# Magnetic Properties of High Temperature Superconductors

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# Meissner Effect (History)

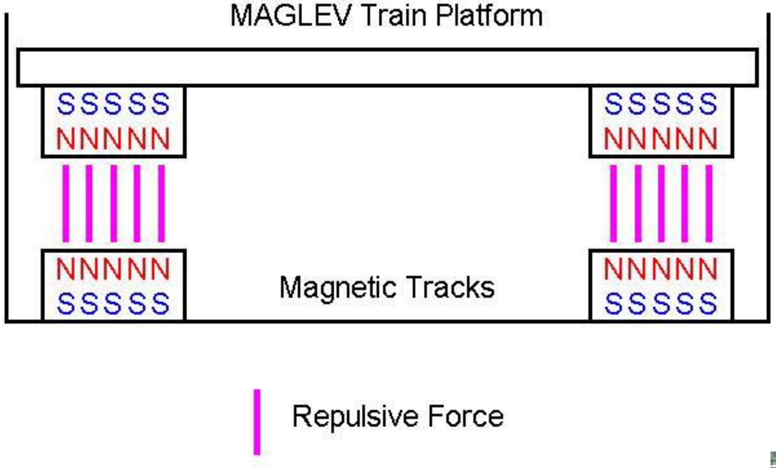
## History of Meissner Effect

There is a magnetic link to superconductivity. It is called diamagnetism, another name for the Meissner Effect. The Meissner effect is the total exclusion of magnetic fields from the inside of a superconductor. It was discovered by Walter Meissner and Robert Ochsenfeld in 1933. They discovered that a superconducting material would repel a magnetic field. The Meissner effect shows that a magnet can be levitated over a superconductive material. The Meissner effect occurs with Type I and Type II superconductor as we will discuss below.

# Applications of the Meissner Effect

Magnetic Levitated trains

Superconductors are used in different applications. Superconductors are used in magnetic levitation. This eliminates friction between the train and its tracks. On the track there are North and South pole on the sides. In between the tracks there are superconductors. The poles and the superconductors repel each other forcing the train to float on top of the superconductors. The first commercial use of magnetic levitated trains was in 1990. It was a nationally funded project in Japan.




http://my.execpc.com/~rhoadley/magtrain.htm
and superconductivity.org

# Pellet Prepared for Meissner Measurement

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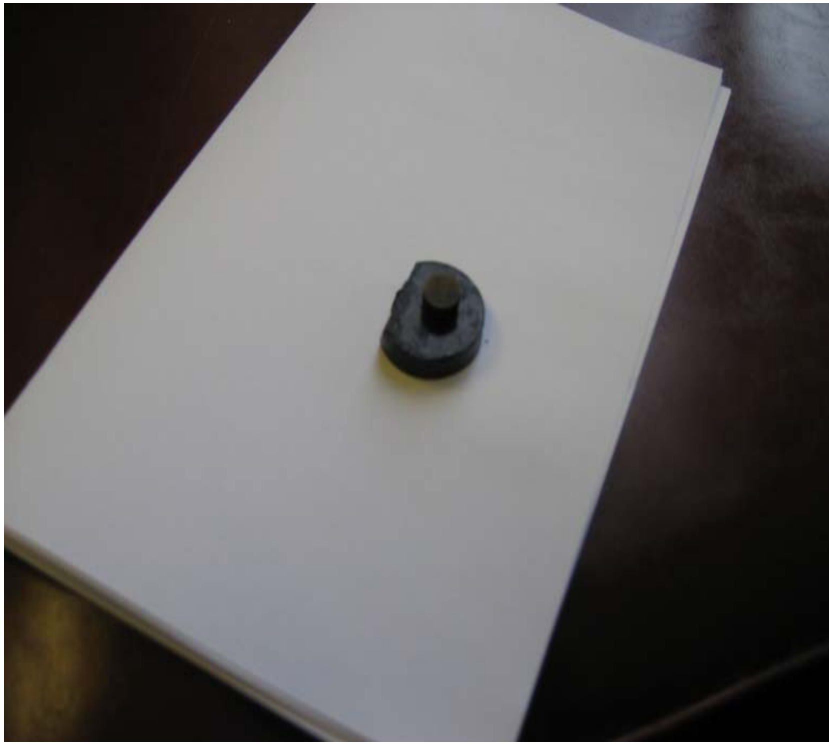
In this project we prepared a sample of $YBa_2Cu_3O_{6+x}$ (YBCO) by solid state reaction methods. Specifically, we combined the oxides and carbonates of the metal atoms ($Y_2O_3$, $BaCO_3$ and CuO) in the correct stochiometric ratio, ground the combined powder and heated it for several cycles. The final powder was then pressed into a pellet. On we right we show the pellet with a magnet. Note that we cut off a corner to provide a sample for resistivity measurements.



