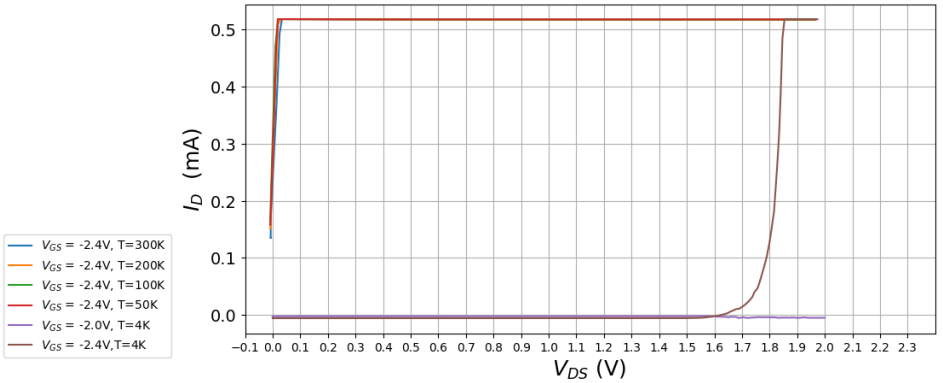
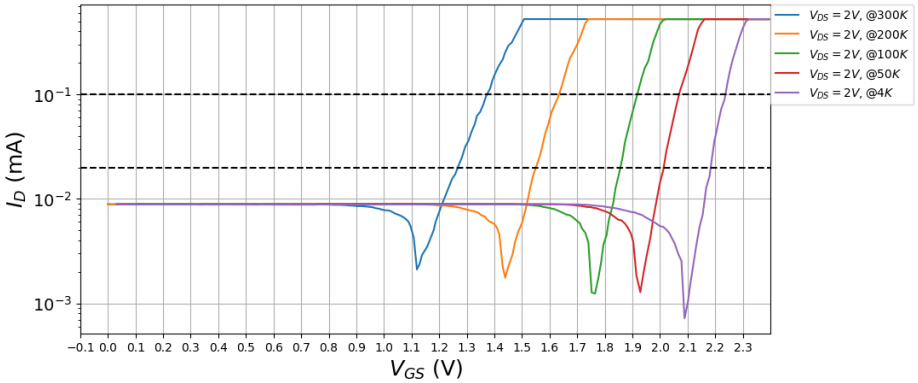
MOSFET Characterization at Cryo

Giovanni Michel

Northwestern

How to deduce the Subthreshold-Swing vs. Temperature





$SS = 143.\frac{mV}{dec}$ T=300K $114.\frac{mV}{dec}$ 200K $114\ \frac{mV}{dec}$ 100K $129\frac{mV}{dec}$ 50K

- The first plot shows the *I-V* plot for a P-type device.
- The second plot shows the $\log(I_D)$ vs. V_{GS}.
- Subthreshold-Swing equation:

$$SS = \left(\frac{d[\log_{10}(I_D)]}{d(V_{GS})}\right)^{-1} * 1000$$

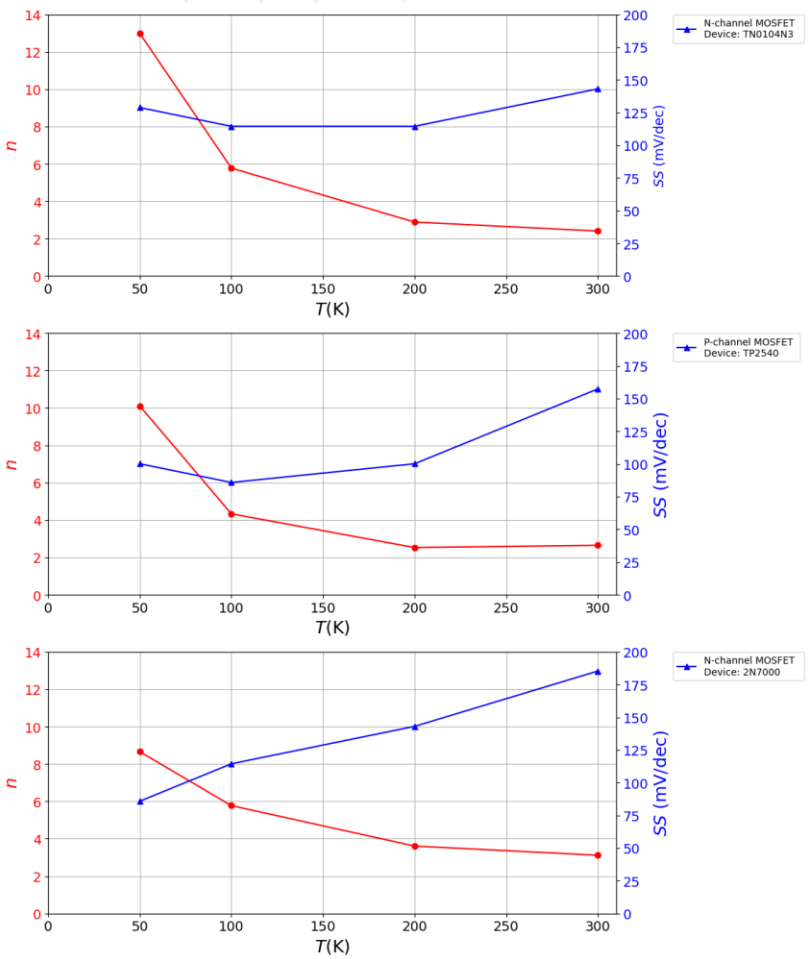
Measured Subthreshold-slope at cryogenic temperatures

