Magnetic Susceptibility of 123 Superconductor

Ricardo Vasquez
Department of Physics, Purdue University, West Lafayette, IN
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Abstract

Superconductors experience a drastic change in magnetic properties at critical temperatures and below. High temperature superconductors have the same behavior. The experiment realized focuses on observing how these property changes occur for a superconducting tablet of $Yba_2Cu_3O_7$ that is cooled down to temperatures below its critical temperature. The results of the experiment tell us that the magnetic field crossing the tablet is reduced right after the tablet has reached the critical temperate Tc and temperatures below. This reduction supports the Meissner effect, which consists of the exclusion of any magnetic field from the material's interior at temperatures Tc and below. We fabricated a 10gr. Tablet of 123 material and tested it magnetic properties behavior around Tc and below. The Tc temperature of 123 material is typically 91^oK.

I.- Introduction

High temperature superconductors (discovered in 1987[3]) opened up the hope for the creation of a new technological revolution. They have not yet impacted our society to the extent that they can be called a technological revolution. However, it is still a field of study and research that has the potential of bringing up new, interesting and useful applications. In principle, there are two essential properties that characterize superconductivity in a material. Both of them are reached at certain critical temperatures and below. The first one is zero resistivity and the second one is a complete exclusion of magnetic fields from inside the material. This experiment focuses on the magnetic behavior of the superconducting material. Once a specimen reaches the Tc or lower temperatures, the magnetic field lines are expelled from the material. (see fig. 1) This phenomenon is called the Meissner effect.

Meissner and Ochsenfeld[2] were able to show that superconductors always exclude a magnetic field from its interior, independently of the procedure followed to get the superconducting material in a magnetic field for temperature equal or lower than the Tc temperature.

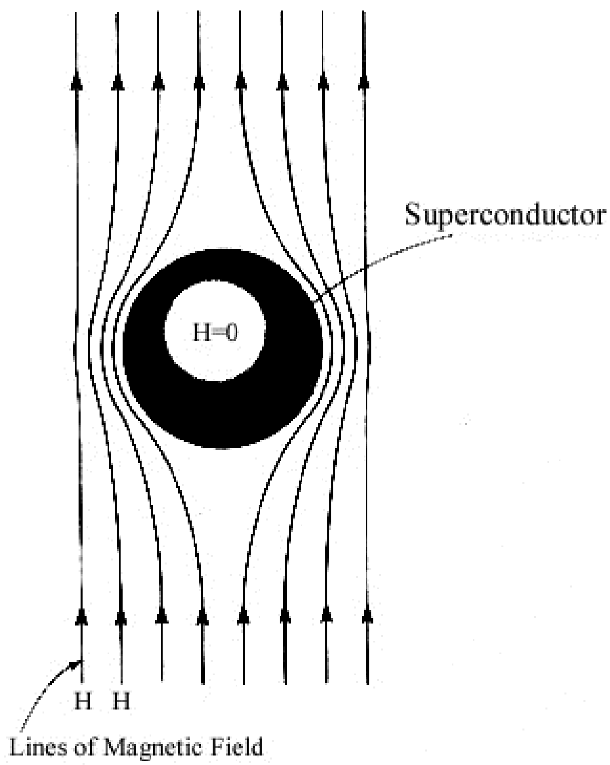

Fig1. Representation of the Meissner Effect. Complete exclusion of the Magnetic Field. [2]

II. Experimental procedure

The high temperature superconductor used was $Yba_2Cu_3O_7$. The following powder oxides were mixed to make the compound: Y_2O_3, $BaCO_3$ and Cu0. A tablet of 10gr. was prepared by following the stoichiometry of the following reaction

$$\frac{1}{2}Y_2O_3 + 2BaCO_3 + 3CuO \rightarrow Yba_2Cu_3O_7$$

The amounts used of each one of the powders: 1.6947g of Y_2O_3, 5.924g of $BaCO_3$, 3.5816g of CuO. The 123-material was fabricated by mixing the powders and die pressing them into a tablet. The tablet annealed inside of a furnace on a high oxygen concentration environment. The furnace was programmed to ramp temperature at 2^{o}C per minute and ramp down 1^{o}C per minute until 965^{o}C was reach. It stayed at 965^{o}C. The tablet was then finely grinned and the process was repeated: it was die pressed and then it was baked with the same temperature profiles 980 ^{o}C. The sample had an inch of diameter and 1/5 inch of height.

