PPMS Training – ETO Measurements

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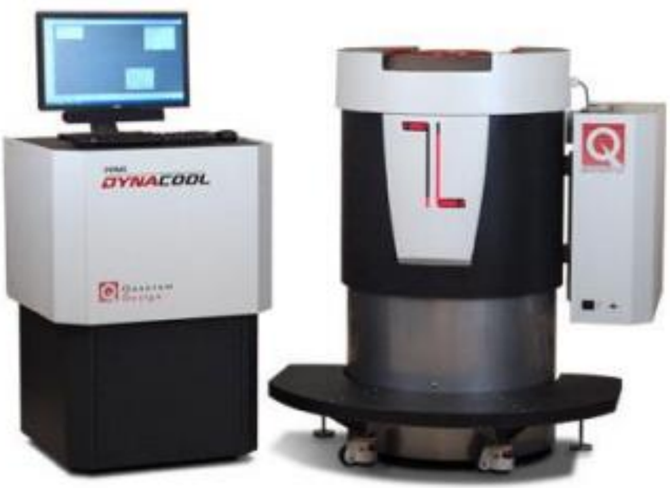
Background

DynaCool Physical Properties Measurement System (PPMS)



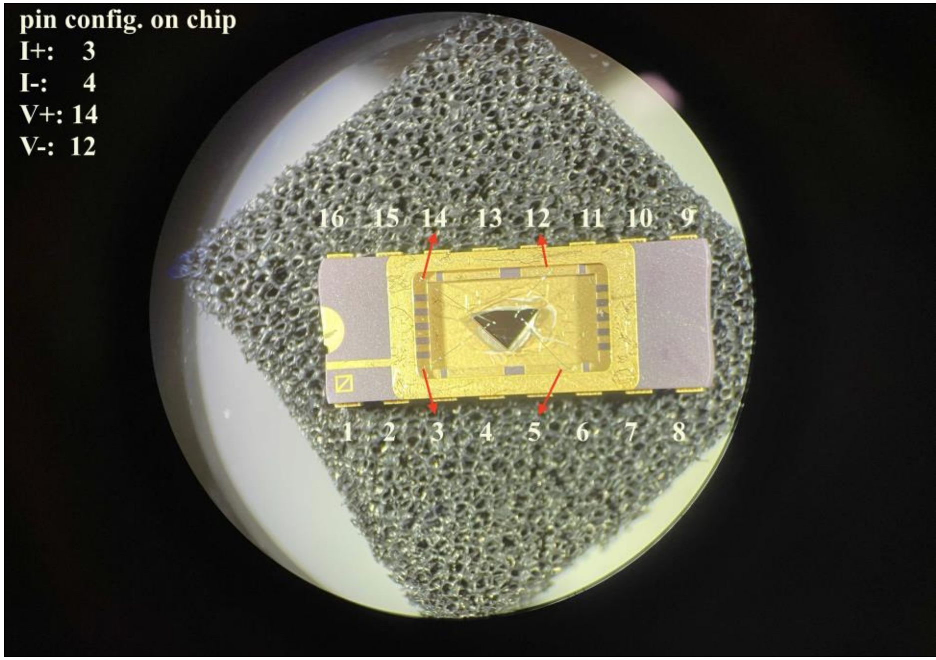
Samples mount on "pucks" which insert in system

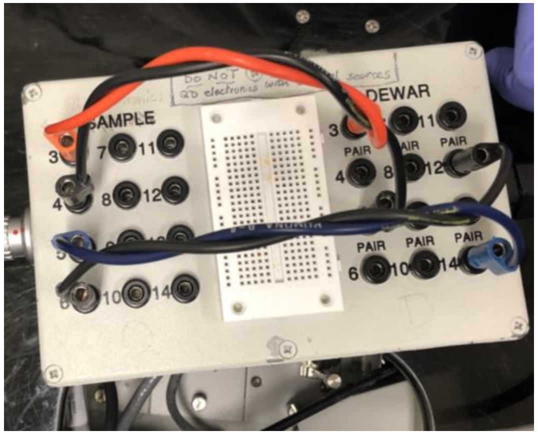
- General field/temperature platform:
  - Temperature: 1.8 – 400 K
  - Magnetic field: +/- 9 tesla (90 kOe)
  - 25mm diameter sample space
- Hosts wide variety of automated measurements...
- Electrical transport: magnetoresistance, Hall effect, I-V curves; external gating possible
  - Micro-ohm up to 5 giga-ohm
  - Automated sample rotation
- Heat Capacity micro-calorimeter
- Thermal Transport:
  - Thermal conductivity
  - Seebeck & Nernst effects
- Magnetometry: DC magnetic moment using VSM
  - 10^{-6} emu up to 100 emu
- Ferromagnetic Resonance (FMR) to 18 GHz