- Study of 3 different MOSFET devices 2 N-channel and 1 N-channel.
- See appendix A for SS and I-V preliminary data.
- Subthreshold-slope, SS vs. T in the blue lines.

$$SS = n \ln(10) \frac{kT}{q}$$

- SS vs. T, scaling factor is on the left side of the plot in the red lines.

$$n = 1 + \frac{C_d}{C_i}$$



Solving for ϕ_F using depletion width model of MOSFET

- W_M , the depletion width under the channel is defined in terms of ϕ_F , the Fermi potential as

$$W_M = \left(\frac{\epsilon_0 \epsilon_s}{qN_{a,d}} 2|\phi_F|\right)^{\frac{1}{2}}$$

- C_d , the depletion capacitance is expressed in terms of the depletion width as

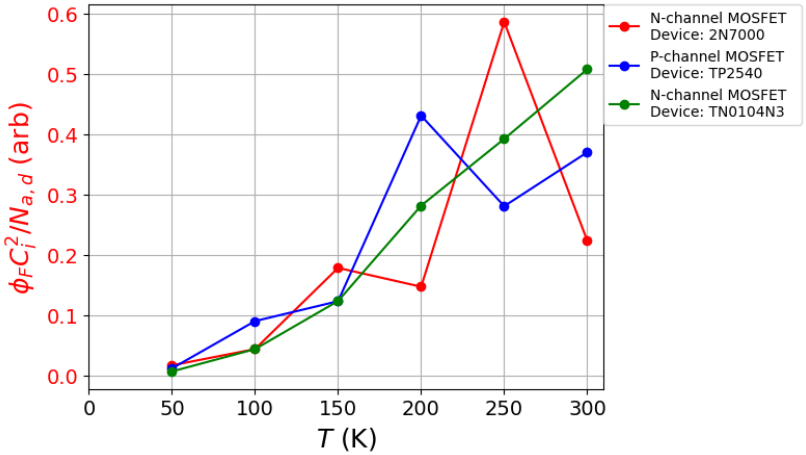
$$C_d = \frac{\epsilon_0 \epsilon_s}{W_M}$$

- From n, the scaling factor I can deduce the depletion capacitance. Then I plug the new equation for the depletion capacitance. The goal was to isolate ϕ_F since this is needed to get the depletion width.

