Investigation of α-Sn thin films

Christian Bunker

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Background

- β-Sn or white tin is the metallic phase of tin that we are accustomed to in daily life
- α-Sn or gray tin is a semiconductor with a diamond cubic structure
- α-Sn is interesting because it exhibits band inversion in the bulk without having to make a compound or heterostructure

Band structure

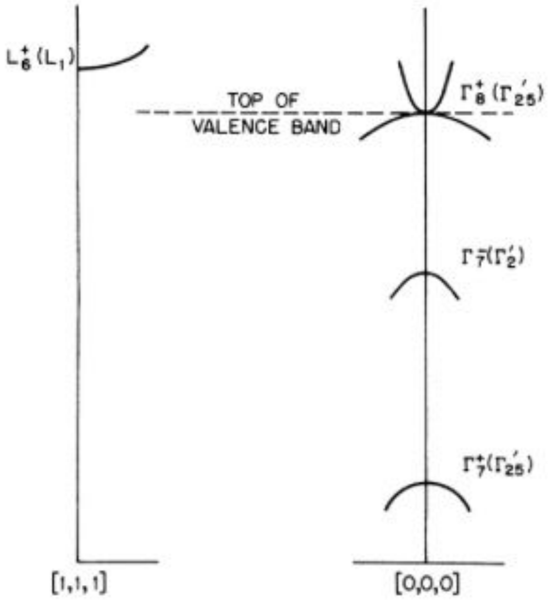


FIG. 1. Energy-band extrema for the proposed model of gray tin.

Samples

- 48 nm (100) α-Sn, on CdTe substrate
- 18 nm (100) α-Sn, on CdTe substrate

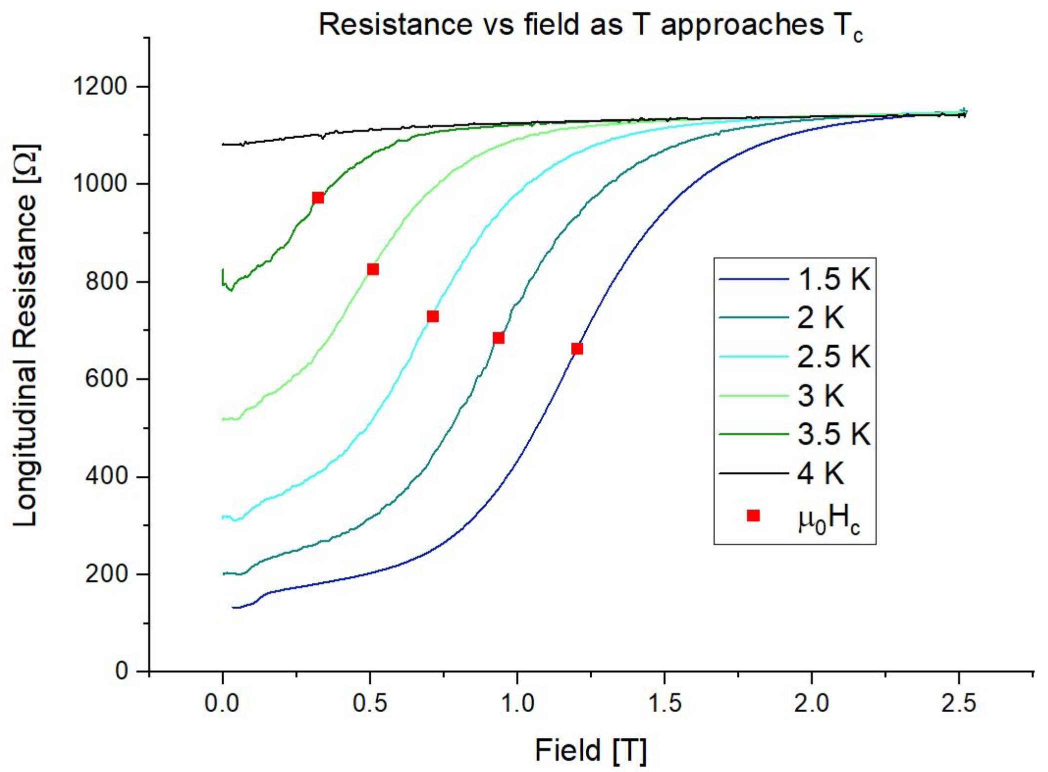
Superconductivity

- Bulk β-Sn exhibits superconductivity at 3.72 K
- Thin film β-Sn exhibits superconductivity at 3.71 K
- Previous papers have claimed that pockets of β-Sn can form in α-Sn thin films
- This leads to potential superconductivity

48 nm B field sweeps

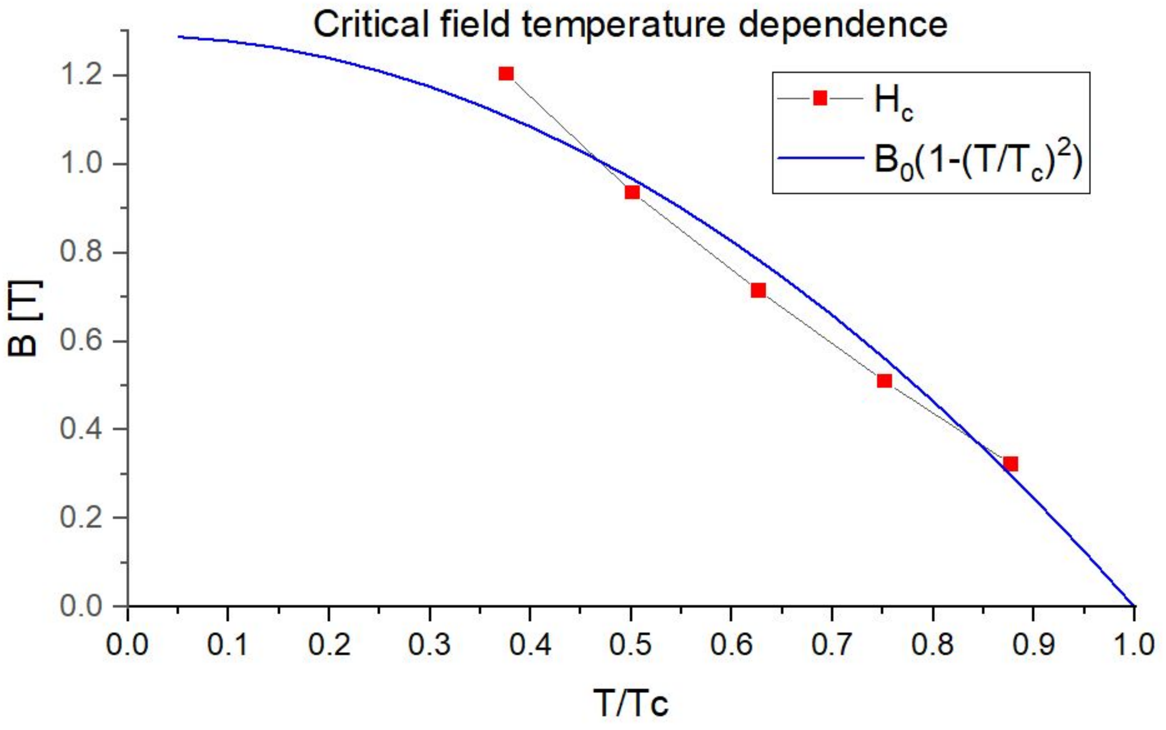
- 1 microamp current
- H_c decreases with T
- Floor of the resistance curve increases with T
- Logistic fit determined critical field

