# Synthesis of Superconductor

Last revised: 2025/02/06

# Preparation

**Collect the following items**

- Agate mortar (clean with sponge after use)
- Label one zip-lock bag with student ID and name
  (To collect the synthesized superconductor)

**From your personal equipment**

- One plastic spatula
- Mask (self-prepared)

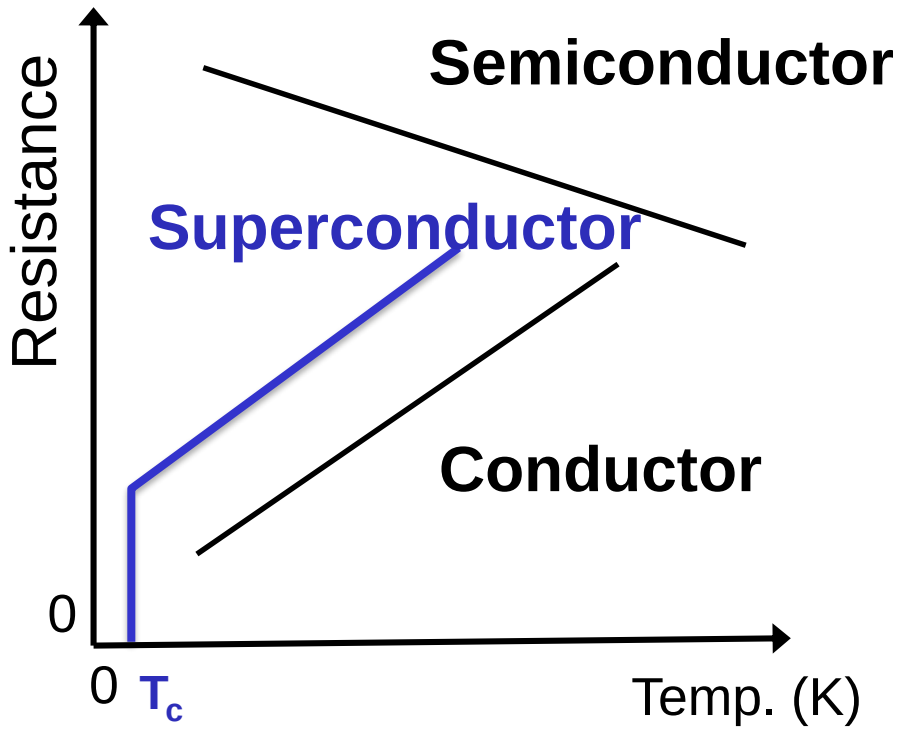
# Superconductors

- **Metal conductors**

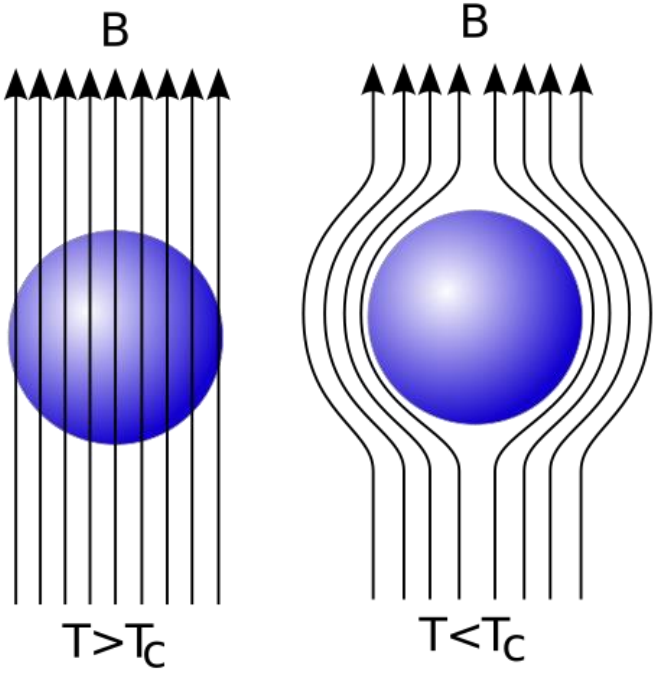
  Conductivity decreases with increasing temperature
- **Semiconductors**