$$C_d = C_i(n-1)$$

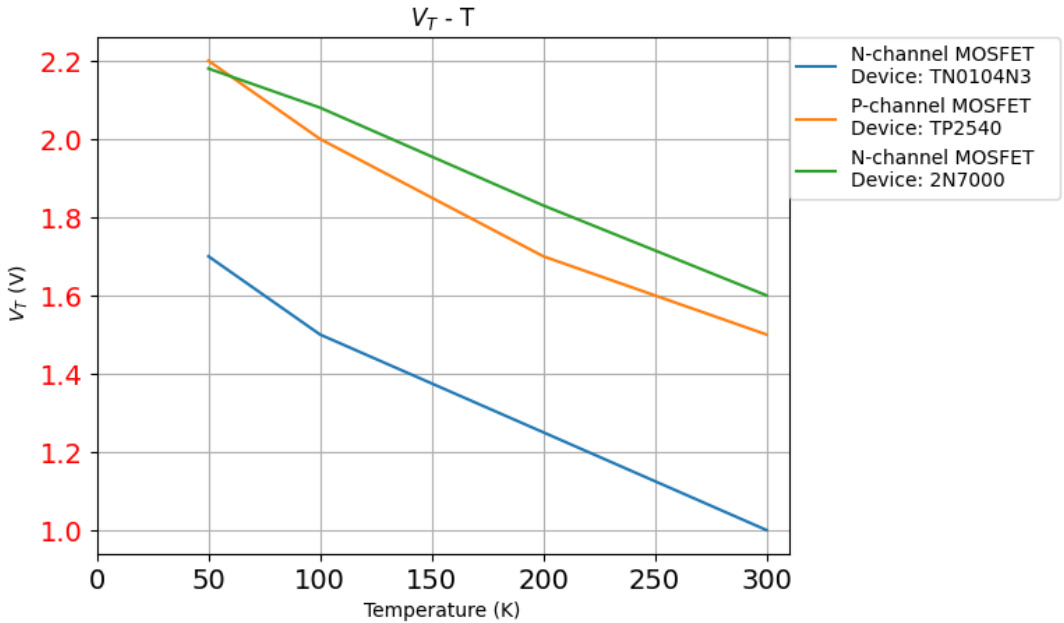
$$\phi_F = \frac{qN_{a,d}W_M^2}{2\epsilon_0\epsilon_s} = \frac{q\epsilon_s\epsilon_0 N_{a,d}}{2C_d^2}$$

