

YBCO Superconductor Production in the High School

[Lawrence J. Flint](#)

Abstract

In the summer of 2001 I involved myself with a research project at the Material Research Science and Engineering Center (MRSEC) at [Penn State University](#) to determine whether or not a Yttrium-Barium-Copper-Oxide (YBCO) ceramic superconductor sample could be produced using methods and equipment common to a high school science laboratory. The goal was to consistently produce sample pellets of high enough quality as to demonstrate the Meissner effect. My research was supported by the Research Experience for Teachers (RET) program.

There are a number of ways to test a material to see whether or not it is superconductive. The simplest and most impressive way is to immerse a pellet of the material in a bath of a cryogenic liquid and test to see if the material excludes a magnetic field. If it does then a small magnet with a strong magnetic field will levitate above the sample.

This demonstration of the Meissner effect is commonly performed in middle and high school science classes using commercially available superconductivity demonstration kits. It is desirable for students to have an understanding of how these materials are produced and see the fruits of their experiment in an impressive display of true levitation.

A total of 45 samples were produced using a variety of methods as described below. It proved to be difficult to predict the quality of each sample based on the methods and materials employed for each trial. The degree to which each sample could support the levitation of a magnet varied greatly. All but two samples successfully demonstrate the Meissner effect.

Method

The interest in pursuing this project arose during a workshop on advanced ceramic materials offered at Penn State early in the summer of 2001. Here is a [PowerPoint presentation](#) that was prepared for delivery to a group of middle and high school science teachers at the conclusion of the workshop. It is much better to [download the presentation](#) and run it on your computer than viewing it integrated in a browser window.

The techniques employed in the production of YBCO superconductors were initially derived from the Ceramics Module of the Materials World Modules available from Northwestern University. The Materials World module provided a great deal of information on making superconductors but has some flawed technique as was discovered during the failed initial attempt. The use of Darvan-C and water to slip cast YBCO on a plaster of paris plate mold was very ineffective. Further literature searches yielded many very good works that better explained the technique used to make this material.

One thing that was encountered during the literature review was the amount of inconsistency in materials and technique. Each paper presented different findings - this made me wonder whether or not it really makes a great deal of difference as to how YBCO is synthesized. [Here is an index of all the works used in this research.](#)

YBCO superconductors can be prepared in the solid state reaction of yttrium oxide, barium carbonate, and copper (II) oxide in an oxygen rich environment. This reaction takes place at high temperature (above 900C). After the reaction the YBCO should be reground to a fine powder and pressed into a pellet. This pellet is then sintered at around the same temperature as the initial firing to calcinate the sample.

Most of the literature regarding the production of YBCO superconducting materials refers to the use of high quality laboratory equipment common to research laboratories. Current basic and applied research in the field of superconductivity relies on the use of good equipment to produce high quality samples used for a variety of analysis.

The quality of a superconducting material does not have to be superior in order to demonstrate the Meissner effect. Even a crudely prepared sample at least has a few regions that will be superconductive to such a degree as to produce the desired effect.

The first samples were prepared meticulously utilizing the finest laboratory equipment, materials, and techniques available in our laboratory and from chemical supply companies. If the initial samples worked well then the procedure would be incrementally changed to introduce lower quality reactants and equipment. It was desirable to see what changes would be detrimental to the sample quality.

Typical process for research use	Optimal process for high school use
Agate mortar and pestle	Ceramic mortar and pestle
Alumina crucible for reaction	Ceramic crucible for reaction
Alumina plate for calcination	Ceramic tile (wall tile) for calcination
Programmable muffle furnace for firing	Art kiln for firing
High purity reactants	Low quality reactants
Pellet press	No pellet press
Multiple grinding/firing cycles	One grind/firing to final product
Oxygen enriched firing environment	Ambient oxygen environment

Procedure

Following is a detailed description of the procedure used to prepare the early samples:

Sample 1

The following reactants were ground to a very fine powder in an agate mortar and pestle that was thoroughly cleaned with 1.0M HCl followed by 50% acetone solution and 50% methanol solution.

Mass	Sample	Quality/Source
3.76 g	Y ₂ O ₃	99.9% REacton (Alfa Aesar stock #11180 - 250g)
13.16 g	BaCO ₃	99.8% assay (Alfa Aesar stock #14341 - 250g)
7.95 g	CuO	99.7% metals basis (Alfa Aesar stock #41692 - 100g)

The reactant (24.40 g) was placed in an alumina crucible that was cleaned in the same method as the mortar and pestle. The remaining 0.47 g of reactant was lost in the transfer to the crucible. The ratio of reactant was preserved since it was homogeneously mixed in the grinding process. The sample powder was a medium grey color.

The crucible with reactant was then fired in a Thermolyne programmable benchtop muffle furnace in order to react the constituent chemicals for the YBCO. This sample was the only item placed in the furnace. The was heated from ambient temperature to 935C at a rate of 0.80C per minute where the temperature was held +/- 2C for 420 minutes. The temperature was then programmed at a rate of 0.80C per minute to ambient temperature. The cooling rate was consistent for approximately 240 minutes after which the cooling rate steadily increased to a maximum of 2.0C per minute for the remaining time since the interior volume of the furnace is well insulated.