  Conductivity increases with increasing temperature
- **Superconductors**

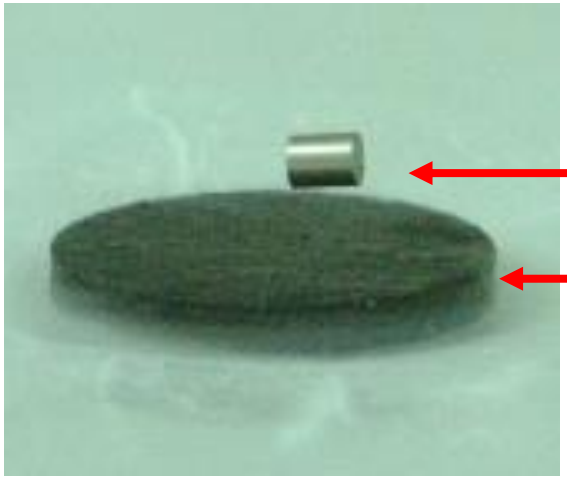
  Zero resistance at transition temperature, $T_c$



# Properties of Superconductor



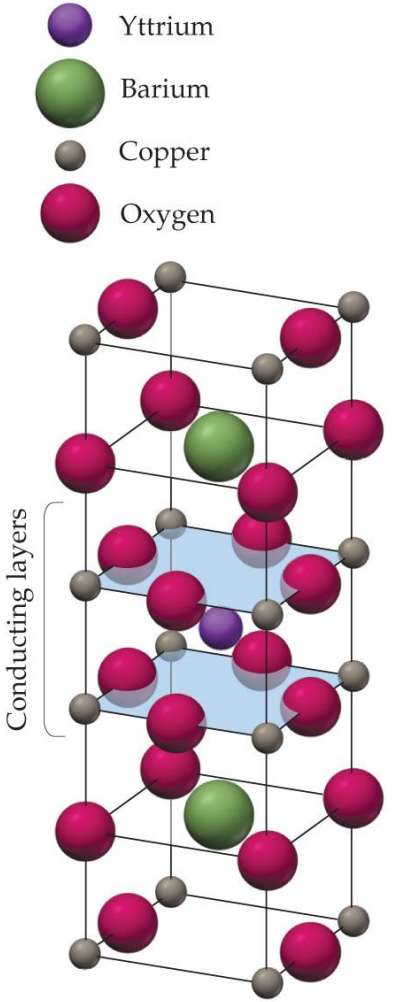

The Meissner effect




- At superconducting transition temperature, $T_c$
  - Zero resistance
  - Meissner effect

# YBCO Superconductor

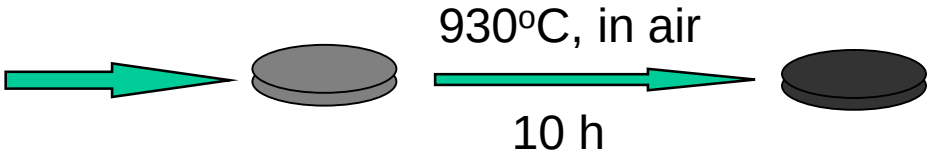
- Yttrium Barium Copper Oxide (YBCO) superconductor
- Chemical formula: $YBa_2Cu_3O_{7-x}$
- Crystalline structure
- $T_c$: **95 K**
  (Boiling point of liquid nitrogen: 77 K)
- Synthetic methods
  - **Solid-state reaction**
  - Sol-gel method
  - Co-precipitation




Unit cell

# Experiment Tasks

**Yttrium oxide, $Y_2O_3$**
**Barium carbonate, $BaCO_3$**
**Copper(II) oxide, CuO**




Y : Ba : Cu = 1 : 2 : 3

Grind, press, and sinter

Property test

Synthesize YBCO superconductor by solid-state reaction

1. Weigh starting materials according to atomic ratio
2. Grind the chemicals to homogeneous
3. Press the mixture into pellet
4. Sinter at 930°C for 10 h
5. Test the Meissner effect

