Critical Temperature of YBCO and BSCCO Superconductors

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Abstract

don't leave us guessing what your results are! An abstract should "stand-alone" containing the key information needed to know what was done, how it was done, and what your key results were. Your result wasn't that you discovered superconductivity, or that you measured the critical temperature. Your result is that you found it to be a particular value, and it either agreed or disagreed with previous reports in the literature, that it indicated your material was either single phase or multiple phase (if you saw multiple transitions) and that you were able confirm the phase(s) or not from the transition temperature(s).

Superconductors are materials that lose their electrical resistance when they fall below a certain temperature. This is called the critical temperature. We determine the critical temperatures of two superconductors, $\mathrm{YtBa_2Cu_3O_{7-\delta}}$ and $\mathrm{Bi_2Sr_2Ca_{n-1}Cu_nO_9}$ to be $xx \pm yy$ K and $uu \pm vv$ Krespectively, by measuring the voltage across the resistor as a function of temperature. This reads as if you just measured the voltage, without passing any current. That would be a measurement of thermoelectric voltage, as with a thermocouple. You actually determined the critical temperature by passing a known current through the sample, measured the resulting voltage drop across the sample to find the resistance, then looked to see when the resistance became zero. Or reached the halfway point in the transition to zero. or some other criteria.

I. INTRODUCTION

In 1911, Kamerlingh Onnes discovered superconductivity in mercury. Instead of a gradual decrease in the electrical resistance as the temperature decreased, he found a sudden loss of resistance when the temperature went below 4.2 K. The temperature at which the resistance disappears is called the critical temperature. In addition to having no resistance, superconductors also exhibit perfect diamagnetism, which means they exclude all magnetic field flux from their interior. This property, called the Meissner effect, was discovered in 1933.[1] A common demonstration of the Meissner effect is to place a a magnet on top of a superconductor above its critical temperature. When the superconductor is cooled to become superconducting, the magnet will start to levitate above the superconductor.

The main application of superconductors is in making high field magnets from superconducting wires. They can also be used to make levitation trains or to create magnetic fields used in magnetic resonance imaging and in high energy physics to accelerate and control the path of particles.[2]

Superconductivity has been found to occur in elements, alloys, binary compounds, and other materials. Roughly 70 years after superconductivity was discovered, ceramic materials with critical temperatures above the liquid nitrogen temperature of 77 K were found.[4] These "high temperature" superconductors were made up of alternating layers of rare earth atoms and copper and oxygen atoms.[2] In our experiment, we look at two high temperature superconductors, $\mathrm{YtBa_2Cu_3O_{7-\delta}}$ and $\mathrm{Bi_2Sr_2Ca_{n-1}Cu_nO_9}$, where $\mathrm{n} = 1, 2,$ or, 3. The amount of oxygen in $\mathrm{YtBa_2Cu_3O_{7-\delta}}$ determines if the material will be superconducting.[?] For $\mathrm{Bi_2Sr_2Ca_{n-1}Cu_nO_9}$, the critical temperature is depends on the value of n. and these values are ?, according to ? source.

II. AIMS

you should either expand on this — with more specific aims — or leave this section out. One sentence does not justify a section!

1. To determine the critical temperature of YBCO and BSCCO.

III. PROCEDURE

The YBCO and BSCCO superconductors were obtained from Colorado Superconductor Inc. Each superconductor is contained in a brass casing with three pairs of leads. One pair was for attaching to the current source, another pair was used to measure voltage across the superconductor, and the last pair that of the thermocouple inside the casing. The thermocouple produces a voltage when one part of the circuit has a temperature different from a reference point. We used different methods to measure the critical temperature of the two superconductors. For the YBCO, we connected it to a source with an alternating current of ± 1 mA. The alternating current The voltage across the YBCO sample, V_{YBCO}, and the voltage across the thermocouple junction, V_T were measured with two nanovoltmeters. you should explain the point of reversing the current and how this helps more accurately determine the true ΔV The voltage across the YBCO sample was converted into a resistance reading by the nanovoltmeter. Include circuit diagrams.