$$f(x) = B + \frac{A - B}{1 + (x/x_0)^p}$$



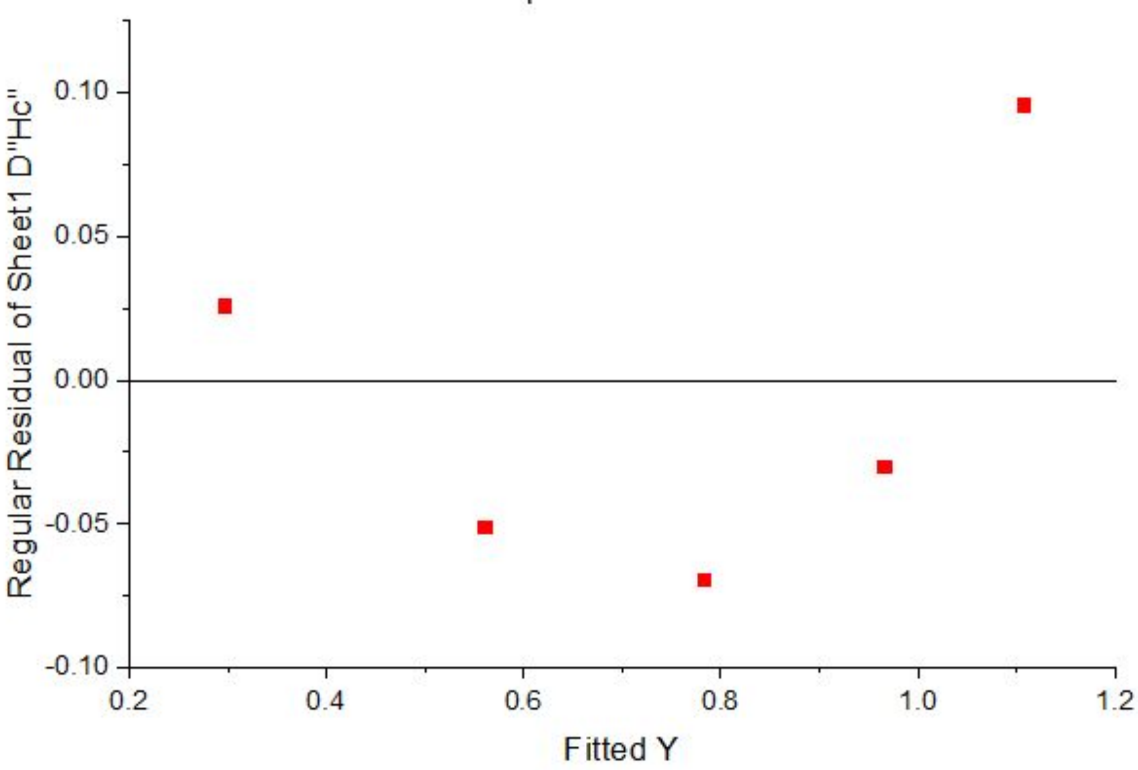
48 nm B field sweeps

- Fit is used to determine the critical field at 0 K, B_0
- Quadratic fit is typical for bulk samples and continuous films