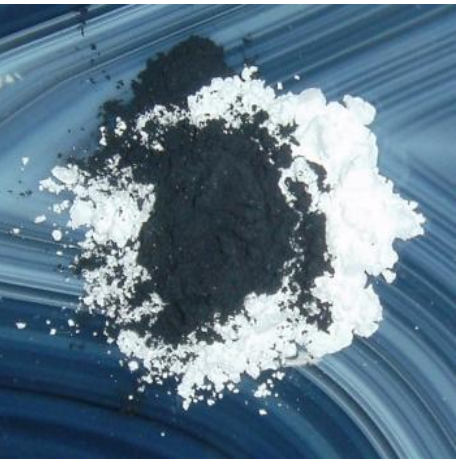
# Step 1: Calculation of Formula

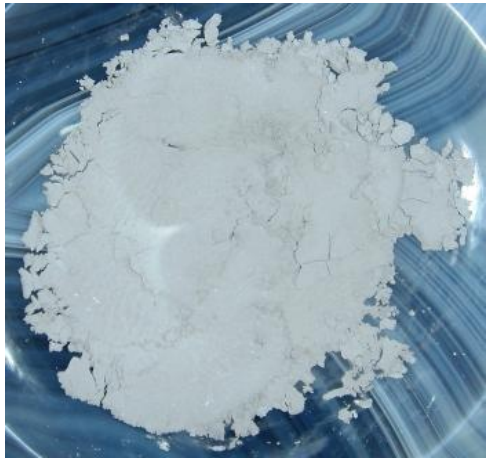
- To synthesize **0.004 mol** $YBa_2Cu_3O_{7-x}$
  (Y : Ba : Cu = 1 : 2 : 3 )

  - **$Y_2O_3$** **1/2 × 0.004 × 225.82 = 0.4516** ➡ **0.45 g**
  - **$BaCO_3$** **2 × 0.004 × 197.31 = 1.5785** ➡ **1.58 g**
  - **CuO** **3 × 0.004 × 79.55 = 0.9546** ➡ **0.95 g**

✓ The stochiometric amount of starting materials is critical to the success of the experiment!

# Step 2: Grind and Mix the Reactants



**Still contains white powder**

- Use agate mortar to contain the chemicals
- Mix chemicals with plastic spatula first, then grind
- Grind until color appears gray and homogeneous, that may take about 10~15 min.
- Collect the ground powder in a piece of weighing paper

✓ Agate mortar is expensive (NTD 9,000~15,000) and easily broken, handle with cares

