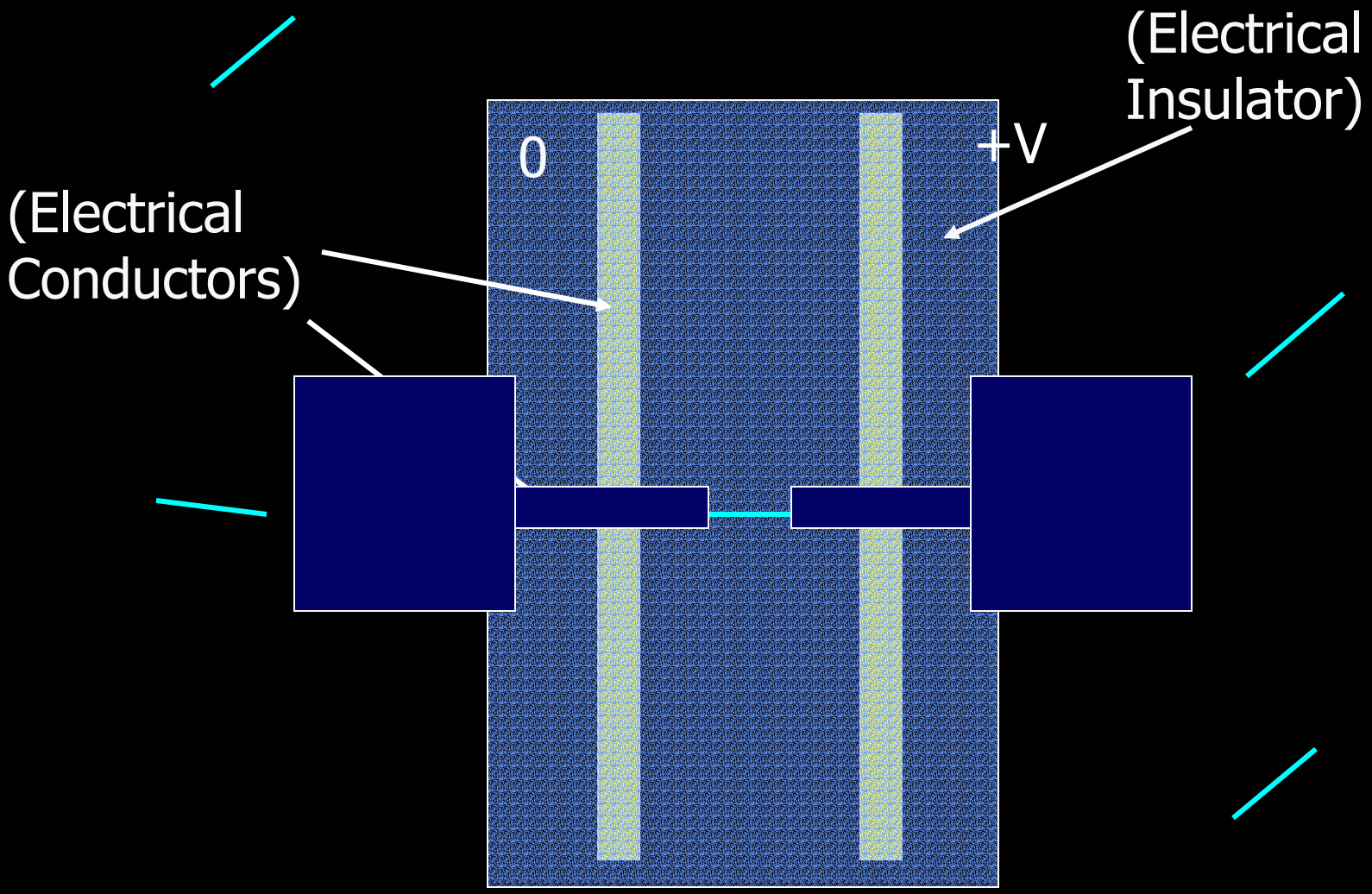
MEMS with Nanotechnology

- Sensing aspect can be greatly enhanced by nanowires
  - Smaller
  - Highly Sensitive
- Examples
  - Resistivity of Nanowire Related to Atmospheric Conditions