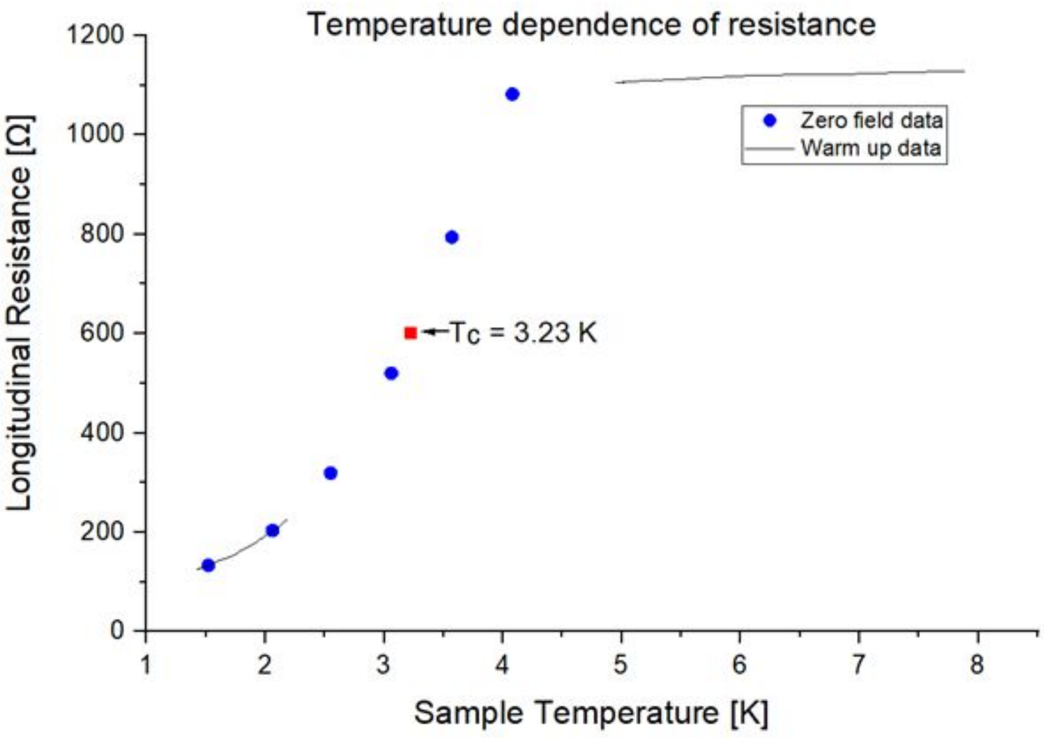
48 nm B field sweeps

- Residuals show a poor fit
- Sample may not be continuous



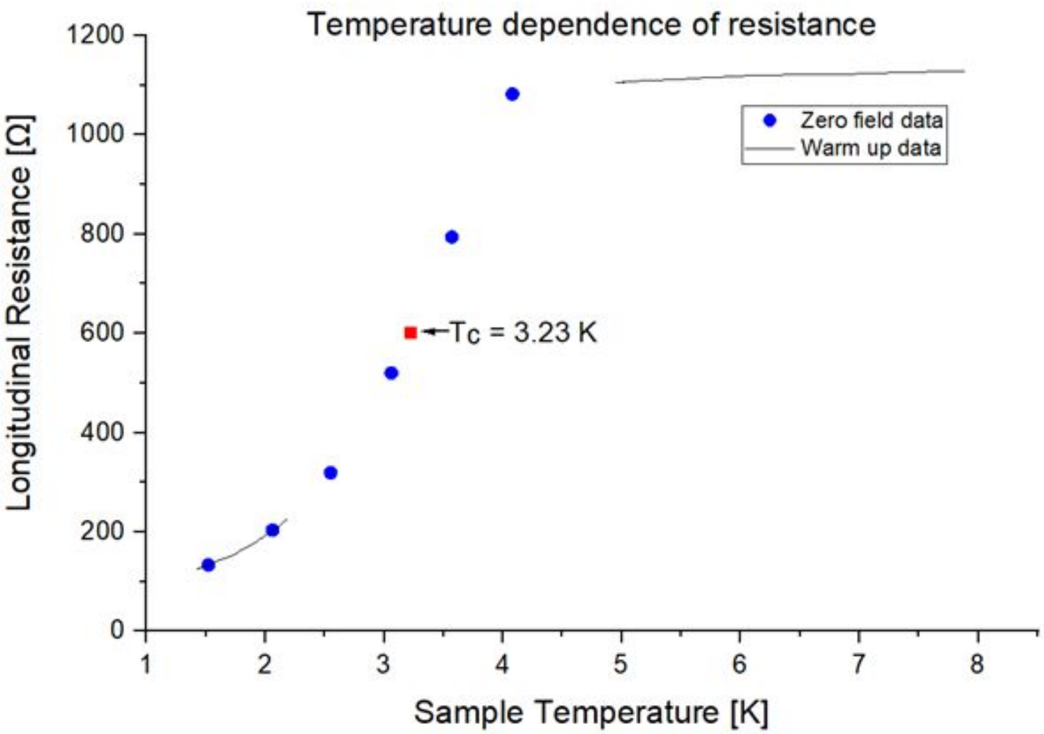
48 nm temperature sweep

- Temperature sweep shows strong evidence of superconductivity
- Previous papers suggest superconductivity in α-Sn is due to pockets of β-Sn which is superconducting



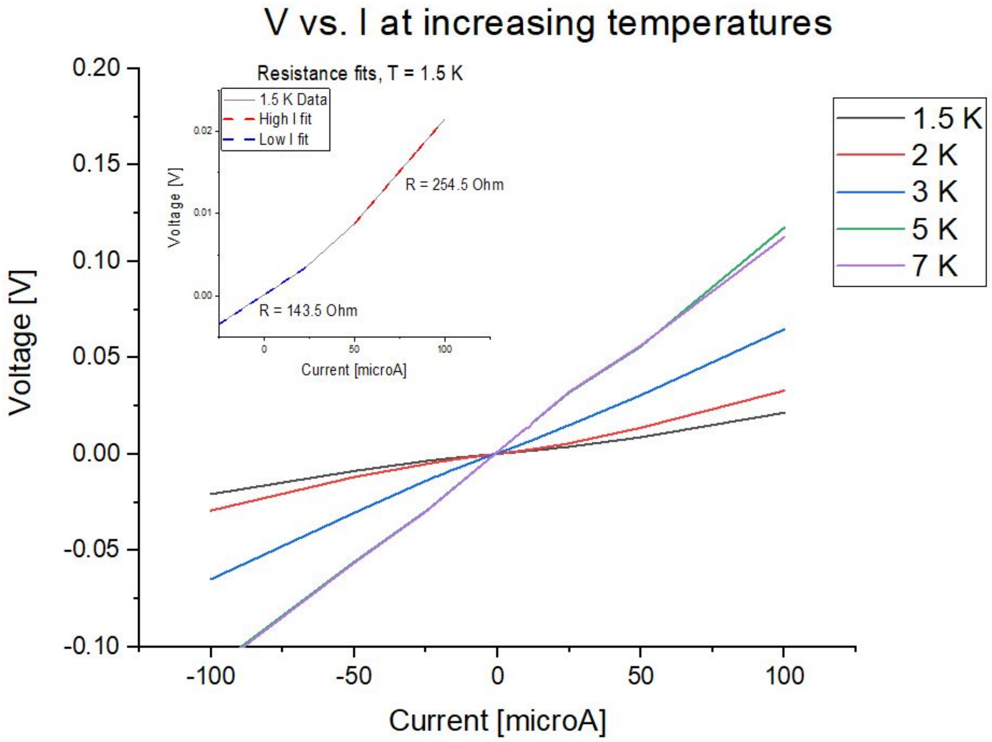
48 nm temperature sweep

- β-Sn reaches critical temperature at 3.71 K
- α-Sn is expected to reach superconductivity at lower temperature due to pocket effect



48 nm current sweep

- Expect to see an I_c for $T < T_c$ above which R approaches its typical $T > T_c$ value
- Need to investigate higher currents (~1 mA)