Finally, didn't you do some measurements at other values of current? for example, 10 mA and 100 mA, in addition to 1 mA? YOu were supposed to, and I thought you had. I can't find those results anywhere in your paper.

We placed the superconductor inside a styrofoam cup filled with sand. The sand reduces the rate at which the superconductor heats up, which allows us to gather more data points. We cooled the YBCO sample by pouring liquid nitrogen into the styrofoam cup. We waited for the superconductor to settle to a minimum temperature. Then we recorded V_{YBCO} and V_T as it warmed up to above its critical temperature.

We used a two-phase lock-in amplifier for the BSCCO experiment. An AC circuit set up for the measurement of resistance is susceptible to contributions from capacitors and inductors. Although there are no explicit capacitors or inductors in our circuit, they are effectively present due to the electrical cables used and construction of the circuit. The lock-in amplifier allows us to extract the resistance of superconductor from the other contributions. Since changes in V_{BSCCO} due to resistance are in phase with applied voltage and the contributions of capacitors and inductors are out of phase, our signal is just the in phase component. Since the resistance of the BSCCO at room temperature is on the order of mΩs, we can generate an AC current with an RMS amplitude of approximately ± 1 mA in the circuit by connecting the BSCCO in series with a 1 kΩ resistor, and with a AC voltage source with an RMS amplitude of 1 V.

IV. RESULTS AND ANALYSIS

First, to convert our thermocouple voltage into a usable temperature, we transcribed the chart provided in the Teachspin manualColorado Superconductor Inc that came with the YBCO and BSCCO samples and and plotted temperature vs voltage (see Fig. 1). While it was best fit piecemeal, a single curve was able to cover our temperature range, and we used that function to convert our thermocouple voltages in later fits.