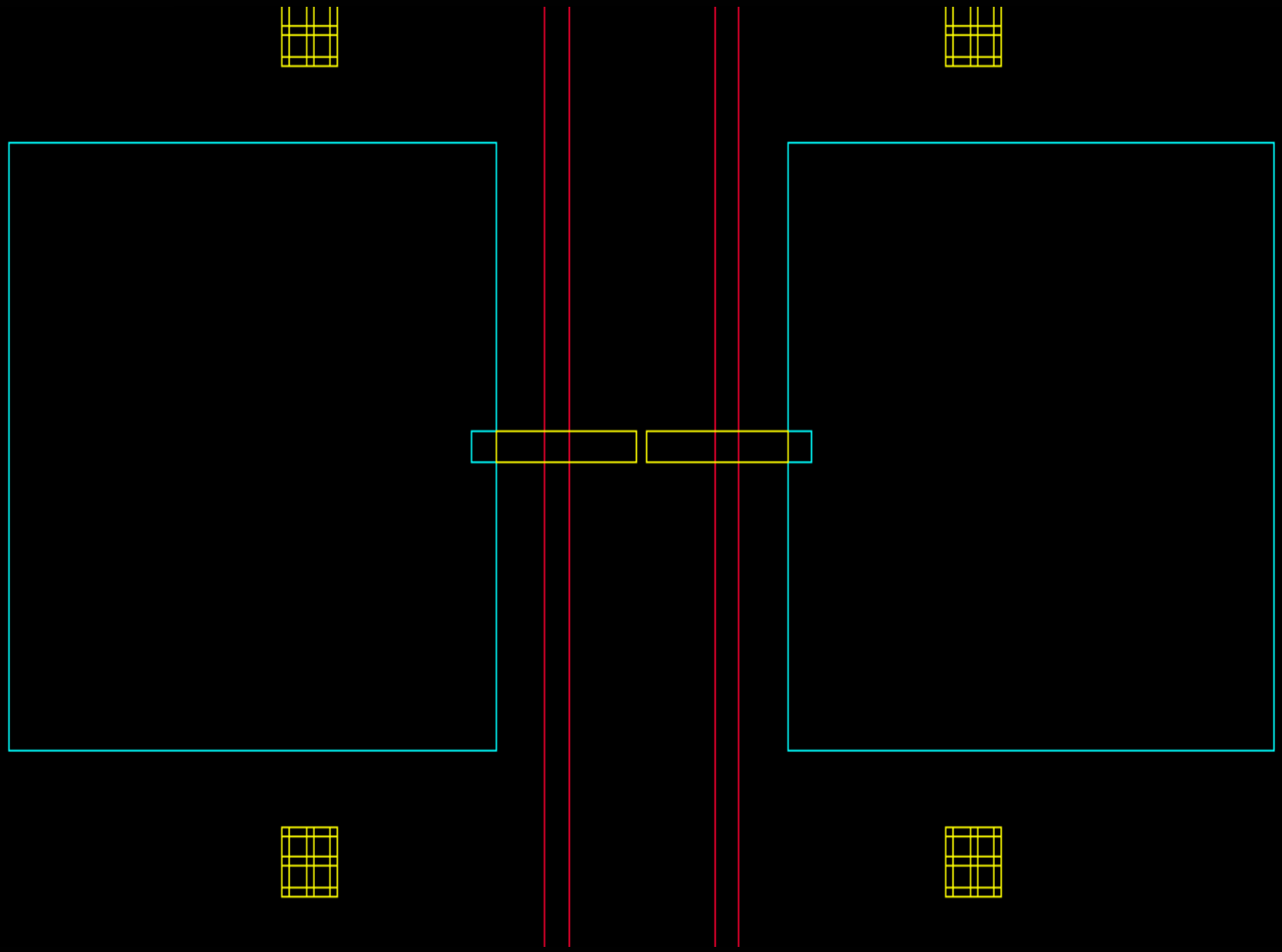
Project Overview

- Goal:
  - Assemble, Integrate, and Characterize Nanowires
- Relevance
  - Proof of Concept
  - Observations / Data for more complex NEMS devices

