

NIST Summer Internship
Semiconductor Electronics Division

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Outline

- NIST
- Summer Goals
 - Nanowire research
 - Nitrogen box for MMR microprobe
 - Bringing up the MMR microprobe

What is NIST?

From automated teller machines and atomic clocks to mammograms and semiconductors, innumerable products and services rely in some way on technology, measurement, and standards provided by the National Institute of Standards and Technology.

Founded in 1901, NIST is a non-regulatory federal agency within the U.S. Commerce Department's Technology Administration. NIST's mission is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.

Key Aspects

NIST's Core Purpose:

Enabling a better future.

NIST's mission:

To develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.

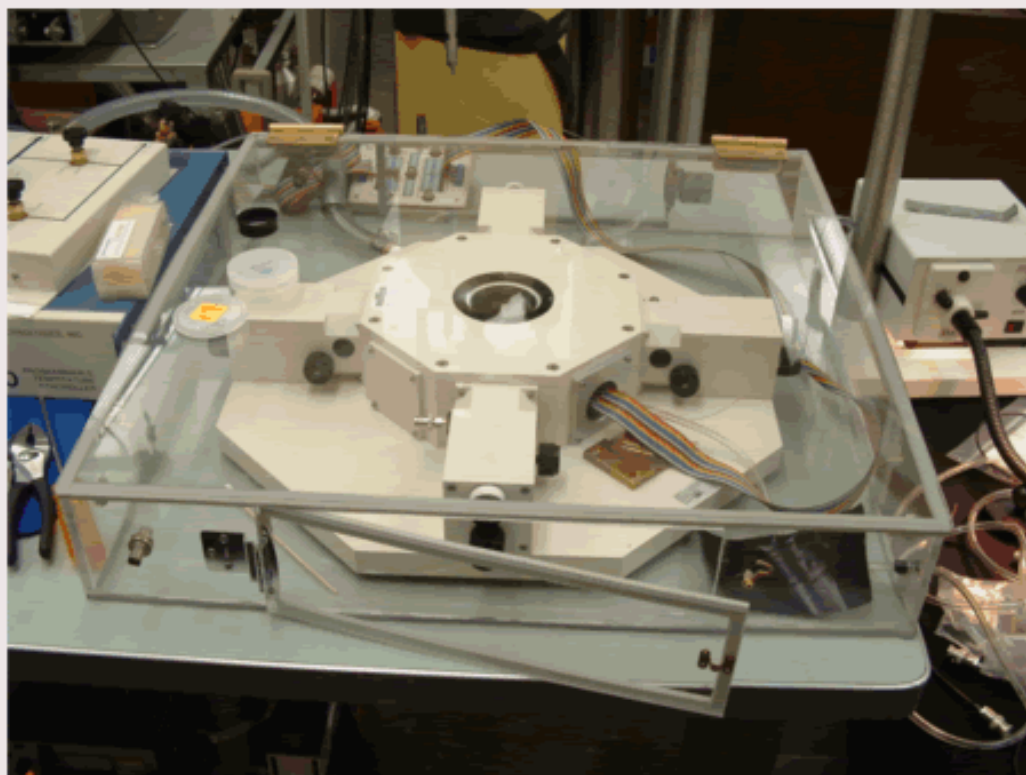
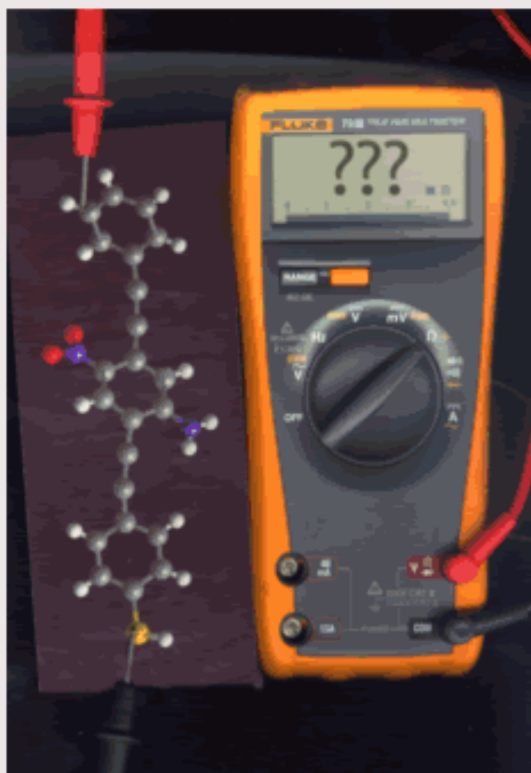
NIST's vision:

To be the global leader in measurement and enabling technology, delivering outstanding value to the nation.