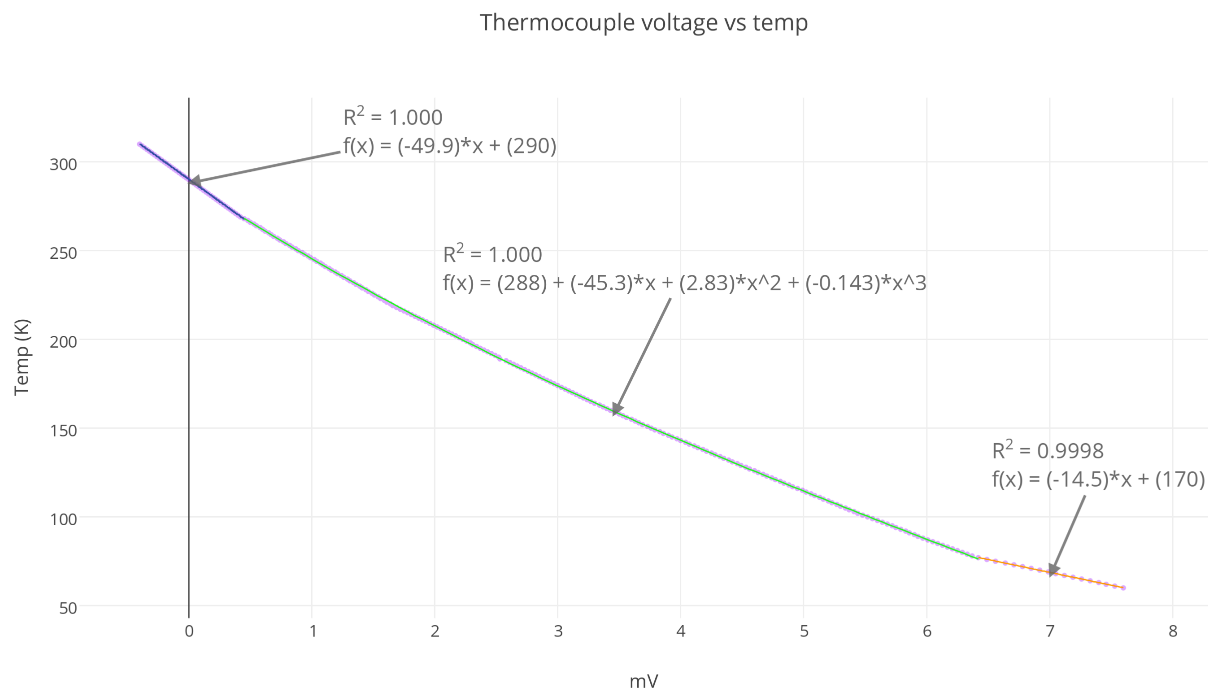

FIG. 1. Figure 1: PROOFREAD! Plot of Temperature and thermocouple voltage transcribed from the Teachspin manualColorado Superconductor Inc , with fit lines across different sections.

We gathered data across two warm-ups of the YBCO sample, the first at equal time intervals between points (see Fig. 2) and the second focusing on taking more points during the transition period than elsewhere (see Fig. 3).

In order to determine the critical temperature, we found the point along the transition period that was exactly in betweendo you mean halfway between? the trend line for resistance during non-superconductivity and the trend line for resistance during superconductivity, and noted the corresponding temperature. The error in our voltage readings was very low (on the order of 0.000005mV), so the larger element of error is looking at the width of the transition zone, which was defined between the first points to clearly deviate from the trend lines. This yielded results of a T_C of 98.03K and 98.67K per trial, with a range of 91K to 100K and 94K to 101K, respectively.

does this mean your first transition occurs at $T_C = 98.0 \pm 4.5$ K or that the transition begins at 91 K, ends at 100 K, and has a midpoint at 98 K? If the latter, what do you take to be the uncertainty in your determination of that midpoint? Also, you mention two trials, but only show one. Finally, why 4 sig figs for the critical temperature, if your uncertainty is on the order of 0.5 to 4.5 K, depending on how you define it. That said, I like the method used to find the 1/2 way point (by drawing a line with 1/2 the slope seen in the resistive state). If you don't yet have a criteria for uncertainty for that value, one common definition is from 10 percent to 90 percent. So you could plot lines with slopes that are 10 percent and 90 percent to find those boundry points.

