High-Temperature Superconductivity in YBCO

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指导老师：姚红英

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Outline

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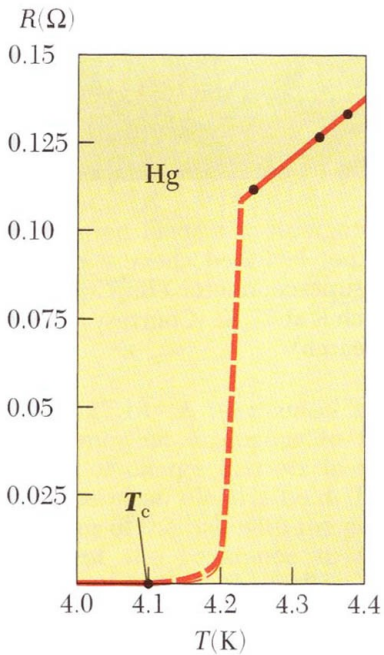

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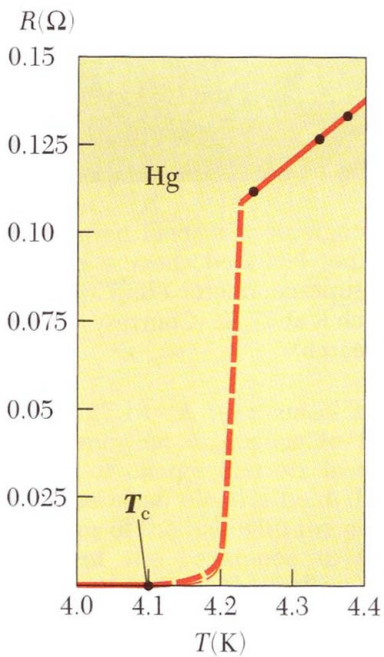

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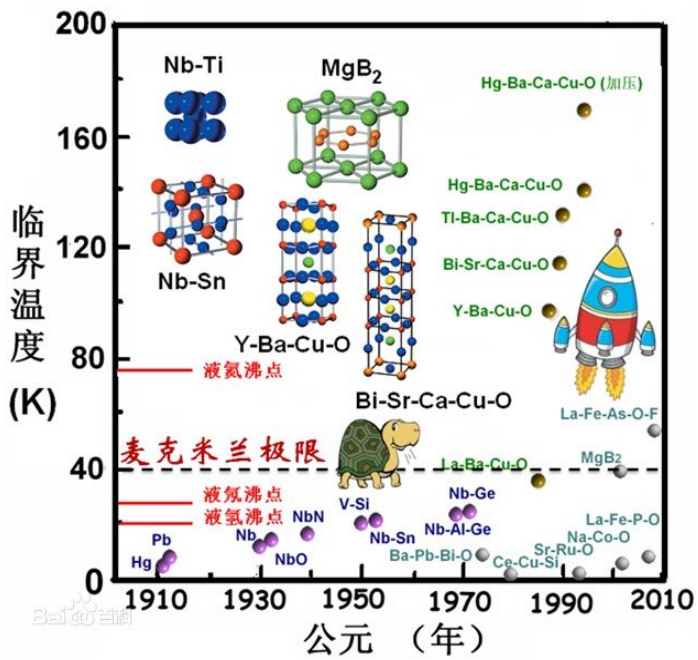

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Increase the critical temperature T_c, then Nature, Science, even PRL!

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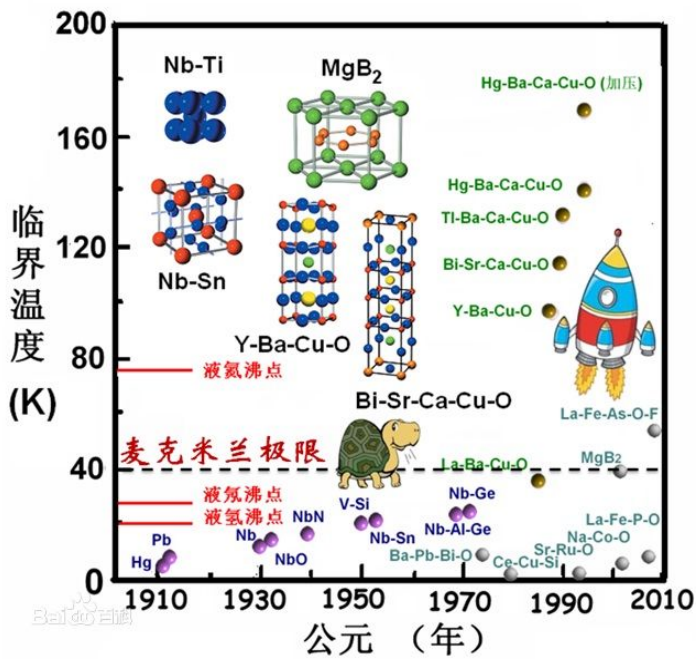

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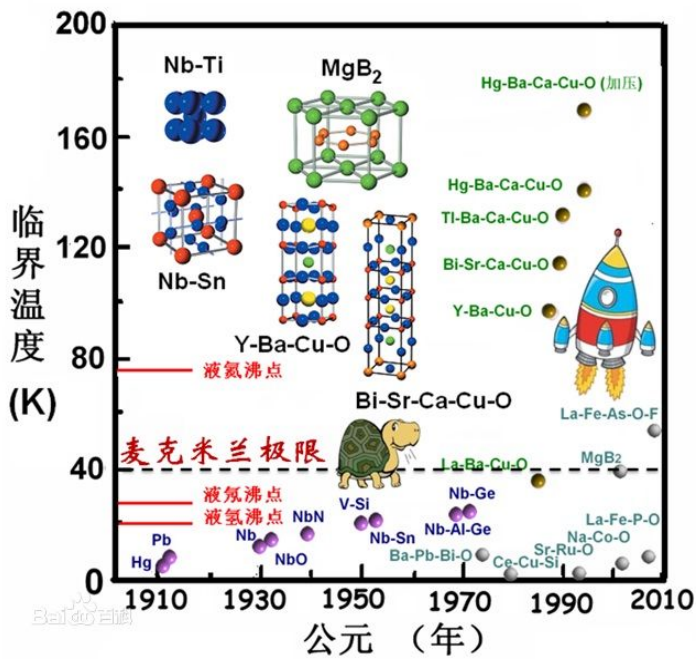

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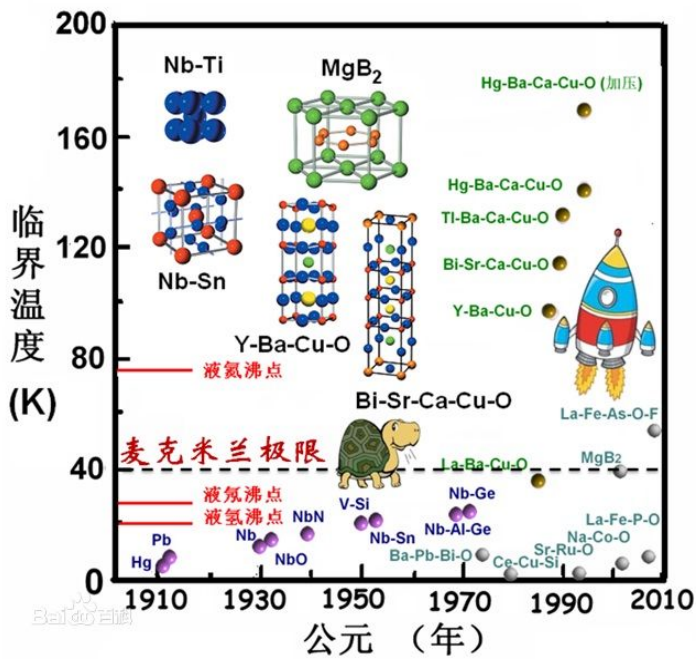

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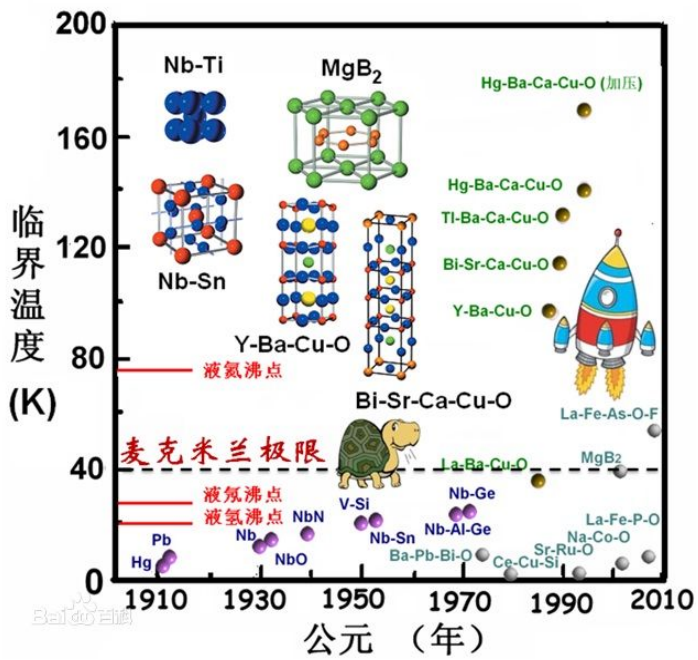

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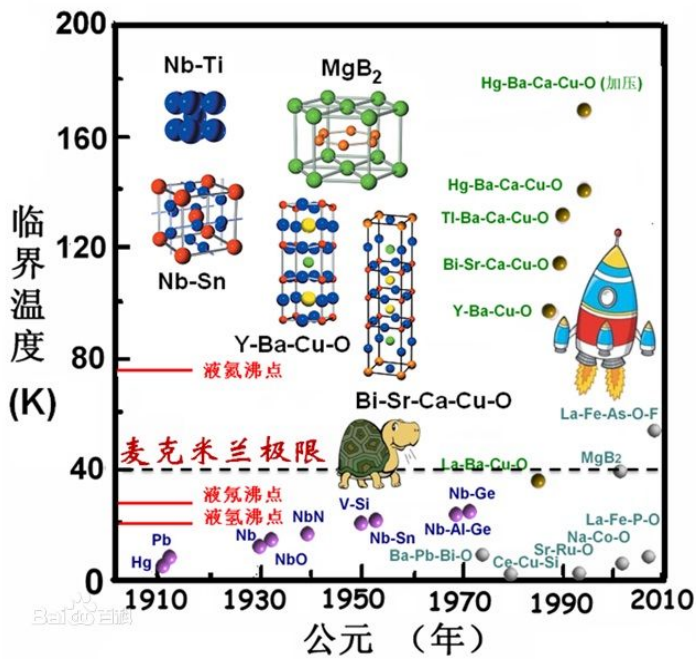

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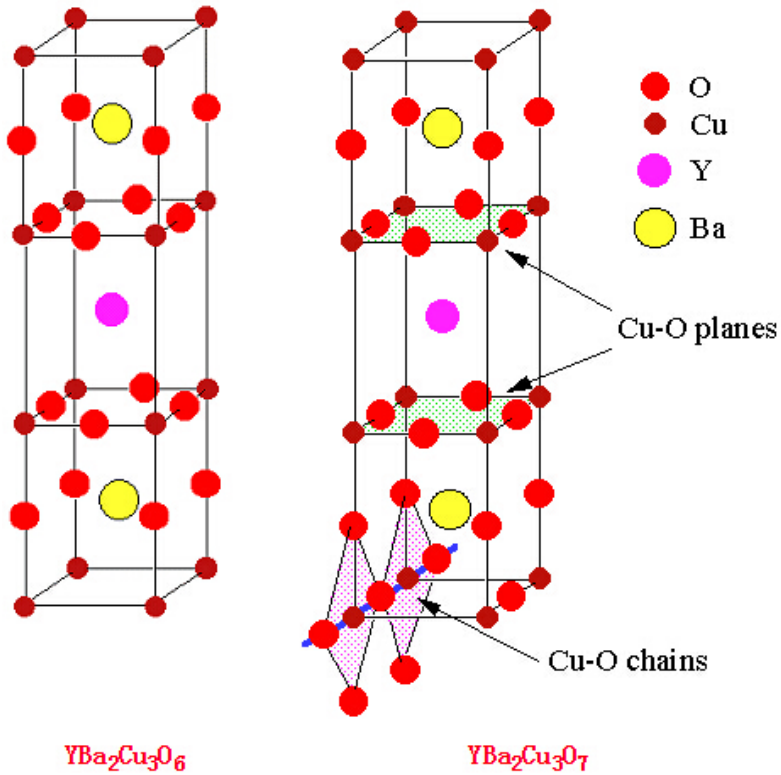