[1]

Set up

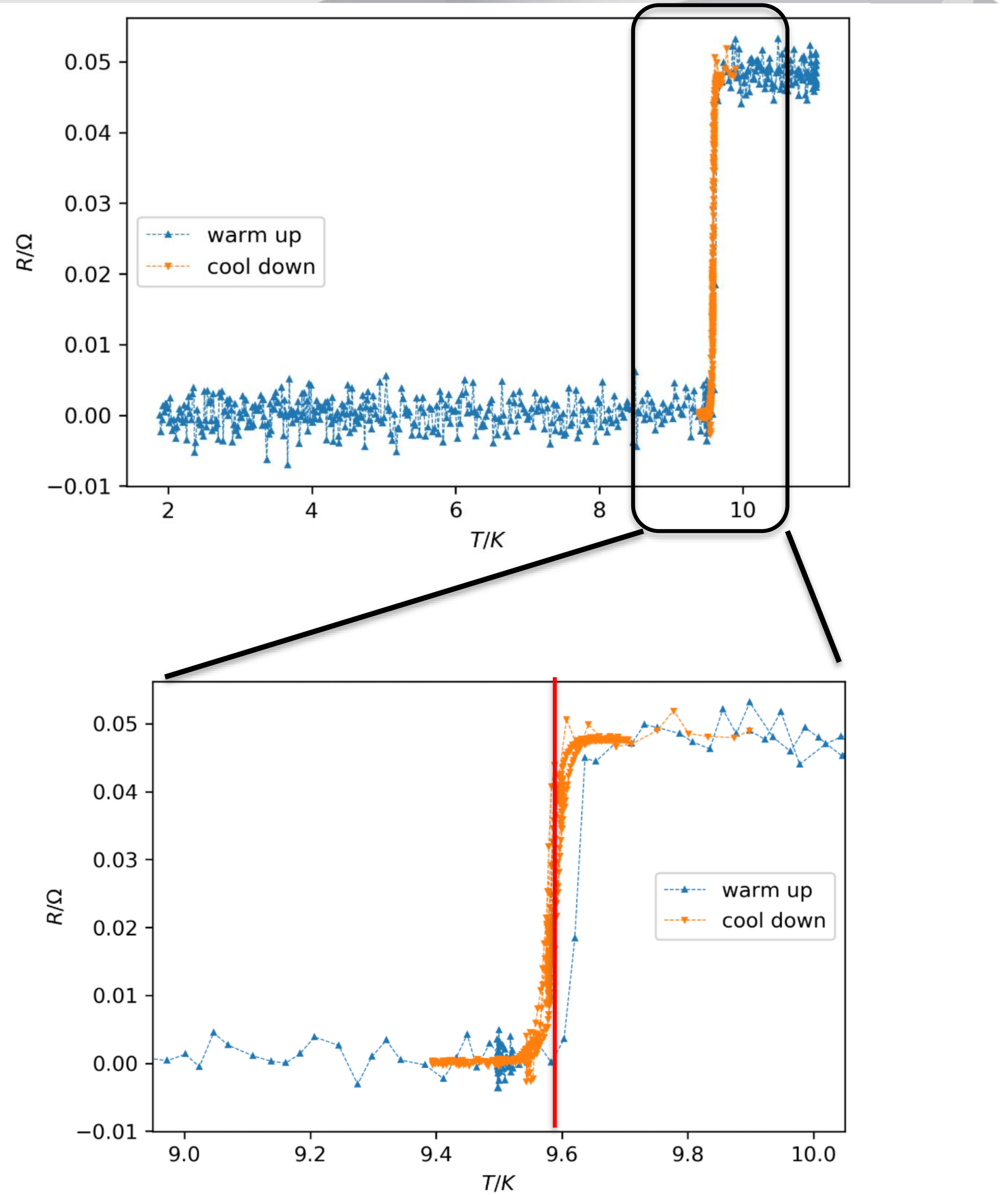
- **Our sample:** 150 nm Nb film over a sapphire substrate.
- **Wirebond:** Al
- **Goal:** Critical Temp (Tc) measurement using a low resistance 4-point measurement.
    - Also investigated:
        - Critical H field
        - Self-heating Current