Since the purpose of the experiment was to analyze the behavior of the magnetic susceptibility of the superconductor at the critical temperature and below, we made use of two copper-wire coils to create a magnetic field. Both coils were going to be varnished to the superconducting sample faces so that each coils sits in front of the other. That means, if we drive an AC current on one of the coils it will create a changing magnetic field at the center. This changing magnetic field will cause a changing magnetic flux in the second coil, translated into and induced *emf* according to Faraday's law of electromagnetic induction[4]. The diameter of the coils was half the size of that of the tablet. The reason for this will come clear with the following explanation.

The driving coil carried an AC current of 55-65mA. The other coil, which we refer to as the pick up coil, was always connected to a Voltmeter just to measure the induced *emf* on it. Since the tablet rested in between, any drastic changes in the magnetic field lines making it across the superconductor would be noticeable by a drastic change in the *emf* measured.

The superconducting specimen and the coils were placed inside of a Cryostat. The induced *emf* on the pick up coils is measured and it's tested to make sure that the system is behaving as expected at room temperature. The temperature readings are taken from a ____________ placed in good thermal contact with one of the sides of the specimen. It was attached using some thermal grease.

The ends of the coils were soldered to the wiring already installed in the Cryostat. The cavity of the Cryostat was then covered with a radiation shield, which isolates the cavity from room temperature. The driving coil was then connected to an AC power supply and a 5Ω in series (see fig 2). In order to have a changing current and keep the magnetic field changing. The pick up coil was connected to a voltmeter to measure the *emf* induced by changing magnetic flux through it, making it across the specimen. (see fig 3.)

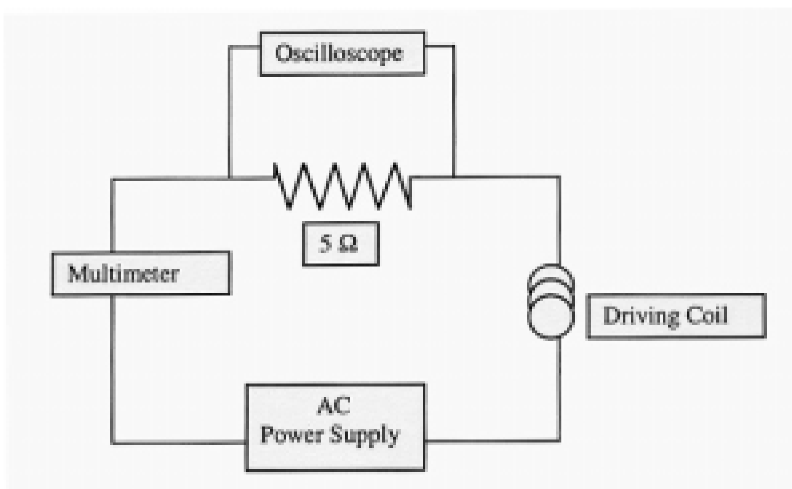

Fig 2.- Diagram of the Driving coil's setup.

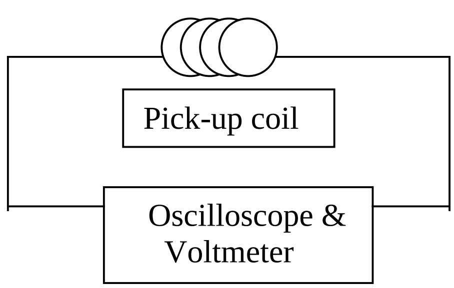

Fig 3.- Diagram of the Pick up coil.