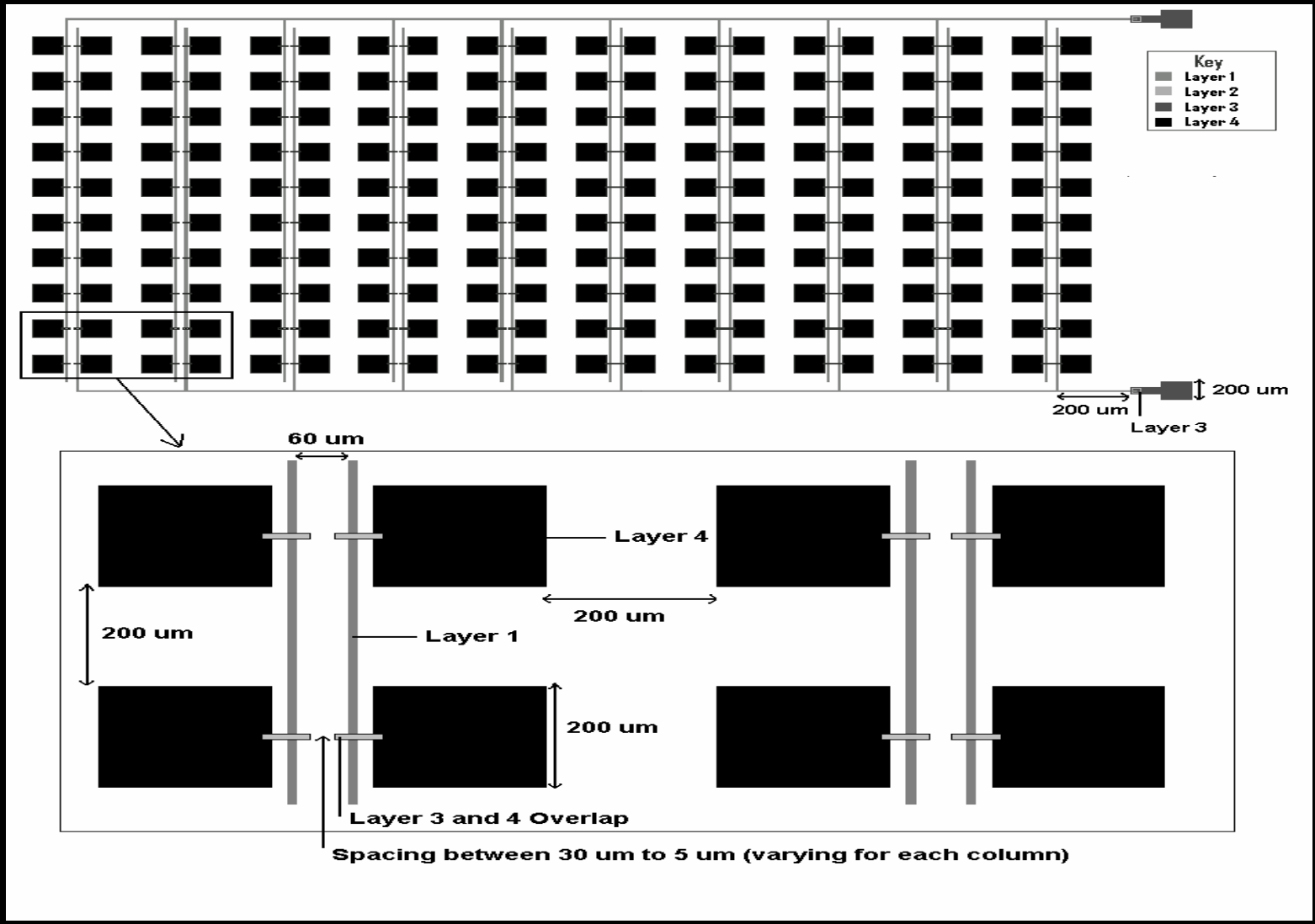
Wafer Design: Nanowire Assembly (Theory)