Following the intial firing the sample had a mass of 21.13 g. This drop in mass is consistent with the reaction stoichiometry which suggests that oxygen is evolved from the sample. The color of the sample changed dramatically from its initial medium grey color to a matte black. The size of the grains varies from very small to approximately 0.1 mm. The variety of grain size is very apparent and not regular.

The sample was reground in a very clean agate mortar and pestle. One half of this reground sample was placed in the same, clean crucible as it had originally been fired in. This was done so that it may be calcinated one more time to produce a theoretically higher grade product (*Sample 2*).

The other half was prepared for sintering into a final pellet. The half to be pelletized was placed in a pellet press. It was pressed at a pressure of 6700psi (10 metric tons) for ten minutes. The pressure was then slowly released over the course of two minutes. The pellet had a mass of 12.02 g and was 3.07cm in diameter and 0.50 cm in height (volume=14.8 cm³). The pellet was then placed on a 4cm diameter alumina plate and fired with the alumina crucible containing the regrind.

The firing sequence was exactly the same as the initial firing except the target temperature was 940C to ensure proper sintering.

The sintered pellet successfully demonstrated the Meissner effect, showing that it is not essential to regrind and recalcinate the high quality sample. The final size of the pellet is 2.88 cm in diameter and 0.44 cm in

thickness (volume=11.5 cm³). This translates to a 22% reduction in volume as it is sintered.

Sample 2

The refired sample from the original batch was removed from the furnace, reground, and fired following the initial sequence with a 940C target temperature. This sample demonstrated the Meissner effect as well as the first sample. The size of the grains on the surface of the second sample were smaller. Tests for brittleness were not conducted but both the first and second samples were very solid and resisted breakage with firm hand pressure.

Subsequent samples

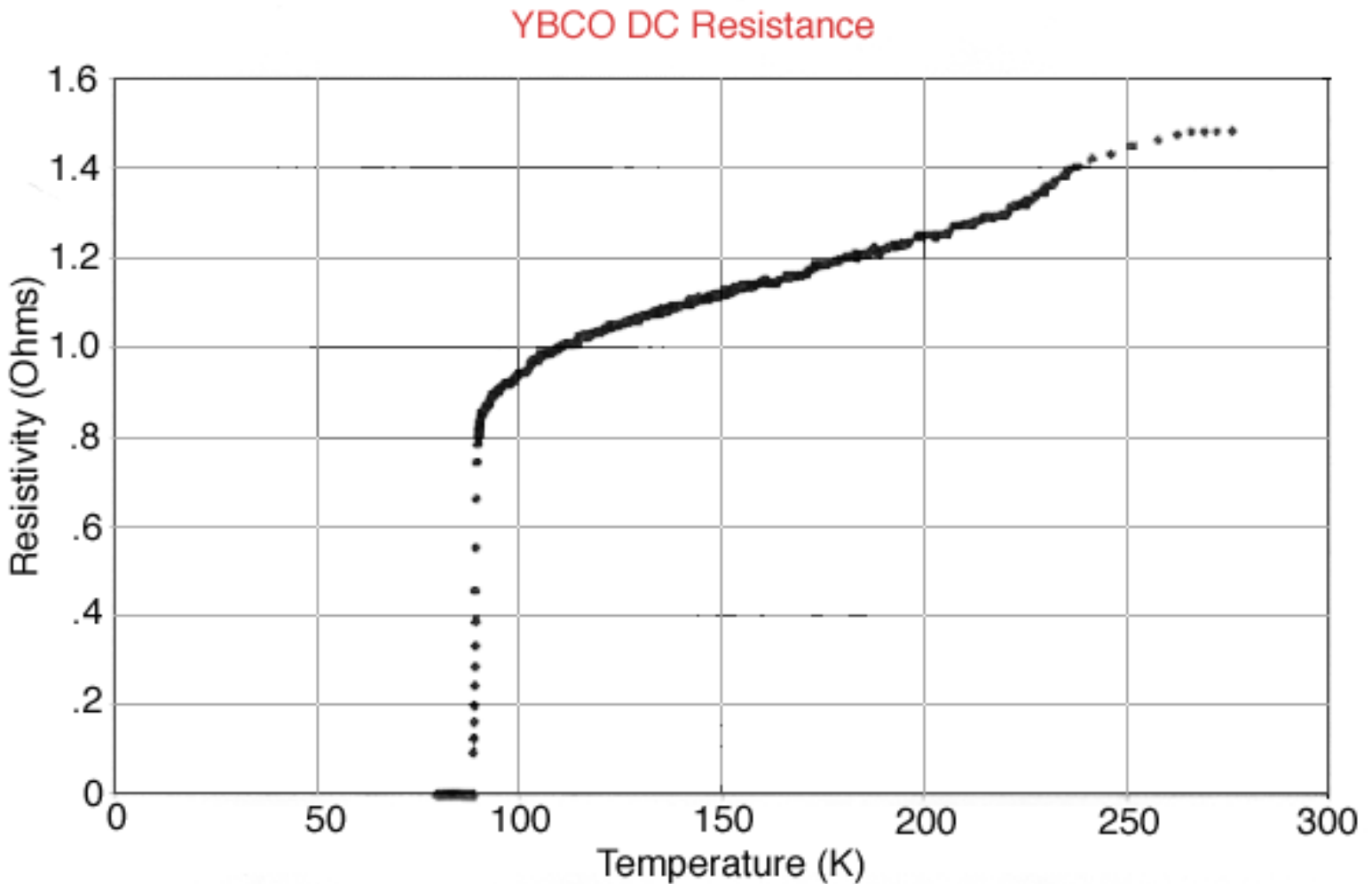
All future samples were prepared using the same methods as before but with varying equipment and materials. The remaining sample types are recorded in the trial [data table](#):

