Experiment 7: Observing Superconductivity and Meissner Effect

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ABSTRACT

In the early 1900's scientists began studying materials and gases in the extremely low temperatures, an incredible property Superconductivity was discovered. To gain a better understanding of the transition of a conductor becoming a superconductor we constructed an experiment, with two metal alloys YBCO and BSCCO. To achieve Superconductivity you must cool certain metals to a minimum threshold temperature, at these temperatures all resistance is lost and current can flow effortlessly. These threshold temperatures are incredibly low so to cool the metal we used Liquid Nitrogen which has a low enough boiling temperature to reach the minimum threshold of both metals. As a final testament to see if we achieved true superconductivity we observed the Meissner effect which essentially is magnetic levitation.

I. INTRODUCTION AND THEORY

The initial discovery of Superconductivity occurred in 1911 by H. Kamerlignh Onnes, he showed that mercury could achieve a point of 0 resistance, when mercury nears 4.2 Kelvin in temperature. He showed that the electrical resisitivity of materials disappear when they achieve a critical Temperature T_c, occurring only when cooled.

The superconductors we utilize for our laboratory are part of a set of ceramic oxides, whose critical temperatures for reaching superconductivity is above the boiling point of liquid nitrogen (77 Kelvin). These new high-temperature superconductors were discovered in the 80's but the research has not shown why superconductivity is shown at these temperatures. The YBCO and BSCCO are $(YBa_2Cu_3O_7) and (Bi_2Sr_2Ca_2Cu_3O_{10})$ respectively, these are ceramic composites, later on scientist show that the structure of atoms effect the phonons, and the phonon-electron interactions in the atom determine the critical frequency for superconductivity; in our lab the composites were provided by Colorado Superconductor. The resistivity was the main focus of our laboratory as well as the temperature, current, and voltage.

The last thing we observed as a test for reaching superconductivity was the Meissner effect, discovered by Meissner and Ochesenfeld in 1933, which they conveyed a a material that is transitioning into the superconductive state expels magnetic fields, a material that is transitioning since it has no resistance it also has no emf. A classical observation would use Faraday's law as a basis for what would occur, the fact that the magnetic field of an object changes goes against this reasoning, superconductivity shows that magnetic lines in the material leave and then remains at this state of no emf, which allows for levitation to occur making superconductors easily distinct from a normal material.

A precaution that had to be made was the fact we were using liquid nitrogen. Liquid nitrogen can cause cryogenic burns which if used by a doctor can be used to remove skin ailments, and as well as asphyxiation and shooting projectiles, this is done because it evaporates and causes pressure changes. To account for this we wore goggles as well as gloves when interacting with containers of liquid nitrogen. The Leidenfrost effect also provides protection against burns from the liquid nitrogen. We also used Styrofoam to make the material would not harm us in any way. In the end our experiment was more observational than computational, the numerical values we extracted from the scenario being the resistance, voltage, current, and temperature.

II. EXPERIMENTAL ARRANGEMENT AND PROCEDURE

Our main procedure can be broken down basically as submersing materials in liquid nitrogen and then measuring them. To break into details, we used two CS superconducting probes each measuring the YBCO and the BSCCO composites, a levitation kit with rare earth magnets to test if the materials are superconducting. The main measuring device was a MyDAQ which supplied the current and voltage for our initial measurements, a mechanical DC supply provided the current for a second set of data. A stand , clamp, rod, lab jack, 2 Styrofoam cryostats which we used 1, a screwdriver to change cables on the myDAQ ,hook-up wire tweezers, insulated current limiting resistors, insulated copper, and the most dangerous component liquid nitrogen.

The main component of our experiment was setting up the measuring device which was the myDAQ with the use of Lab-View to properly code the device to receive our values from the myDAQ and to properly use data methods to break them down.

To make sure we were not making mistakes we prepared our protection against liquid nitrogen which included a pair of safety glasses and gloves, as well as Styrofoam to contain it properly without any damage. rare earth metals which were specifically for magnetism were also fragile and must have been treated with proper protection as well as the probes and their leads which could have been damaged greatly. We were always careful to handle the CS probes with care.

The first thing we did was use the NI ELVISmx digital multimeter to test all our leads from the CS probe for the YBCO and BSCCO probes. We tested all the combine combinations of the 2 current, 2 voltage, and 2 thermocouple wires, allowing us to move throughout the rest of the experiment with ease. Then we tested an initial test of reaching superconductivity with both of the probes. This would require us to pour liquid nitrogen in a Styrofoam container and hen lowering a CS probe that is being held by a stand into the Styrofoam container by either raising the base of the Styrofoam or the stand holding the CS probe. We measured the initial reaction using the myDAQ and coding in LabView, specifically the LabView has a program called a vi, it specifically has a DAQ Assistant Express vi which allows for accurate recording of what the myDAQ is receiving. The liquid nitrogen bubbles begin to make a loud pop when reaching the critical temperature allowing us to observe the data acquisition of the critical temperature with more precision. Lastly we always made sure to preform all the measurements slowly for accuracy.