NIST's Core Values:

- **People:** We respect, value and support each other in all our activities.
- **Integrity:** We are objective, ethical, and honest.
- **Customer focus:** We anticipate the needs of our customers and are committed to meeting or exceeding their expectations.
- **Excellence:** We expect world-class performance and continuous improvement in all we do.

Summer Agenda



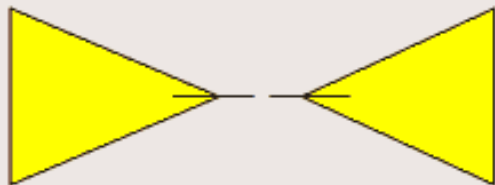
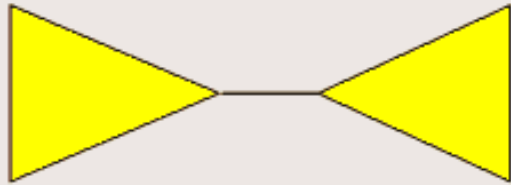
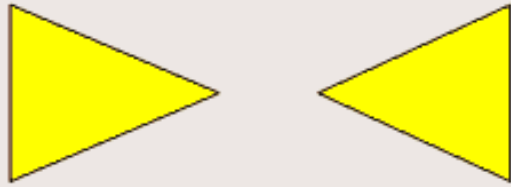
Testing Single Molecules

- Nanowires created at NIST by Ganesh Ramachandran
- Using electromigration technique to test single molecules

Electromigration

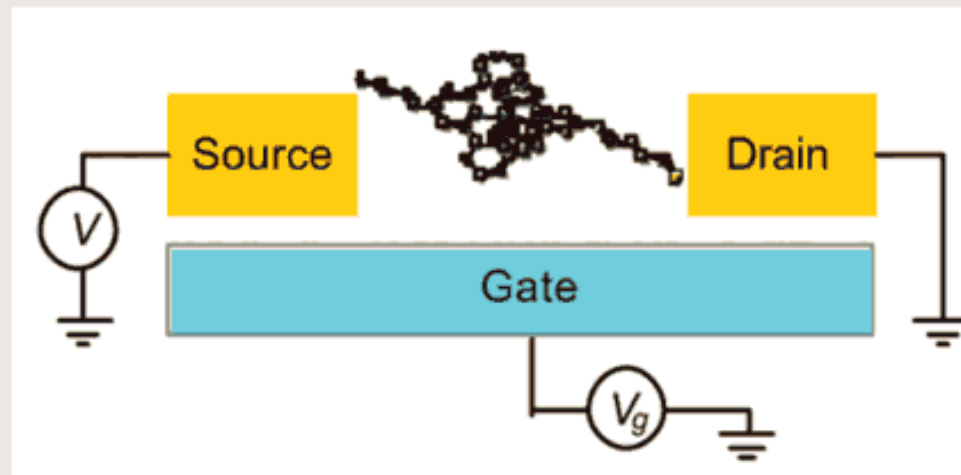
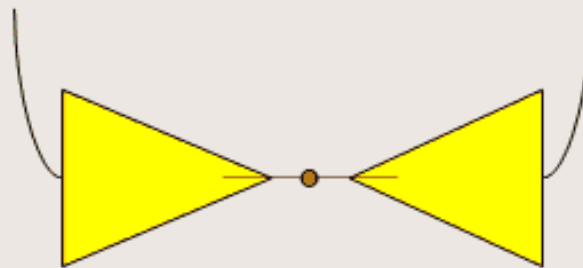
- Nanowire fabricated using e-beam lithography on silicon wafer
- Large voltage applied (0.5 V & 1.0 V) to cause wire to fail
- Current density creates nano-junction in wire