Circuit Design



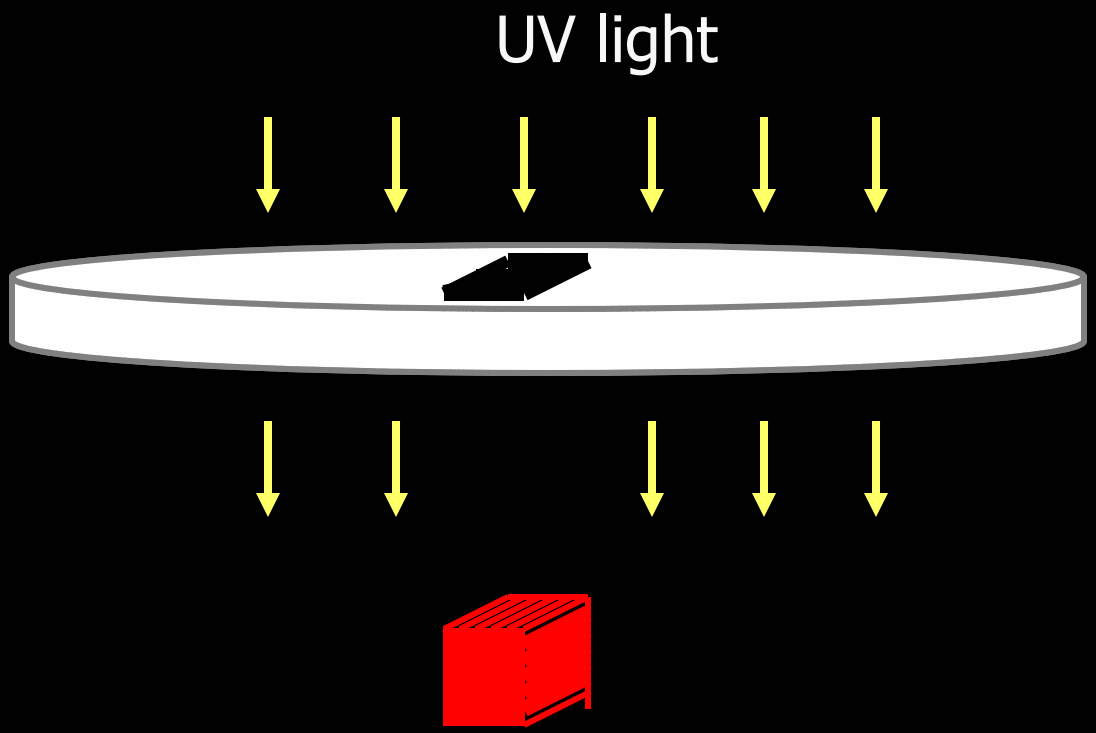
Design Specifications



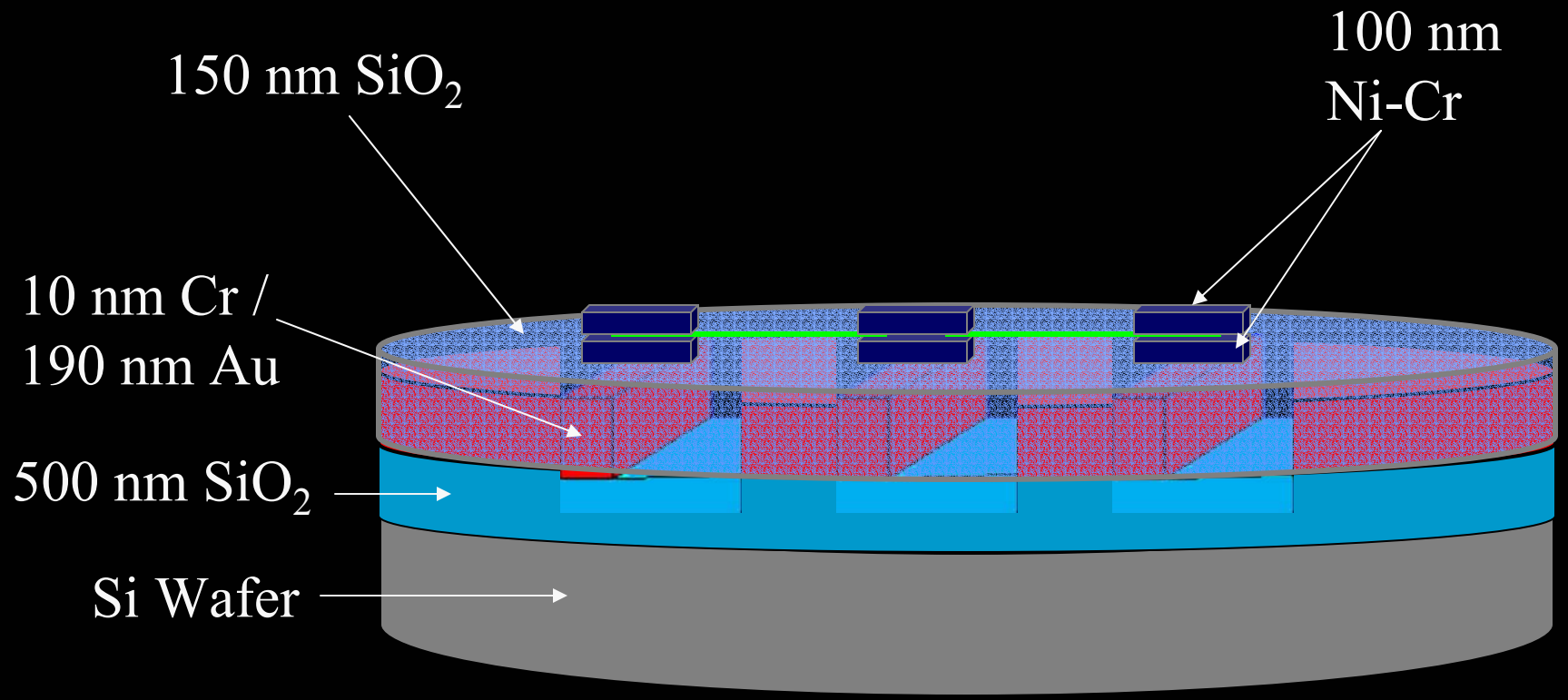
Wafer Fabrication

- Thermal Oxidation
  - Heat Silicon Wafer to grow SiO_2
- Sputter Deposition
  - Vaporization / Condensation
- Mask Production / Photolithography