Each of the superconducting probes have 6 wires, 2 for current which were colored black and 2 for voltage which were colored yellow, the last 2 are for the T-type thermocouple which had a positive and negative output. Since our main data collection method was with the myDAQ, we provided and acquired the current, voltage, and temperature voltage to and from the probe. We made sure the current we inputted into the CS probe did not exceed 1.5 Ampere's. We placed the Current leads in the Analog input 0's positive and negative and then we placed the thermocouple voltage leads into the Analog input 1 positive and then for the current leads we placed them in the DGNV and 5V positions on the myDAQ because at those positions the myDAQ can feed it a proper current. We then began coding in LabView to gather a live feed of data when we place the probe in a fresh vat of liquid nitrogen; using the stand, clamp, and rod to properly place the probe without damaging or removing any connections.

The main area of our experiment was setting up the code for proper data acquisition, and we collected the cooling data and warming data for YBCO and BSCCO leading to our results.

III. DATA, ANALYSIS, AND RESULTS

One of the most useful equations in electrical engineering is Ohm's law, it can be converted into a variety of ways to show the values of various electromagnetic scenarios. For us it will be used in very basic form of ohms law.

$$V = IR \qquad [1]$$

Where V is the voltage, I is the current and R is the resistance. In the system we are observing we inputted a 1.25 A current into the probe and thus the ceramic, and inputted a voltage of about 1 volt. What we did is then use our LabView vi to collect all the information of temperature, current, and voltage, and then calculated the resistance by dividing the voltage by current in real time which provided all our data which I present below. We first acquired cooling then heating data which is the order presented below.

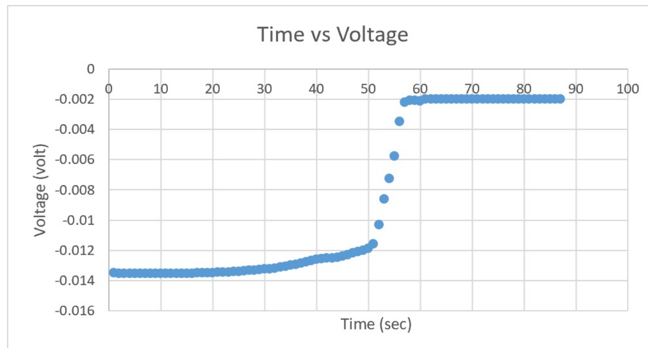

Figure 1:This is the time versus the voltage we received when we were cooling the system, you can see the voltage have a sharp rise towards 0 which is expected if resistance is 0.

This graph shows as time went on during the voltage went to 0, indicating that the superconductive state may be reached and following the prediction that Ohms law presents for this particular scenario

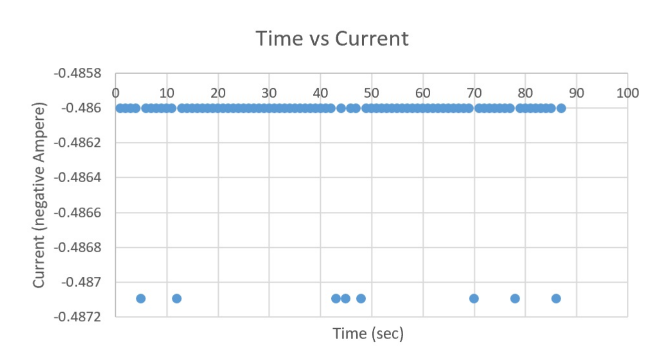

Figure 2: This is the results of our initial observation, it did not exceed the max count of the G-M counter and helped us get a gauge of how the data would turn out.

this graph shows the current we received, for some reason certain values would drop we had no way of predicting this, we also believed the current would rise but it is not presented well in this graph.

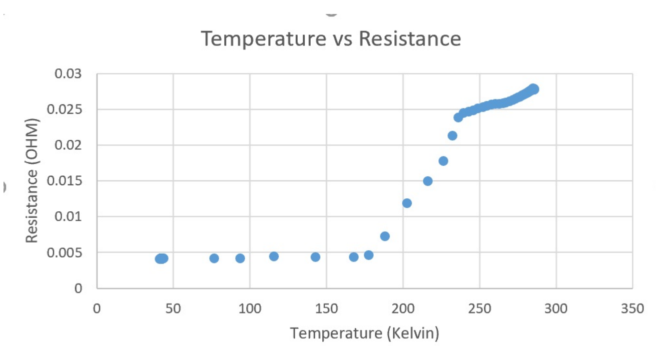

Figure 3: This shows the gamma radiation sample without covering, it follows what we should get for the gamma source that has aged and decayed at a distance properly .