Basic Design



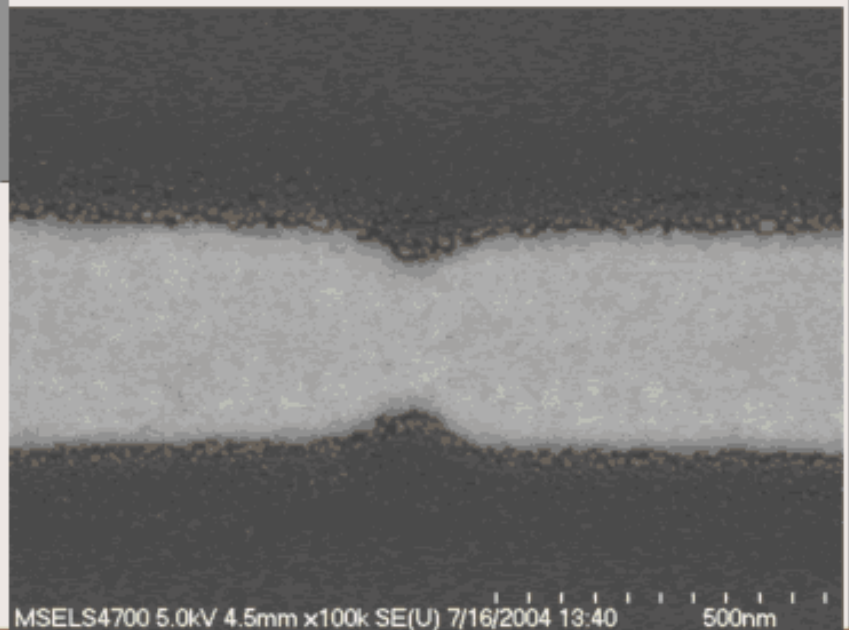
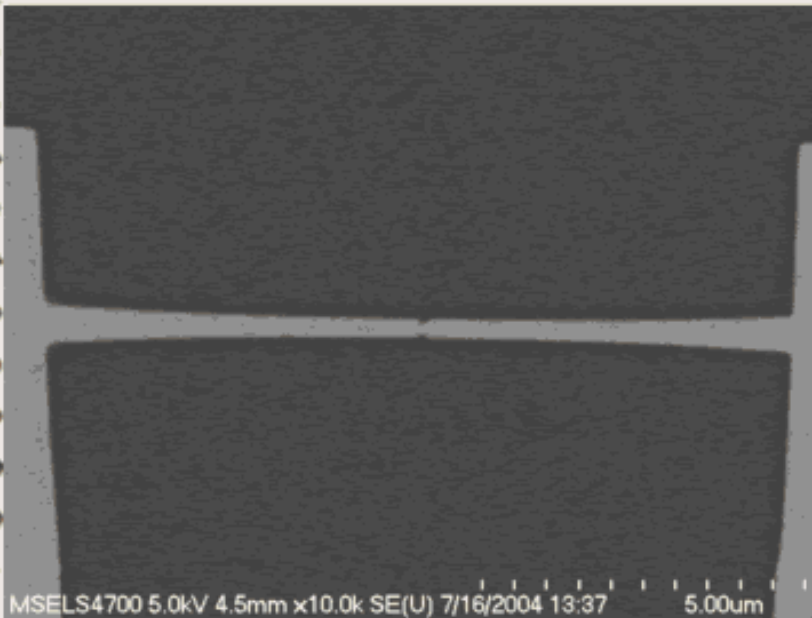
- Gold pads laid for probes
- Nanowire constructed by e-beam lithography
- Electromigration causes nanojunction

