Critical Temperature of YBCO and BSCCO Superconductors

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(Dated: November 25, 2014)

Abstract

This article explains and illustrates the use of LaTeX in preparing manuscripts for submission to the American Journal of Physics (AJP). While it is not a comprehensive reference, we hope it will suffice for the needs of most AJP authors.

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. This phenomenon can be used to make levitation trains. Superconductors are also used 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.[3] 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 $\mathrm{n} = 1, 2,\ \mathrm{or}, 3$. 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.

II. AIMS

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 has a resistance that varies with temperature, so we can determine the temperature of superconductor by measuring the voltage across the thermocouple.

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 voltage across the YBCO sample, V_{YBCO}, and the voltage across the thermocouple, V_T were measured with two nanovoltmeters. 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. In an AC circuit, the measurement of resistance includes 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. The lock-in amplifier allows us to extract the resistance of superconductor from the other contributions because the resistance will be in phase with the signal, while the contributions of capacitors and inductors will be out of phase. Since the resistance of the BSCCO at room temperature is on the order of mΩs, we can get approximately ± 1 mA in the circuit by connecting the BSCCO in series with a 1 kΩ resistor, and with a AC voltage source of 1 V.

IV. RESULTS AND ANALYSIS

V. DISCUSSION

VI. CONCLUSION

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

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

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