$$\frac{\phi_F C_i^2}{N_{a,d}} = \frac{q\epsilon_s\epsilon_0}{2(n-1)^2}$$

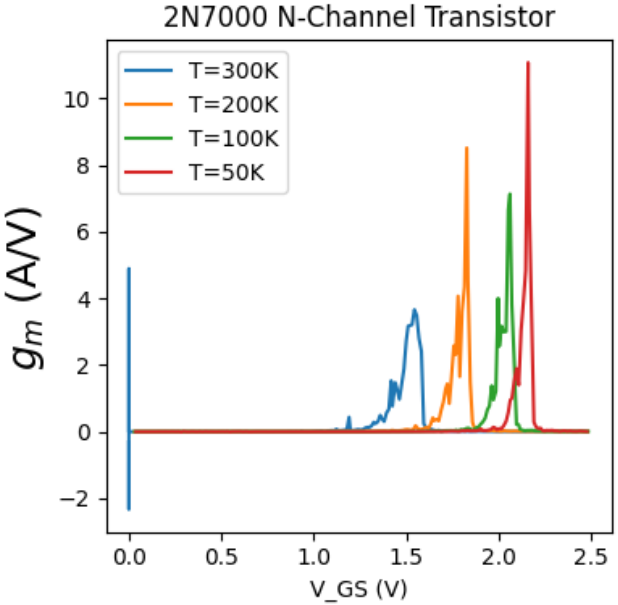


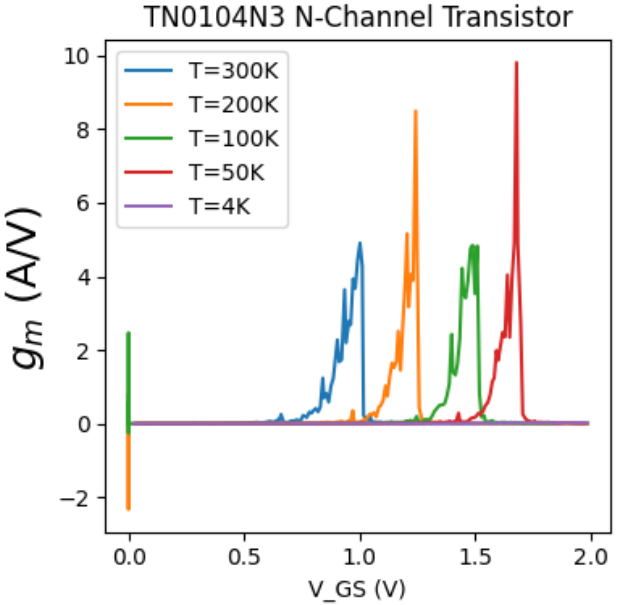
Plot for $V_t(T)$

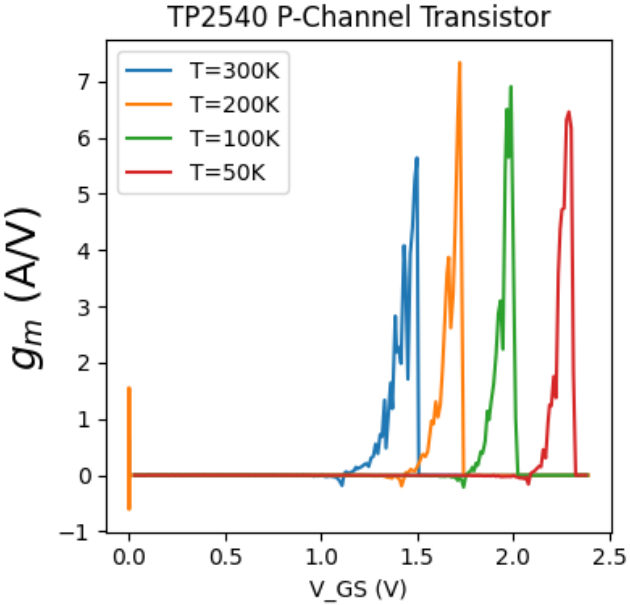
- From the data collected our measurements show that as T, the temperature decreases, V_t the voltage threshold increases.



Plots for $g_m(T)$

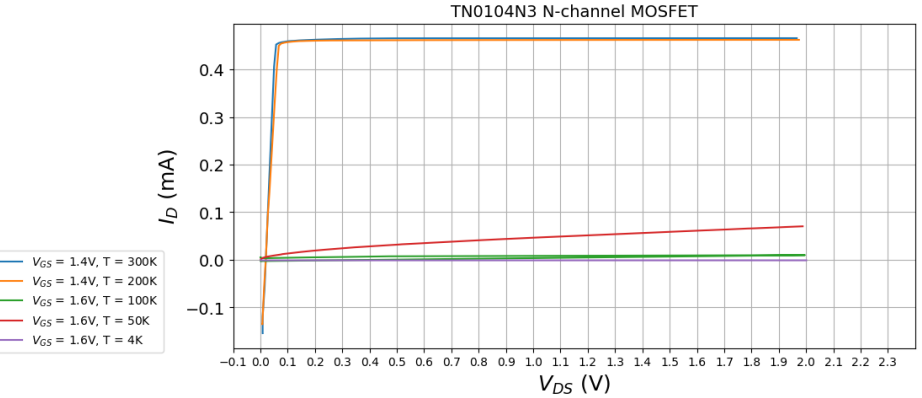


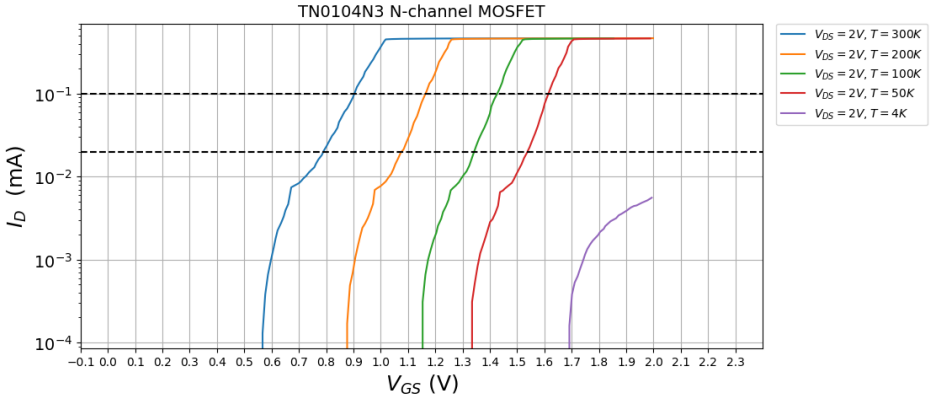




Note for P-MOS, $-V_{GS} = V_{GS}$, we multiplied by -1 when plotting

Appendix A.1





- I-V Measurements for n-type device and Subthreshold-Swing.