Masks / Photolithography



Wafer Fabrication

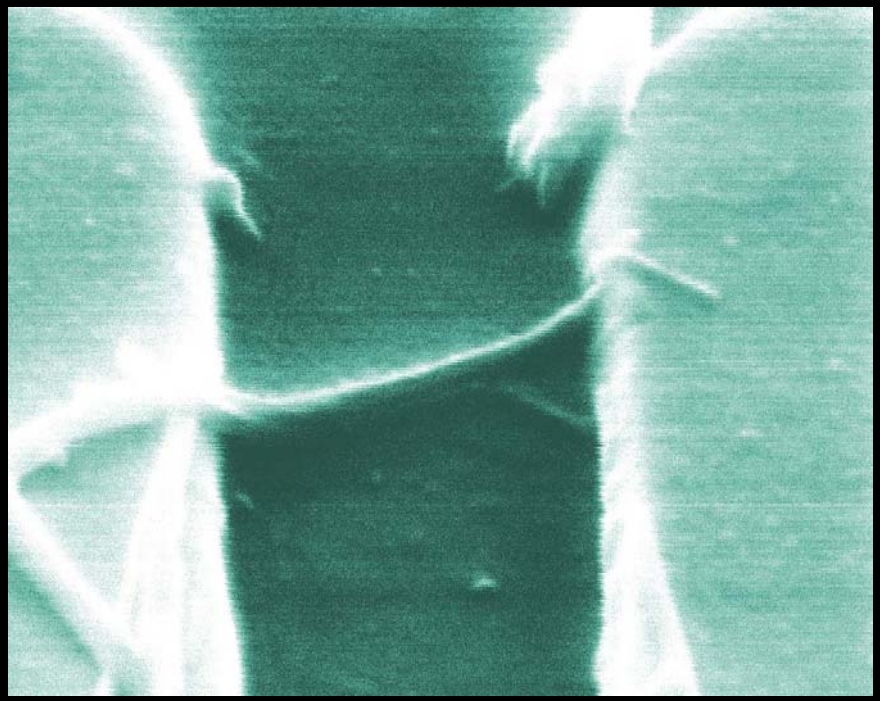


Characterization and Discussion of Different Nanostructures

- Assembled on varying gap sizes
- Successfully assembled 3 different structures
  - GaAs nanowires
  - Rh nanowires
  - Multi-walled carbon nanotubes (MWNTs)
- Data gathered varies due to size limitations

GaAs nanowires

- Successfully assembled on chips with gap size of 1-3 µm
- Optimal conditions for assembly
  - V_{pp} = 10 V
  - Frequency = 100 kHz
  - t = 60 s



Gap size = 1.5 µm

Testing of GaAs nanowires

- Could not measure electrically
  - Could not probe existing chips from the outside world
  - A final mask layer was designed to make tests possible
  - Photolithography tools did not have small enough resolution to align this final layer
  - Mask may be sent elsewhere with chip to perform final layer of processing