Analysis

Although the demonstration of the Meissner effect is sufficient to ensure the material is superconductive, this is only a qualitative observation. A quantitative study was conducted using one of the pellets to see if its electrical resistance truly drops to near zero ohms below the critical temperature.

The predicted critical temperature (T_c) of this material is 92K, the temperature at which the sample becomes superconductive. This ceramic oxide that is normally a resistor at room temperature becomes superconductive below its critical temperature.

Below is an example of a resistance curve for a YBCO superconducting thin film. Although a macroscale pellet was used instead of a thin film the same curve can be expected since resistance is generally independent of sample dimensions for such a material.



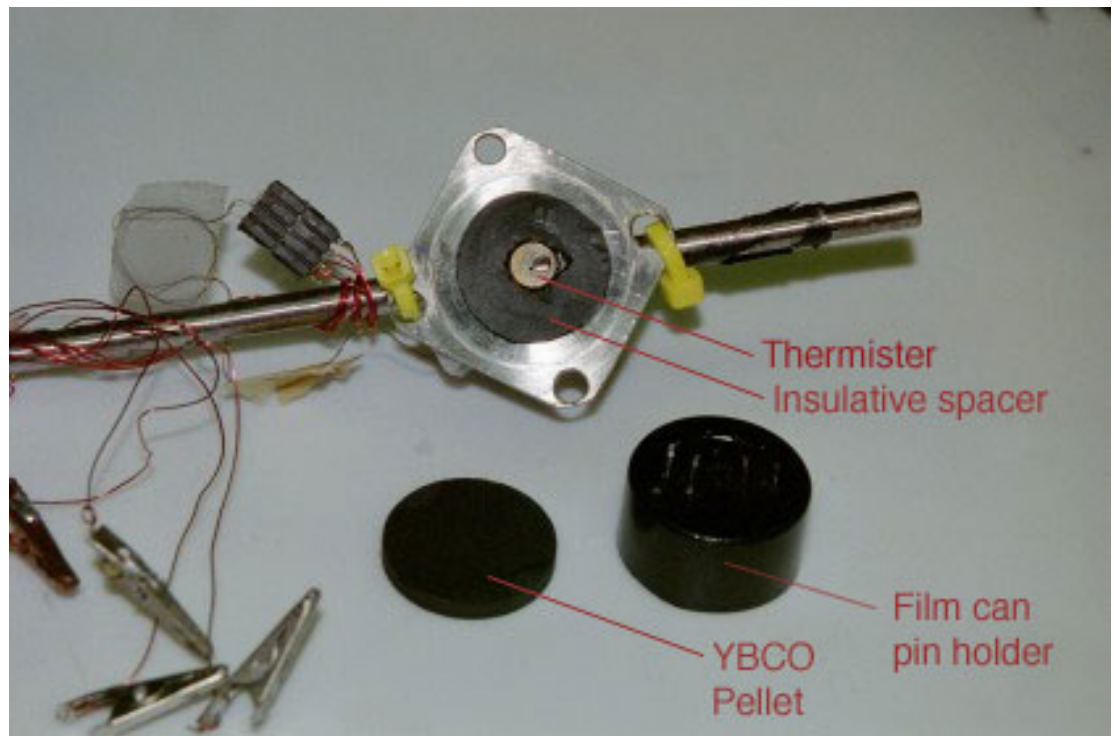
The resistance of the sample drops linearly as the sample is cooled from room temperature to near 100K. This linear drop in temperature is typical of most ceramic oxides. Between 100K and the critical temperature of 92K the resistance begins to fall appreciably. At the critical temperature the resistance falls drastically to near zero ohms within a range of a few Kelvin. Once the sample is cooled below the critical temperature the resistance is zero.

Sample #5 was selected to determine the critical temperature of these YBCO pellets. It was selected since it was produced under the most typical circumstances, is of typical dimensions, and demonstrates the Meissner effect. Below is an image of a typical YBCO superconducting disk with a powerful permanent magnet levitating above. You can [download a PowerPoint slide](#) that has a spinning magnet animated GIF. The magnet spins freely and only slows down due to air resistance.