The Cryostat was then evacuated with a turbo pump until a pressure of 1.52e-2 Torr was reached. Then the refrigerator was turned on and the behavior of the pick up voltage was recorded and plotted.

III.- Results

The plots of normalized[†] induced voltage vs. temperature show that at a temperature of about 89oK upon cooling and at 87oK upon heating the pick up voltage experiences a drastic change in behavior. The induced voltage starts decreasing at a higher rate below these temperatures, seeming that the magnetic field lines are having a larger problem crossing the material, letting the magnetic flux through the pick up coil change much less. (see fig. 3, 4).

[†] Normalized pickup voltage. The pick up voltage divided by the driving current in the driving coil. This normalization is done because the current on the driving coil changes with temperature as the resistance of the coil changes.

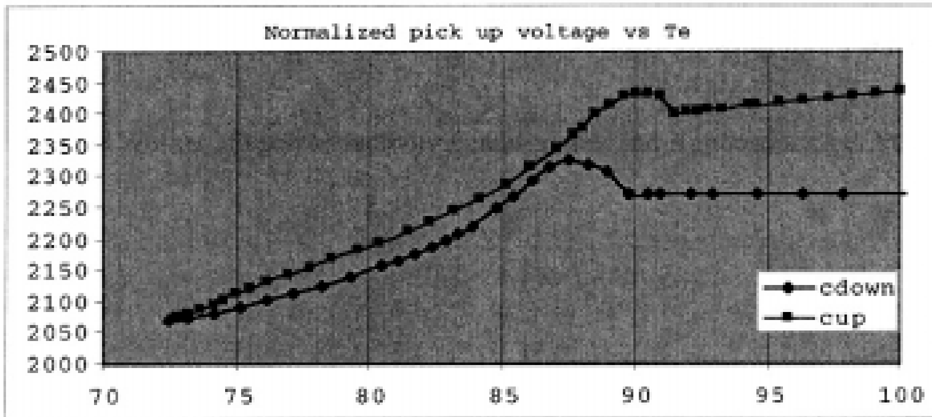

Fig 3.- Normalized pick up voltage[1] vs. temperature.

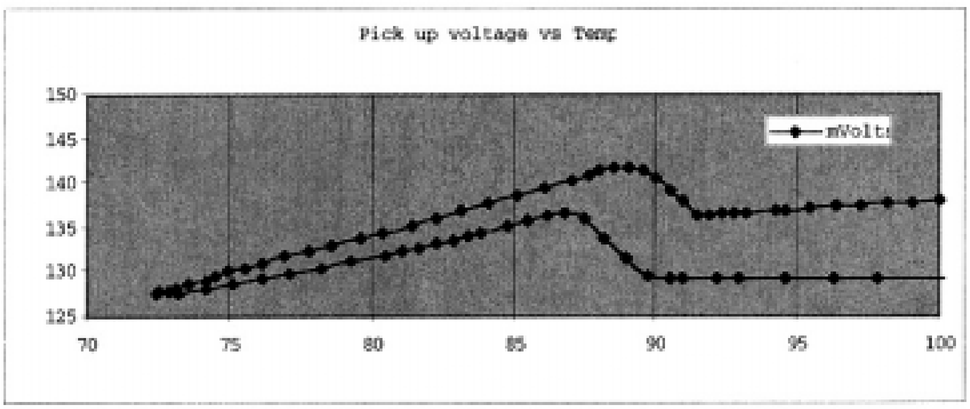

Fig 4.- Original pick up voltage (not normalized) vs temperature.

Acknowledgements

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References

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[2] Vivaldi G. *Superconductivity: the Next Revolution?* , Cambridge University Press 1993.

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[4] Reitz, et al; *Foundations of electromagnetic theory;* 4th edition, Addison-Wesley 1993 pp 279-281.