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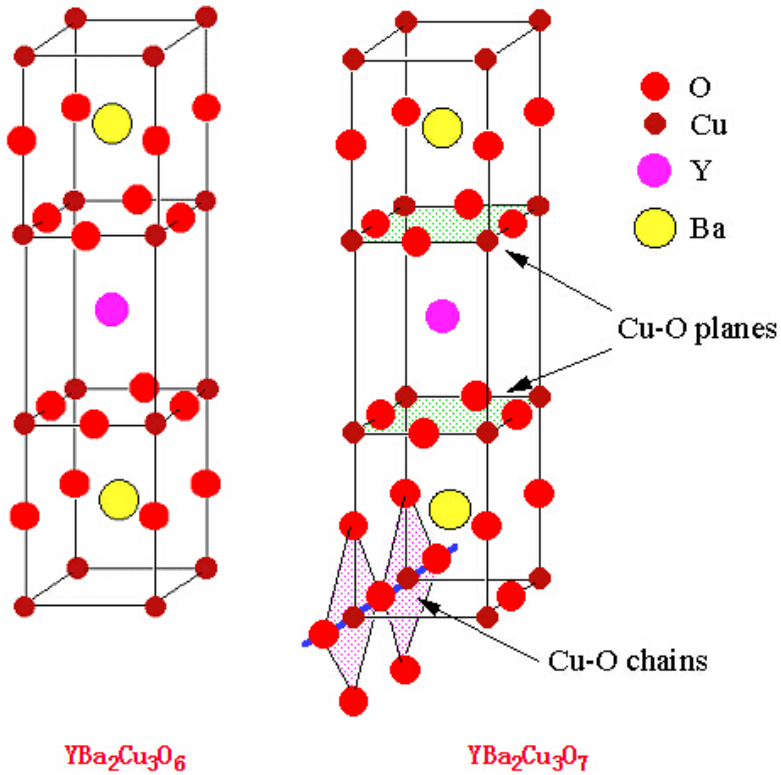
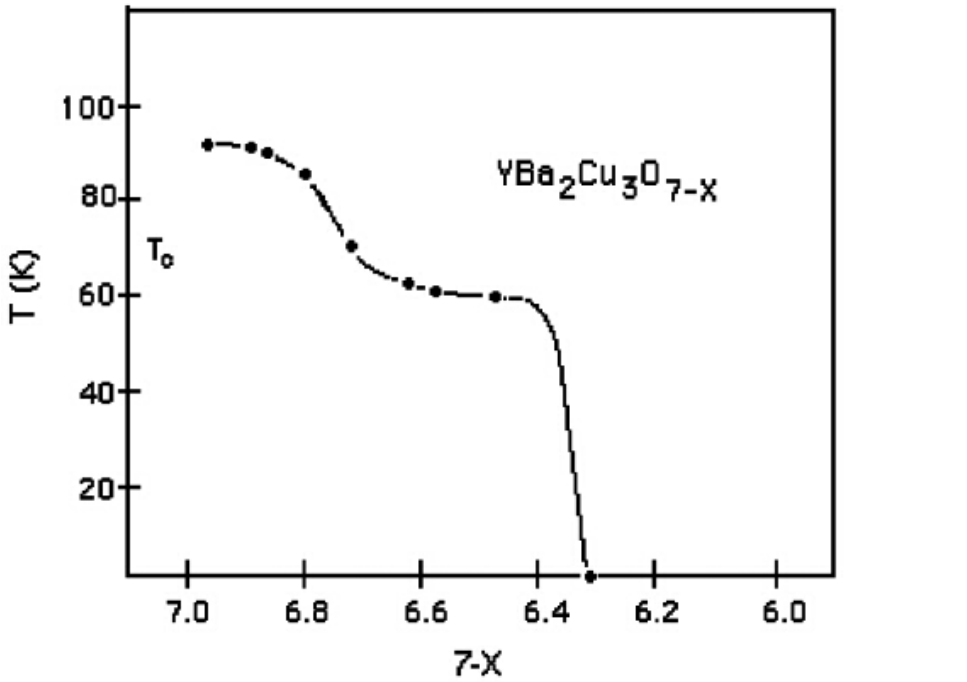




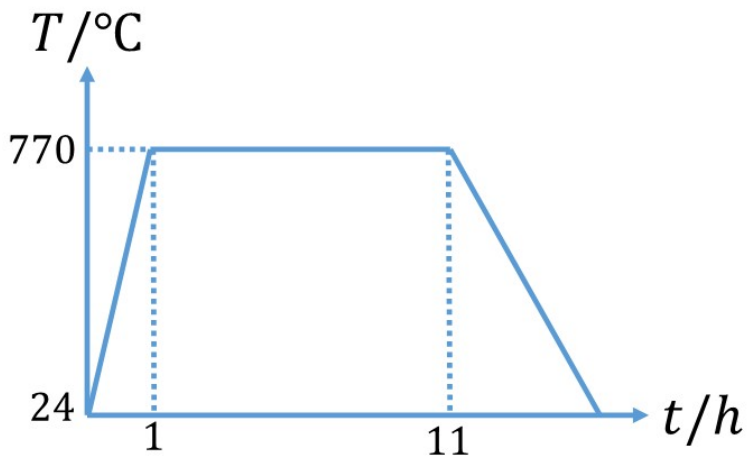
T_c as a function of oxygen content in $YBa_2Cu_3O_{7-X}$

Pretreatment

Y_2O_3: 0.76g

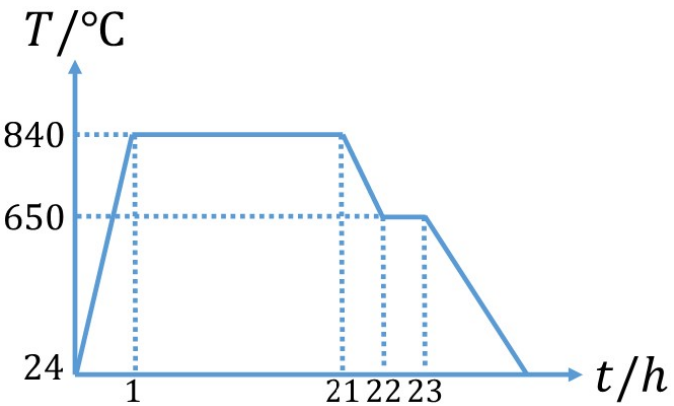
$BaCO_3$: 1.60g

CuO: 2.65g

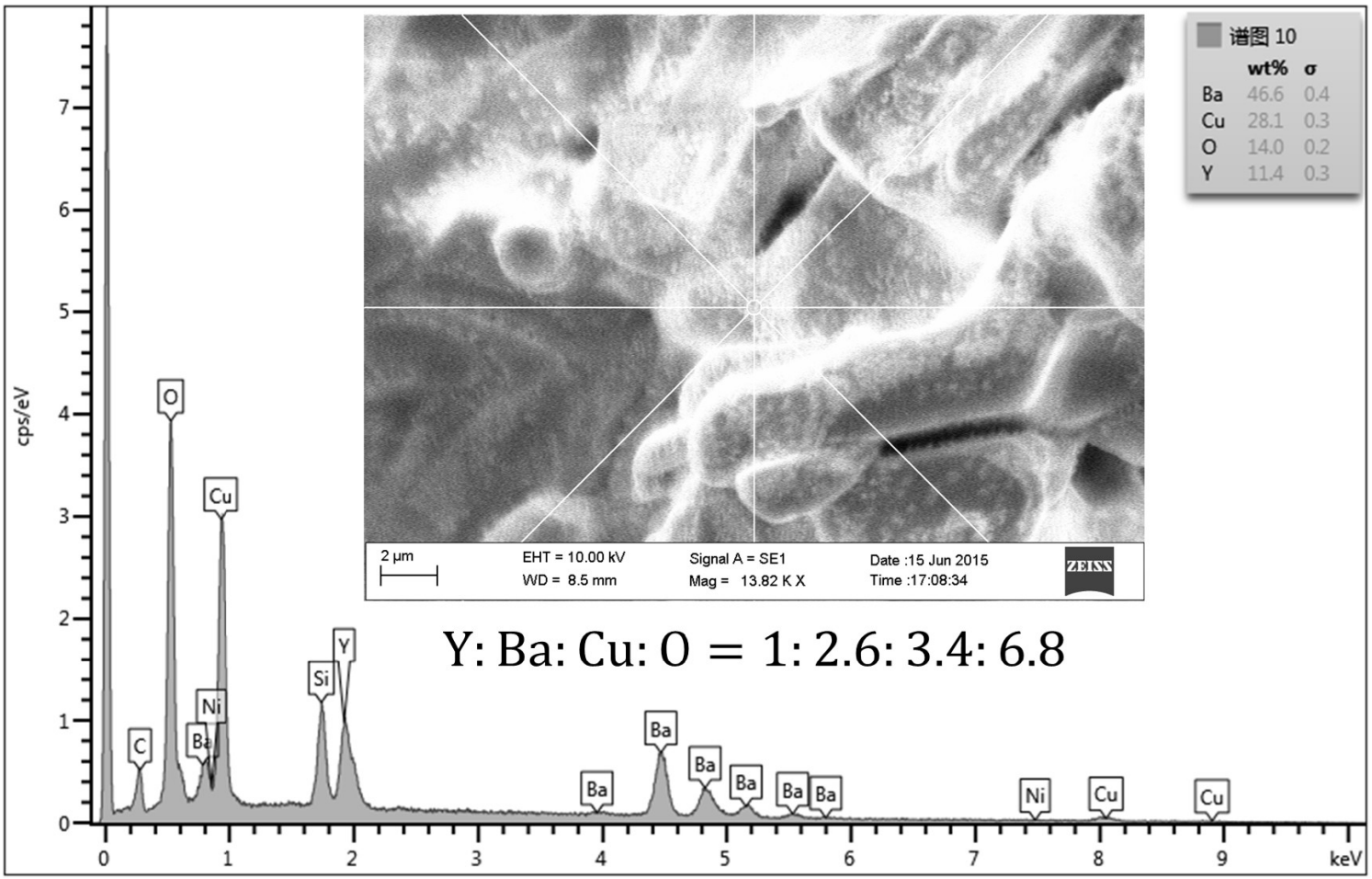


High temperature burning

$$\frac{1}{2}O_2 + Y_2O_3 + 4BaCO_3 + 6CuO \Longrightarrow 2YBa_2Cu_3O_7 + 4CO_2$$