Single Molecule in Junction



Bottom Figure From: Jiwoong Park, Ph.D. Thesis

Actual Device



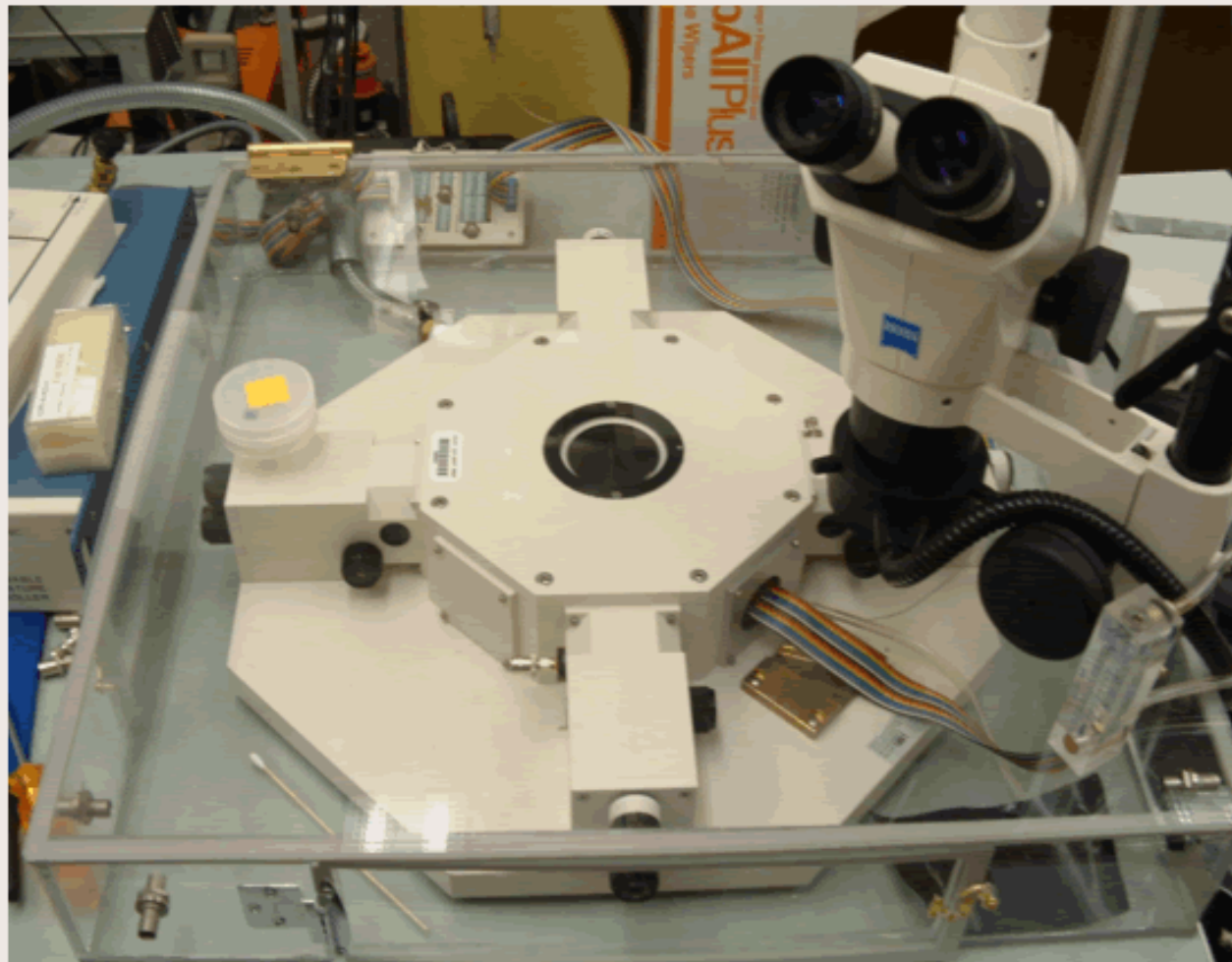
Need for Low Temperature Measurements

- Keep break clean
 - Gold is messy at the nano-scale
- Reduce electrical noise in sample
- Reduce heat of molecule in junction

Need for Low Temperature Measurements

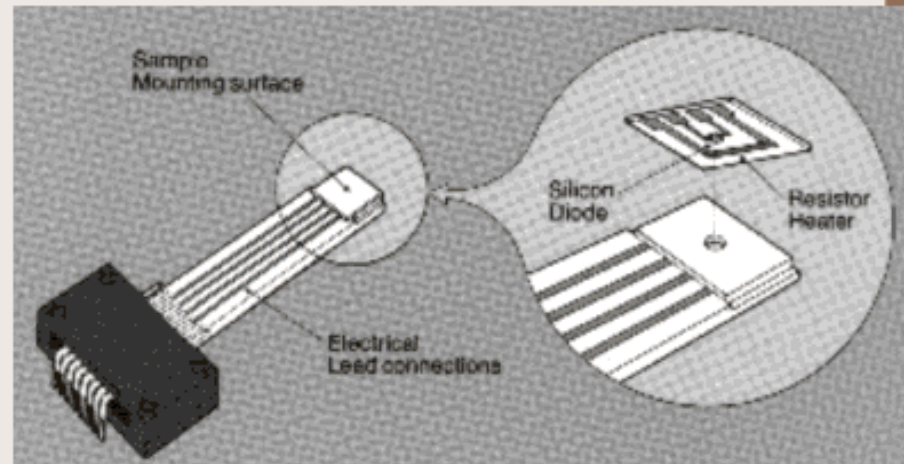
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MMR Low Temperature Microprobe Station



Micro Miniature Refrigerator

- Cryogenic refrigerator
- Joule-Thomson cooling
 - Countercurrent heat exchanger
- Ceramic cold stage with temperature sensor and resistive heater
- Range of operation 70 K to 580 K



Joule-Thomson Cooling

- Occurs when non-ideal gas expands from high to low pressure at constant enthalpy
- Effect can be amplified by using previously cooled gas to pre-cool incoming gas in a heat exchanger

Declogging/Rundown Procedures

- Purge system at 500 PSI for twenty minutes at room temperature
- Purge system at 500 PSI for 5-10 minutes at 325 K
- Set temperature to 298 K and increase Nitrogen Line pressure to 2000 PSI
- Set target temperature to 77 K
- After rundown, Nitrogen tank main valve closed to bring temperature of system to room temperature
- System is kept under vacuum at all times

What is Clogging?