A custom made test rig was constructed to measure the resistance both above and below the critical temperature. The design of the rig does not permit a slow cooling rate in order to accurately measure temperatures at high temperature resolutions. This apparatus could be modified so as to cool it at a rate sufficient to measure at higher temperature resolutions.

A hole was drilled in the center of a small metal plate to hold a silicon thermister in place. The thermister has four leads that run from it to the temperature controller. The thermister does not ride directly against the metal rod but rather has a 1 mm thick piece of plastic between it and the rod.



A piece of insulative plastic was fashioned to fit over the metal plate and around the thermister. The face of the thermister extends just slightly beyond the face of the insulative spacer to ensure good contact between the thermister and the sample. This design also allows the thermister and pellet to be thermally isolated from the rest of the rig.

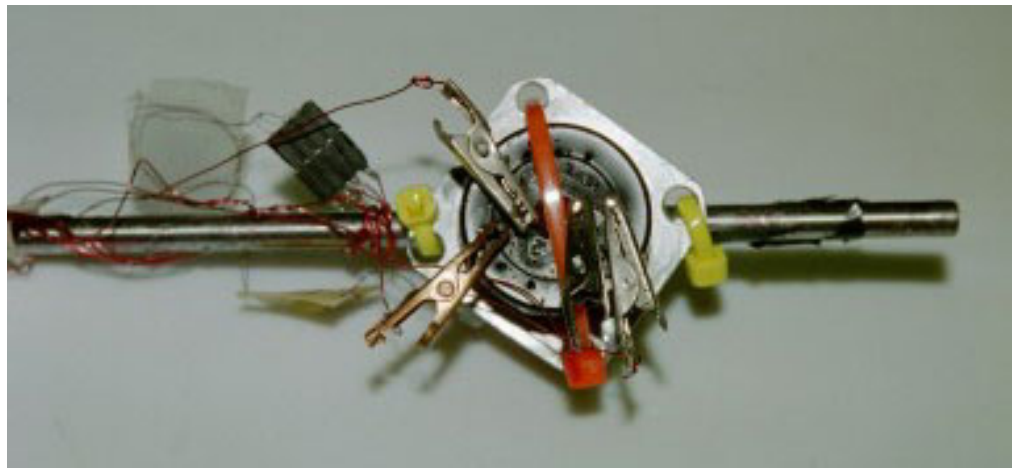
In order to measure the resistance accurately a four point measurement technique was employed. Four equally spaced metal pins were inserted into the bottom of a plastic film can that was cut to about half its initial height. The pellet is only 0.5 mm smaller in diameter than the inside diameter of the film can (call it luck).

Furthermore the plastic parts were subjected to repeated cryogenic cooling and ambient temperature

heating cycles to ensure they would not be damaged during testing.

The rig is assembled by placing the YBCO pellet against the thermister and insulative spacer then attaching the film can pin holder to the rest of the assembly.

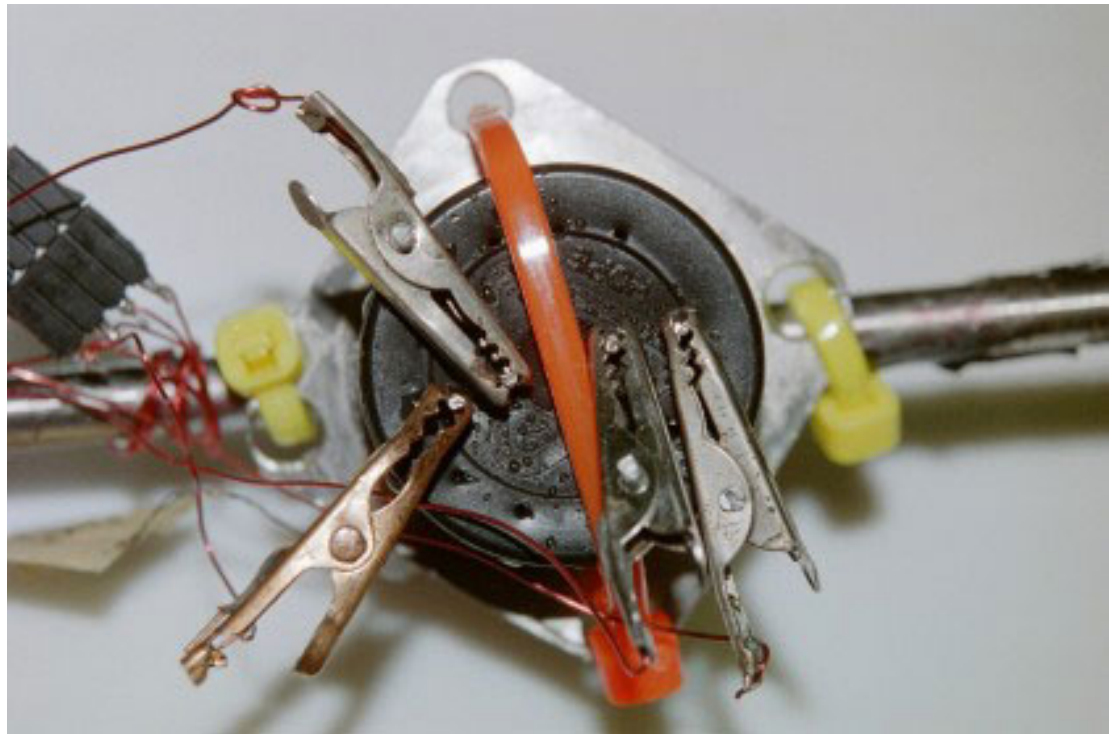
The entire assembly is secured with plastic cable ties that holds all of the pieces together and applies the necessary pressure to hold the pins against the YBCO pellet. This apparatus was constructed with scrap materials and readily available supplies at no cost.