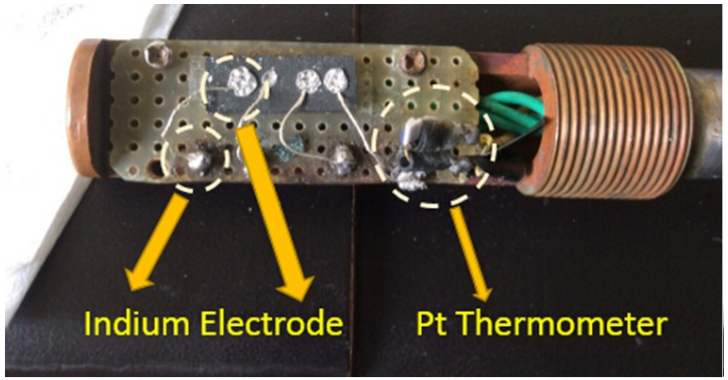


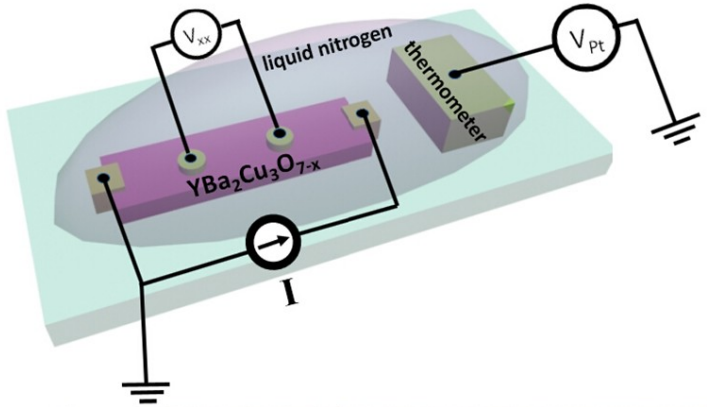
EDX (Energy Dispersive X-Ray Spectroscopy)



$$Y: Ba: Cu: O = 1: 2.6: 3.4: 6.8$$

Device and Equipment





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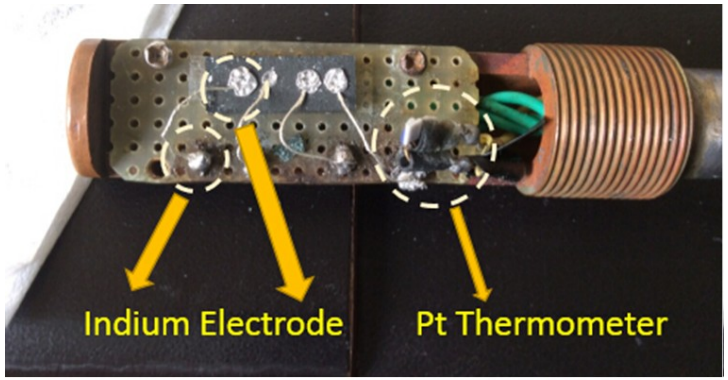

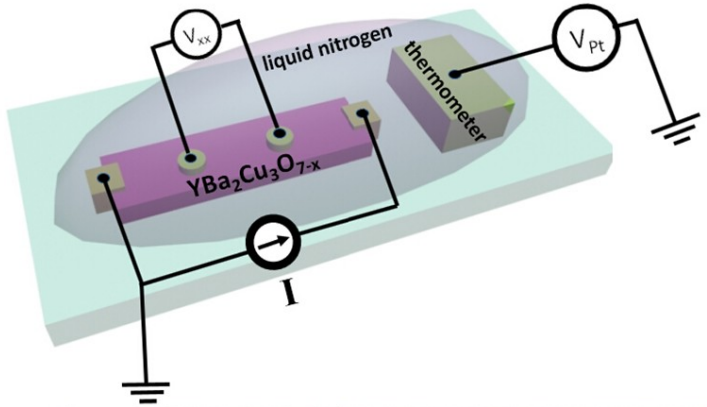

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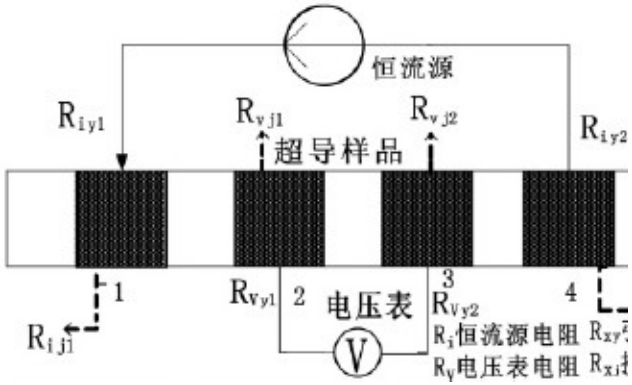
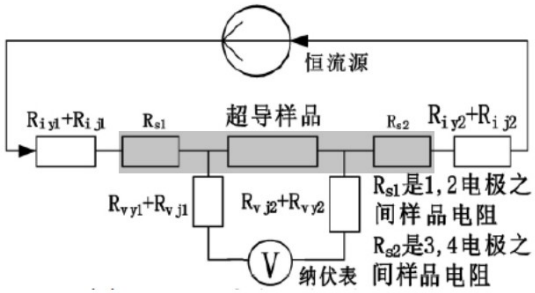
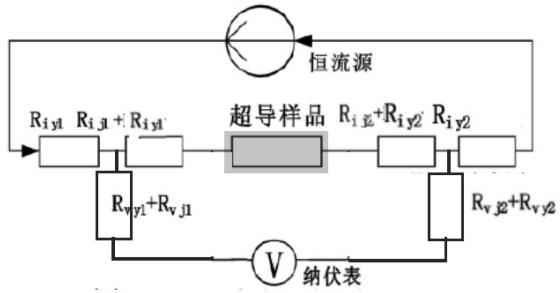
Why 4-terminal method: Contact resistance

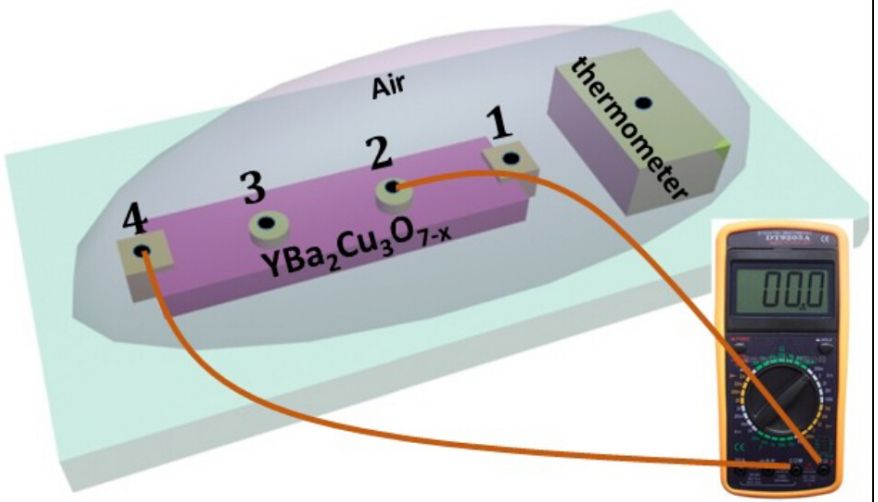


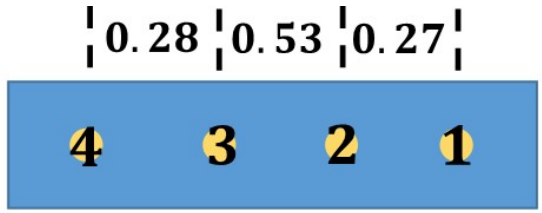


Four-terminal



Two-terminal



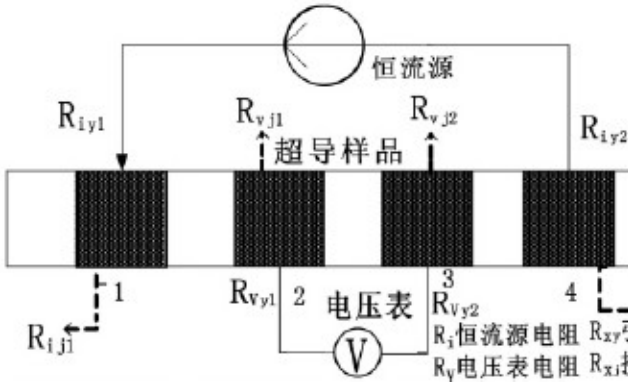


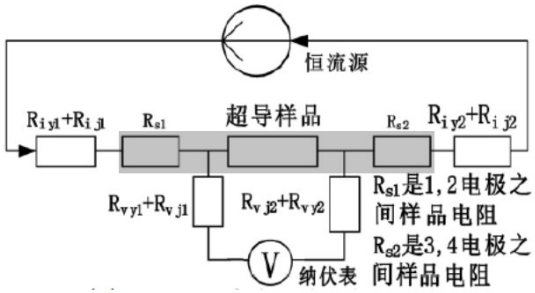
Unit: cm

	12	13	14	23	24	34
R/Ω	285	34	38	248	252	5.7

Contact resistance $\gg R_{YBCO}$

Why 4-terminal method: Contact resistance





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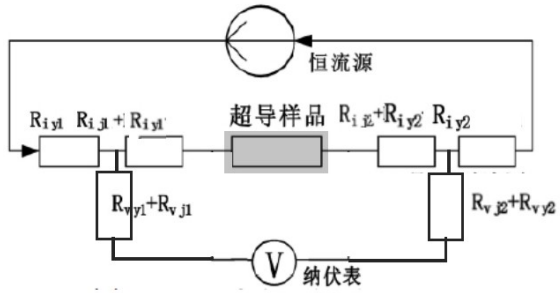

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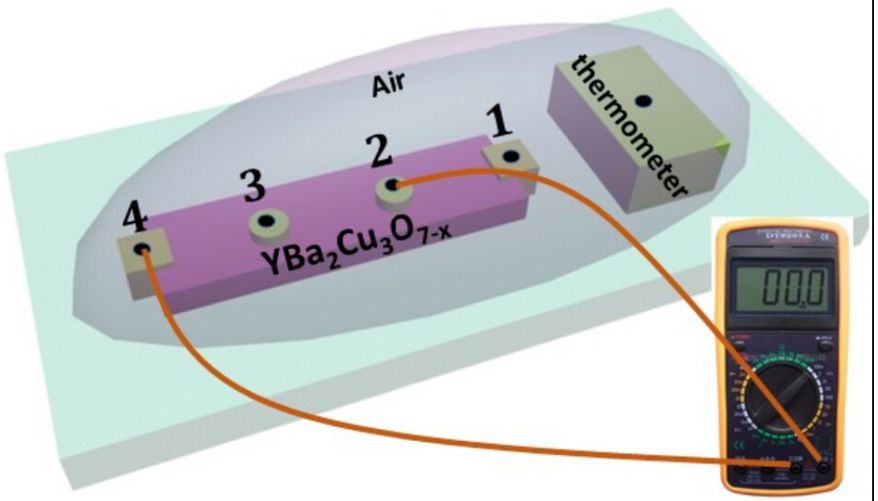

