Lab 5 - Superconductivity

Eric Nguyen Group 4

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Abstract

The goal of this experiment is to observe the resistance of a superconductor at low temperatures, expecting the resistance to approach zero past some transition temperature T_c. To enable measurement of the sample's resistivity at low temperatures, I make use of a cryostsat. I found that the superconductor indeed reached a resistance of zero once cooled down enough past a certain T_c.

Introduction

One of the topics in recent physics literature that motivates the study of superconductors is that of topology and spin-orbit coupling. This led to the discovery of topological insulators which support the idea 'spinless' superconductivity. [1]

Experimental Method

The experiment involves measuring the resistance across the BSCCO superconductor sample while its temperature cools down below the transition temperature T_c and then measure its resistance again while its temperature heats back up past the transition temperature T_c.

Equipment

Temperature variable cryostat, The BSCCO sample, Sample temperature indicator, Sample state temperature control, Bi-polar current source, Sample voltage amplifier, Sample stage heater power source

Procedure

First, I configured the voltage amplifier with the following settings: **Input Gain = 100**, **Second Stage Gain = 10**, **Time Constant = .1 Seconds**, and set input switches to **10M**Ω. Then, I measured the voltage across at sample bias currents of ± 1 mA, ± 10 mA, and ± 100 mA at room temperature. Afterwards, I set the sample bias current to 100 mA and intermittently poured liquid nitrogen into cryostat through the funnel on top until the sample temperature reaches 85K, recording the voltage every 10 minutes or so. Once the

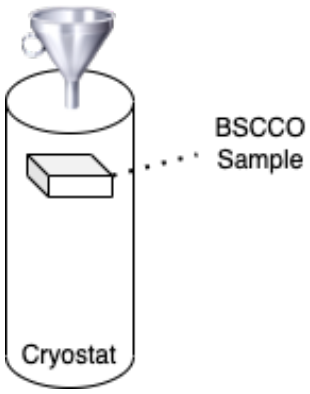

Figure 1: Apparatus diagram of cryostat and BSCCO sample

sample reached 85K, I started heating up the sample in small increments and once again measured its resistance.

Theoretical Background

To determine the voltage we need to obtain the desired sample temperature, we use the equation

$$V = 1146.4 - 0.4576T - 0.3476T \ln T. \tag{1}$$

Then to determine the resistance across the sample, we measure voltage for both positive polarity V_+ and negative polarity V_- and use the equation

$$\frac{1}{2}(V_+ - V_-)/GI_{\text{Bias}} \tag{2}$$

where $G = 100$ is the input gain and I_{Bias} is the sample bias current.

Results and Analysis

While in both the cooling down and heating up processes the resistance versus temperature curve share a similar shape, the curves do not overlap with one another. The most likely reason for this is that the resistance starts increasing at a higher temperature when the sample is heating up while the resistance reaches zero at a lower temperature for when the sample is cooling down. Indeed, the difference appears to be a shift in temperatures starting from the initial transition temperature T_{c_0} to the onset transition temperature $T_{c_{\text{onset}}}$.

Conclusion

I found that the BSCCO sample indeed is a superconductor. That is, the sample's resistance reached zero after it's temperature dropped below a certain transition temperature.

Table 1: Temperature and resistance data during cooling of BSCCO sample

Sample Temperature (K)	Voltage (V) Polarity +	Voltage (V) Polarity -	Resistance (Ohms)
280.2	1.800	-1.820	0.0362
271.5	1.786	-1.785	0.0357
260.5	1.723	-1.748	0.0347
249.0	1.680	-1.699	0.0338
239.0	1.638	-1.657	0.0330
230.0	1.606	-1.618	0.0322
199.5	1.486	-1.481	0.0297
168.1	1.346	-1.328	0.0267
140.6	1.220	-1.186	0.0241
120.0	1.100	-1.056	0.0216
112.9	1.042	-0.993	0.0204
105.0	0.881	-0.826	0.0171
101.9	0.679	-0.613	0.0129
99.31	0.347	-0.301	0.00648
98.50	0.170	-0.190	0.00360
97.00	0.092	-0.101	0.00193
94.52	0.014	-0.030	0.00044
93.02	-0.009	-0.011	0.00002
91.31	-0.011	-0.013	0.00002
90.61	-0.012	-0.011	-0.00001
89.90	-0.008	-0.009	0.00001
89.46	-0.007	-0.010	0.00003
89.16	-0.012	-0.014	0.00002