The pins are simple pushpins with the plastic removed. The base of the film can holds each pin securely in place against the sample since the material is plastic.

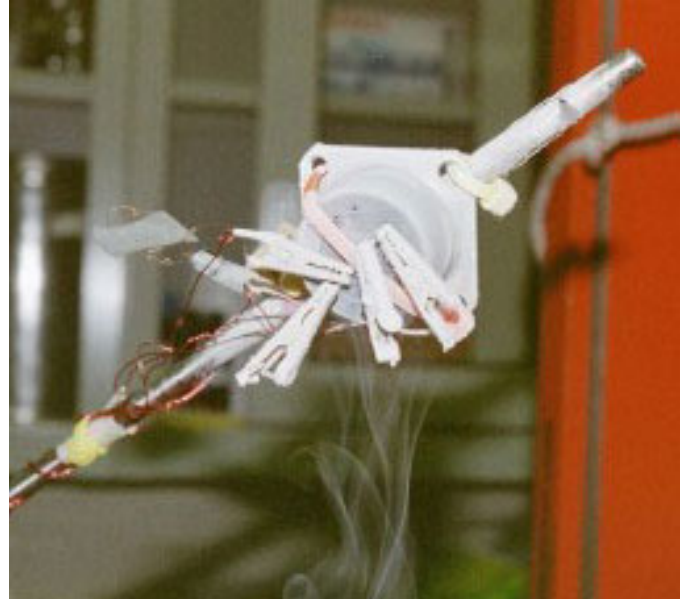
Closeup picture of alligator clip attachment.

The four point measurement scheme was set up with the current leads on the outboard pins and the voltage leads on the inboard pins.



A metal rod was used to dip the apparatus into a bath of liquid nitrogen at 77K. The sample was immersed for such time as to ensure it and the dip rod both came to thermal equilibrium. Although some thermal energy is conducted down the rod, this has a negligible effect on the outcome of the experiment.

Picture of the rig immediately after removal from the liquid nitrogen. Brrr... cold!



The thermister's temperature/resistance curve was entered into the temperature controller and was confirmed by checking its ambient temperature and temperature when immersed in LN₂.

The resistance of the sample at ambient temperature (298K) was 76.871 ohm. The photograph to the right shows the resistance of the sample measured 0.001 ohm at 76.883K. The display on the temperature controller has been computer enhanced and is shown below.





It was too difficult to determine the critical temperature of the sample since the cooling rate of the sample and the thermister were different. The response time of the thermister was much shorter than the cooling rate of the sample as evidenced by the drastic drop in sample resistance over five seconds after the temperature of the thermister fell below 78K. This is attributed to the considerably greater mass of the sample as compared to that of the thermister.

It is not necessary to use a thermister and temperature control unit to perform this segment of the experiment. It is well known that the temperature of liquid nitrogen is 77K and the critical temperature of YBCO is appreciably greater than 77K. If the sample can be slowly cooled rather than using a rapid dunking method then a temperature/resistance curve can be extrapolated.

Conclusion:

- It is possible to produce high quality YBCO pellet samples using relatively low quality equipment and inexpensive reactants.
- It is possible to measure the resistance of a YBCO pellet sample at ambient temperature and below the critical temperature using relatively inexpensive measuring devices and can be performed in a high school science course
- There seems to be no correlation between the degree to which a sample exhibits the Meissner effect and the methods and materials that were employed. Both low and high quality samples were produced using both high and low quality techniques.

Future study

The next variable to be studied is the firing sequence and firing equipment. The research conducted to this point was done with the use of a Thermolyne programmable muffle furnace. This furnace has a programmable temperature controller and digital display. Since the cost of such a furnace is probably beyond the reach of most public schools budgets there are a few options available to the high school teacher:

- Borrow a muffle furnace from a local university or commercial research laboratory.
- Apply for a grant to pursue this research at their school.
- Seek the donation of a furnace.
- Use an art kiln.

Future study in the use of microwave sintering techniques are in order. It has been demonstrated that ceramic oxides are quite easy to sinter with the use of a consumer microwave oven that has been modified. Modifications include a variac that adjusts the power output of the magnetron, hole in the top of the oven cavity to insert a thermister (to monitor reaction temperature), and the insertion of an insulative reaction

vessel.

A grant is being pursued to continue this study.