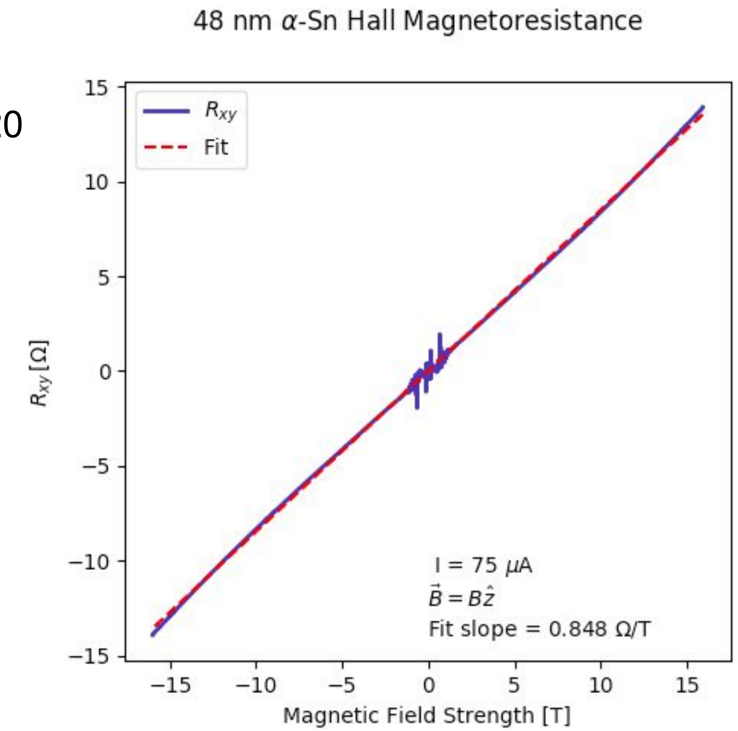
Magnetotransport

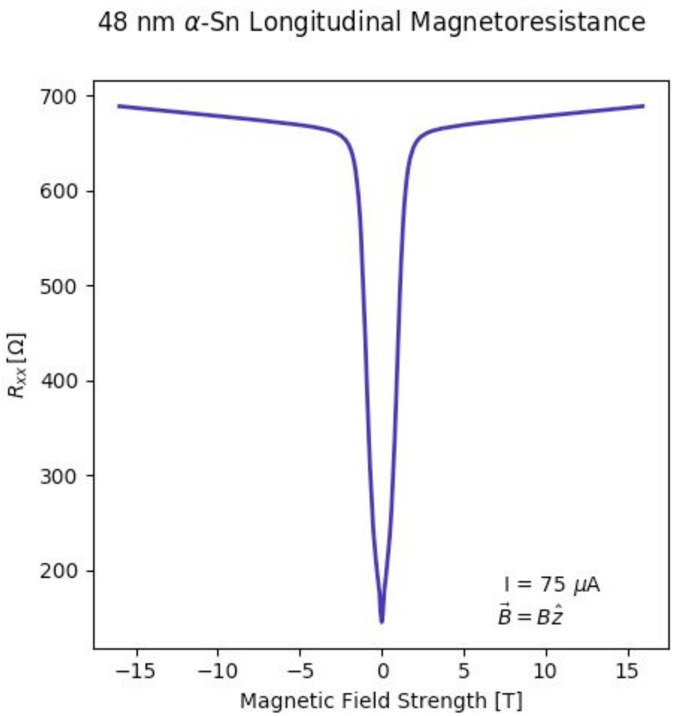
- Use a five point setup to determine the magnetoresistance

- Mixing inevitable occurs between longitudinal and Hall voltage, so we treat the data by taking the even part of the longitudinal voltage and the odd part of the hall voltage

48 nm Magnetotransport

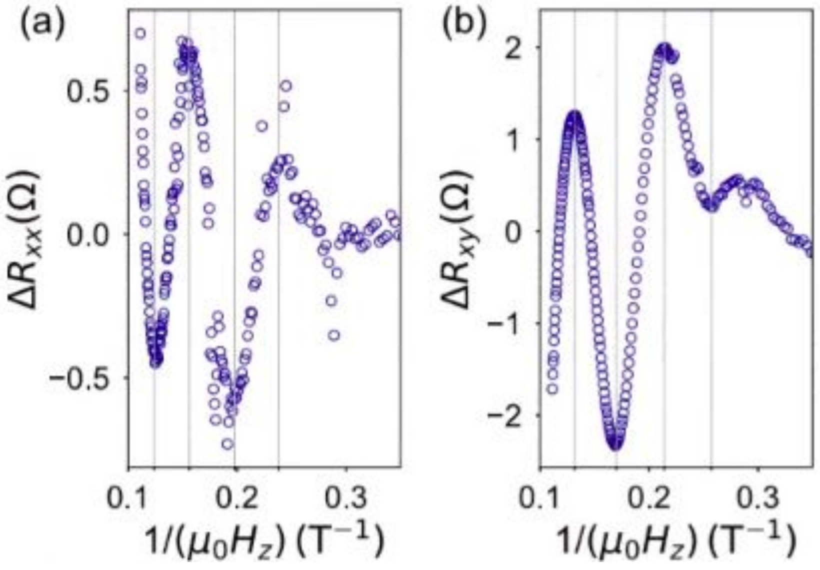
Carrier density n=1.51e20 cm^-3





Shubnikov-de Haas

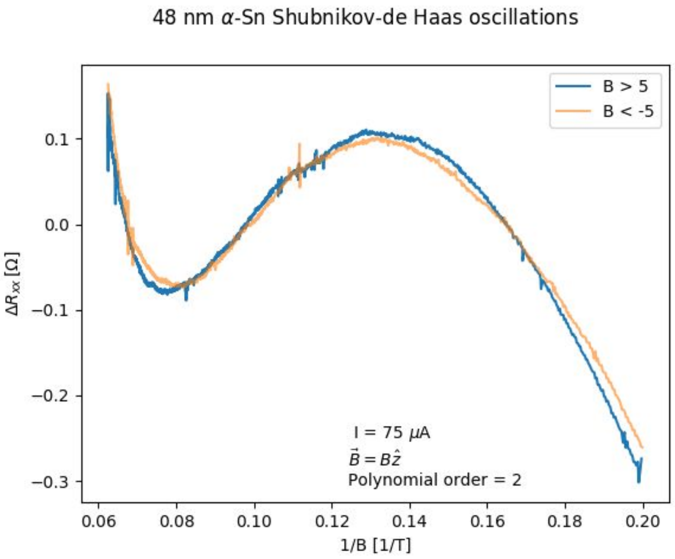
- After a subtracting a low order polynomial fit, should see oscillations in high field ($|B| > 5$ T) R_{xx} and R_{xy} data