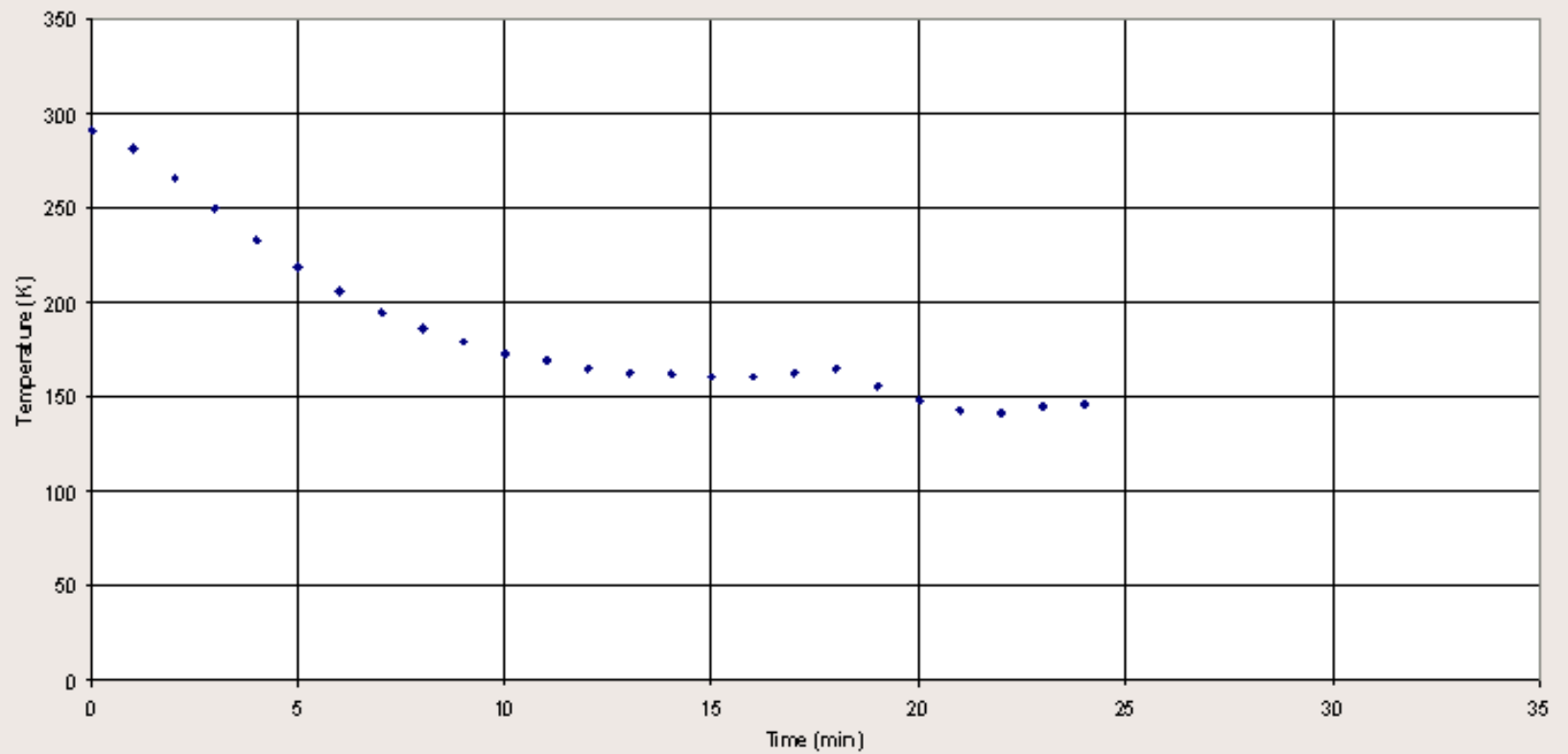
- Clogging is the formation of ice within the etched channels of the Joule-Thomson refrigerator.
- Moisture enters the system via the Nitrogen gas, or some opening/leak within the system

Detecting Clogging

- Clogging is indicated by a decrease in the refrigerator gas flow rate
- Continued clogging results in a rising temperature within the refrigerator