# Simple Meissner Test

**Procedure**

**1. Carefully pour a small amount of liquid nitrogen into the a dish or styrofoam cup until the liquid is about a quarter of an inch deep.**

**Result: The liquid would begin to boil rapidly for a short time. Wait until it stops.**

**2. Use a tweezer and carefully place the superconducting pellet in the liquid until its top is a little bit covered with the surface of the liquid nitrogen.**

**Result: The nitrogen will begin to boil again so, allow it to stop boiling.**

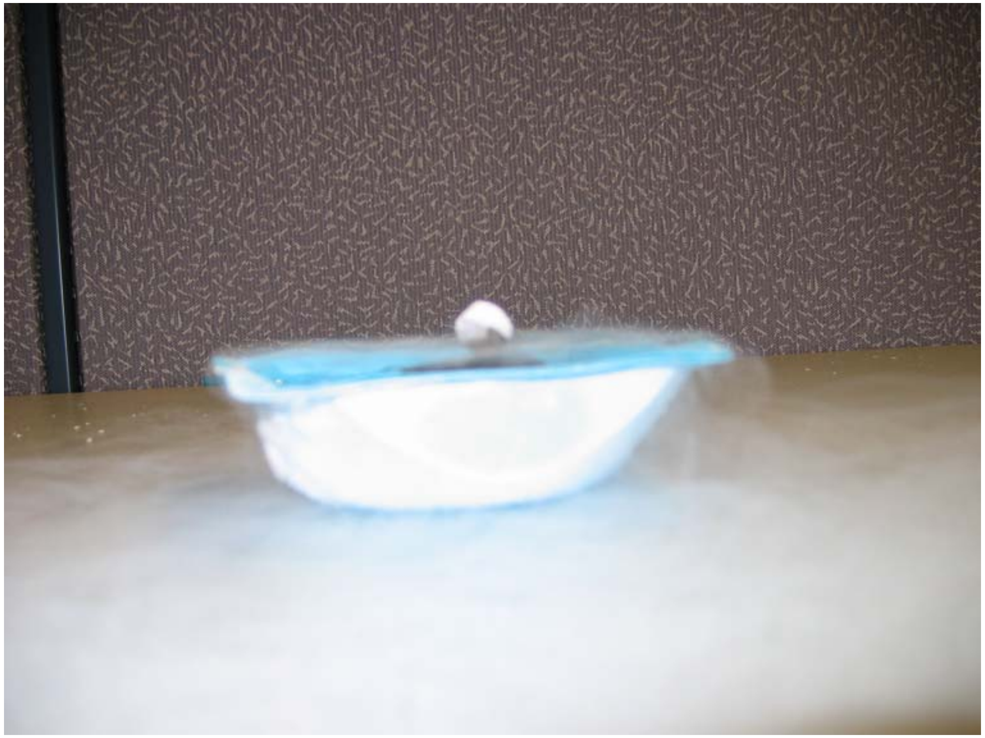
**3.Use your tweezers and pick up the provided magnet. Now attempt to balance it on top of the superconducting pellet.**

**Result: Instead of settling down on the surface the magnet will simply float a few millimeters above the superconductor.**