Rh nanowires

- Optimal conditions for assembly
- 1-3 μm

  V_{pp} = 15 V

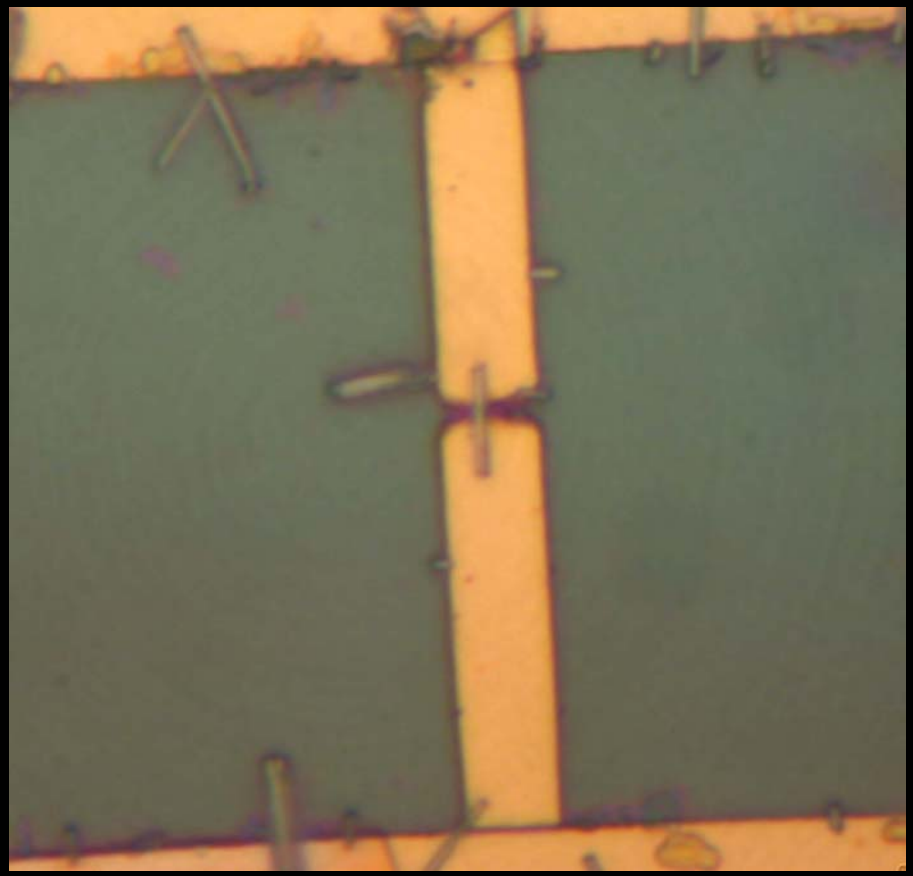
  freq = 100 kHz

  t = 5 min
- 5-30 μm

  V_{pp} = 35 V