# Step 3.1: Pressing Apparatus


Pressure gauge

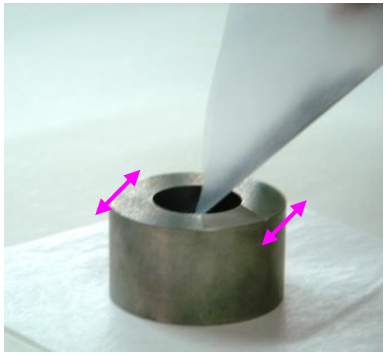
Hydraulic press

Parts of dies

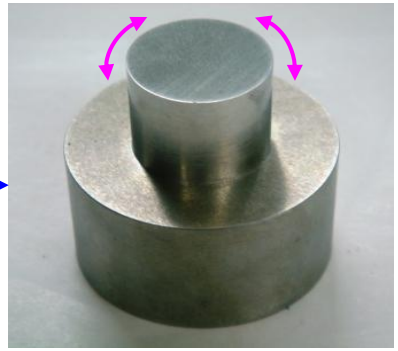
Hollow ring

# Step 3.2: Press into Pellet

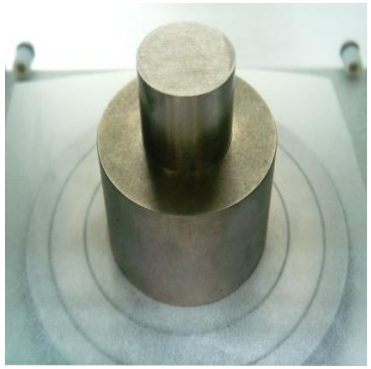
Place die on a weighing paper



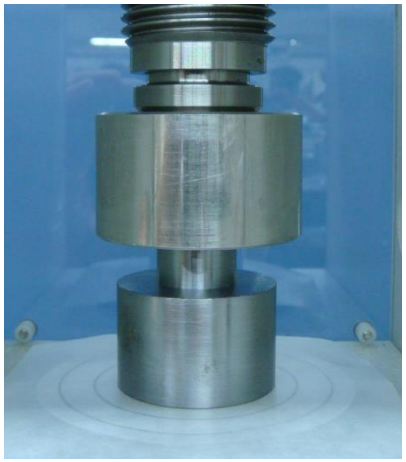
Transfer powder into die evenly



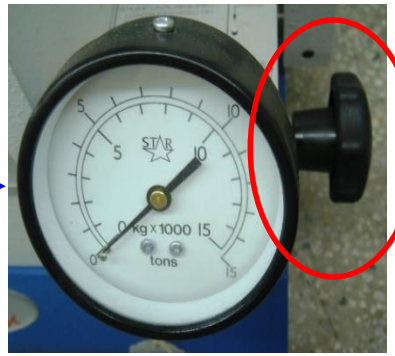
Rotate the die to even up powder



Place the dies on **center of hydraulic platform**

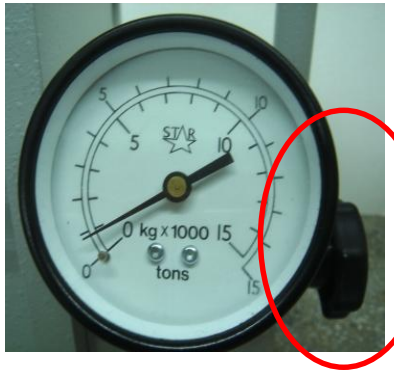


Fix the dies in position



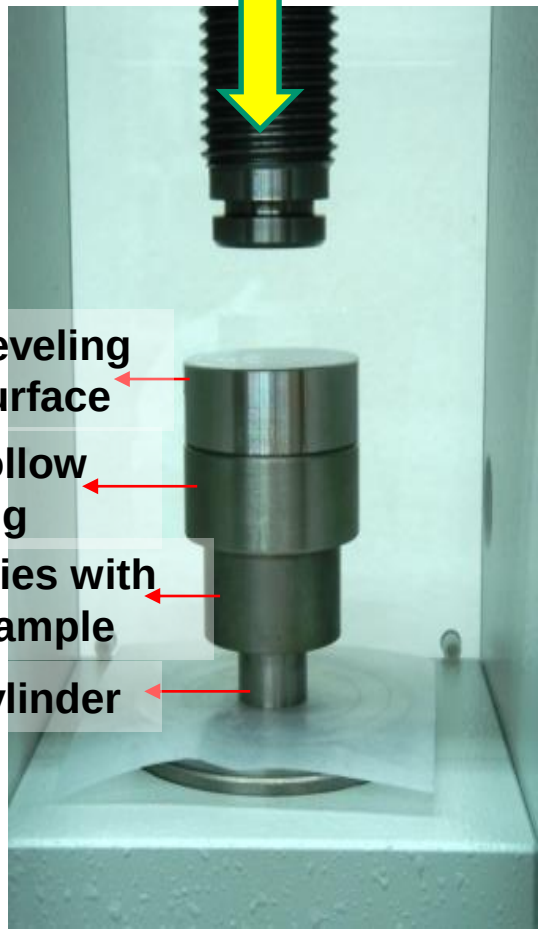

Close the valve clockwise

Apply the **pressure to 1 ton/cm$^2$ for 1 min.**

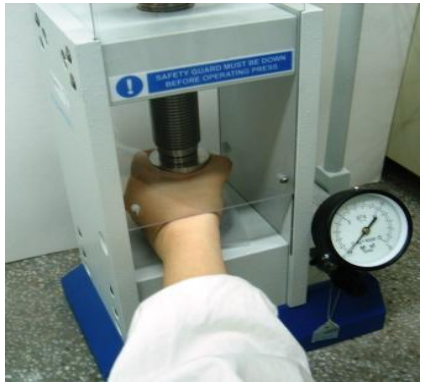



Release the valve **counter-clockwise**

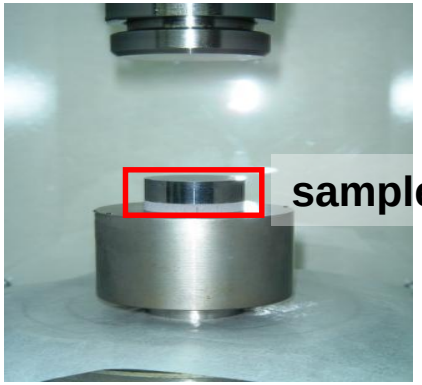
# Step 3.3: Obtain Pellet



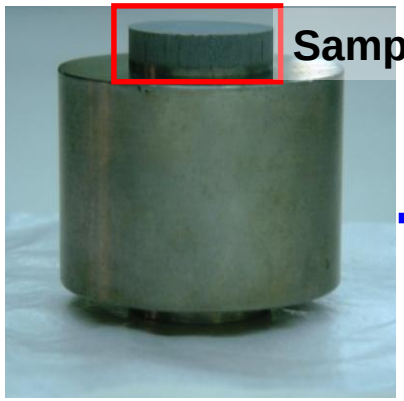

- Place the dies **in center of platform upside down**
- Setup the hollow ring and leveling surface