**Precautions: When pouring Liquid nitrogen prevent splashing, do not touch any items immersed in the liquid nitrogen with your hand until they have warmed to room temperature, to add and remove items from liquid nitrogen use tweezers.**

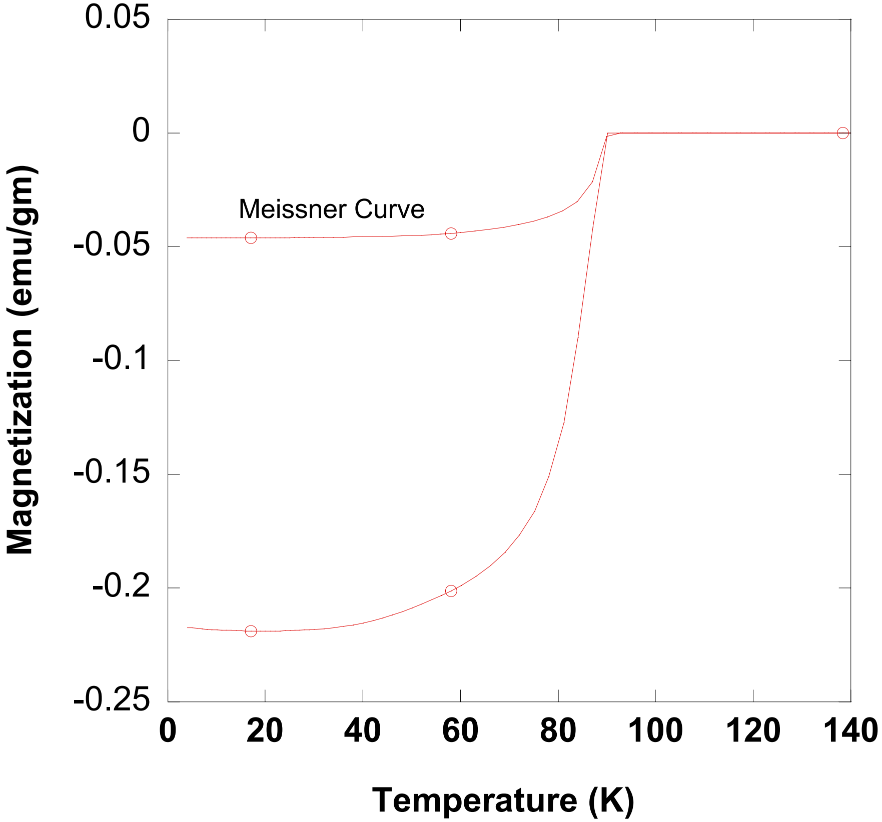
# Simple Meissner Effect Demonstration

In order to determine if the sample which we prepares was superconducting we conducted a set of tests which included x-ray, resistivity and magnetic measurements. Here we show the sample in a bath of liquid nitrogen. You can see a magnet levitated above the supreconducting pellet.



# Magnetization Measurement (Part 1)

The magnetization (M) of the sample was measured in a magnetic field of 20 Oe (H) with a SQUID magnetometer and  converted to emu/gram. The top curve is for cooling in the filed of 20 Oe (Meissner effect) and the lower curve is for warming thin the 20 Oe field.