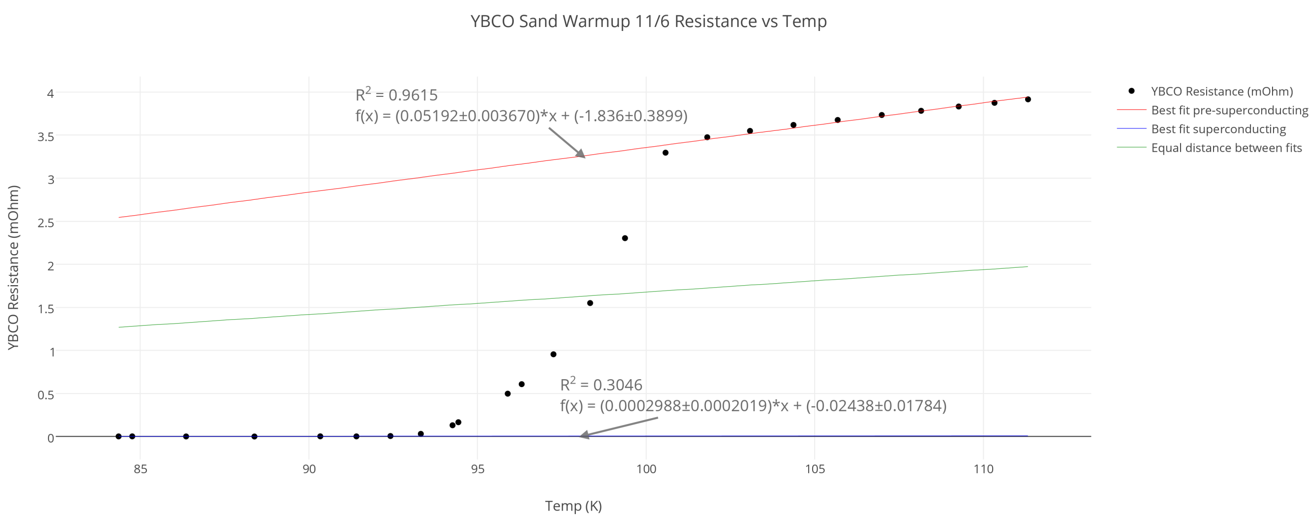

FIG. 2. Plot of resistance vs temperature for YBCO sample, with best fit lines during normal conductivity and during superconductivity, with a third line showing the space equidistant between. Data was gathered every 20 seconds during warm-up.

where is your data on critical currents? You measured the transition for other current values as well. You should show the data, and then either extrapolate the current dependence to the zero current limit, or show your data doesn't show a current dependence for your range

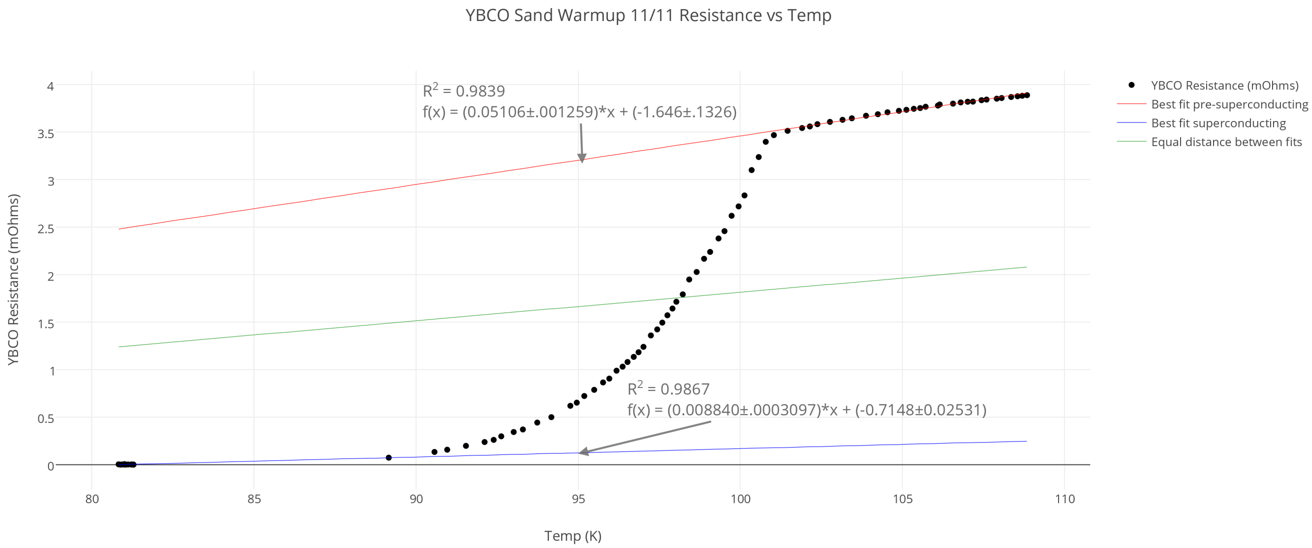

FIG. 3. Plot of resistance vs temperature for YBCO sample, with best fit lines during normal conductivity and during superconductivity, with a third line showing the space equidistant between. Data was gathered every 30 seconds until onset of superconductivity, then every couple seconds throughout the transition period.

of values. There are two parameters of interest in regard to current dependence, by the way. One would be the critical temperature. The other would be the width of the transition (from zero to "normal" resistive state).