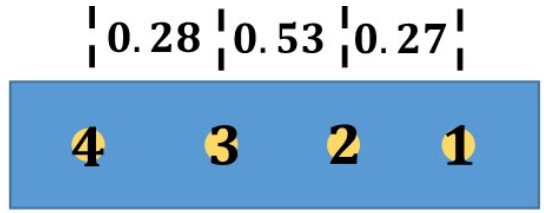

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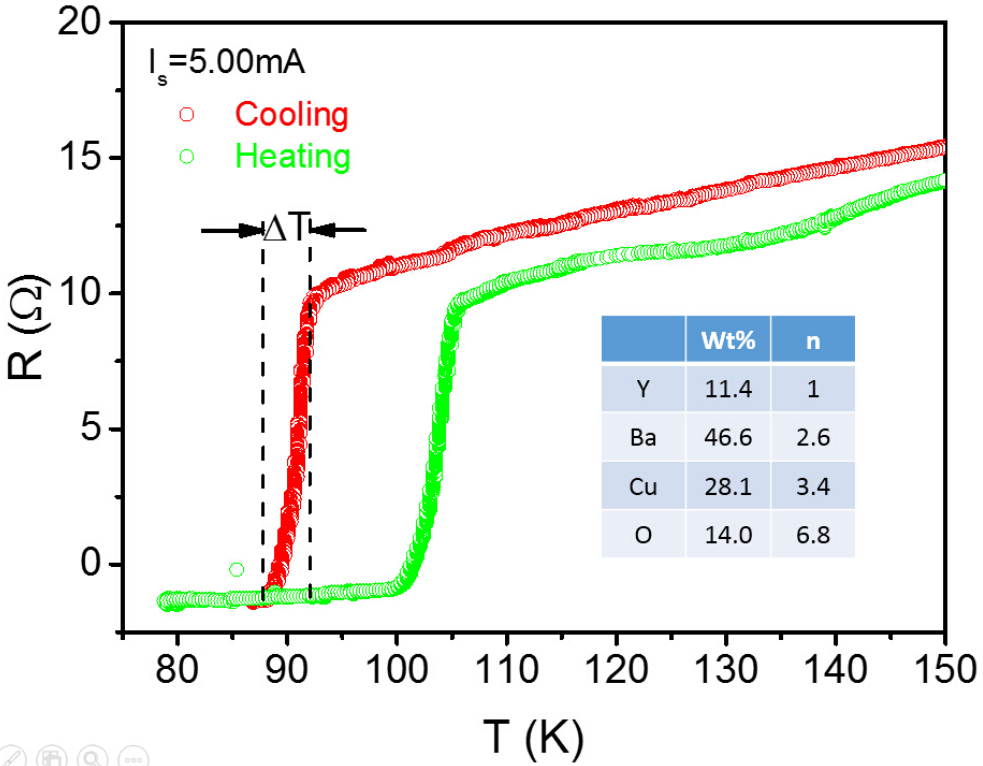

	Wt%	n
Y	11.4	1
Ba	46.6	2.6
Cu	28.1	3.4
O	14.0	6.8

Critical Temperature

Cooling: $T_c^{on} = 92.3K$,
$T_c = 90.8K$, $T_c^0 = 88.2K$,
$\Delta T = 4.1K$

Heating: $T_c^{on} = 105.3K$,
$T_c = 103.5K$, $T_c^0 = 100.2K$,
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$R_{min} \sim -1.2\Omega$

$T > T_c$, $R \propto T$ shows metallic phase

$T < T_c$, $R \to 0$ shows superconducting phase

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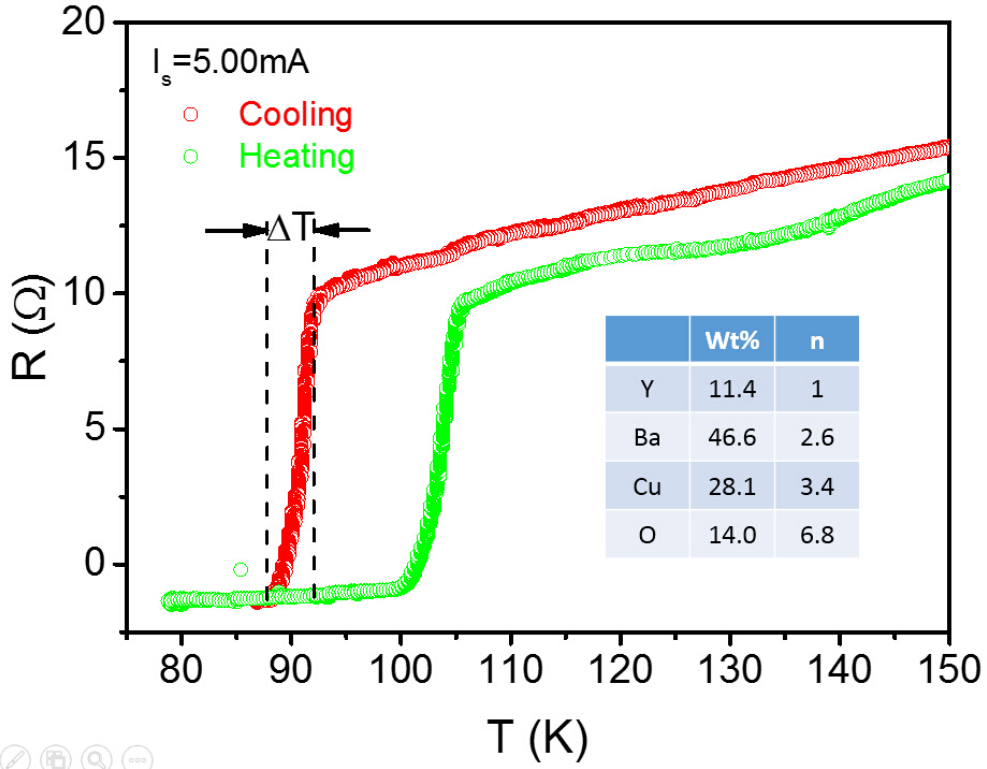

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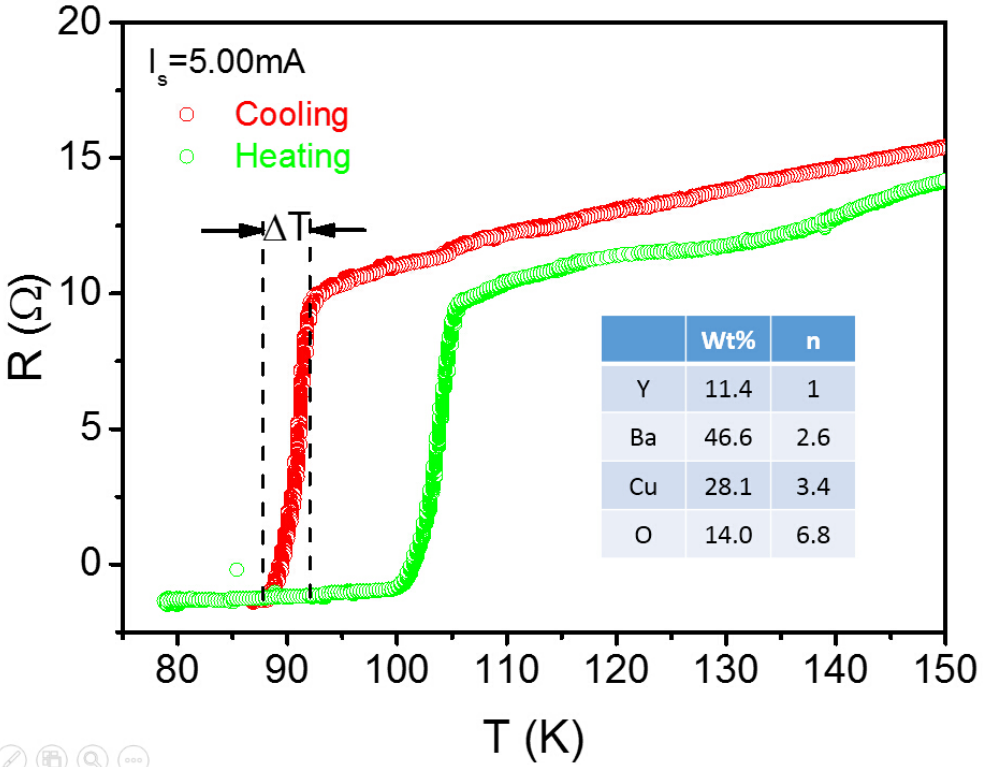

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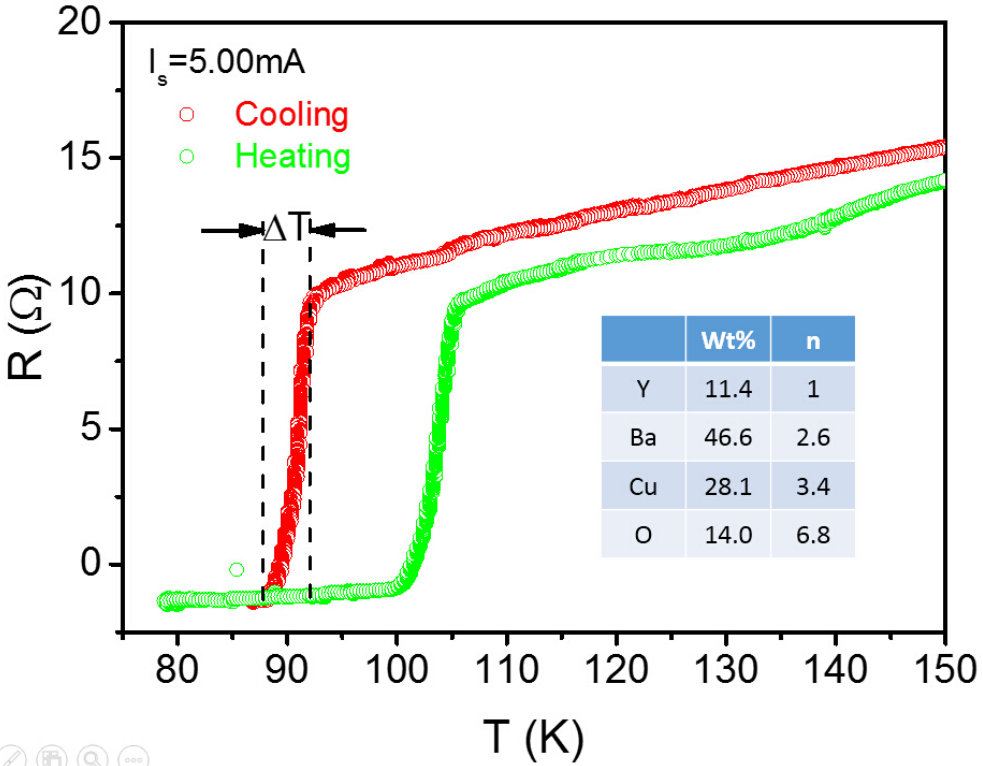

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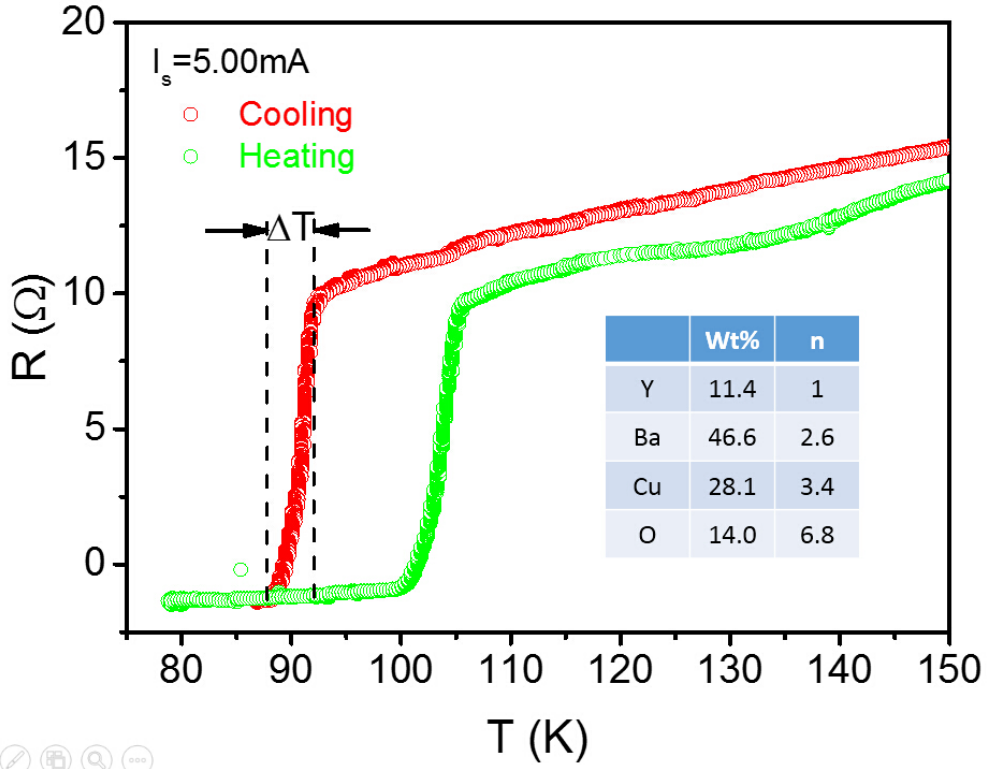