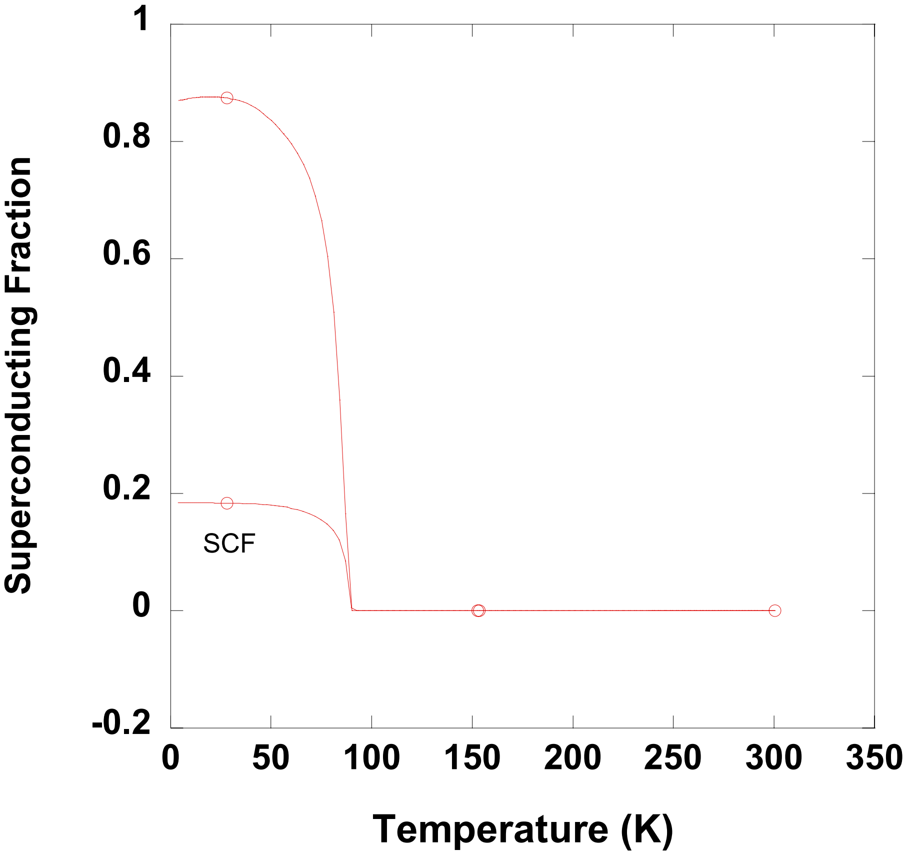


# Magnetization Measurement (Part 2)

The superconducting fraction (SCF) of the sample was obtained using the equation

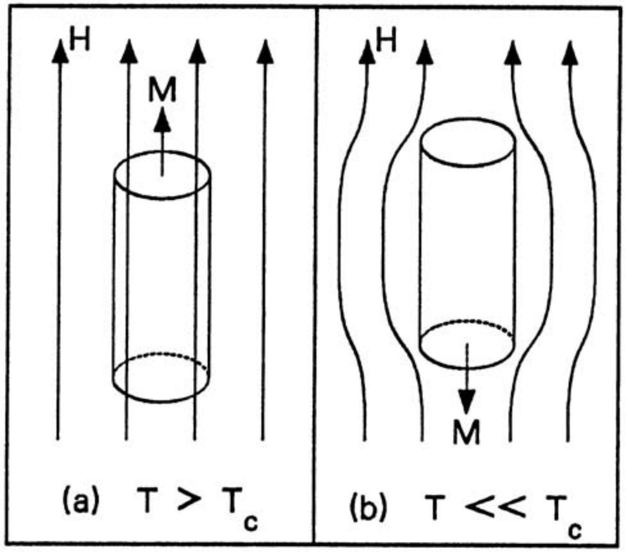
SCF = $- 4 \pi M \rho / H$,

with $\rho$ =6.37 $g/cm^3$ . Note that the SCF obtain from the Meissner Curve is 17%.