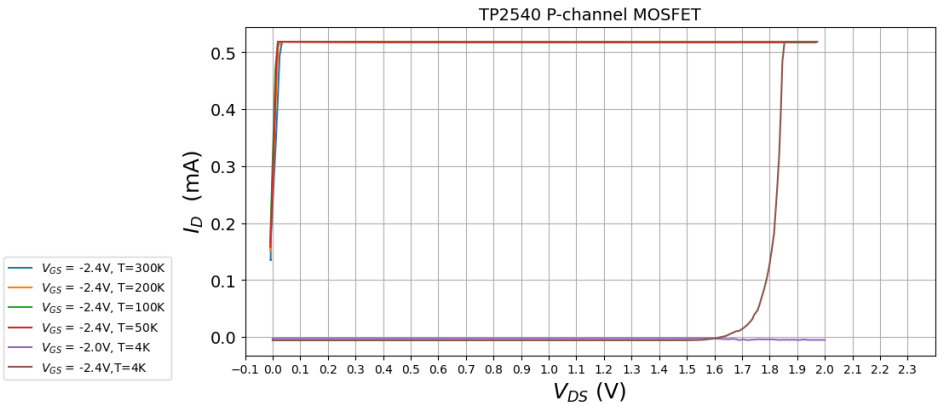
$SS = 143.07 \frac{mV}{dec}$, T=300K

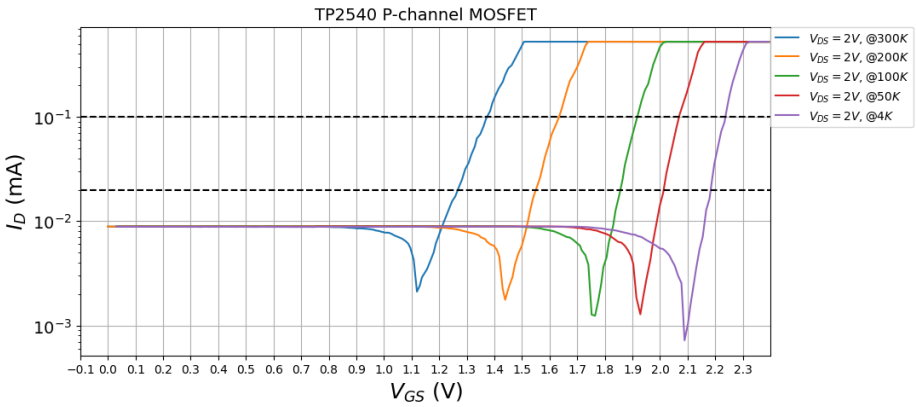
$114.45 \frac{mV}{dec}, 200K$

$114.45 \frac{mV}{dec}, 100K$

$128.76 \frac{mV}{dec}, 50K$

Appendix A.2





- I-V Measurements for p-type device and Subthreshold-Swing.