Next we looked at a sample of BSCCO gathered through the two-phase lock-in amplifier. Only one trial was performed, though data was gathered every 3 seconds for 3 hours. Once the data was plotted, the same procedure was used as with the YBCO sample to determine the critical temperature (see Fig. 4). The critical temperature T_C here was 110K, with a range of 101K to 119K. Of particular interest was the trend during the early pre-superconducting period. While certainly not truly ceasing to superconduct, there appeared to be some jumps in resistance during the superconductive phase, shown closely in Fig. 5. On closer inspection, while there is clearly some upward trend and movement not seen in the YBCO sample, it is not clear enough to pinpoint any specific jumps.

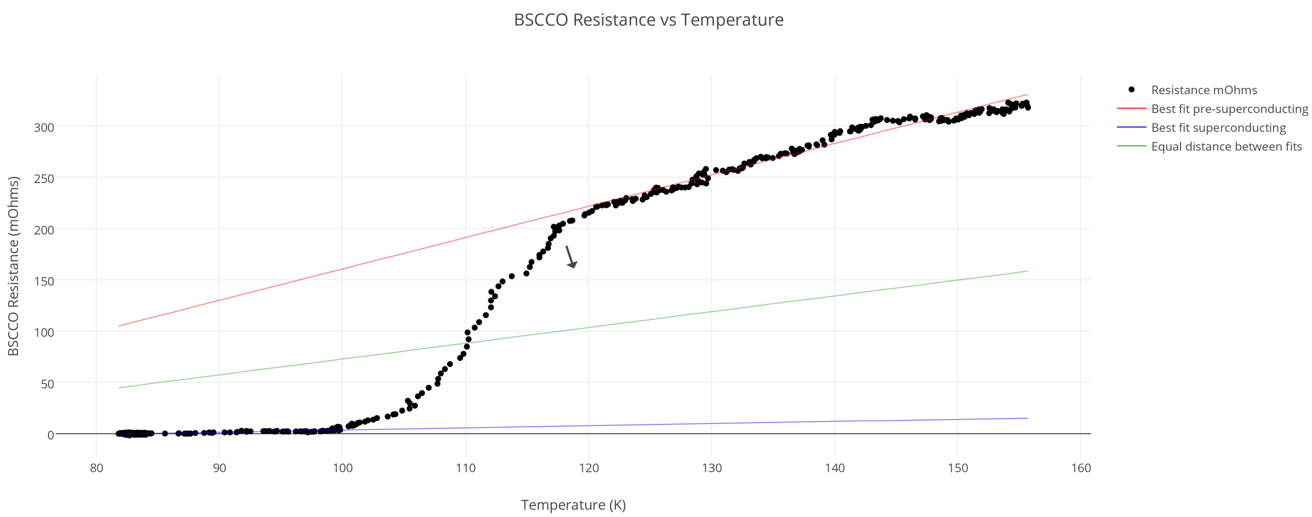

FIG. 4. Plot of resistance vs temperature for BSCCO sample, with best fit lines during normal conductivity and during superconductivity, with a third line showing the space equidistant between.