# Discussion (Part 1)

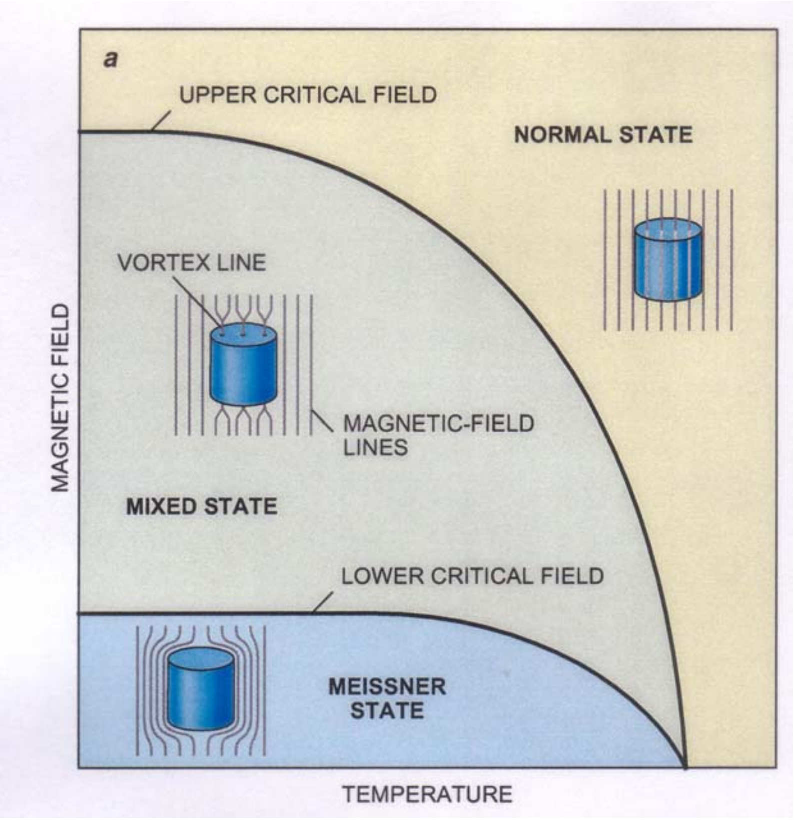
Above the critical temperature the magnetic lines (magnetic flux) penetrate the samples and induce a magnetization (paramagnetism) parallel to the magnetic filed. When a superconducting sample is cooled below the critical temperature, it expels the external magnetic field. That is, the sample exhibits perfect diamagnetism. Below Tc an external field induces a current is the sample which creates a magnetic moment opposing the external field. The result is that a superconductor in a magnetic field wants to move out of the field.




From Chemistry of Superconducting Materials, T. A. Vanderah

# Discussion (Part 2)

In the case of a type II superconductor such as YBCO things are a little more complicated. In low magnetic fields the superconductor expels the external magnetic field. If the Magnetic field is increase above the lower critical field Hc1 it enters the material but the filed lines are in discrete bundles. If the field is further increased beyond Hc2 supreconductivity is destroyed and the materials becomes non-superconducting (normal state).




Scientific American, Feb. 1993

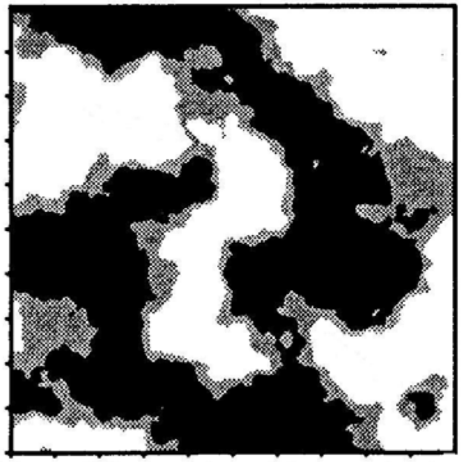
# Discussion (Part 3)

We conducted addition tests which included resistivity and x-ray diffraction in addition in this test. We observed the time required before the magnet levitated above the superconducting pellet was quite long. This suggested that the critical temperature for a large part of the sample was near 77 K (- 196 C). From the x-ray and resitivity measurements we found that the sample is composed of $YBa_2Cu_3O_{6+x}$ with a distribution x values. The resistivity measurements show a large drop in resistivity near 90 K. The combined observations suggest that the sample is composed mainly of a component with Tc~ 77K and a smaller component with Tc~90K. Preparing the sample in flowing oxygen or at a controlled oxygen pressure will help to produce a samples with only one x value.

# Summary

The sample prepared is composed of multiple components with one superconducting component having a Tc of 90 and a large normal phase. Electrons are forced to take a difficult path thorough the material above Tc producing a high resistivity and low diamagnetic moment

Percolation Model



# Acknowledgments

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