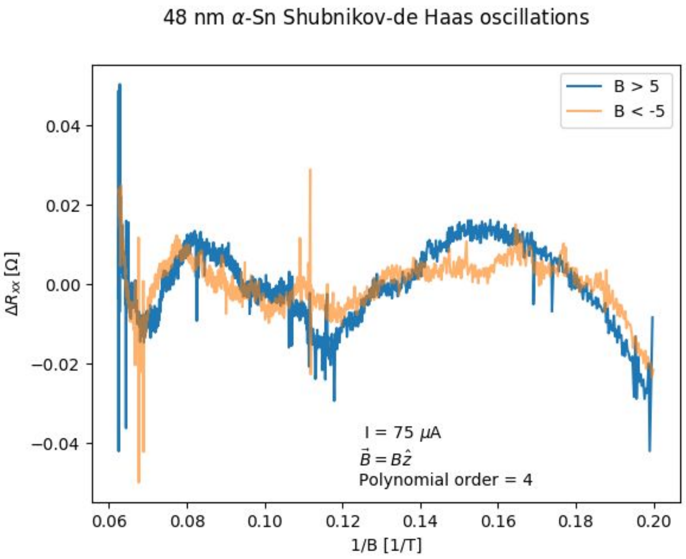


Barbadienne et al

Shubnikov-de Haas

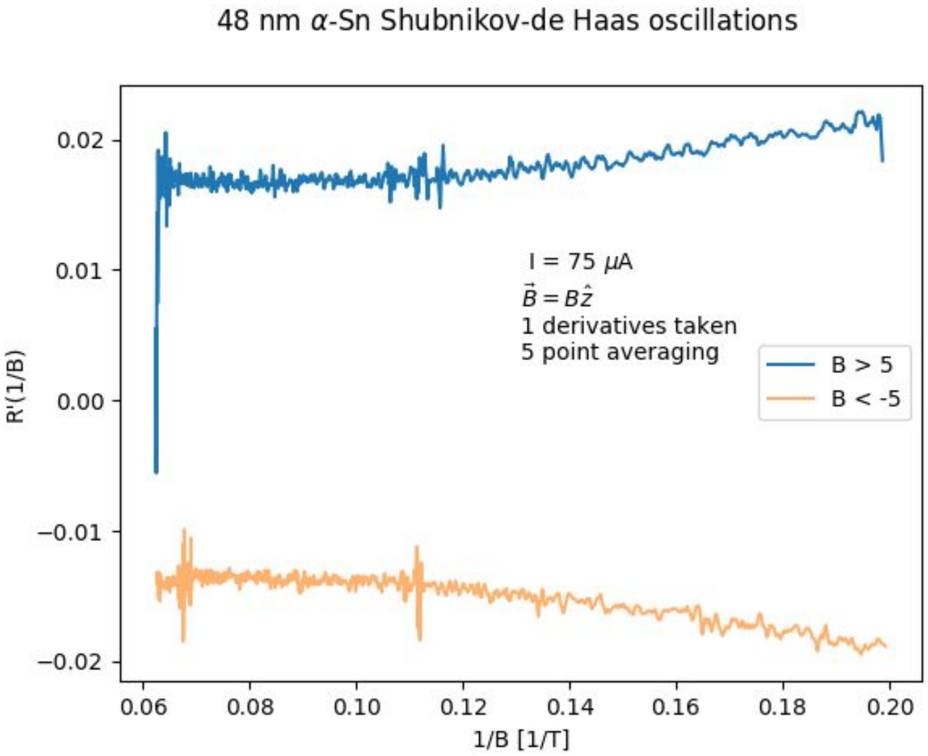
- Oscillations should be the same at positive and negative B
- Oscillations should be independent of polynomial order





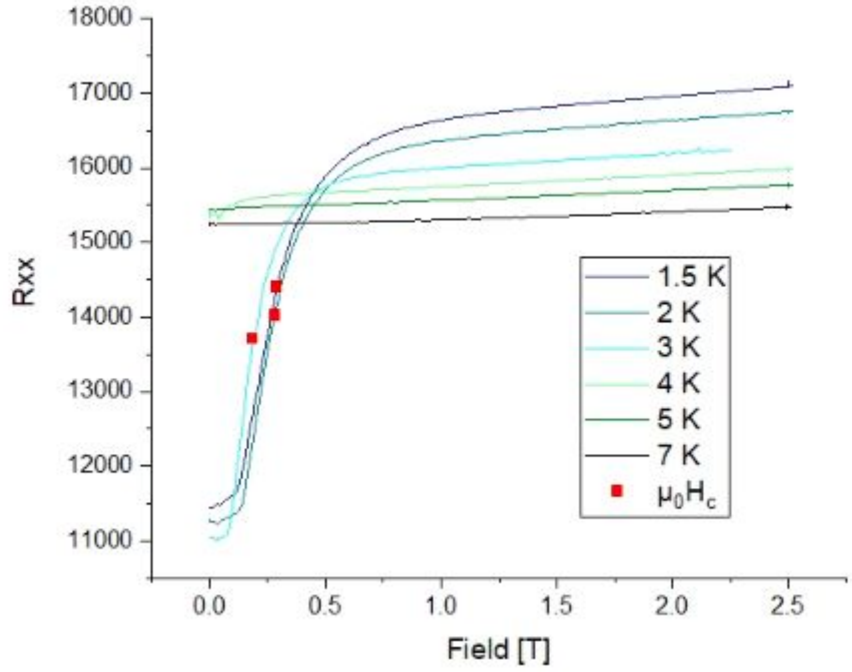
SdH derivative method

- Take derivative and do a window average smoothing method
- Results show no oscillations