Tc Measurement: R vs T

- Measure Tc: ~ 9.6 K
- Bulk Tc for Nb: 9.2 K
- For Nb thin films: ~ 9.5 K
- Transition window: ~ 0.1 K



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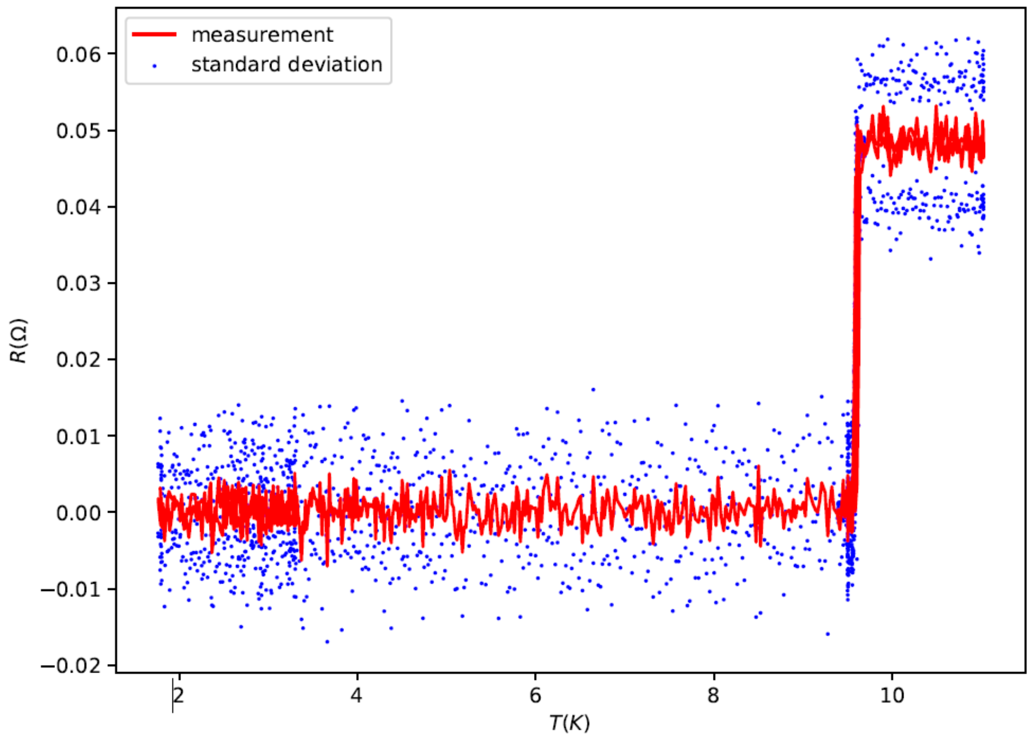
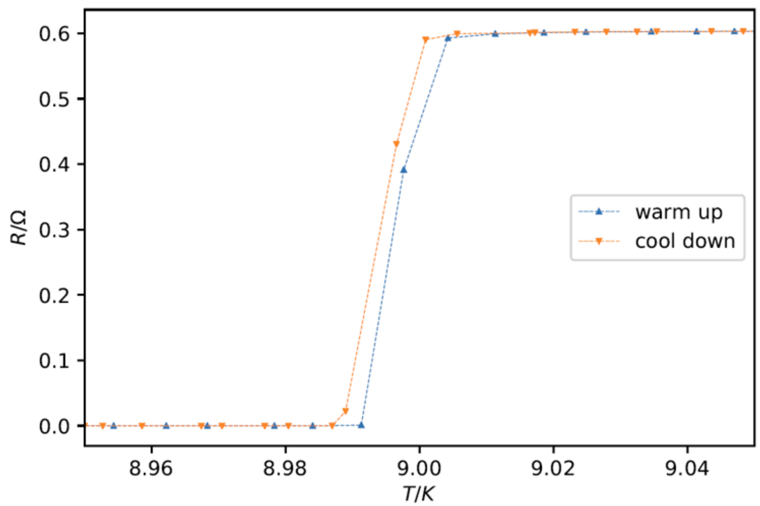
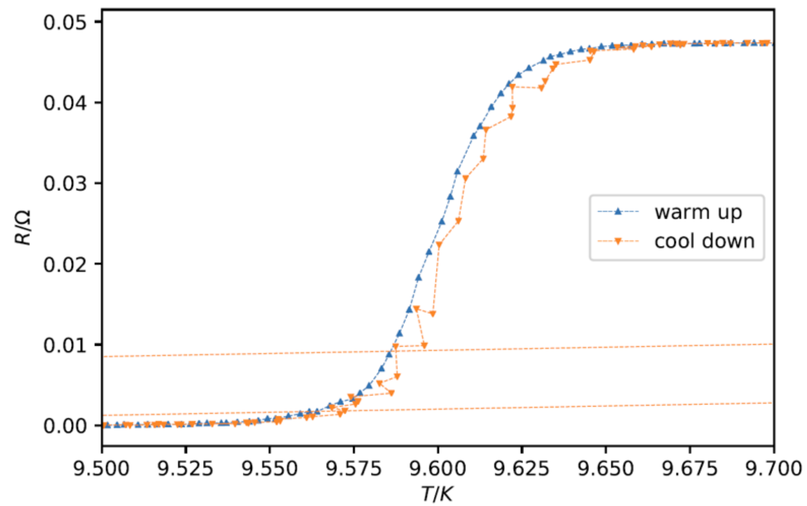