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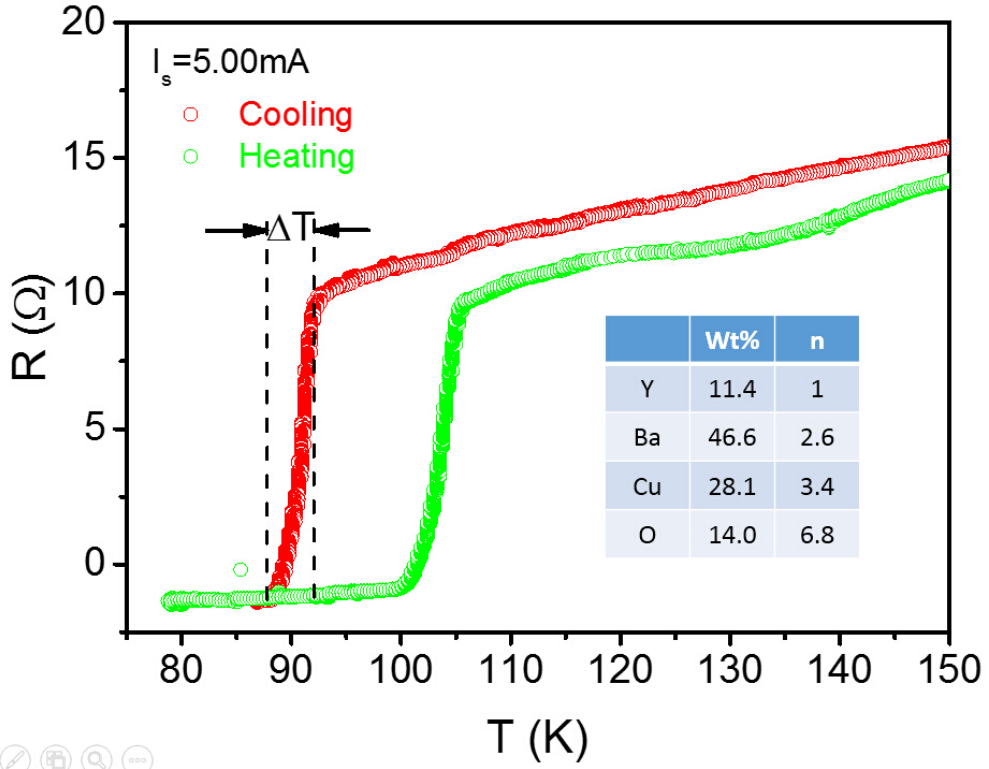

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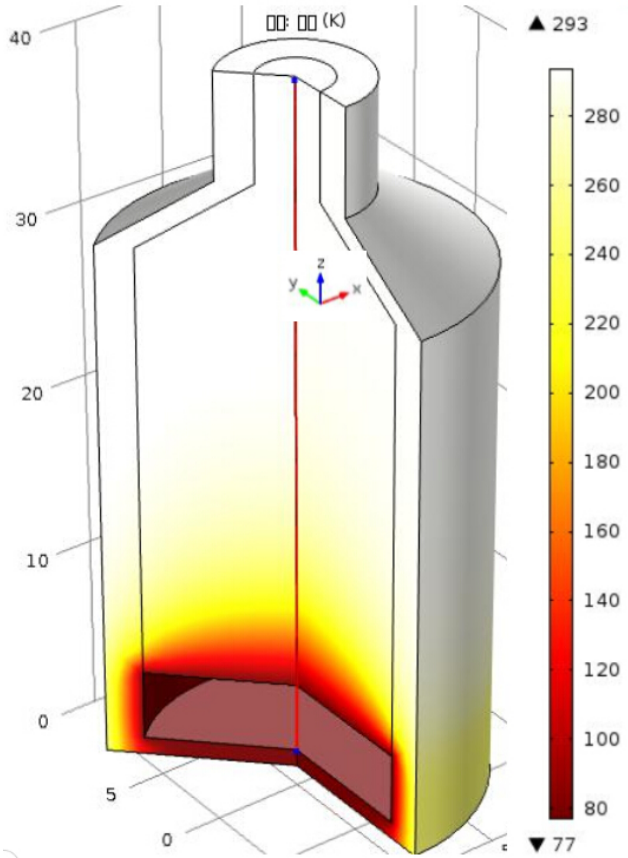
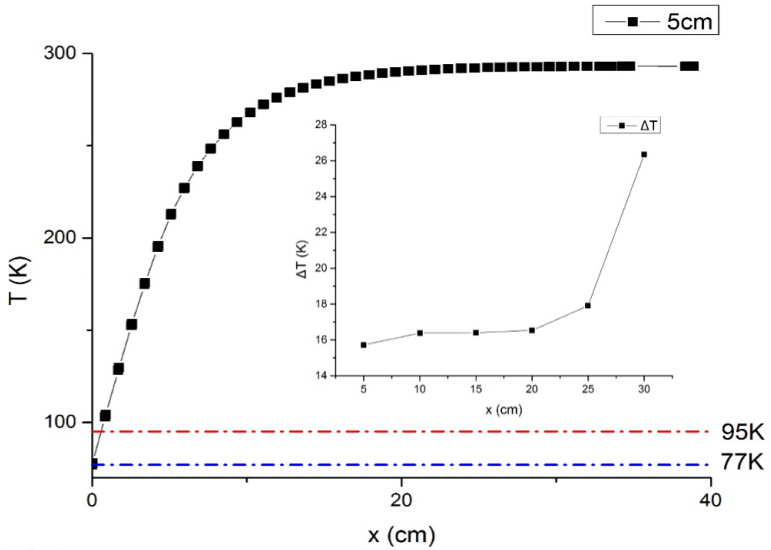
Critical region model





$$\rho = \begin{cases} 0, T < T_c \\ \rho_c + a(T - T_c) \end{cases}, \quad T(x) = 77 + 30.92x$$

When $T_2 < T_c$ at 2 point, $\Delta x_0 = \frac{T_c - T_2}{30.92}$

$$R = \frac{1}{s}\int_{\Delta x_0}^{5.3} [\rho_c + a(T(x) - T_c)]\mathrm{d}x$$

$$= \frac{1}{s}[-a\frac{(T_2 - T_c)^2}{30.92} - \frac{\rho_c}{30.92}(T_2 - T_c) + 5.3\rho_c + 5.3^2 \times 30.92a]$$

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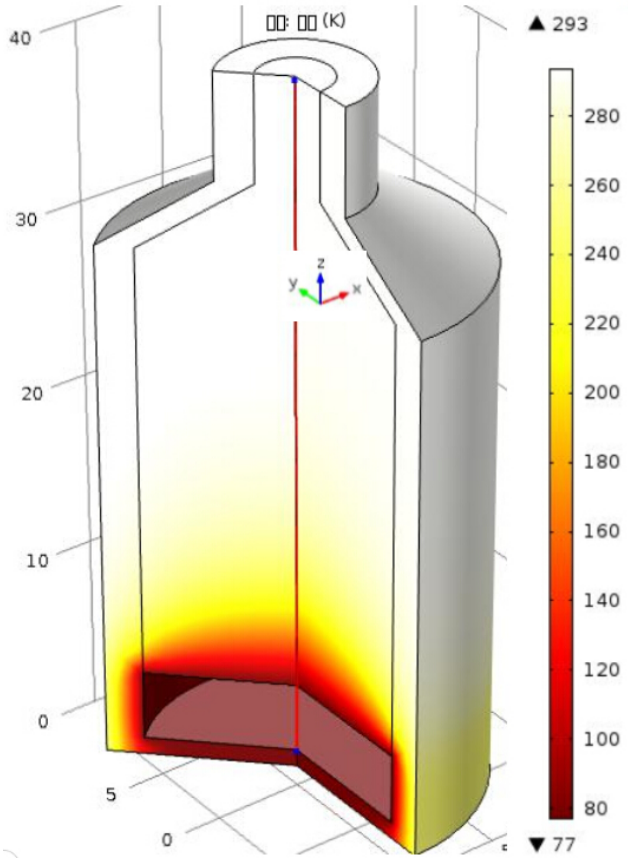

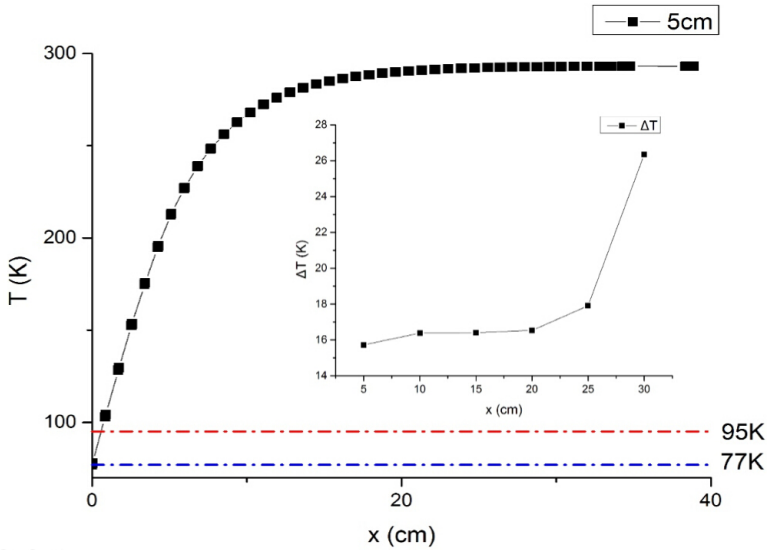

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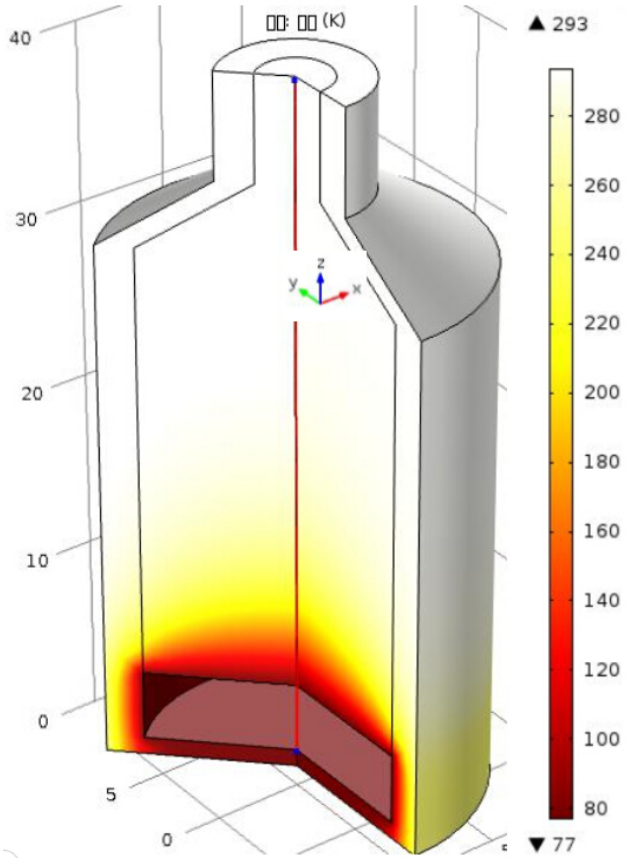