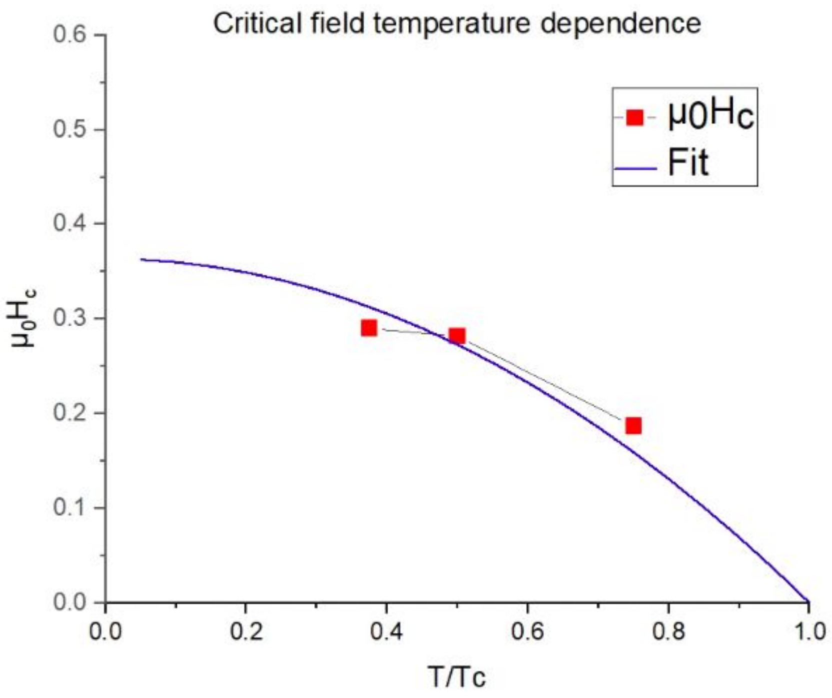
18 nm B field sweep

- Sudden rather than gradual shift



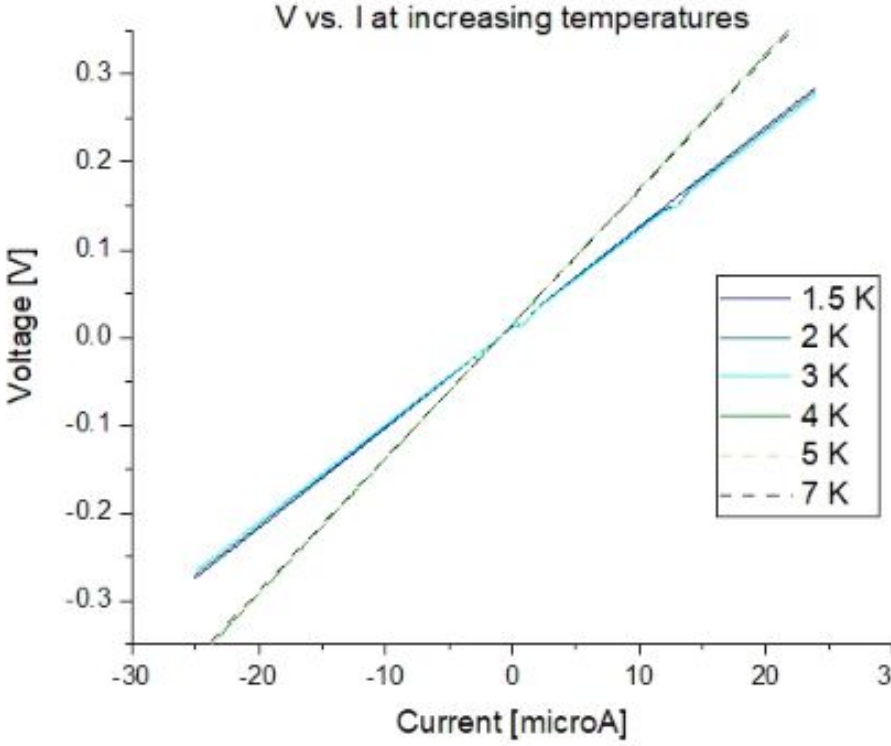
18 nm B field sweep

- Much lower critical fields and B_0 than 48 nm sample
- Still much higher than critical fields reported in literature for β-Sn thin films

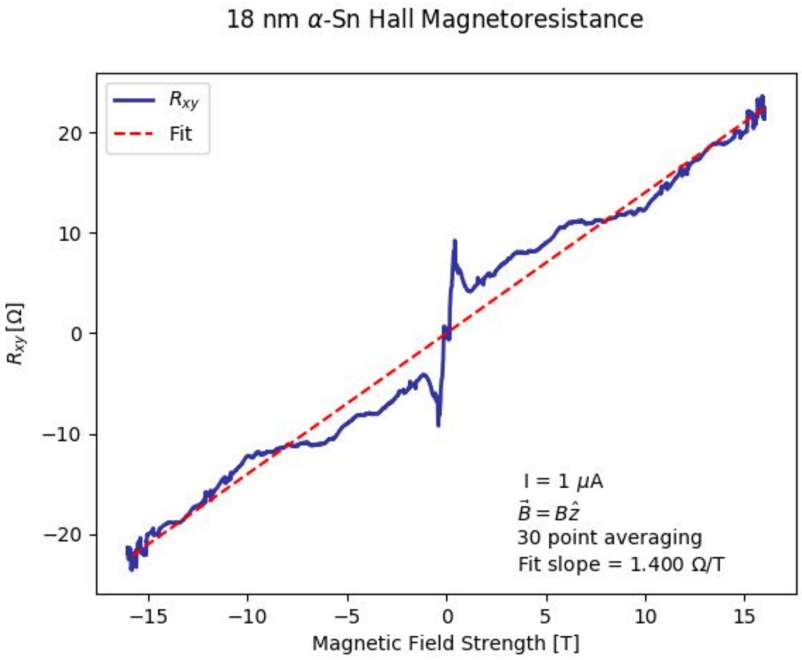


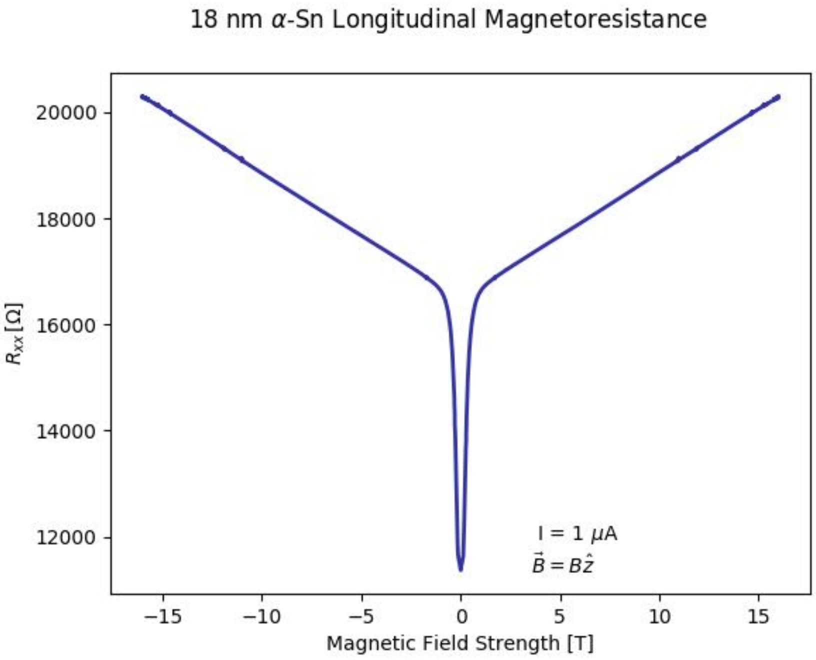
18 nm current sweep

- Again don't see strong evidence of critical current, should look at higher currents
- 3 K < T < 4 K data needed