This shows the resistance versus temperature basically showing that at low enough temperatures the resistance becomes 0 for this graph we are looking at the BSCCO and it shows that it has 0 resitance at around 175 Kelvin.

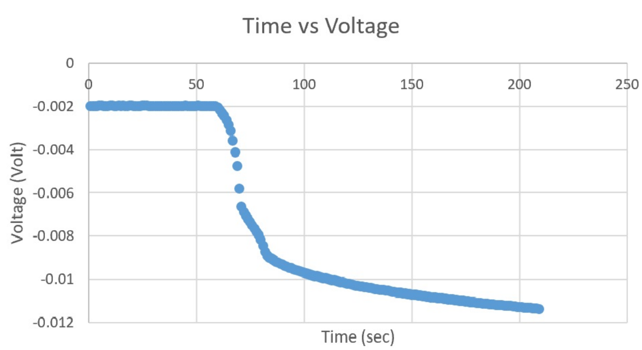

Figure 4: This shows the Time versus Voltage of the warming up system it shows the voltage having a drop back to negative 1 which should be 1 but we measured incorrectly.

When you warm up a system that has been placed into superconductivity you observe basically a opposite graphs than what cooling provides , what the graphs should display is voltage jumping to a number instead of 0, the same occurring for resistance in the circuit with steady rising with temperature afterwards. The current should drop after becoming a very large number. In our particular operation we were able to display the resistance and voltage graphs well but the current had issues with data collection.

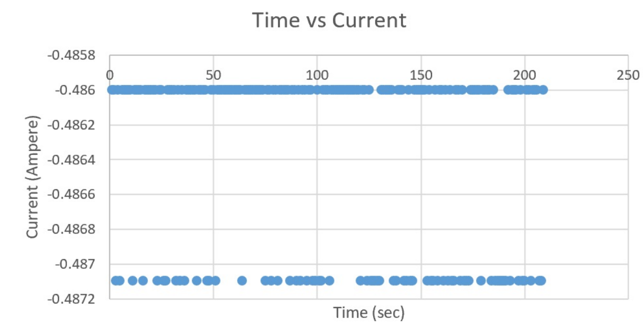

Figure 5: This shows the time versus the current, we had problems collecting the data causing our graphs to form improperly .

The Current we received was having problems, this was a significant source of error for our set up we had no real reason why the data would not properly collect other than a problem with the leads or just a problem with the LabView software that would not allow us to collect values.

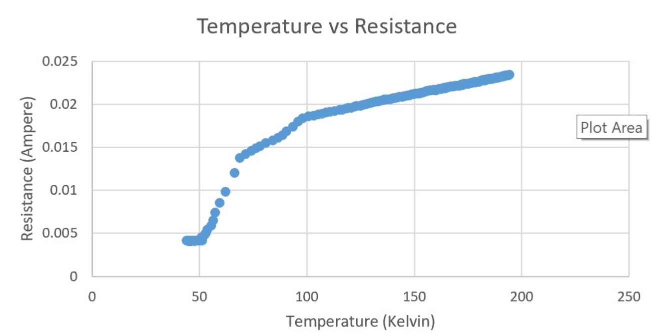

Figure 6: This graph shows the resistance versus the temperature, showing as temperature is higher you have higher resistance .

This is the last result we received it shows the resistance rising because this measurement is showing the warming up of the BSCCO composite, we got a good graph overall, though we were receiving errors because the current would have points of dropping and the smoothness was determined by how fast or slow we would take the measurements.

The last thing we determined was if the Meissner effect was occurring which would also allow for levitation. We never used a Gauss meter to get the transitioning phase but we were able to observe the levitation of the magnet over the YBCO sample.

The data clearly shows a drop occur for both samples and that the resistance drops completely at certain temperatures, though both sets of data for cooling and the other for warming

IV. CONCLUSION

The result of our experiment was that we were able to reach the superconducting phase for both YBCO and BSCCO as well as placed magnets atop of them, both of these actions were a success. For our data the results can only be observed truly analytically as we do not have to convert much other than for the equation of Ohm's law. The most difficult part of the lab was not the operation itself but rather creating the overall code that would provide us our graphs, collect our data, and give both of those in real time. While the myDAQ was useful for providing the initial current and voltage but the current generator we used was far more useful as its accuracy. The BSCCO material had a critical temperature at about 50 Kelvin and has massive fall in its resistance at about 60 Kelvin. The YBCO as well showed the superconducting effects in the myDAQ and the ability to make earth magnets to levitate. In the end this experiment did not require great data manipulation but rather constructing a program to properly collect and read the data that we need to observe the experiment numerically. We achieved this using the programming software called LabView which had programs specific for it allowing it to manipulate the myDAQ and collect data in real time. In the end we were able to show both superconductivity and magnetic levitation occur for both composites but not with the cleanest set of data.