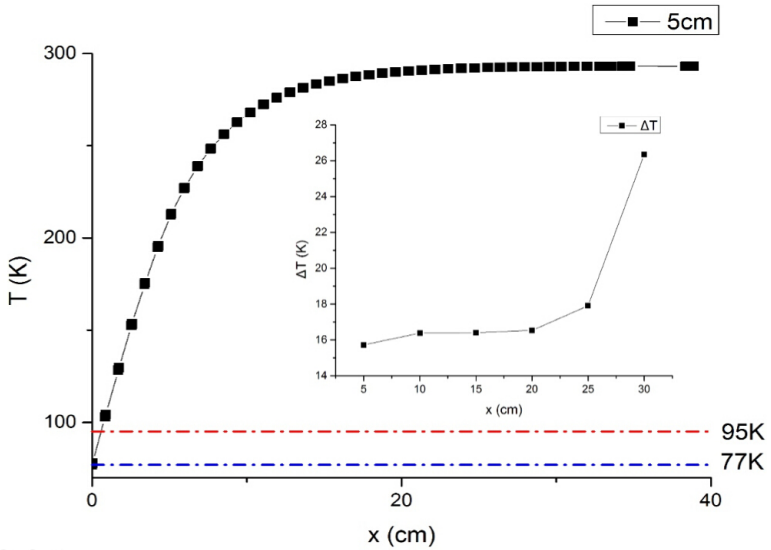

$$\rho = \begin{cases} 0, T < T_c \\ \rho_c + a(T - T_c) \end{cases}, \quad T(x) = 77 + 30.92x$$

When $T_2 < T_c$ at 2 point, $\Delta x_0 = \frac{T_c - T_2}{30.92}$

$$R = \frac{1}{s}\int_{\Delta x_0}^{5.3} [\rho_c + a(T(x) - T_c)]\mathrm{d}x$$
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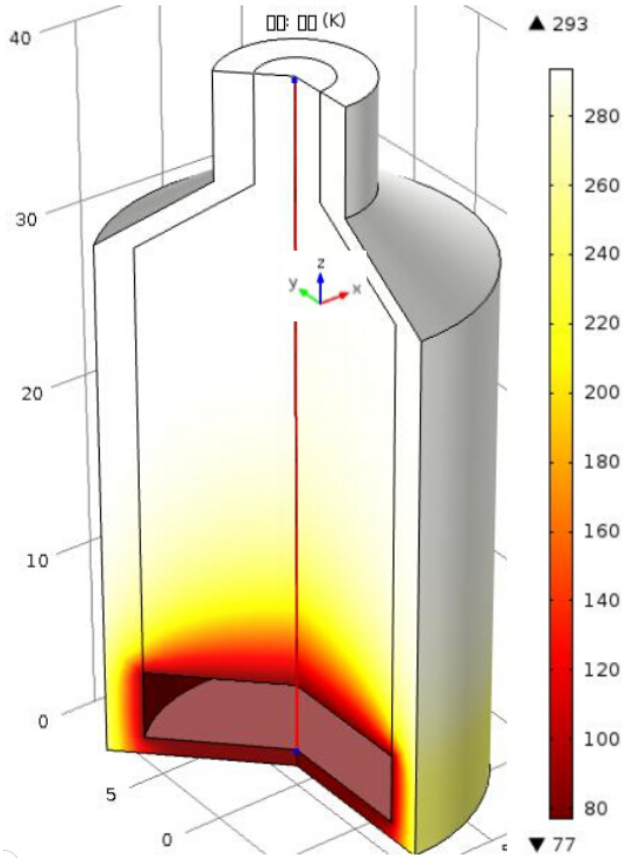

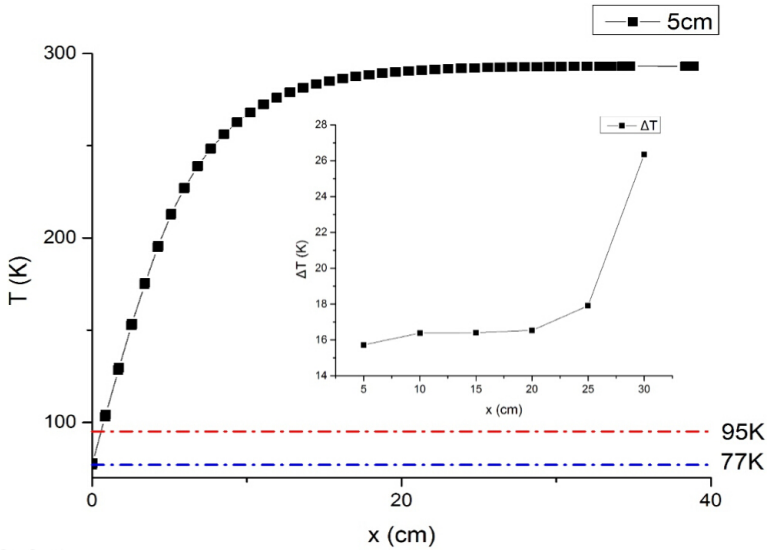

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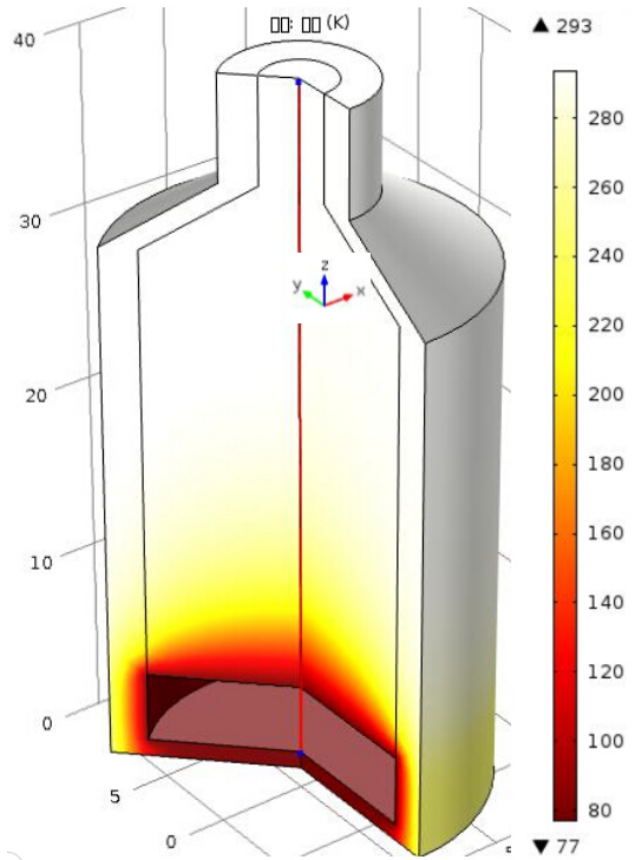

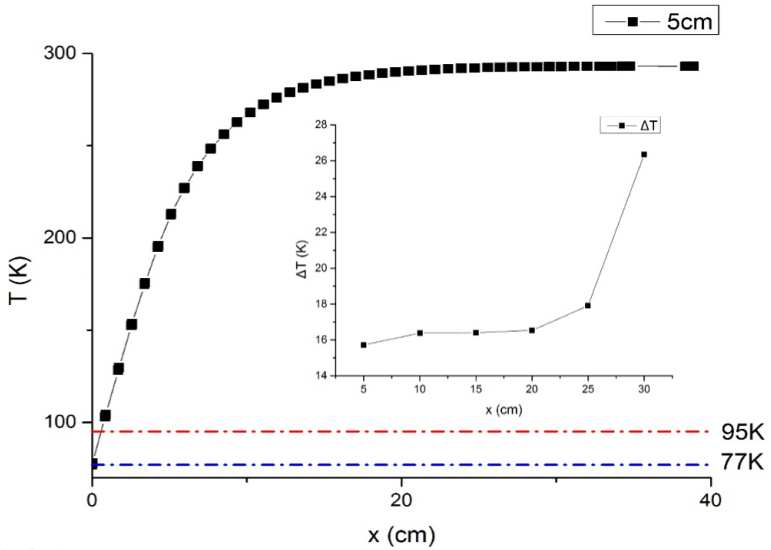

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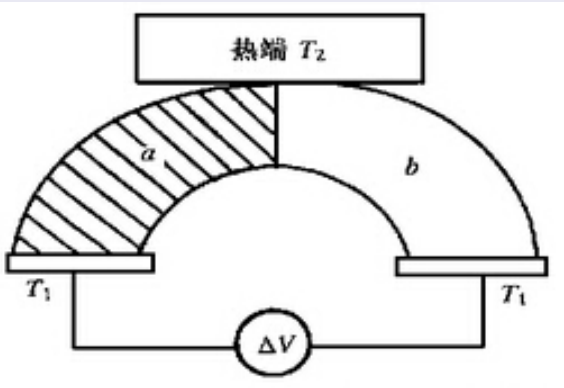
Why $R_{min} < 0$: Thermoelectricity

Seebeck effect



Thermal emf is

$$U_{emf} = -S\nabla T$$

where S is the Seebeck coefficient.

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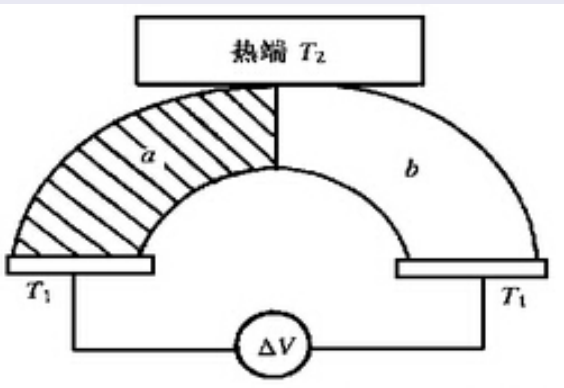

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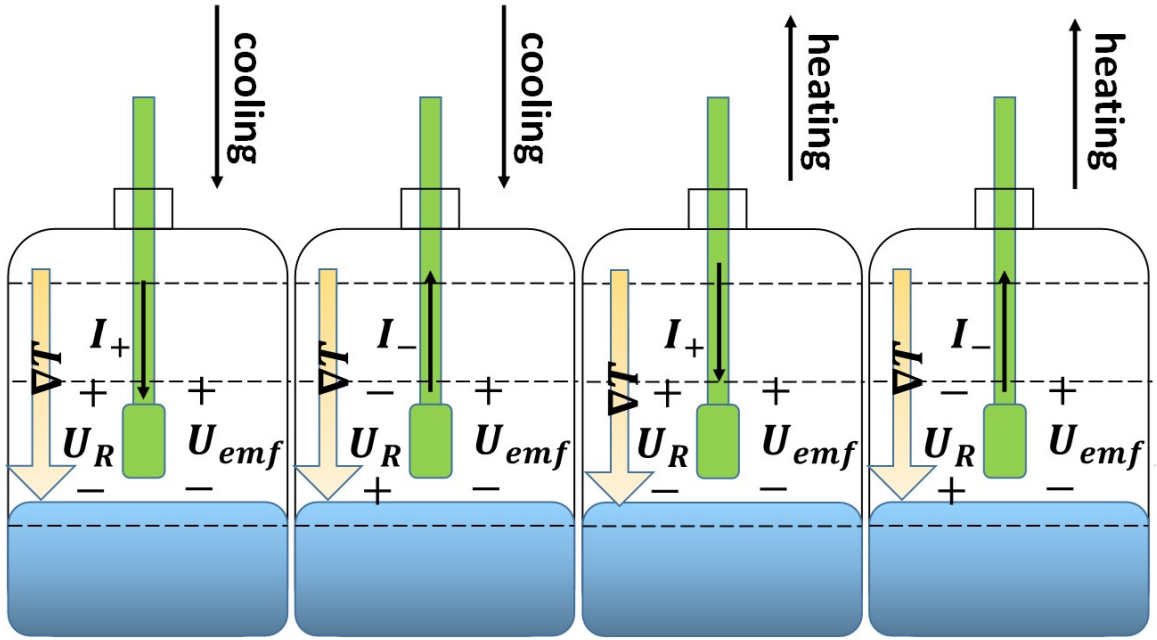
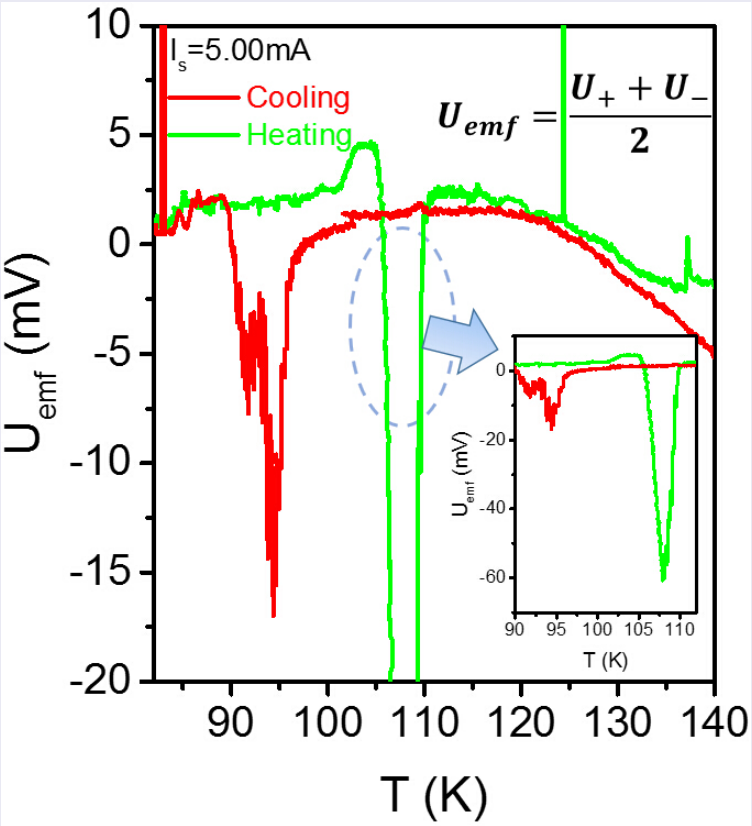