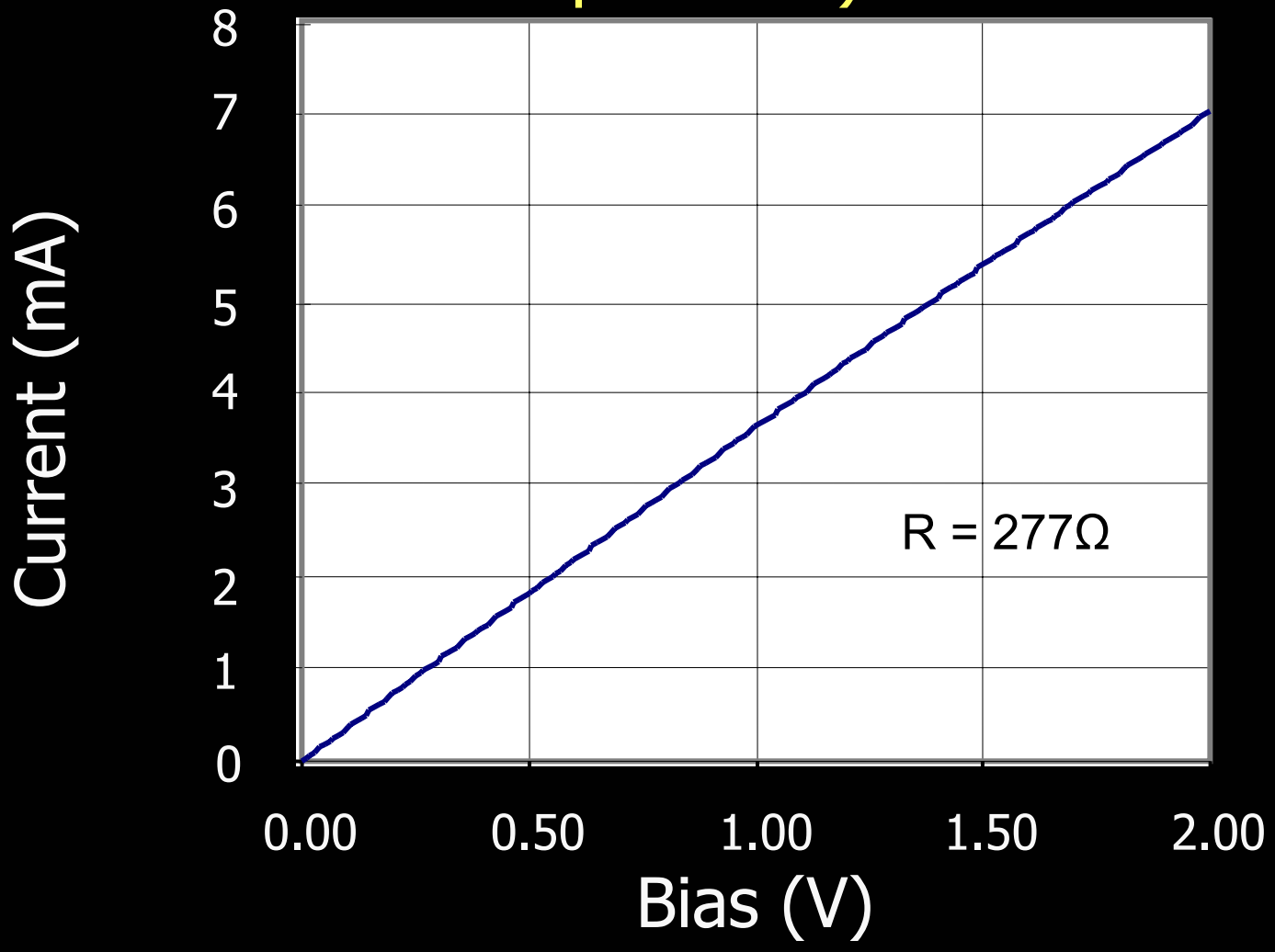
  freq = 100 kHz

  t = 5 min



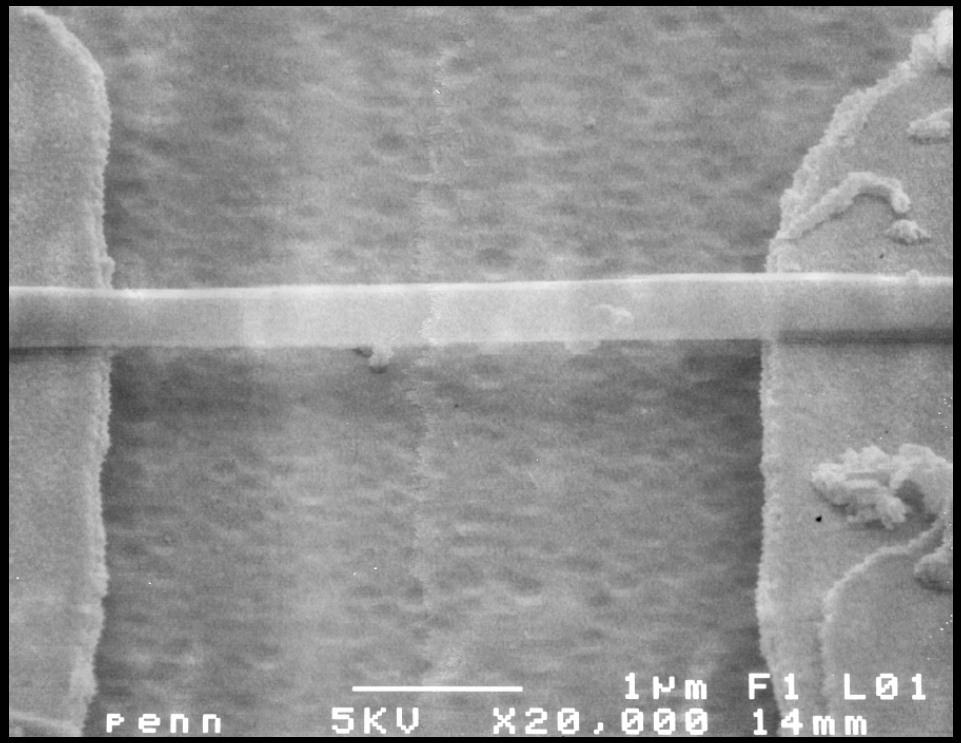
Assembled Rh nanowire

Current vs. Voltage for Rh rods (Room Temperature)