A PowerPoint presentation that summarizes this work can be [downloaded](#) or [viewed in your web browser](#). The downloaded version works much better. This PowerPoint presentation was delivered to the Physics I course at [Williamsport Area High School](#) to prepare them for their *Physics Of...* presentations

Upon completion of this study the author will submit the results for publication in a variety of scientific and science education journals including the Journal of Chemical Education and The Physics Teacher.

Sites I maintain

- [MrFlint.com](#)
- [DiscoveryRide.com](#)
- [BikeHostel.com](#)
- [WalkOnPart - Music](#)
- [LHU GOLD](#)
- [My WebCam](#)
- [Flint's Summer 2000](#)
- [Flint's Summer 2001](#)
- [Flint's Summer 2002](#)
- [Flint's Summer 2003](#)



[Traveling](#) **NEW**

Who is Flint?

- [The guy](#)
- [The teacher](#)
- [The fam](#)
- [The student](#)
- [Life's Little Joys](#)

Contact Flint

- [E-Mail Me](#)
- [Instant Messenger](#)
- [Offline contact](#)

Other stuff

- [My bookmarks](#)
- [eBay Searches](#)
- [Web site design](#)
- [Bicycling](#)
- [Computers](#)
- [Honda Insight](#)
- [Rants & Raves](#)
- [Online deals](#)
- [College Life](#)

Donate to the DiscoveryRide Scholarship Fund

Visit the [DiscoveryRide](#) web site and make a secure donation today to benefit Lock Haven University Science Education programs

Yes, Virginia, there is a Santa Claus.

[He lives in Snowmass, Colorado](#)



What am I up to?

It's the summer again so I'm on vacation from work. This summer is a busy one like every one before. I'm taking classes, doing research, and heading out west for a week long vacation.

[Read my summer plans](#)

I got two new bikes this spring. They are both extraordinary machines and symbols of fine American design and craftsmanship. [Read about them here.](#)

I rode a Rans Rocket recumbent from coast to coast following the TransAmerica bicycle route last summer. I raised money for a science education scholarship at [Lock Haven University](#) and used the ride to develop the [DiscoveryRide](#) web site which features science learning activities related to the ride.



Character isn't defined by the chances you take, but by how you make use of the chances you get.



© 2000-2003
Lawrence J. Flint
7.19.2003

PENNSTATE



URGENT NEWS

- About Penn State
- Prospective Students
- Academic Programs
- Outreach Programs
- Campuses and Colleges
- Visitor's Guide
- Alumni and Friends

Welcome to

PENN STATE

[Directories](#) | [Calendars](#) | [Jobs](#) | [Info Tech](#) | [Contact Us](#) | [Search](#)

PENN STATE *Making Life Better*

- News and Announcements
- Research
- Arts and Performance
- Libraries
- Athletics and Recreation
- Current Students
- Faculty and Staff Services

The Pennsylvania State University ©2003
Design and content are provided by the [Office of University Relations](#).
Technical support is provided by the [Information Technology Services \(ITS\)](#).

[About This Site](#) | [Text-only Version](#) | [Contacts](#) | [Search Links](#)
[Nondiscrimination Statement](#) | [Equal Opportunity Policy](#) | [Copyright](#) | [Privacy Information](#)

This page was last updated on Saturday, July 26, 2003.
Thank you for visiting Penn State.
Please direct questions to [AskPSU](#).

[Security changes on network required, disruptions possible](#)

Works Cited - YBCO research

- Chang, P.H. Ceramics Module - Mechanics of Materials Modules. Northwestern Univeristy 2000.
- Cozzi, A.D. et. al. Microstructural Evolution of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ using microwave energy. *Unknown book source.
- Experiment 51: Conductivity and Superconductivity. Physics 301 Laboratory Manual. University of Urbana-Champaign. Revised Oct. 1999. Downloaded from web site.
- FitzGerald. Superconducting YBCO Advanced Laboratory. Web site:
www.oberlin.edu/~sfgerald/phy414/mainybco.pdf. Rev. Feb. 19, 2001. Downloaded July 7, 2001.
- Heintz, J.M. Oxi-nitrate synthesis of non-carbonated $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ powders. Physica C.290. 1997. 132-142.
- Reverchon, E. et. al. Supercritical antisolvent precipitation: A new technique for preparing submicronic yttrium poders to improve YBCO superconductors. J. Mater. Res. Vol. 13, No. 2, Feb. 1998.
- Superconductors Model 1000 kit manual. Future Science. Web site:
www.futurescience.com/manual/sc1000.html. Viewed on August 10, 2001.

