

Magnetization of Superconductors

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This experiment investigates the properties of type-I (Pb) and type-II (YBCO) superconductors through the magnetization measured with a [Quantum Design](#) SQUID magnetometer.

I. Type I superconductors

Type I superconductors (such as Pb and In) exhibit perfect diamagnetism – they expel all magnetic flux while in the superconducting state (below critical temperature T_c and below critical magnetic field H_c).

Procedure:

Prof. Heiman help you load the samples and show you how to program measurement sequences.

The high-purity Pb wire should be mounted vertically in the straw, so that it is parallel to the applied field. Why? Measure its dimensions.

Using a small applied field ($H = 20$ Oe), measure the magnetic moment $m(T)$ for increasing temperature through the expected T_c for Pb. Always cool the sample to low temperature first, then collect $m(T)$ data for increasing T . Determine T_c with good precision (~ 0.1 K). Does the size of the diamagnetic response match your predictions? What are the systematic and random errors in this measurement?

Measure $m(H)$ for several temperatures below T_c . Measure from $H = 0$ to 1000 Oe. Does the shape of the $m(H)$ curve match your expectations for an ideal Type I superconductor? If not, why not? Determine the H_c (with error) and plot $H_c(T)$. Compare this curve to the theoretical prediction.

II. Type II Superconductor

Type II superconductors do not expel all the magnetic flux at once like the type-I materials. Instead, the magnetic field creeps in slowly as the density of magnetic flux vortices increases for increasing temperature until T_c is reached, where all the flux is expelled. However, they have two critical fields, H_{c1} and H_{c2} , the lower and upper critical fields, respectively. They do behave like type-I superconductors at low magnetic fields below the lower critical field H_{c1} . At higher fields above H_{c1} the magnetic flux begins to penetrate the sample as flux lines or vortices and becomes non superconducting for fields above H_{c2} .

In this experiment you will use a polycrystalline YBCO (Yttrium Barium Copper Oxide) sample that has an ideal T_c of about 90 K.

Using a low field ($H = 20$ Oe), determine T_c for the sample and measure $m(T)$ from $T = 10$ K to 100 K. Where does the sample exhibit partial diamagnetism and perfect diamagnetism?

Using a high field ($H = 5$ T), measure $m(T)$ from $T = 10$ K to 100 K.
Explain any difference.

Instructions for [Quantum Design](#) SQUID Magnetometer

The Pb and YBCO samples are mounted in plastic straws, which can be found on the black table located to the left of the magnetometer. Someone will show you how to mount a sample on the long sample rod and then insert it into the magnetometer.

DO NOT
open the top of the sample chamber
unless the temperature is 300 K.

INSTALL SAMPLE

- (1) Confirm that the sample temperature is 300 K
- (2) Mouse click on the Remove/Install button in computer program,
Check to see if yellow “venting” light is on
- (3) Remove sample:
 - Remove the black stopper from the top of the sample chamber. Note: do not leave the black cap off the top for more than one minute.
 - If there is a sample rod already in (as observed by a blue metallic part visible at the top of the sample tube) insert the white screw one turn, then lift the blue metal part rod a few cm out of the sample tube.
 - Unscrew the black stopper, then slowly remove the long sample rod completely out.
 - Replace black cap.
- (4) Mount Sample: mount straw with the sample onto the black sample rod; place a small black plug on the bottom
- (5) Put the removed sample in its labeled paper straw-cover, which should be on the top of the magnetometer
- (6) Place your labeled paper straw-cover on top of the magnetometer
- (7) Install sample:
 - Slowly lower the sample rod with your sample straw attached. Do not drop the rod when near the end.
 - When nearly fully inserted, insert the white screw one turn, then push the rod down gently
 - Remove screw, then use the end of the screw to gently push down on the blue metal
 - Reinstall the black plug (screw up) on the top of the sample chamber
- (8) Record your name, sample, and helium level in the log book

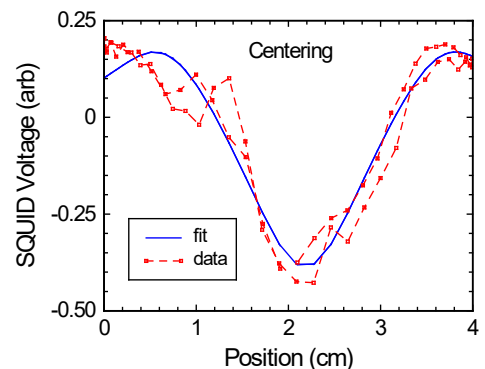
SOFTWARE CONTROL

The next processes are done via the computer.

- (1) Click the Purge Sample button
- (2) Then immediately click the Finished button
- (3) Type in the name of your sample; click OK

Center the Sample

- (1) Click Target Field at the bottom to set field to $H=5000$ Oe
- (2) Click Center /RSO at the top; then click Center; a graph will soon appear
- (3) If minima for Pb (maxima for YBCO) is not within 0.3cm of 2cm; click Adjust Position/Adjust Automatically
- (4) Close window when observed minima is at 2.0 cm



Run Sequence

- (1) Click on the Change button under Selected Sequence on the left
- (2) Go to C:\ALL DATA\APL lab
- (3) Move all old *.dat, *.gph and *.lastscan files into another subdirectory
- (4) Open the sequence Pb.seq – click Run on the left
- (5) After the sample has cooled and begins collecting data (~1 hour), click View on the left
- (6) After sequence is finished (~3-4 hours), move all your *.dat, *.gph and *.lastscan files into another subdirectory.
- (7) Create txt file of your data. Right click on the data plot and click Table View and copy the H, T, m columns.

Install the YBCO sample, center it, and run the sequence YBCO.seq.

Example sequences

***** M vs T 20G 2-8K *****

Set Datafile: C:\ALL DATA\APL lab\M(T) 20G 2-8K

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Set Magnetic Field 20.00 Oe, No Overshoot, Hi Res Enabled

Waitfor Field:Stable Delay:20secs

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Scan Temp from 2.000K to 6.500K at 10.000K/min in 0.5K increments (10 steps) Settle

Waitfor Temp:Stable Delay:30secs

Measure RSO: 4.00 cm, 2 cyc, 2 meas, 1.0 Hz, Center, AutoRng, Long, Iterative Reg., track:Yes, raw:No, diag:No

End Scan

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Scan Temp from 6.600K to 8.000K at 10.000K/min in 0.1K increments (15 steps) Settle

Waitfor Temp:Stable Delay:30secs

Measure RSO: 4.00 cm, 2 cyc, 2 meas, 1.0 Hz, Center, AutoRng, Long, Iterative Reg., track:Yes, raw:No, diag:No

End Scan

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Set Magnetic Field 0.00 Oe, No Overshoot, Hi Res Enabled

***** M(H) vs T 2-8K*****

Set Datafile: C:\ALL DATA\APL lab\M(H) vs T 2-8K

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Scan Temp from 2.000K to 8.000K at 2.000K/min in 2K increments (4 steps) Settle

Waitfor Temp:Stable Delay:120secs

Scan Field from 0.00Oe to 800.00 Oe in 25.00 Oe increments (33 steps), Hysteresis Mode, Hi Res Enabled

Waitfor Field:Stable Delay:10secs

Measure RSO: 4.00 cm, 2 cyc, 2 meas, 1.0 Hz, Center, AutoRng, Long, Iterative Reg., track:Yes, raw:No, diag:No

End Scan

Set Magnetic Field 0.00 Oe, Hysteresis Mode, Hi Res Enabled

End Scan

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Set Magnetic Field 0.00 Oe, No Overshoot, Hi Res Enabled