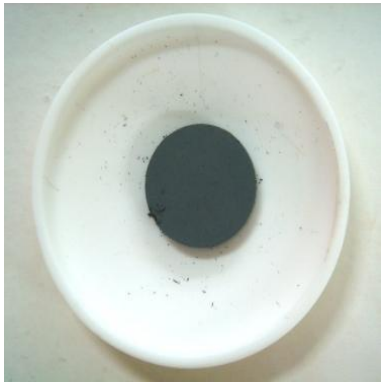
- Close the valve clockwise
- Pull leverage to surface the superconductor pellet




- Release the valve
- Take out the hollow ring




Resulting sample pellet



Place pellet onto an alumina plate with plastic tweezers carefully

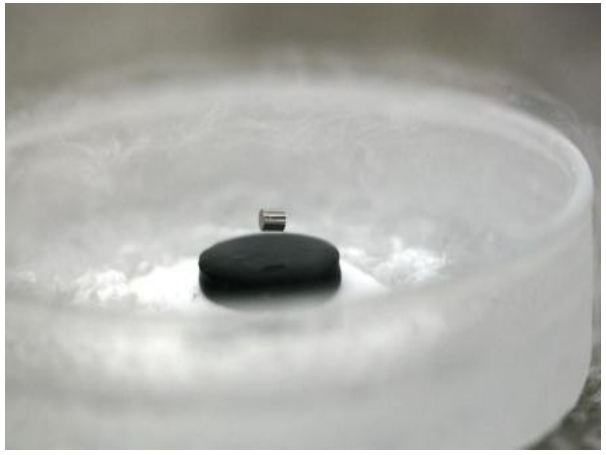
# Step 4: Sinter at 930°C

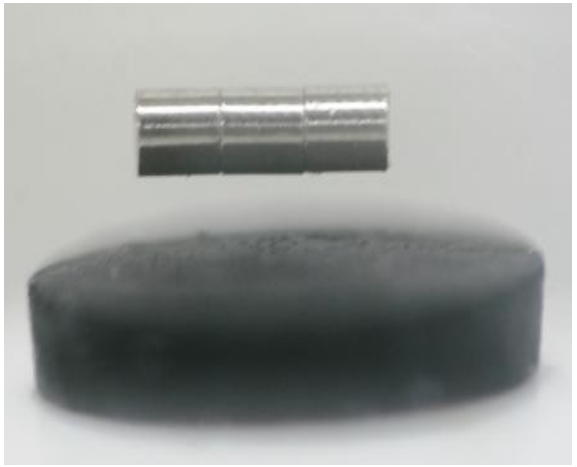
- Place the sample pellet into box furnace
- Sinter the samples at 930°C for 10 h. by raising and lowering the temperature at a rate of 5 °C/min.

✓ The box furnace can hold 4 × 4 = 16 samples

✓ Alumina plate cannot be labeled, record the position in furnace instead

# Step 5: Property Test





- Examine the Meissner Effect by observing the levitation of magnets
  - Place superconductor in petri dish
  - Place magnetic bars on superconductor pellet with plastic tweezers, compare levitation height and amount of magnetic bars
  - Add liquid nitrogen and immerse the superconductor
  - Dry and warm the superconductor with a hair dryer to room temp.

✓ Notice that the magnetic bars are small and easily lost

# Additional Notes

- The dies should be placed in center of platform to prevent uneven application of pressure when pressing
- Pressure should be kept at 1 ton/cm$^2$ for 1 min.
- Clean up the dies thoroughly after each use to avoid the powders pile up in dies that cause it to get stuck
- Avoid direct contact with liquid nitrogen which may cause frostbite

# Clean-Up and Check-Out

- Use sponge to clean agate mortar and pressing dies
- Tuck the lab stools underneath the lab bench
- Clean up the lab bench and check personal equipment inventory (have an associate TA signed the check list)

- This is a **Brief Report** experiment:
  - **Hand in prelab/lab note/report together to the TA**

- Groups on duty shall stay and help clean up the lab