18 nm Magnetotransport

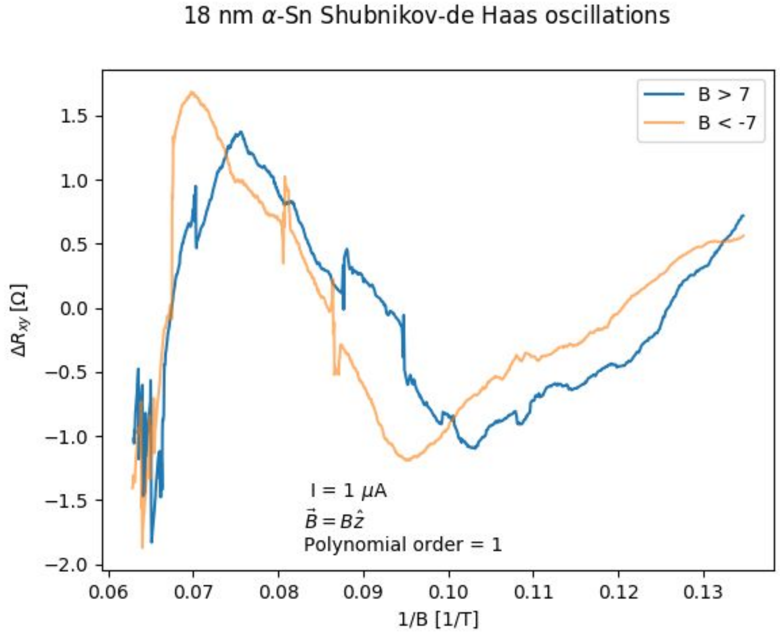


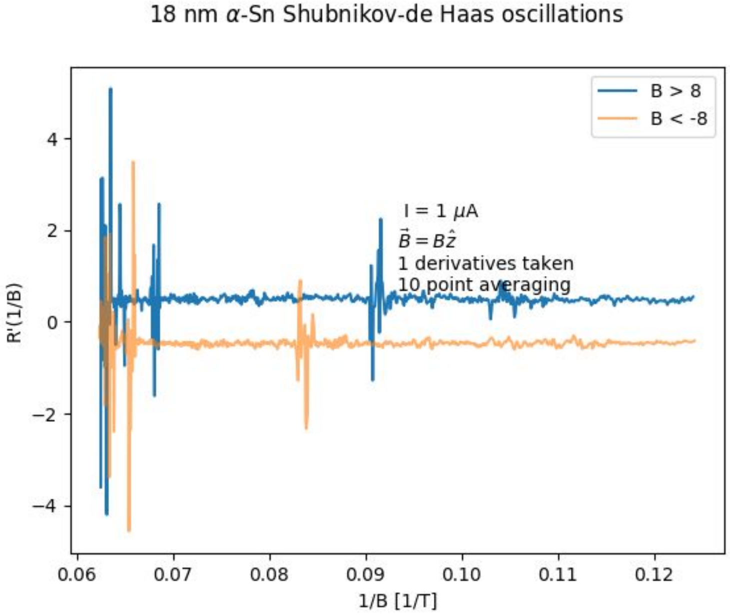


n=2.48e20 cm^-3

Shubnikov-de Haas

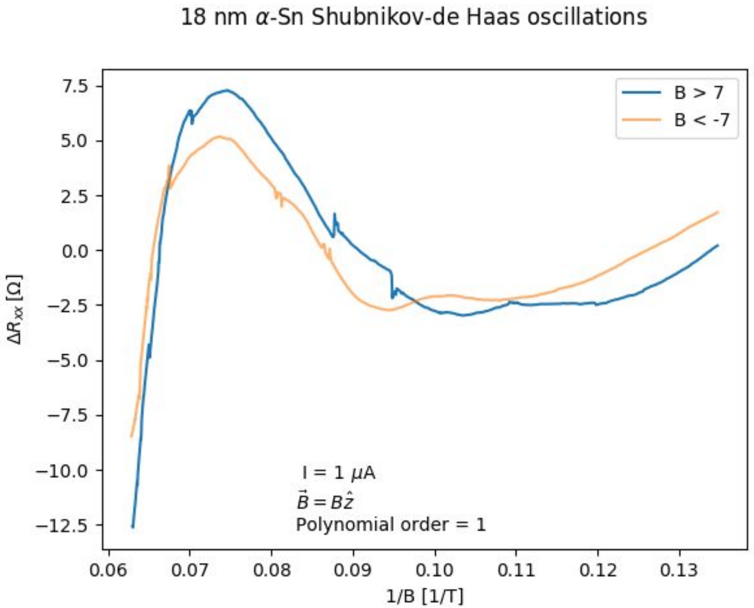
- Perhaps see oscillations in R_{xy}

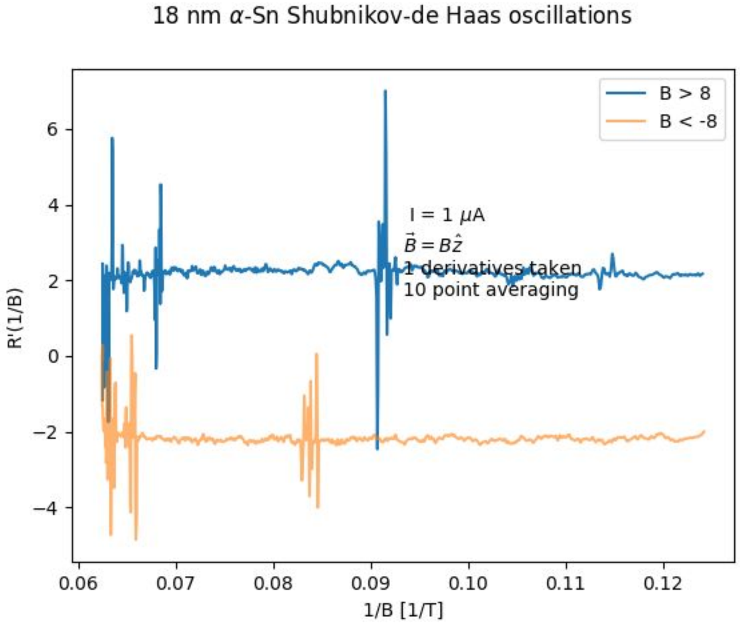




Shubnikov-de Haas

- Probably don't see them in R_{xx}





Next steps

- 48 nm sample
  - Increase current sweep to ±1 mA
  - Retake R vs T data at a slower warmup rate to allow full thermalization
- 18 nm sample
  - Repeat magnetotransport data at a higher current (~ 100 μA) to reduce voltage noise in Hall data
  - Increase current sweep to ±1 mA
  - Take R vs T data

