Critical Temperature Measurement of Superconducting Tapes

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Abstract

- Superconductors exhibit zero electrical resistance below a critical temperature.
- High-temperature superconductors (HTS) operate at higher temperatures than conventional superconductors.
- This study aimed to determine the critical temperature of an HTS tape by measuring its resistance during cooling. A pictorial representation of the experimental setup is shown in Figure 2.
- A four-probe method was used to ensure accurate resistance measurements as seen in Figure 1.
- The results confirmed the superconducting transition at 77 K, aligning with reported values.
- Findings suggest that improving thermal control and lowering current levels could enhance measurement accuracy.

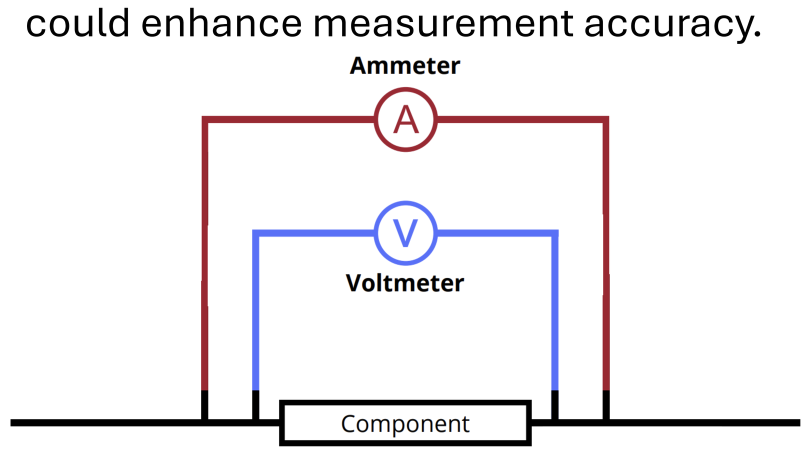

Figure 1: Four-Probe Method

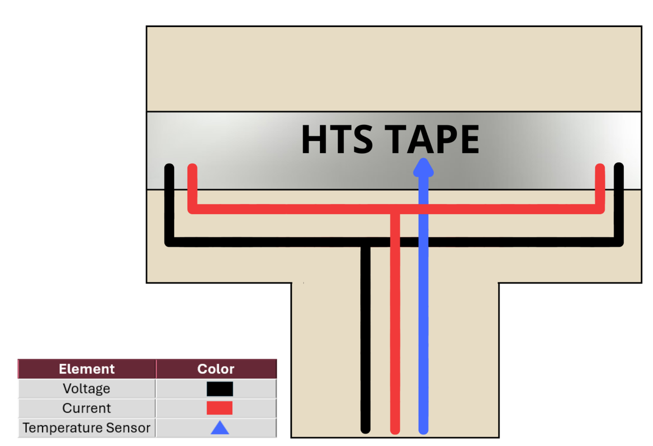

Figure 2: Pictorial Representation

Introduction

- Superconductors are materials that below a certain temperature lose all electrical resistance. High-temperature superconductors (HTS) operate at temperatures higher than traditional superconductors.
- HTS tapes are widely used in power grids, MRI machines, and maglev trains due to their ability to conduct electricity with zero resistance. Understanding their critical temperature is crucial for optimizing their performance.
- While HTS materials are widely studied, precise critical temperature measurements vary based on material composition and experimental conditions.
- The HTS tape will reach superconductivity at a measurable critical temperature where resistance drops to near zero.
- The objective of this experiment is to determine the critical temperature of an HTS tape by measuring its resistance while cooling in liquid Nitrogen.

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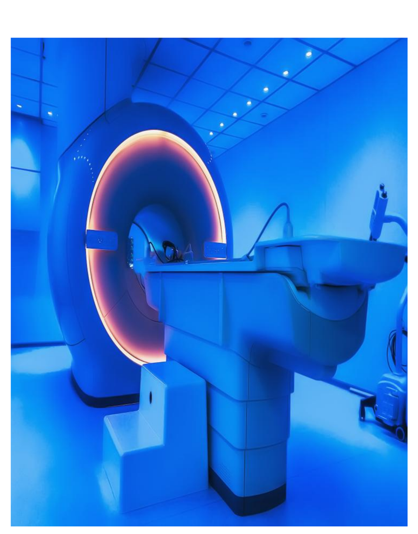
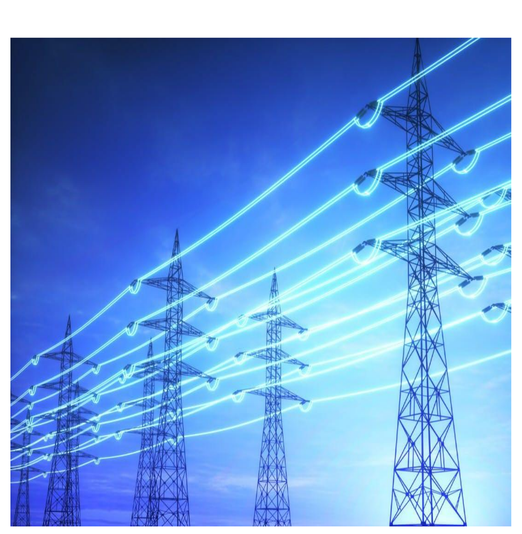