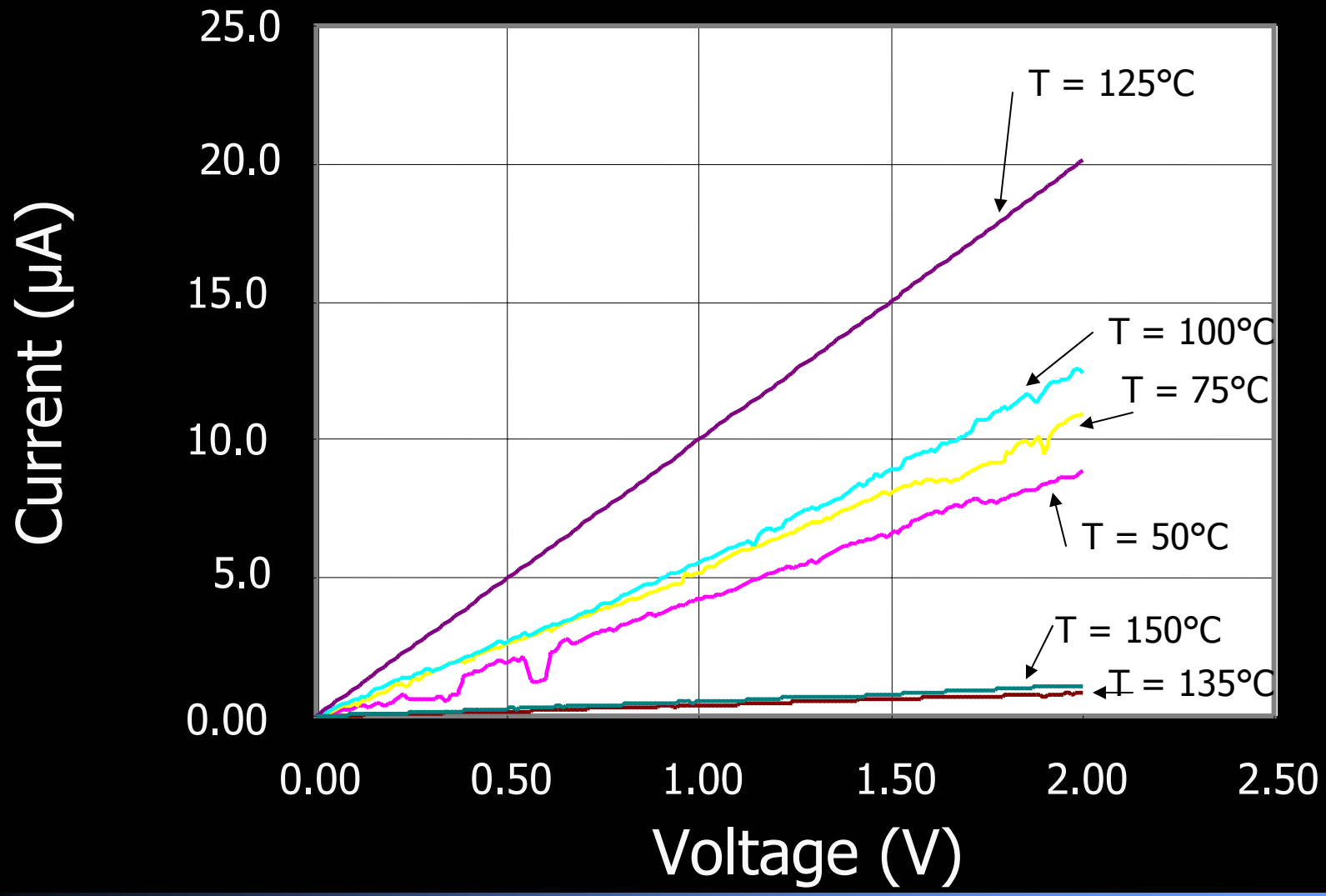
Multi-walled Carbon nanotubes

- Optimal conditions for assembly on 5-30 µm gap size
  - V_{pp} = 35 V
  - freq = 100 kHz
  - t = 5 min
- Most successful in gathering data on MWNTs

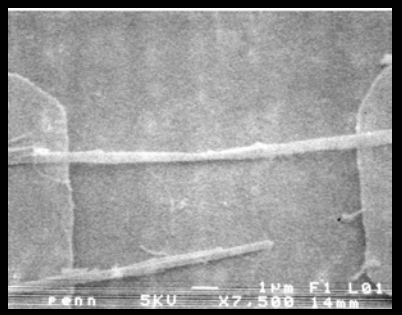


MWNT assembled on a 6 µm gap

Current vs. Voltage for MWNTs at Various Temperatures



A MWNT



MWNT Discussion

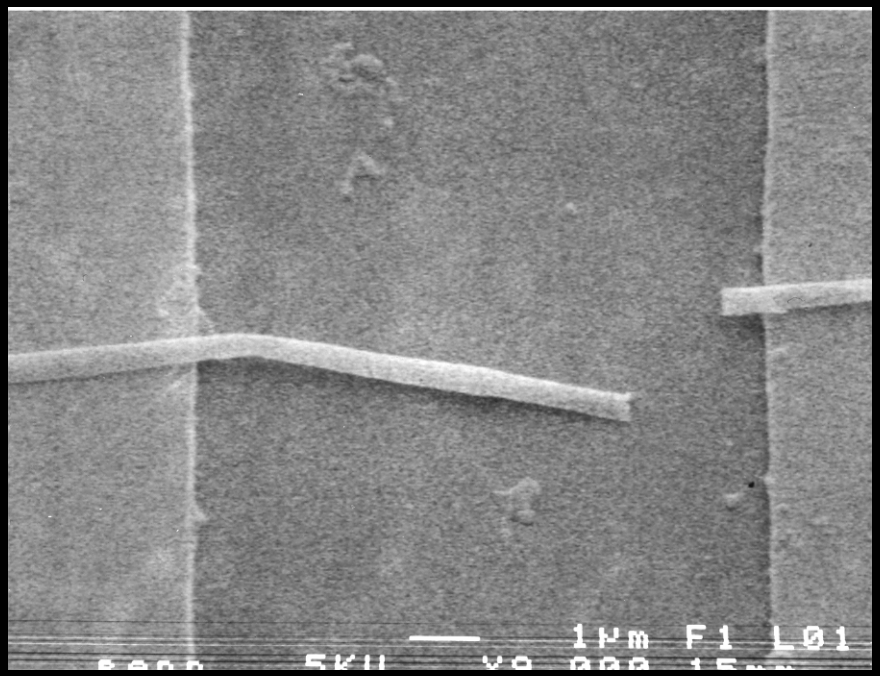
- Possible explanations for jump between 125°C and 135°C:
  - A critical temperature was reached
  - Physical structure of the tubes was permanently changed
  - Supported by the fact that this data was not reversible
  - May actually be measuring contact resistance between MWNT and electrode

Mechanical Characterization

- GaAs nanowires – need to first be clamped – need more precise photolithography tools
- Rh nanowires – can be clamped, but haven't yet
- MWNTs – have been successfully clamped. Tests should be done within a few weeks

Conclusions

- Large pads on the chip create strong capacitive forces
- There is an inverse relationship between temperature and resistance
- There may exist a critical temperature that permanently changes MWNTs



Must be careful when heating MWNTs because they will break

Future Work

- Test other types of nanostructures mechanically and electrically
- Can combine them in an array to act as sensors (of temperature, etc.)
- Applications in everything from medicine (bio-sensors) to electronics (FETs)

Questions