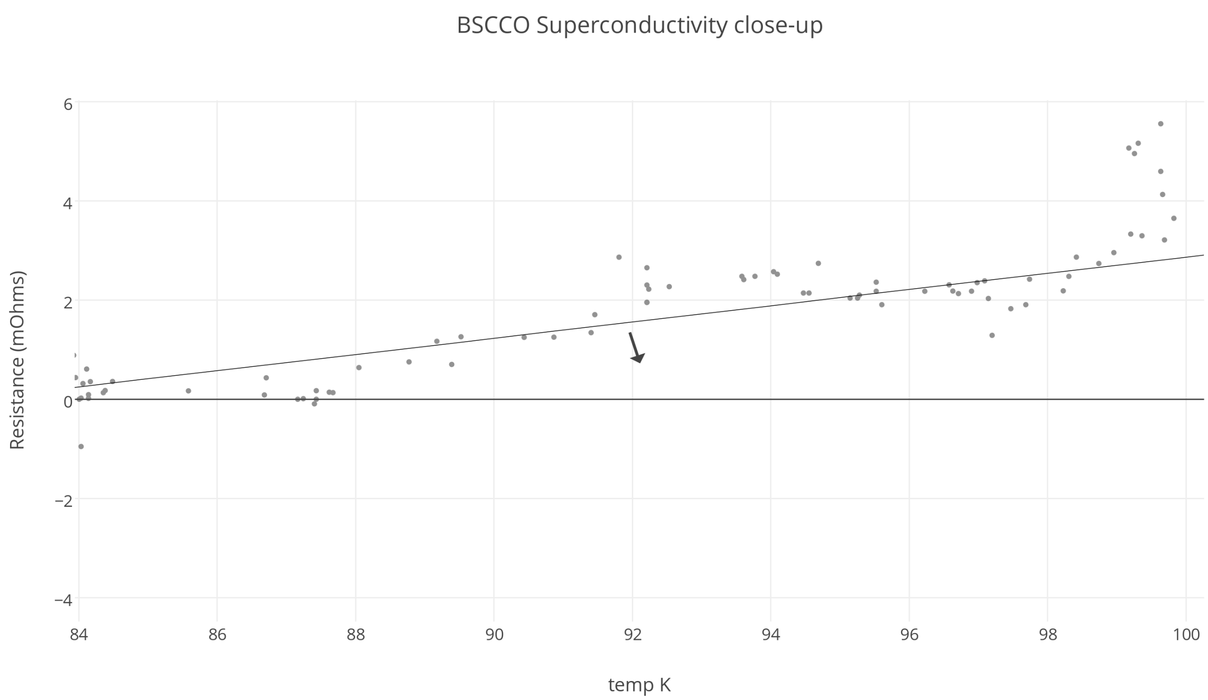

FIG. 5. Close up of the BSCCO sample warm-up during it superconductive phase. Irregularities are definitely present, but jumps are not clear.

V. CONCLUSION

Superconductivity was clearly achieved in both the YBCO and the BSCCO samples, and their transition to being non-superconductive as their temperature increased was recorded. Graphical analysis yielded a critical temperature for YBCO of fix this: 98.35K *pm* 7K and for BSCCO of 110K *pm* 9K. According to the Teachspin manual, YBCO has a critical temperature of 92K, which is within our margin of error; similarly, the BSCCO sample was noted as having a critical temperature of 105K, again within our margin of error. The strange behavior seen during the end of the superconducting phase of the BSCCO sample may also have had to do with the fact that BSCCO can have two other critical temperatures. The general formula is $Bi_{2,1}Sr_{n+1}Ca_{\mathrm{n}-1}Cu_{\mathrm{n}}O_{2n+4+\delta}$. While the sample we had was specified for $n = 3$, it is quite possible that other variations were present in our sample, each with their own critical temperature: T_C for $n = 1$ is 80K and T_C for $n = 2$ is 90K. what is your source for this information about Tc values for n = 1, 2, and 3? While we did not get as cold as 80K, we could be seeing some sections stop superconducting around 90K, alongside the already non-superconducting $n = 1$ material, giving us a not truly flat superconducting zone.

citations should include the "teachspin" manual (or the manual you really used) in addition to the 3 listed below.

[1] Charles Poole, Horacio Farach, and Richard Creswick, *Superconductivity* (Academic Press, 2007).

[2] Ajay Kumar Saxena, *High-Temperature Superconductors* (Springer Berlin Heidelberg, 2010).

[3]

[4] Experiments in Modern Physics. Adrian Constantin Melissinos and Jim Napolitano. Gulf Professional Publishing, 2003