References

1. Bang, Morrison, Rathnayaka, Lyuksyutov, Naugle, and Teizer. Characterization of superconducting Sn thin films and their application to ferromagnet-superconductor hybrids. Thin Solid Films 676, 138-143 (2019).
2. Vail, Taylor, Folkes, and Nichols. Growth and magnetotransport in thin film α-Sn on CdTe. arXiV (2019).
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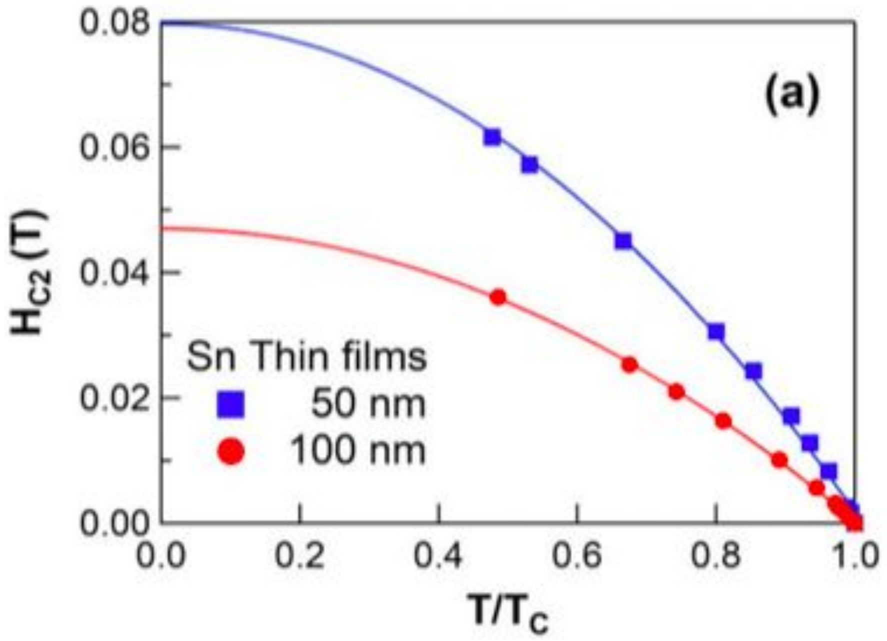
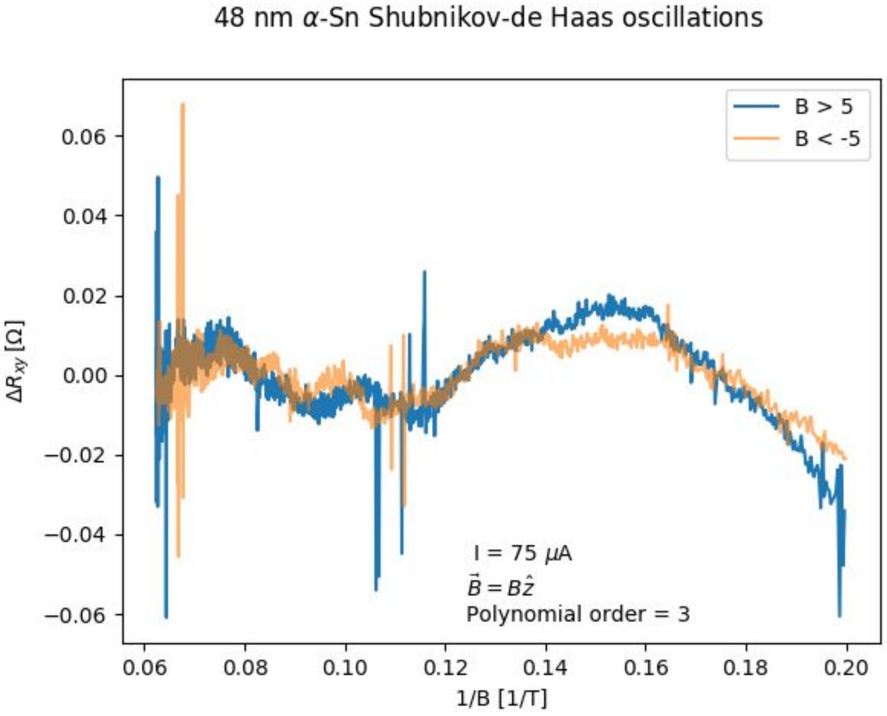
5. Barbadienne, Varignon, Reyren, Marty et al. Angular-resolved photoemission electron spectroscopy and transport studies of the elemental topological insulator alpha Sn. Physical Review B **98,** 195445 (2018)

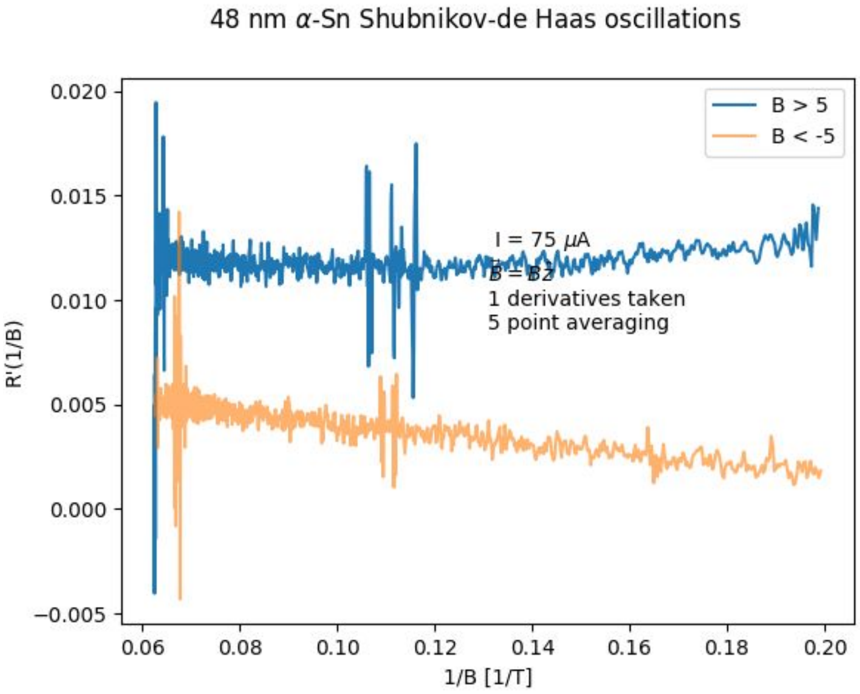
18 nm B field sweep

- Much lower critical fields and B_0
- Still much higher than critical fields reported in literature for β-Sn thin films

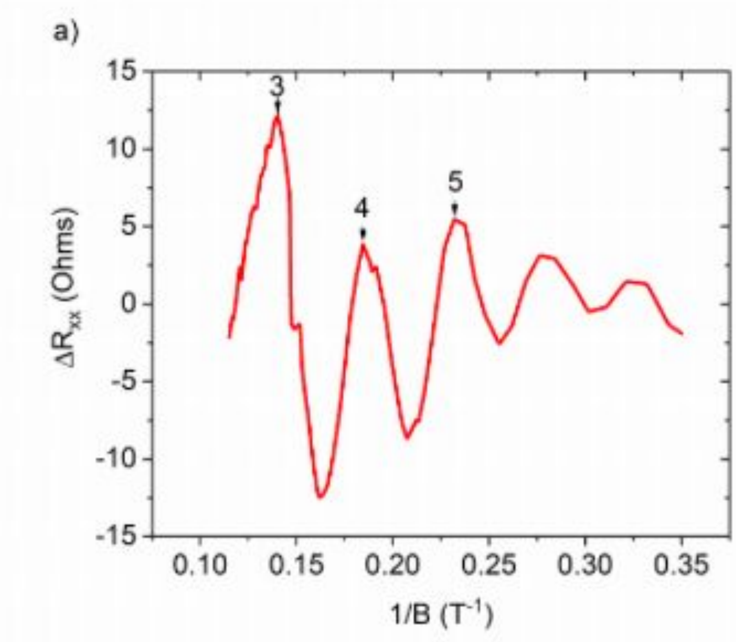


Shubnikov-de Haas





Shubnikov-de Haas



Vail et al (2019)