Methodology

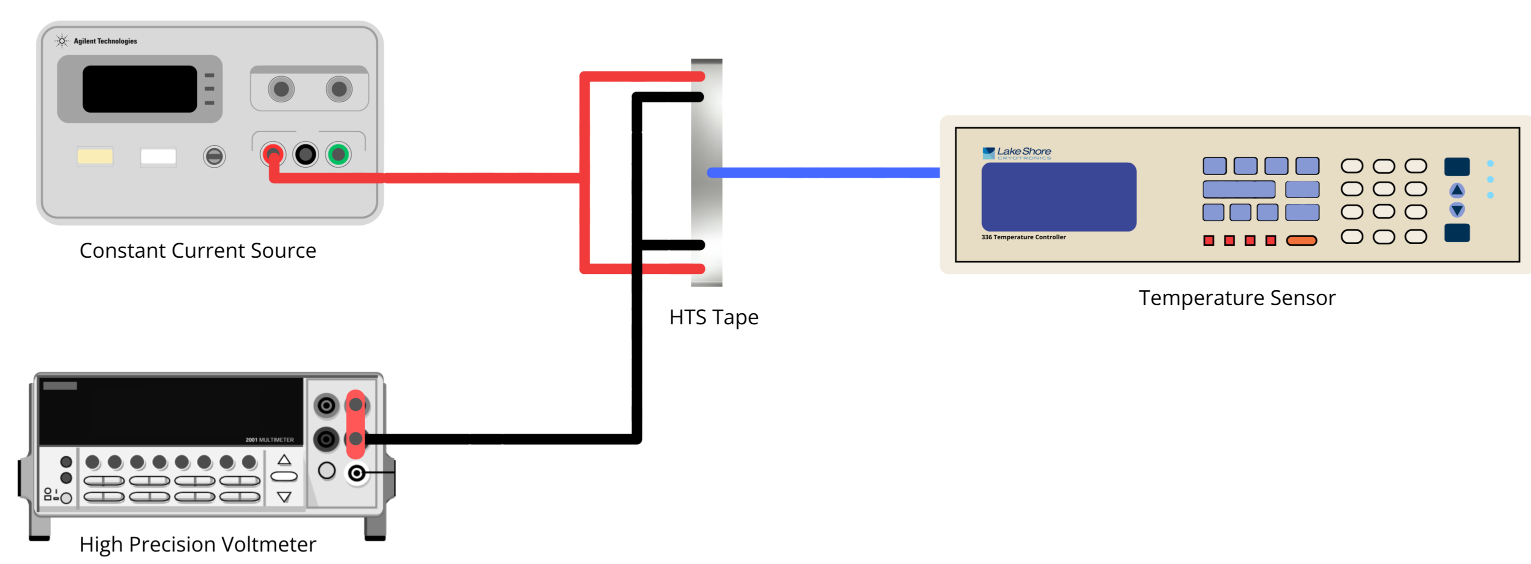


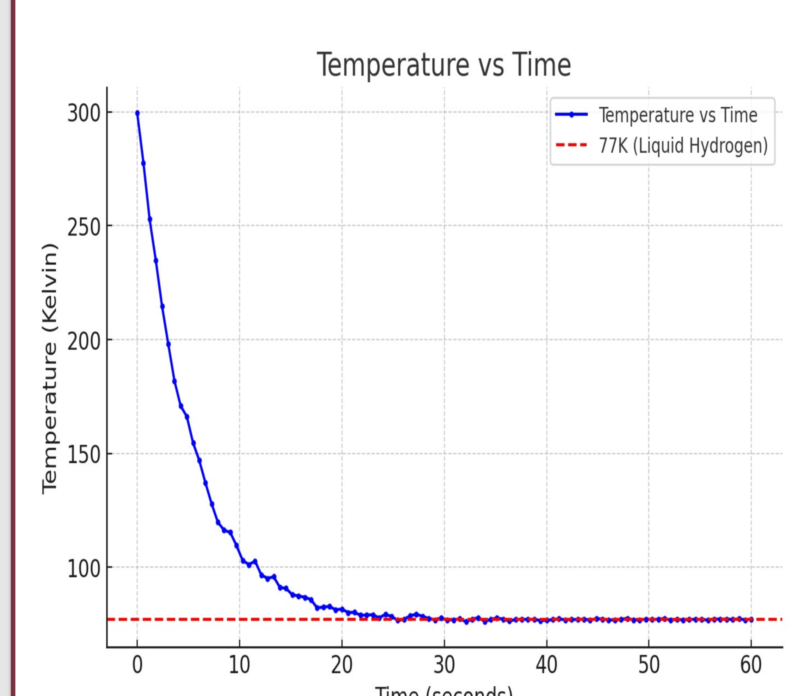
Figure 3: Experiment setup for measuring the critical temperature of HTS tape

Procedure

- The HTS tape was placed in a four-probe circuit.
- A constant 1 A current was applied through the tape.
- The tape was submerged in liquid Nitrogen to cool it down gradually.
- Resistance was recorded as the temperature decreased.
- The critical temperature was identified when resistance dropped to nearly zero, confirming the superconducting transition.
- The experimental setup is depicted in Figure 3.