YBCO Trial Data

Key:

- Sample #: chronological order
- Crucible Type: Alumina crucible or Coors ceramic crucible used in the initial reaction.
- Grindings: Number of times the powder was ground before final sintering. One grinding indicates only an initial mixing and grinding of the reactants. Two grindings indicates the same initial grinding plus one more grinding between initial calcination and pellet sintering.
- Plate Type: Type of plate the pellet was sintered on in the furnace. Alumina plate and ceramic tiles were used.
- Meissner Effect:
 - Negative: magnet did not levitate
 - Low: magnet does not completely levitate; still supported by pellet
 - Medium: magnet levitates at a height equal to or less than the diameter of the magnet
 - High: magnet levitates at a height greater than the diameter of the magnet
- CuO Grade: 97.0% or 99.7% metals basis CuO
- Stability:
 - Good - may be warped slightly when warmed to room temperature from 77K.
 - Broken - damaged upon sintering *or* cracked when roomed to room temperature from 77K.

[Back](#)

Sample #	Crucible Type	Grindings	Plate Type	Meissner Effect	CuO Grade	Stability
1	Alumina	1	Alumina	Medium	99.7%	Good
2	Alumina	2	Alumina	High	99.7%	Good
3	Alumina	1	Alumina	High	97.0%	Good
4	Alumina	1	Alumina	High	97.0%	Good
5	Alumina	1	Alumina	High	97.0%	Good
6	Alumina	1	Alumina	High	97.0%	Good
7	Alumina	1	Alumina	High	97.0%	Good
8	Alumina	1	Alumina	High	99.7%	Good
9	Alumina	1	Alumina	High	97.0%	Good
10	Alumina	1	Alumina	High	97.0%	Broken
11	Alumina	1	Alumina	Medium	97.0%	Good
12	Alumina	1	Alumina	High	97.0%	Good
13	Alumina	1	Alumina	Medium	97.0%	Good
14	Alumina	1	Alumina	Medium	97.0%	Good
15	Alumina	1	Alumina	Medium	97.0%	Good
16	Coors	1	Ceramic	Negative	97.0%	Good
17	Alumina	1	Alumina	Medium	97.0%	Good
18	Coors	1	Alumina	Medium	97.0%	Good
19	Coors	1	Ceramic	Medium	97.0%	Good
20	Coors	1	Alumina	Medium	97.0%	Good
21	Alumina	1	Ceramic	High	97.0%	Good
22	Alumina	1	Alumina	Medium	97.0%	Good
23	Alumina	1	Alumina	Medium	97.0%	Good
24	Alumina	1	Alumina	Medium	97.0%	Good

25	Alumina	1	Coors Cruc.	Low	97.0%	Good
26	Alumina	1	Alumina	Medium	97.0%	Good
27	Alumina	1	Alumina Cruc.	Medium	97.0%	Good
28	Coors	1	Ceramic	Medium	97.0%	Good
29	Alumina	1	Alumina	Low	97.0%	Good
30	Alumina	1	Alumina	Medium	97.0%	Broken
31	Coors	1	Ceramic	Negative	97.0%	Good
32	Alumina	1	Alumina	Medium	97.0%	Good
33	Alumina	1	Alumina	Low	97.0%	Good
34	Alumina	1	Alumina	High	97.0%	Broken
35	Alumina	2	Alumina	High	99.7%	Good
36	Alumina	1	Alumina	High	97.0%	Good
37	Coors	1	Ceramic	Medium	97.0%	Good
38	Coors	1	Ceramic	Negative	97.0%	Good
39	Alumina	2	Alumina	High	97.0%	Good
40	Alumina	2	Alumina	High	97.0%	Good
41	Alumina	2	Alumina	High	97.0%	Good
42	Coors	1	Ceramic	High	97.0%	Good
43	Coors	1	Ceramic	High	97.0%	Good
44	Alumina	1	Ceramic	Low	97.0%	Good
45	Alumina	1	Ceramic	Low	97.0%	Good

[Back](#)



[District Information](#) [News/Events](#) [Community Information](#) [Schools](#) [Contact Us](#)

6/17/03

July 28, 2003

PHOTOCOPY FEE-Pursuant to the Open Records Law the Williamsport Area School District has established a fee of 25 cents per copy for photocopies requested by members of the public. A double sided copy is considered to be two copies. Prepayment is required if fees are expected to exceed \$100. This prepayment will be necessary prior to any copies being made.

[District Calendar](#)
[DocuShare](#)
[Employee Email](#)
[Search](#)
[Site Map](#)
[Student Registration](#)

Our Mission

The mission of the Williamsport Area School District is to ensure that all students acquire the skills and knowledge necessary to maximize their potential.

Click here to view our [District Perspective](#).



[Why is Williamsport home of the Millionaires?](#)

This project involves the study of the historical and cultural aspects of the Williamsport community during the mid-1800's when Williamsport was known as the "lumber capitol of the world" and boasted more millionaires per capita than anyplace else in the country. The project focuses primarily on the background and history of Williamsport's Historic District, West Fourth Street, now known as "Millionaires Row."



[Search](#) | [Contact Us](#) | [Home](#) | [Sitemap](#)

Copyright © 2002 Williamsport Area School District. All rights reserved.
201 West Third Street, Williamsport, PA 17701
PHONE 570-327-5500 * FAX -570-327-8122
[Non-discrimination Policy](#)

Comments and suggestions regarding this website are welcome and may be directed to the [webmaster](#).

