# Experiment 17

# SYNTHESIS OF SUPERCONDUCTOR

## Objective

The purpose of this experiment is to synthesize a high-temperature superconductor, $YBa_2Cu_3O_{7-x}$ ($x \leq 0.25$) by solid-state reaction, and investigate its properties.

## Lab techniques

- Operating grinding, hydraulic pressing, and calcination
- Handling of liquid nitrogen
- Weighing chemicals

## Introduction

A superconductor exhibits superconductivity, namely zero electrical resistance, and the Meissner effect at the superconducting critical temperature ($T_c$). The Meissner effect is the exclusion of a magnetic field from a superconductor during its transition to the superconducting state, which could levitate a bar magnet.

In this experiment, yttrium oxide, barium carbonate, and copper oxide are used as starting materials to synthesize $YBa_2Cu_3O_{7-x}$ (abbreviated as Y-123), a superconductor with a $T_c$ at ~95 K, by solid-state reaction. The Y-123 superconductor can levitate a bar magnet at liquid nitrogen temperature (77 K) to show the Meissner effect (Fig. 17-1), which indicates positive superconductivity.

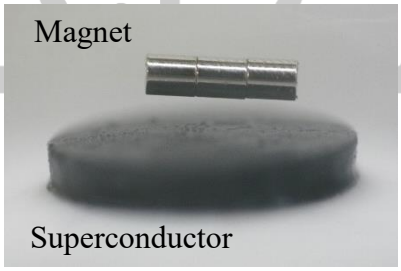



Figure 17-1 Y-123 superconductor levitates a magnet at liquid nitrogen temperature

## Apparatus

I. Preparation:

plastic spatula, alumina crucible lid, and face mask (self-prepared).

Shared: electronic balance, agate mortar and pestle, hydraulic press, dies, plastic

tweezers, cellulose sponge, and box furnace.

II. Test:

Shared: plastic tweezers, bar magnet (Nd-Fe-B), petri dish, Dewar flask, cryo-gloves, and hair dryer.

## Chemicals

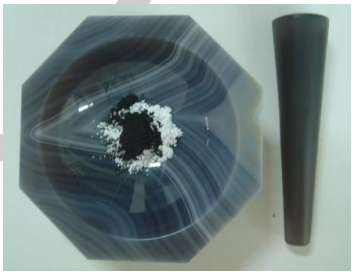
Yttrium oxide, $Y_2O_3$

Barium carbonate, $BaCO_3$

Copper(II) oxide, CuO

Liquid nitrogen, $N_2(l)$

## Procedure

| | Procedure | Illustration |
|---|---|---|
| I. Synthesis of superconductor | | |
| 1. | Calculate the stoichiometric amount of $Y_2O_3$, $BaCO_3$, and CuO to make the molar ratio of Y : Ba : Cu atoms equal to 1 : 2 : 3 to synthesize 0.004 mol of $YBa_2Cu_3O_{7-x}$.<br>Note 1: Include the calculations in the prelab report.<br>Note 2: The high-purity chemicals used in this experiment are very expensive. Avoid wasting. |  |
| 2. | Measure precisely the required amounts of $Y_2O_3$, $BaCO_3$, and CuO. Transfer them into an agate mortar.<br>Note 1: Wear a face mask while mixing and grinding powders to avoid inhaling chemical powders.<br>Note 2: The agate mortar is also quite expensive. Handle it with care. |  |

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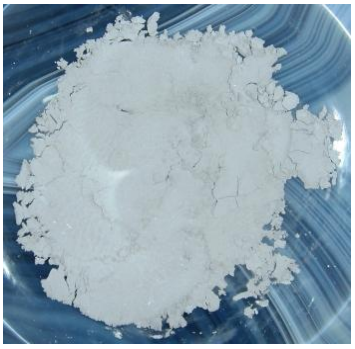
| 3. | Use a plastic spatula to mix the staring materials, then grind the chemicals for at least 10 min, until a homogeneous fine powder is obtained.<br><br>Note 1: Use a plastic spatula to avoid scratching the agate mortar.<br>Note 2: Wash the agate mortar with water and sponge, then dry it with paper tissues after use. |  |
| 4. | Transfer the mixed powder to a weighing paper. Use the hydraulic press and dies to press the powder under a pressure of 1 ton·cm$^{-2}$ for 1 min, then a round ingot with diameter of 2 cm and thickness of about 0.3 cm is obtained.<br><br>Note 1: The pressure should not exceed 1 ton·cm$^{-2}$ to avoid cracking during calcining.<br>Note 2: After use, wash the pressing dies thoroughly with water and sponge to remove powders stuck to its surface and then wipe-dry. |  |
| 5. | (1) Place the sample on an alumina crucible lid with plastic tweezers, and put it into the box furnace.<br>(2) Allow it to calcine at 930°C for 10 h in the air by raising and lowering the temperature at a rate of 5°C·min$^{-1}$.<br>(3) After cooling down to room temperature, take the product out.<br><br>Note: Record the position of the crucible to identify your product. No need to label it since it will be carbonized at high temperature. |  <br>  |
| II. Test of the Meissner effect | | |
| 6. | (1) Place the obtained product in a petri dish, and use plastic tweezers to place one small bar magnet on it to check the interaction.<br>(2) Pour some liquid nitrogen into petri dish, immerse and cool the product.<br>(3) Place one small bar magnet on it, examine the |  |

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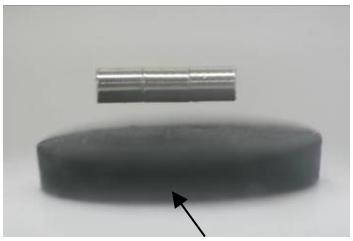
|---|---|---|
| | levitation of the magnet, and measure the height of the levitation.<br>(4) Increase the number of bar magnets to investigate the Meissner effect.<br>Caution: Avoid direct contact with liquid nitrogen, which can cause frostbite. |  <br>Superconductor |
| 7. | At the end of the magnetic-levitation test, dry the superconductor with a hair dryer to warm it to room temperature, remove any moisture on it, and put it in a zipper bag. |  |

## References


1. She, J. L.; Liu, R. S. *J. Chem. Educ.*, **2008**, *85,* pp 825-826.
2. Wu, M. K.; Ashburn, J. R.; Torng, C. T.; Hor, P. H.; Meng, R. L.; Gao, L.; Huang, Z. J.; Wang, Y. Q.; Chu, C. W. *Phys. Rev. Lett.* **1987**, *58*, 908.
3. https://en.wikipedia.org/wiki/Meissner_effect (2024/07/31).