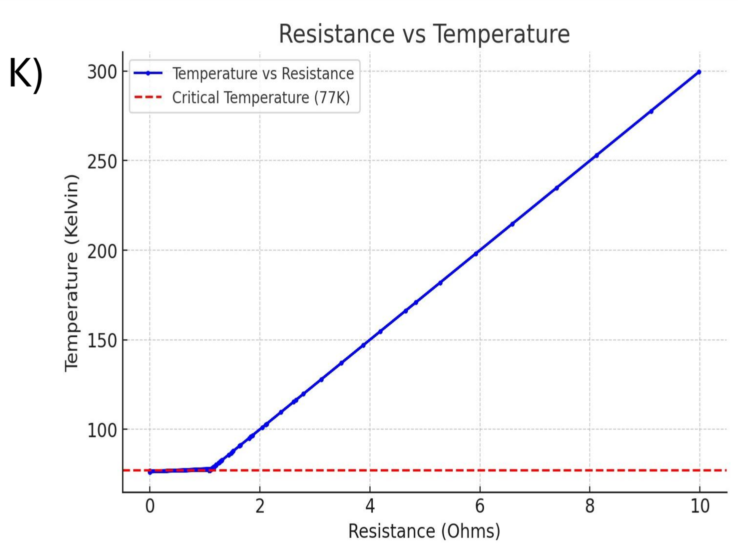
Results

- The critical temperature of the HTS tape was measured by recording its resistance while submerged in liquid Nitrogen at 77 K with a constant 1 A current.
- As the tape cooled, its resistance dropped and became nearly zero, marking the superconducting transition. The temperature at which this happened was recorded as the critical temperature.
- Small fluctuations in resistance were seen near the transition temperature, likely from thermal and electrical noise. Despite this, the data showed a clear drop in resistance, confirming the superconducting state.



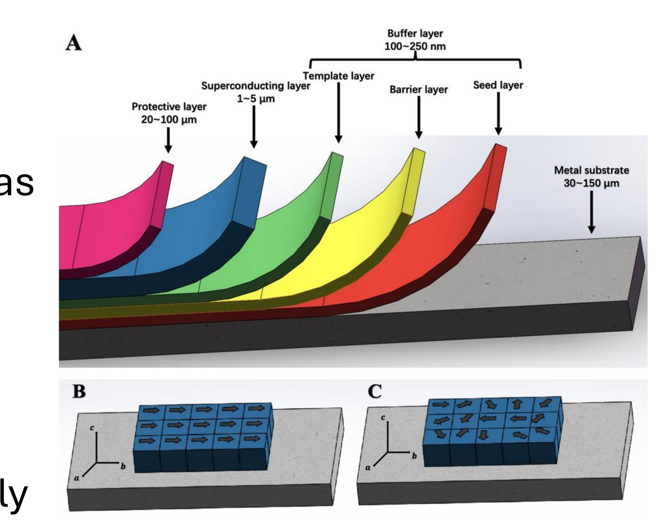
Results (cont.)

- The measured critical temperature (77 K) aligns well with reported values for similar HTS materials, confirming the accuracy of our setup.



Discussion

The four-probe method effectively minimized contact resistance, ensuring accurate measurements. Small variations in resistance could be due to experimental limitations such as slight temperature gradients during the cooling process and electrical noise from the measurement setup. These factors may have contributed to minor fluctuations in resistance near the superconducting transition. However, the overall trend of resistance dropping to nearly zero was clear, confirming the superconductivity of the HTS tape.



Conclusions

- The experiment successfully measured the critical temperature of the HTS tape by tracking its resistance during the cooling process.
- The results confirmed superconductivity, with a clear transition at 77 K.
- The four-probe method worked as expected, reducing errors from contact resistance.
- The observed fluctuations in resistance were minimal and did not affect the overall conclusion of superconductivity.
- This experiment demonstrates the key behavior of superconductors, highlighting their potential use in low-resistance systems.

Resources

Zhu, J., Zhang, Z., Zhang, H., Zhang, M., Qiu, M., & Yuan, W. (2013). Electric measurement of the critical current, AC loss, and current distribution of a prototype HTS cable. IEEE Transactions on Applied Superconductivity, 24(3), 1–4. https://doi.org/10.1109/tasc.2013.2284295