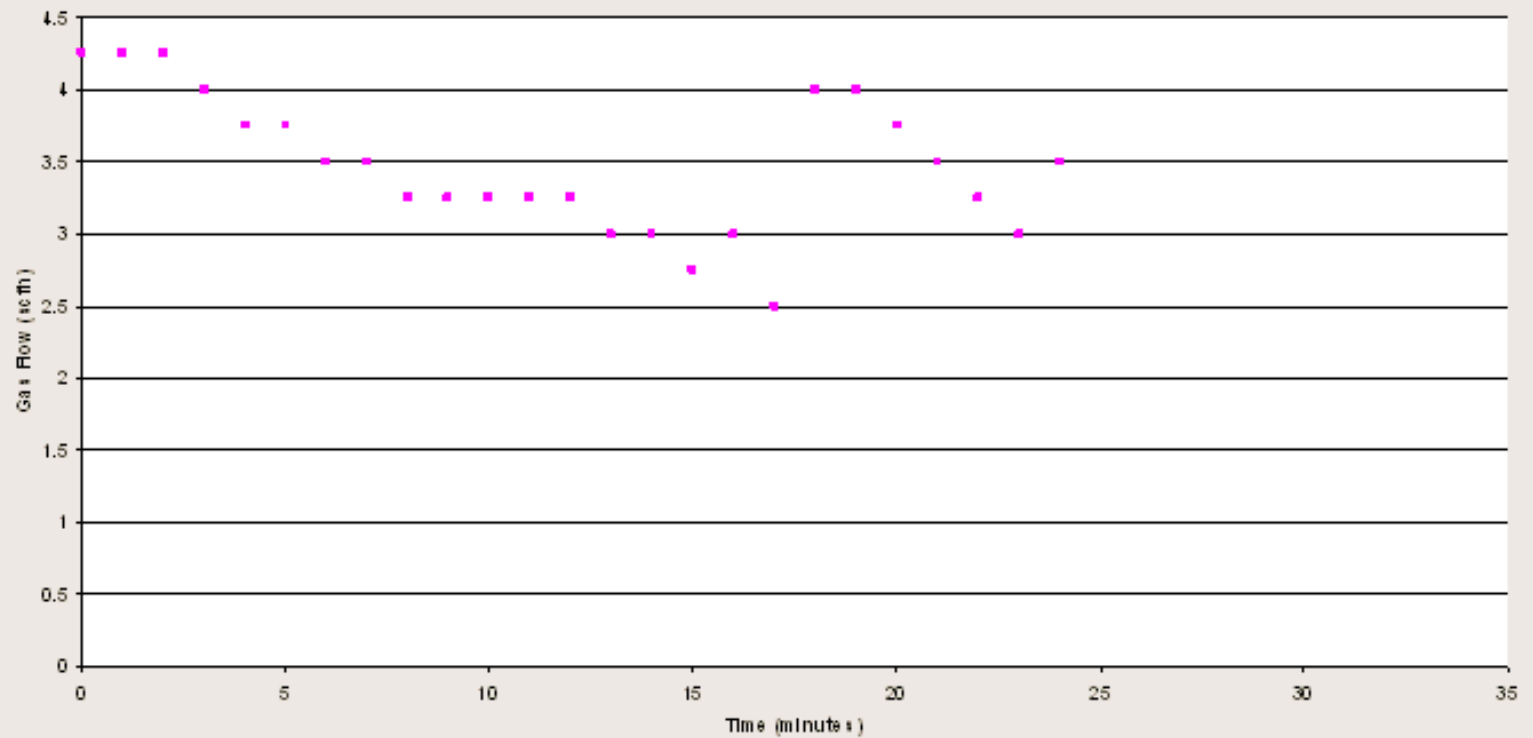
Clogged Run

3:20 PM June 21, 2004



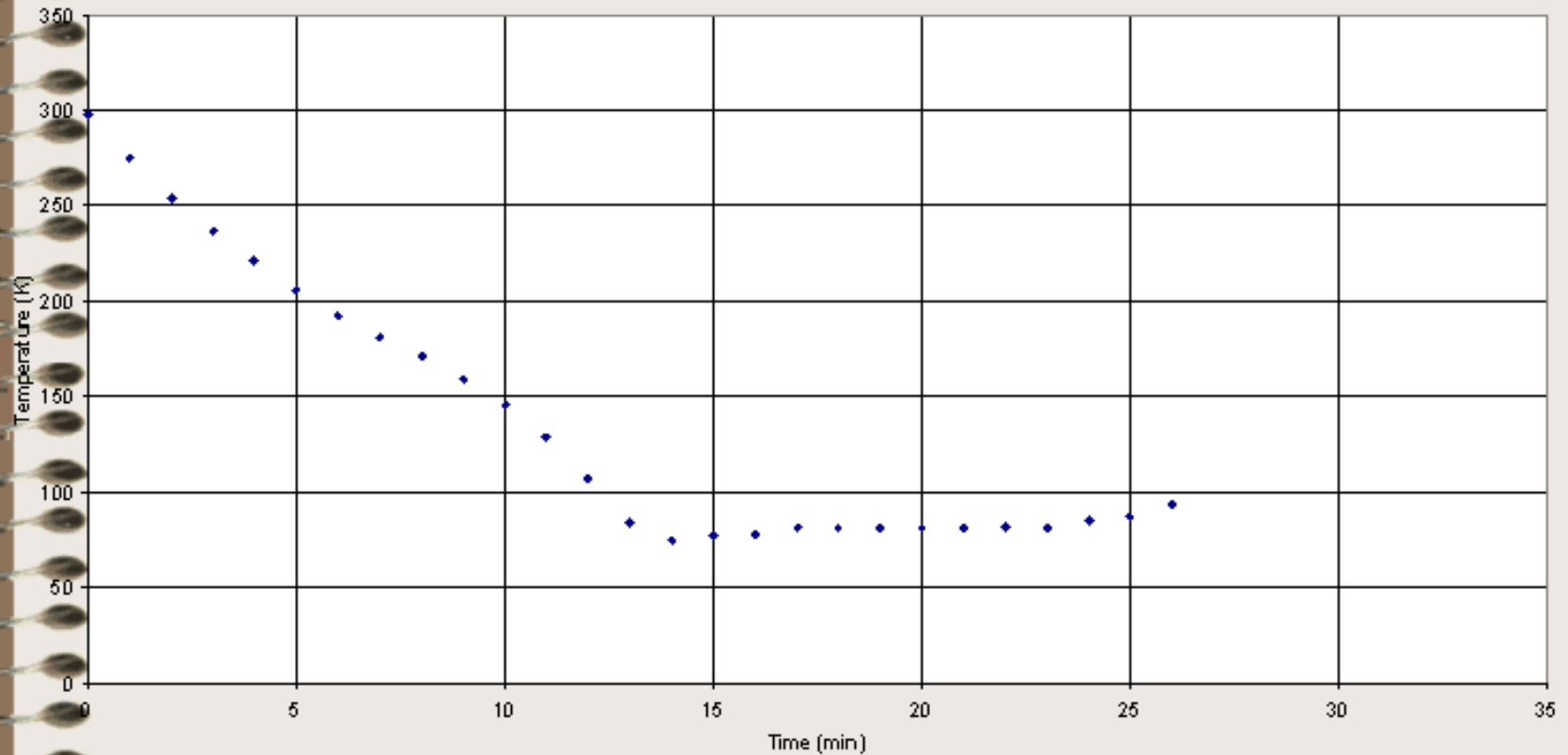
Flow Rate of MMR

3:20 PM June 21, 2004



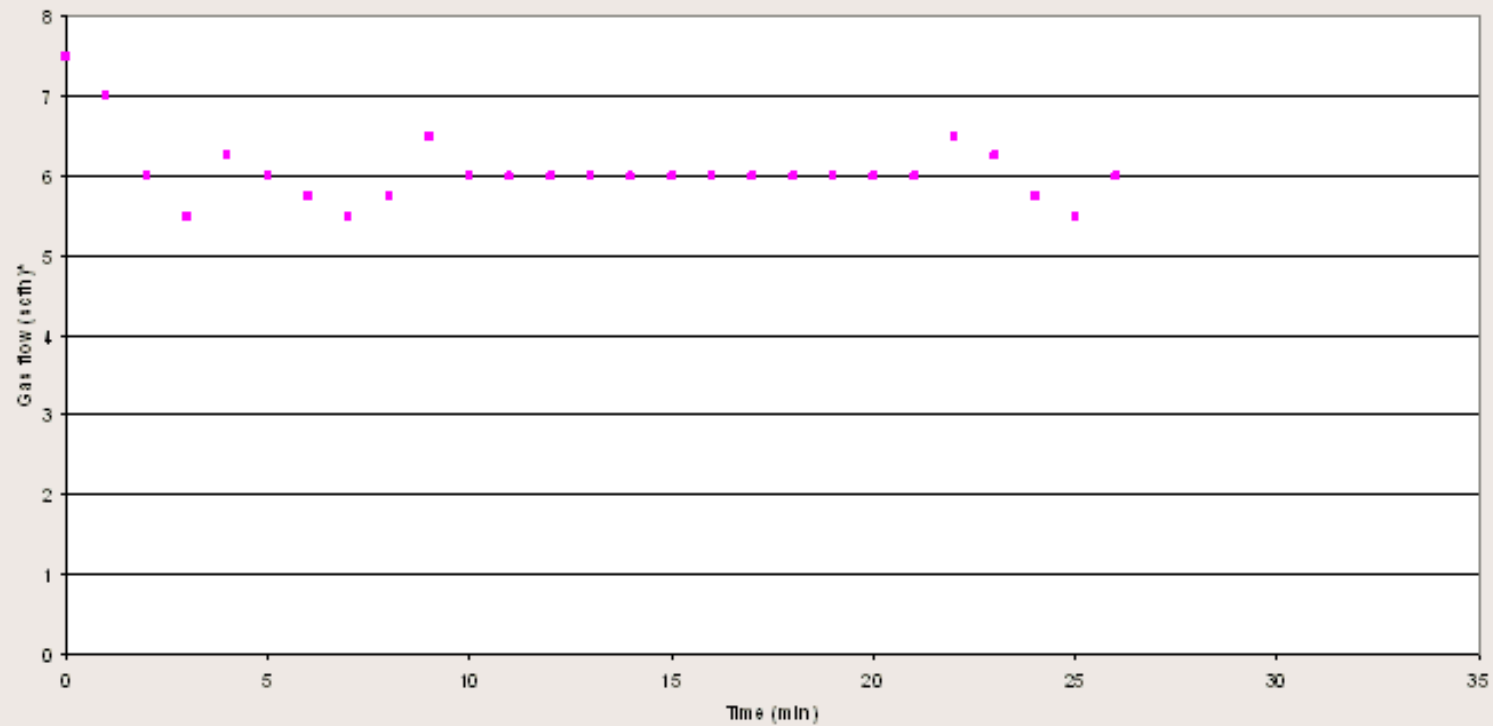
Breaking 80 K

3:40 PM June 25, 2004



Flow Rate of MMR

3:40 PM June 25, 2004

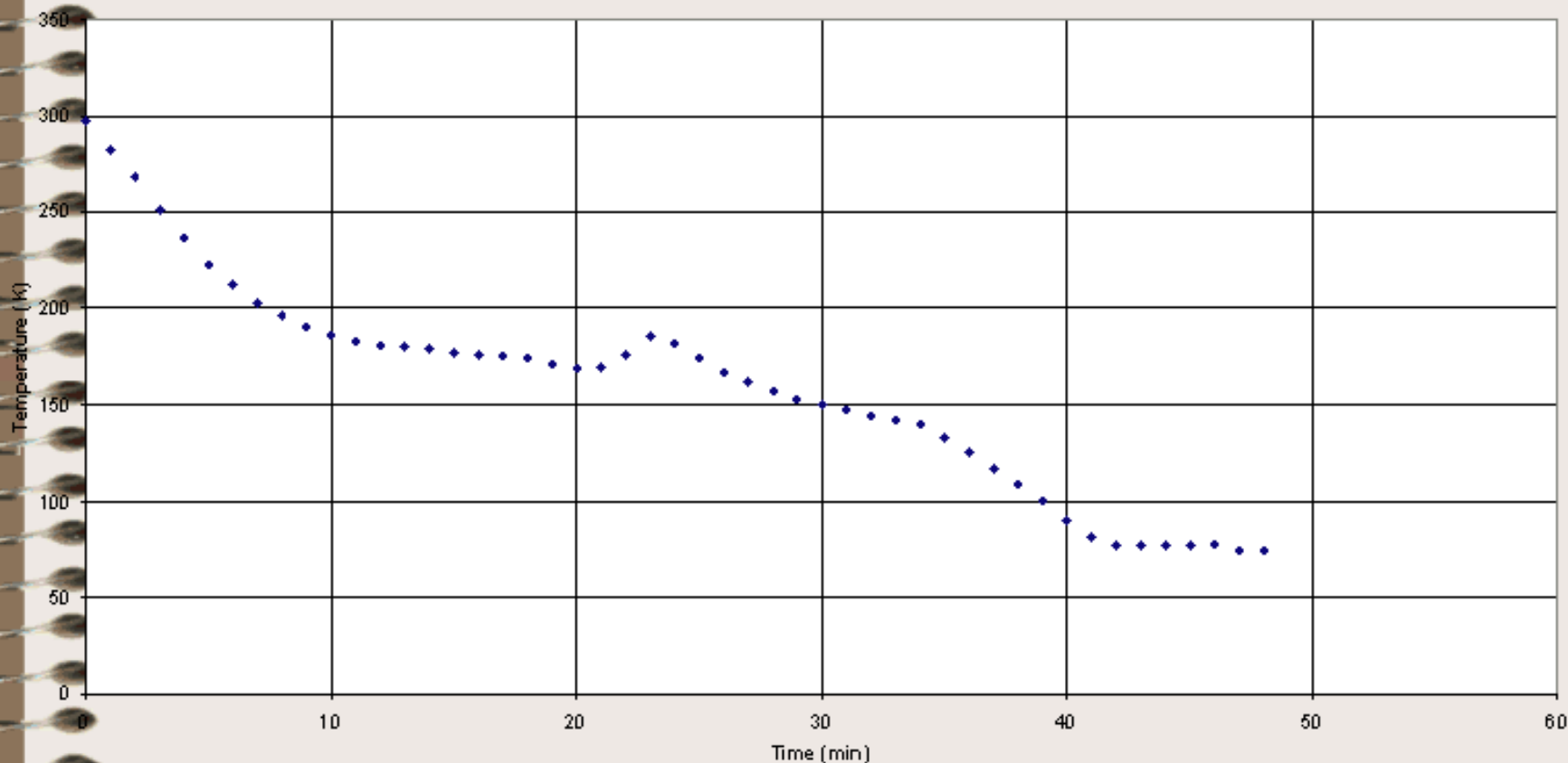


Disaster Happens July 8, 2004

- Discovered Z-axis (vertical) mobility of a low noise probe was faulty
- Entire apparatus re-exposed to air when probe arms were taken off vacuum chamber
- Station placed in positive pressure nitrogen box to minimize exposure to moisture in air

Probe Station Working (again) with a Sample

11:30 AM July 19, 2004



Results Thus Far

- Positive pressure Nitrogen box built and is housing microprobe
- Microprobe is up and running at target temperature (sub 80 K) with a mounted sample
- Samples ready for electromigration testing
- Statistical and Electrical tests are being performed on nanowires

Acknowledgements

- NIST
- My semiconductor group at NIST
- Ganesh Ramachandran for being my Advisor
- MMR Technologies