Reverse current$\Rightarrow$ eliminate U_{emf}

$$\begin{cases} U_+ = RI + U_{emf} \\ U_- = -RI + U_{emf} \end{cases} \Rightarrow U_{emf} = \frac{U_+ + U_-}{2}$$

Thermal emf



$$\nabla T = 15\mathrm{K} \Rightarrow S = 0.3\mathrm{mV/K}$$

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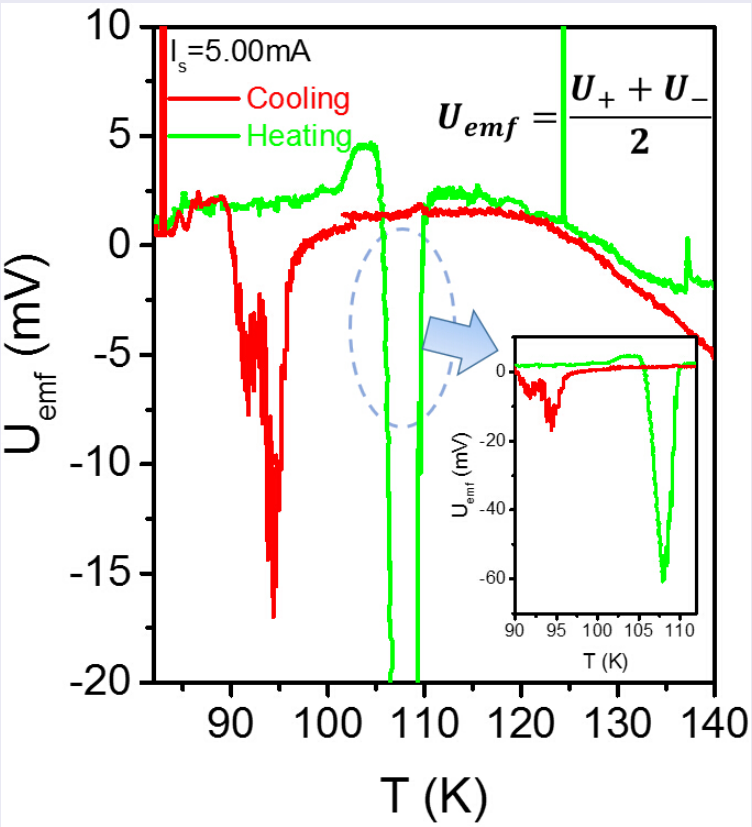

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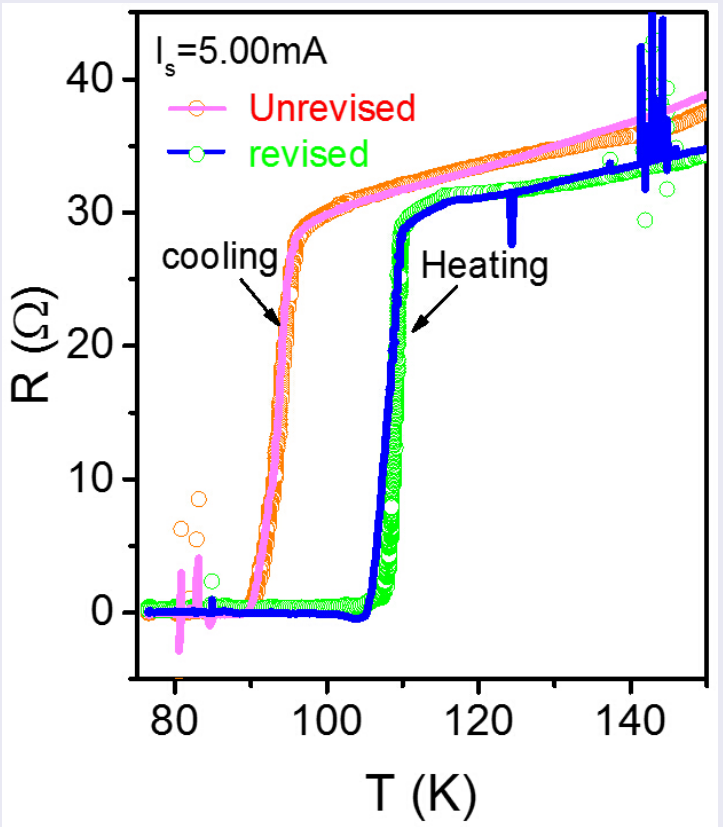
Revise U_{emf}



ΔT and T_c do not have obvious change after revision.

Why $T_{cCooling} < T_{cHeating}$? $\Rightarrow$ Temperature-hysteresis

i) Thermometer delay $\Rightarrow T_{c\mathrm{Cooling}} > T_{c\mathrm{Real}}, T_{c\mathrm{Heating}} < T_{c\mathrm{Real}}$

ii) Temperature gradient caused temperature difference $\Rightarrow$ $T_{c\mathrm{Cooling}}, T_{c\mathrm{Heating}} > T_{c\mathrm{Real}}$

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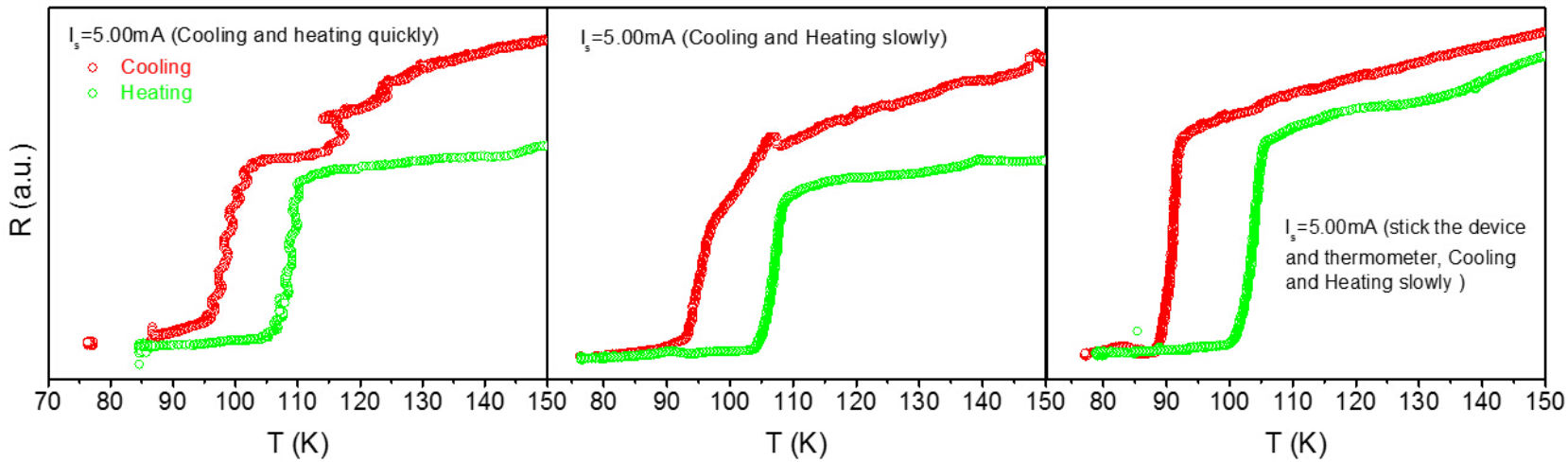
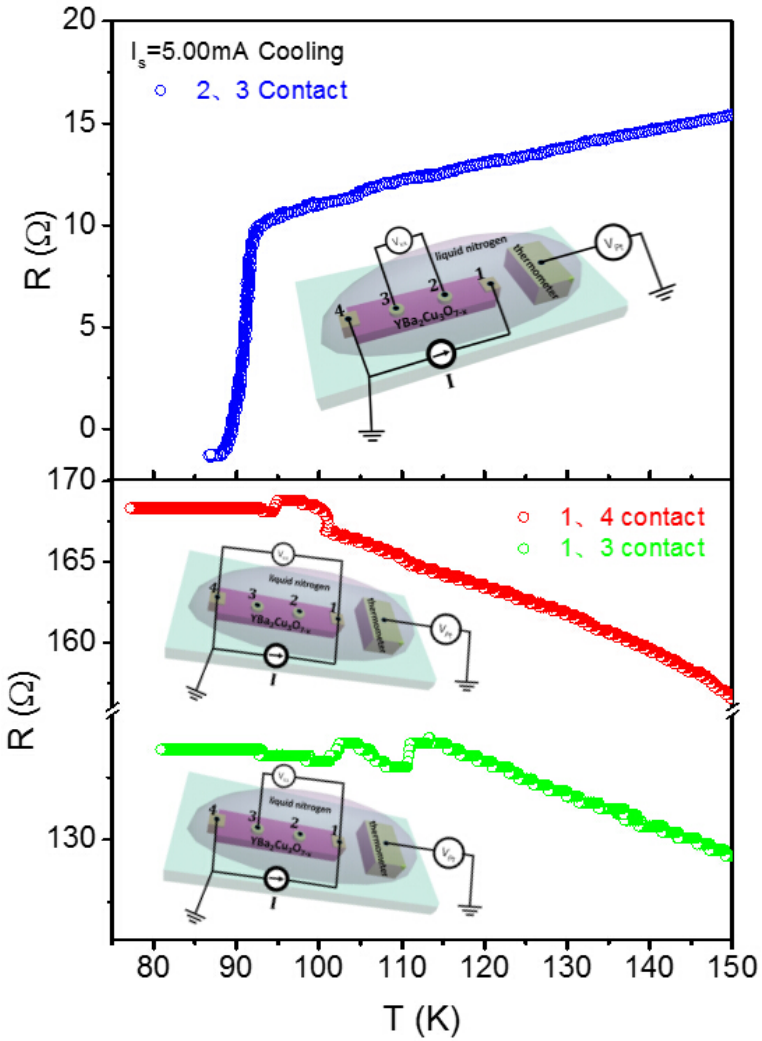


Contact resistance



$$R_c = \frac{R_{14} - R_{23} \times \frac{L}{l}}{2}$$

$R_c - T$ follows barrier rule.