Teaching the Nature of Science with Modern Presentation Techniques

M.Ed. Capstone Project
Lawrence J. Flint

The Physics of...

Introduction

This segment of the project draws heavily on performance-based education strategies. High school physics students will be immersed in a project where they will have to research an area of interest and discover the physical phenomena that govern their area of interest. Students will make 10–15 minute presentations to the class using a variety of media.

Students who are engaged in this project will have the opportunity to

Method

Since this is the first time this project has been integrated into the curriculum there are no example products to show students what they are aiming for. In place of exemplary works the teacher made a presentation to the class on [The Physics of YBCO Superconductors](#) which is also a part of this project. In addition, a sample summary and sample bibliography were provided to illustrate such works.

Students were introduced to this project on the first day of the course as it is mentioned on the syllabus and during class. The [prompt and rubric](#) were distributed during the fourth week of school along with a [crib sheet on preparing summaries and bibliographies in the APA style](#). During the tenth week of school (Nov. 9 and 12) students were given two days of class time in which to prepare their projects for presentation to the class.

The projects were to be completed any time before the winter holiday (Dec. 21, 2001). During the 11th week of the course (week of November 19, 2001) students were given the opportunity to schedule their presentations for during the weeks of December 10 and December 17, 2001.

The other segments of this project work well with the Physics of... student project. Students may prepare PowerPoint presentations, conduct original scientific research, and use the whiteboard. In a way, the students are helping to test technology more commonly used by the teacher. This gives them the opportunity to see the limitations of our classroom resources and experience how difficult science research and science education can be.

Students are given a tremendous amount of latitude in their project selection. The very nature of physics is that of the most fundamental sciences. Everything humans experience can be boiled down to very simple terms. In fact, the universe experienced on the human scale is only constructed of three basic particles and only four fundamental forces. Anything that can be imagined should eventually be explained by physics.

There are many real benefits to this project:

1. Students are exposed to scientific literature during their research. This is probably the first time that they have seen scientific works and should become familiar with the writing style unique to scientists.
2. Students are taught to prepare papers following the MLA style exclusively in school. This project exposes them to a new writing style that they are most likely not familiar with, APA. When they reach college most papers written in the social, behavioral and natural sciences will be expected to be composed following the APA format.
3. It gives students the opportunity to make a live presentation to their fellow students. Having students speak before their peers enhances their communication skills and shows them that public speaking is not relegated only to speech class.
4. It brings a performance-based education project into the course. Pennsylvania requires more and more performance-based education in the new standards that are being adopted.
5. Students have the opportunity to prepare their findings on media they may not be accustomed to such as a PowerPoint presentation, a web site, a poster, or a live demonstration.
6. It breaks up the monotony of the course and infuses a short change in pace in the middle of the year. Most other courses require a major project or paper toward the end of the course. In order to avoid this overload, this project is timed to fall before a major break and not when other projects are likely to be due.

Evaluation

A clearly defined evaluation rubric was designed to aid students in preparing their projects. This criteria will be applied by the teacher to award points for the assignment. So long as students meet the criteria they will earn all of the available credit. Students not fully meeting the criteria will be awarded a portion of the available points as determined by the teacher.

- **Summary** - 15 points

Clearly identifies the area of interest and reports on findings. Direct applications to physics must be evident. Should indicate that the student clearly understands the physics of the subject. At least one single space, typed page in length. Follows APA style.

- **Bibliography** - 15 points

Cites at least three sources of information about the physics of the subject of interest. At least two different media should be cited (print, video, web, etc). Follows APA style. Typed.

- **Presentation** - 70 points

Presentation is of substantial depth and indicates a solid level of understanding. The focus of the presentation should be an in depth description of the physical phenomena of study. Presentations may be given as web sites, PowerPoint Presentations, demonstrations, posters, or a combination of two or more styles. Projects given as papers should be substantial (5+ pages double spaced).

A summary of each student's project may be found [here](#). Examples of student works including PowerPoint presentations are included.

A focus group interview was conducted with each of the three sections of students at the conclusion of the presentations. Students were allowed to give their feedback in an open forum. At the conclusion of the forum the following questions were posed and a quick hand count of votes was taken:

1. Should this project be a part of the course next year?

2. Do you think this project should be a part of other courses?
3. Do you prefer this type of project to laboratory exercises?
4. Do you prefer this type of project to traditional lecture and homework?
5. Did you learn a significant amount about your area of interest as a result of this project?

The outcome of the focus group interviews is as follows:

Reflection

This project is atypical of most high school physics courses. It takes some work and inventiveness on the part of the students and the teacher. Many teachers are not willing to require their students to complete such a project for a few reasons.

- It is laborious on the part of the teacher.
- It is not a required portion of the curriculum.
- Teachers are not well trained on how to do performance based assessment.
- It requires class time to prepare the projects and to deliver them, taking away from traditional course time.
- Such a project is not well received by students.

I found this project to be very invigorating. It gave me as the teacher the opportunity to learn from my students, for I too am a student of our environment. It is also nice to be able to have other people make presentations during class time rather than having to lecture all the time.