Tc Measurement



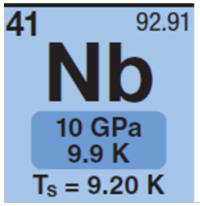
Evaporated without heating

Tc ≈ 8.99 K
Transition width ≈ 0.02 K

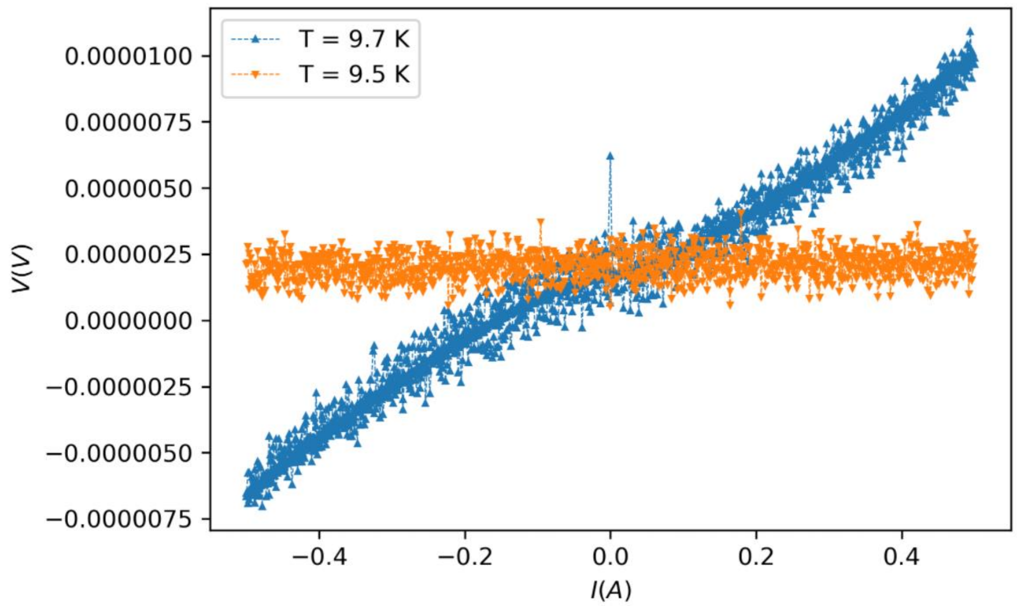


Evaporated @ 700C

Tc ≈ 9.6 K
Transition width ≈ 0.1 K



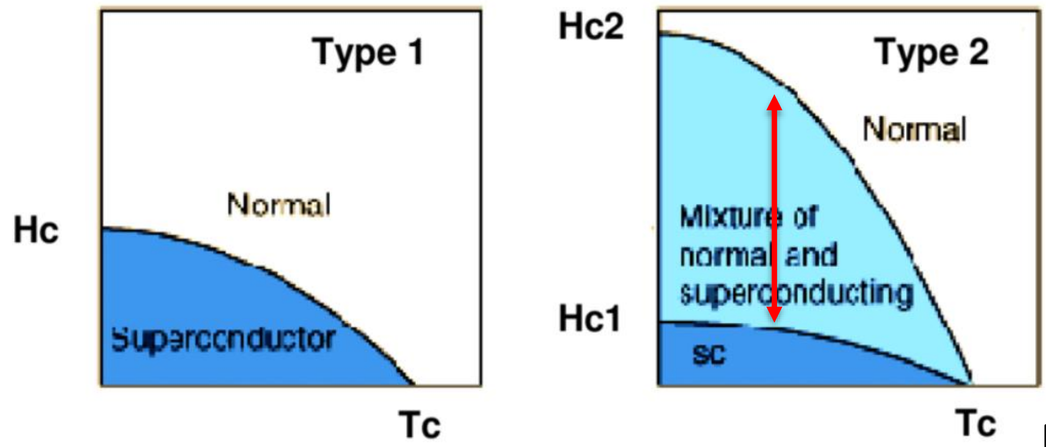
IV Curves and Self-heating Current



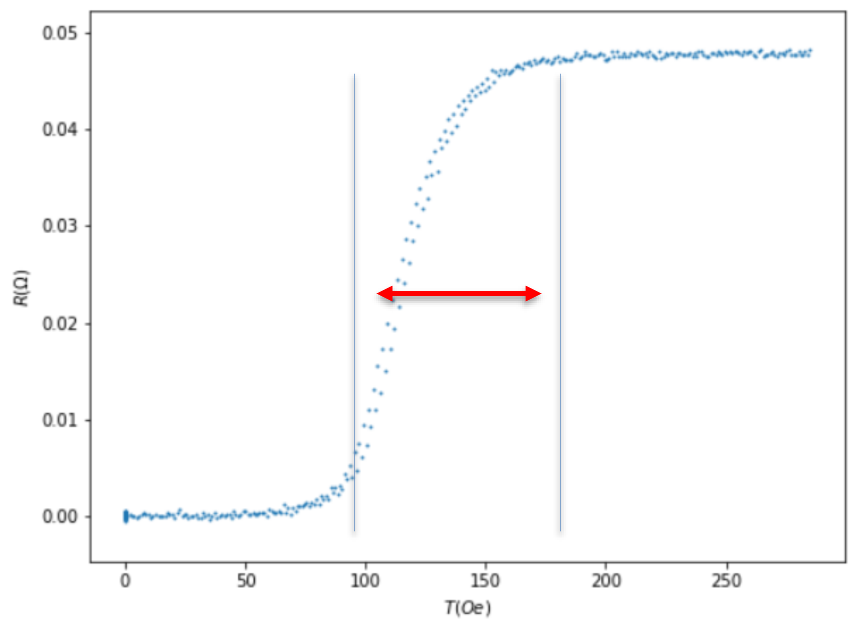
- Applying current to a metal in a superconducting state will not result in a change in voltage, since the resistance is zero (orange).
- However, there is a limit to the amount of current flowing before self-heating of the superconductor starts.
- Beyond that limit, additional current will result in the metal transitioning out of the superconducting state, and a corresponding voltage will appear (blue).

Hc Determination

- Nb film sample is a Type II Superconductor.
- In such materials, H fields are expelled up to a critical H field (Hc1), after which the material partially admits H fields.
- At Hc2, the material no longer behaves as in a superconducting state.



[2]



- In our measurement (taken at 9.5K):
  - Hc1 ~ 75 Oe
  - Hc2 ~ 175 Oe
- This is consistent with previously measured values of Nb. [3]

Conclusion

- T_c, H_{c1}, H_{c2} were all successfully measured and were consistently with known values for Nb films.
- Self-heating current was also investigated using ETO, but further measurements would be required for a well-defined limit. This is not currently a focus of our group, but may be investigated at a later time.

References

1. Dilley, Neil. Birck Nanotechnology Center Wiki, Quantum Design DynaCool PPMS page. Quantum Design DynaCool PPMS - Birck Nanotechnology Center Wiki - Confluence (purdue.edu)
2. Pattini, Francesco. (2009). Growth of oxide thin films for energy devices by Pulsed Electron Deposition.
3. Stromberg, Thorsten Frederick. (1936). The Superconducting Properties of High Purity Niobium. Iowa State University of Science and Technology.

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