Table 2: Temperature and resistance data during heating of BSCCO sample

Sample Temperature (K)	Voltage (V) Polarity +	Voltage (V) Polarity -	Resistance (Ohms)
89.24	-0.010	-0.012	0.00002
99.26	-0.010	-0.008	-0.00002
100.8	-0.011	-0.009	-0.00002
103.1	0.054	-0.076	0.0013
103.9	0.146	-0.170	0.00316
104.9	0.323	-0.347	0.00670
106.0	0.440	-0.464	0.00904
107.2	0.593	-0.617	0.01210
108.0	0.689	-0.713	0.01402
109.0	0.772	-0.796	0.01568
111.2	0.868	-0.896	0.01764
114.0	0.933	-0.962	0.01895
118.9	0.996	-1.026	0.02022
124.2	1.043	-1.072	0.02115

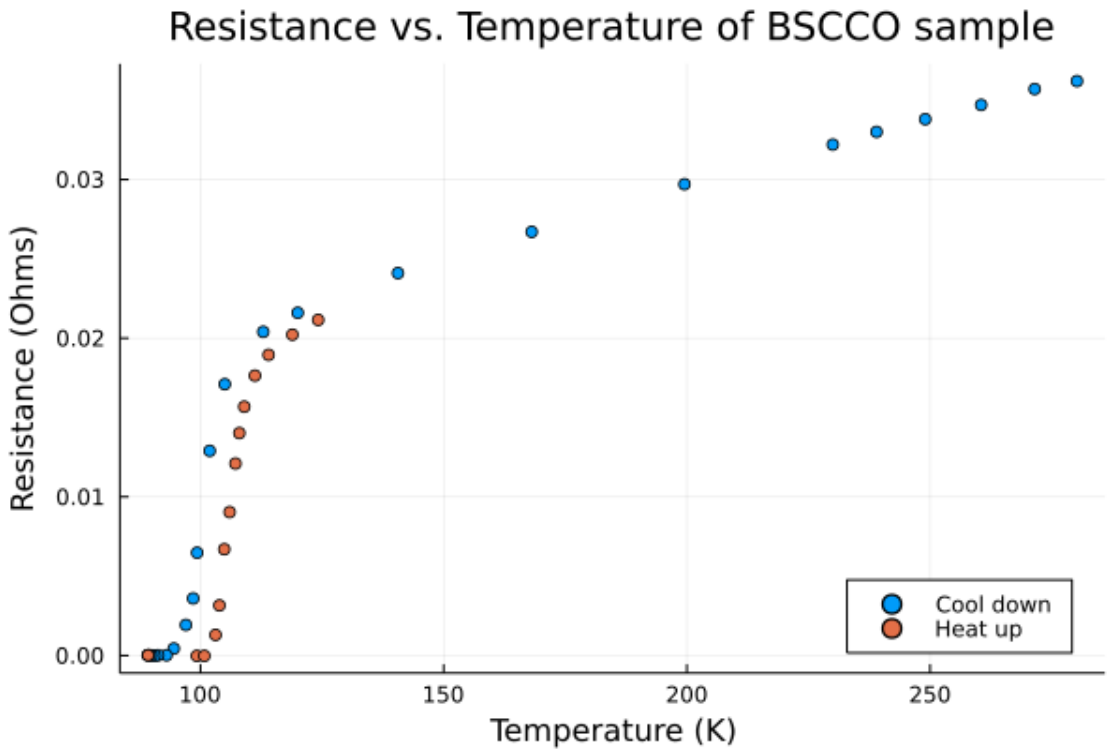

Figure 2: Resistance vs. temperature curve for superconductor BSCCO sample in both cooling down and heating up processes

References

[1] Masatoshi Sato and Yoichi Ando. "Topological superconductors: a review". In: *Reports on Progress in Physics* 80.7 (2017), p. 076501. DOI: 10.1088/1361-6633/aa6ac7. URL: https://doi.org/10.1088/1361-6633/aa6ac7.