$SS = 157.37\frac{mV}{dec}$, T=300K

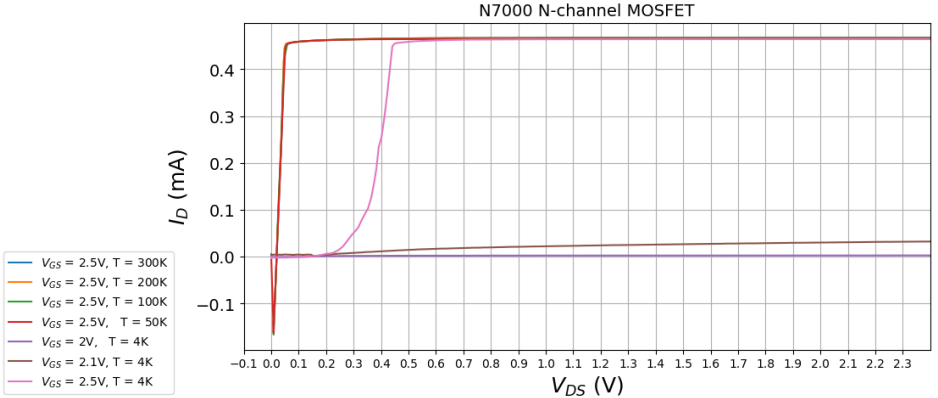
$100.14\frac{mV}{dec}, 200K$

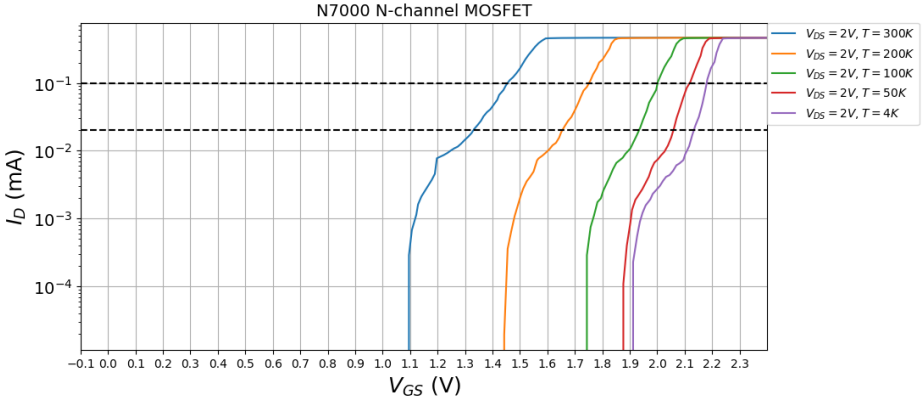
$85.84\frac{mV}{dec}, 100K$

$100.14\frac{mV}{dec}, 50K$

$71.53\frac{mV}{dec}, 4K$

Appendix A.3





- I-V Measurements for n-type device and Subthreshold-Swing.

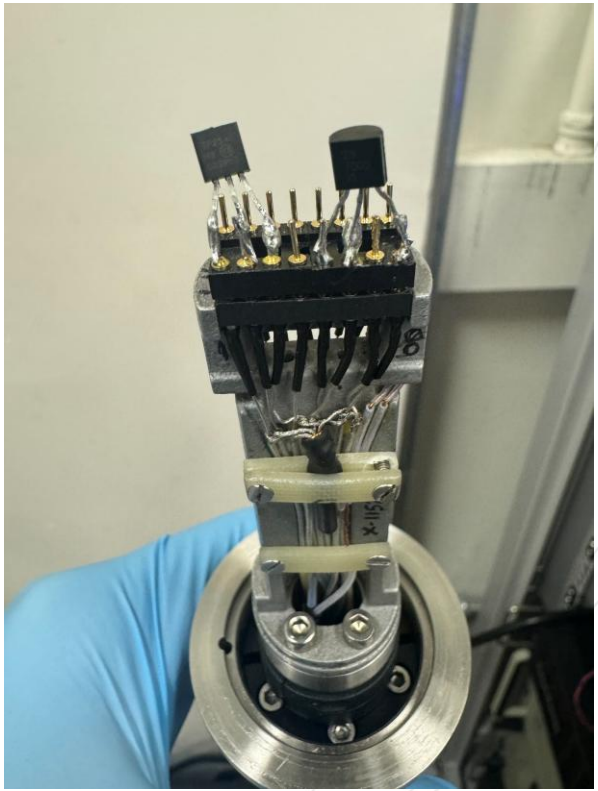
$SS = 185.98\frac{mV}{dec}$, T=300K

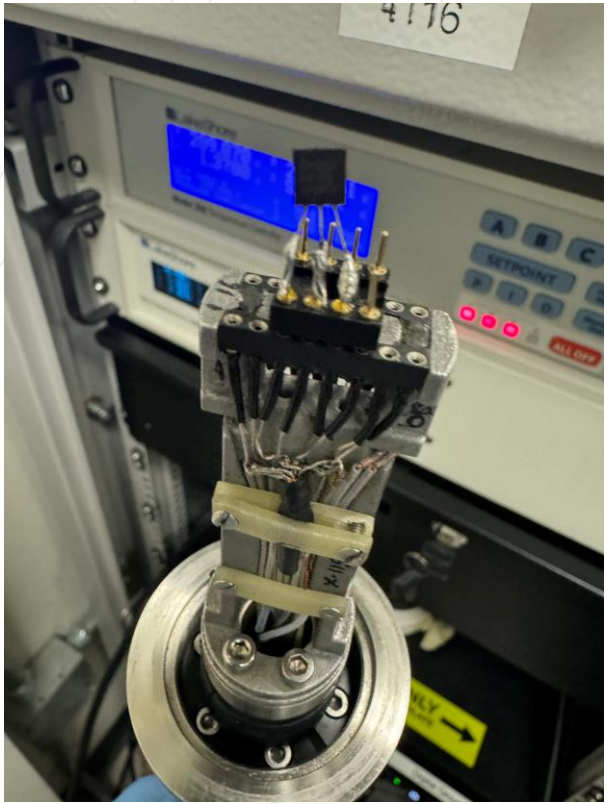
$143.06\frac{mV}{dec}, 200K$

$114.45\frac{mV}{dec}, 100K$

$85.84\frac{mV}{dec}, 50K$

$85.84\frac{mV}{dec}, 4K$




4176