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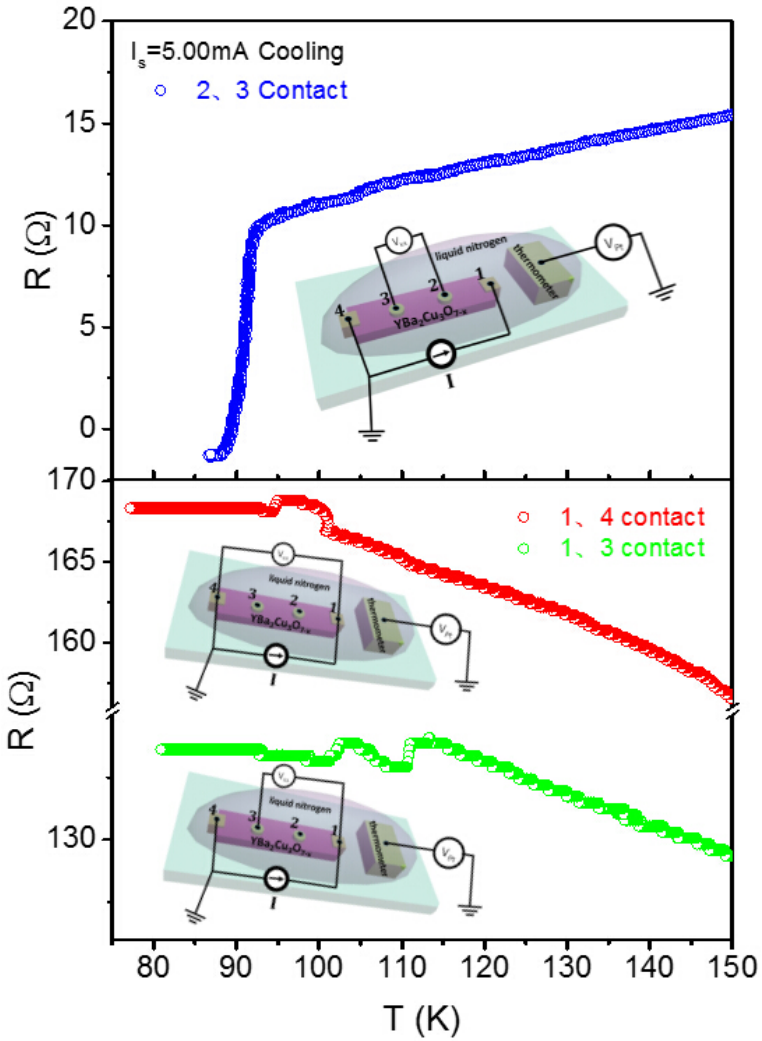

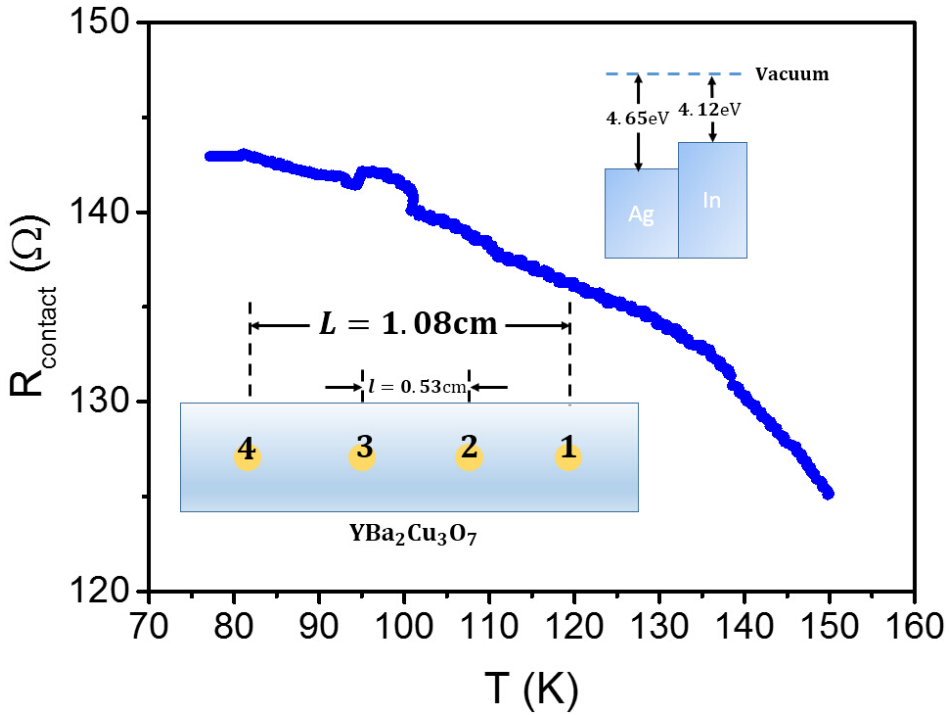

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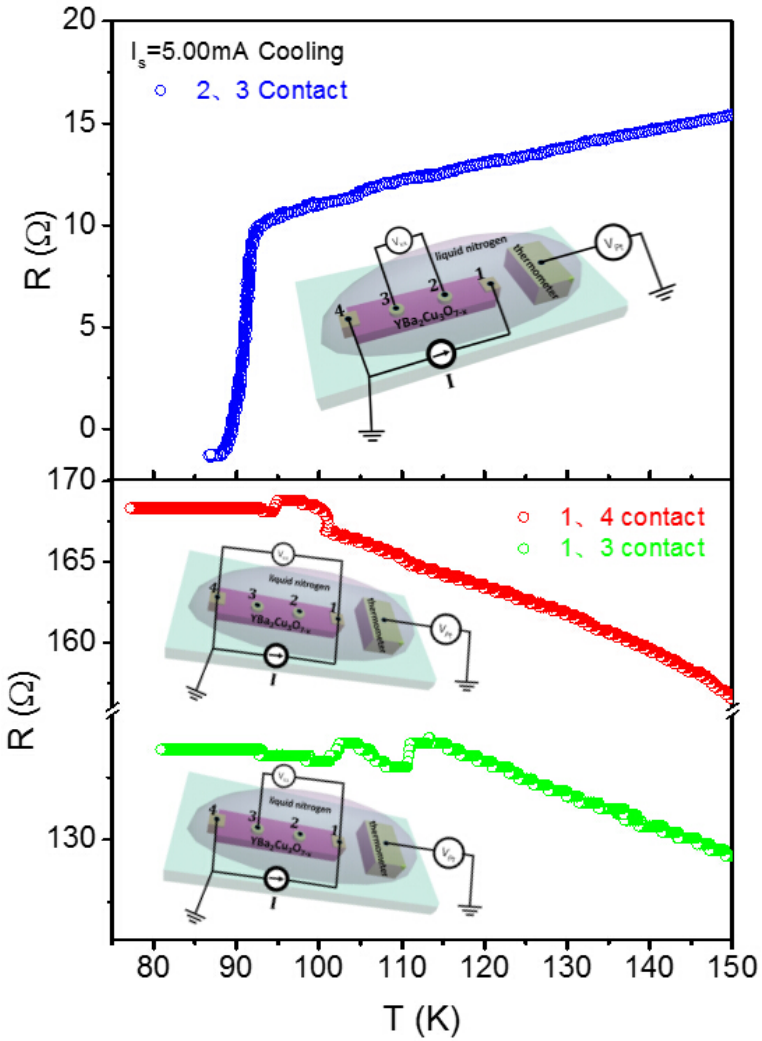

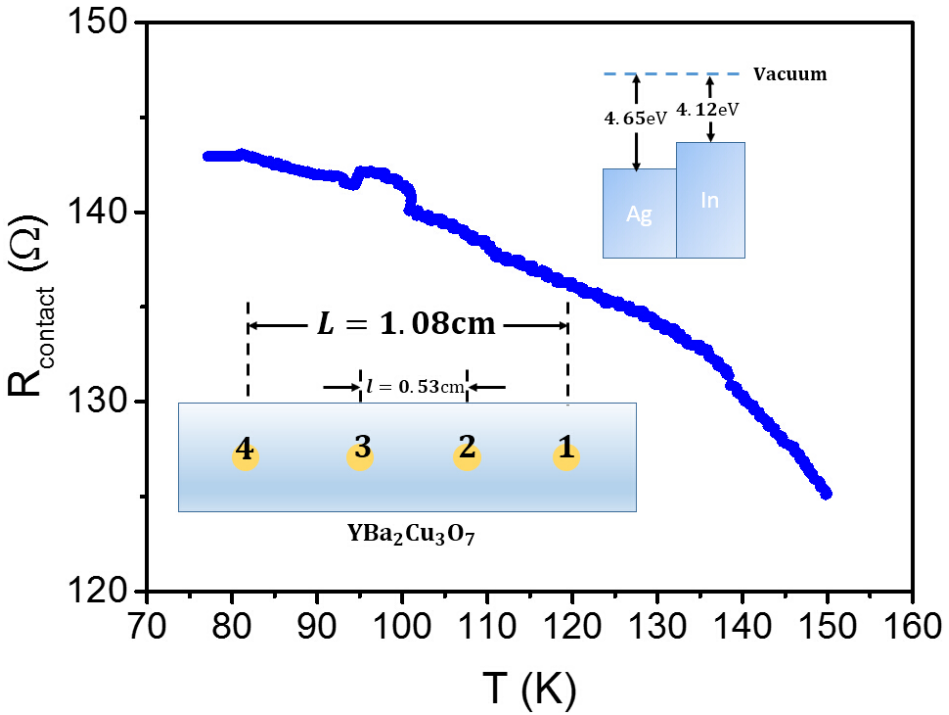

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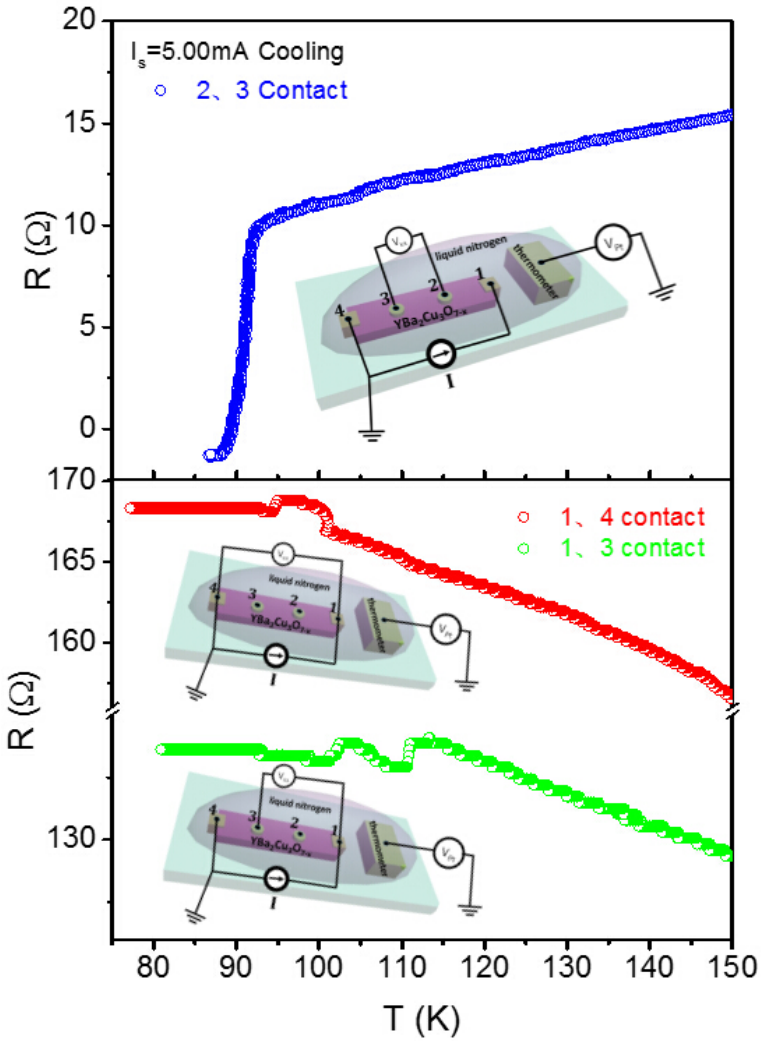

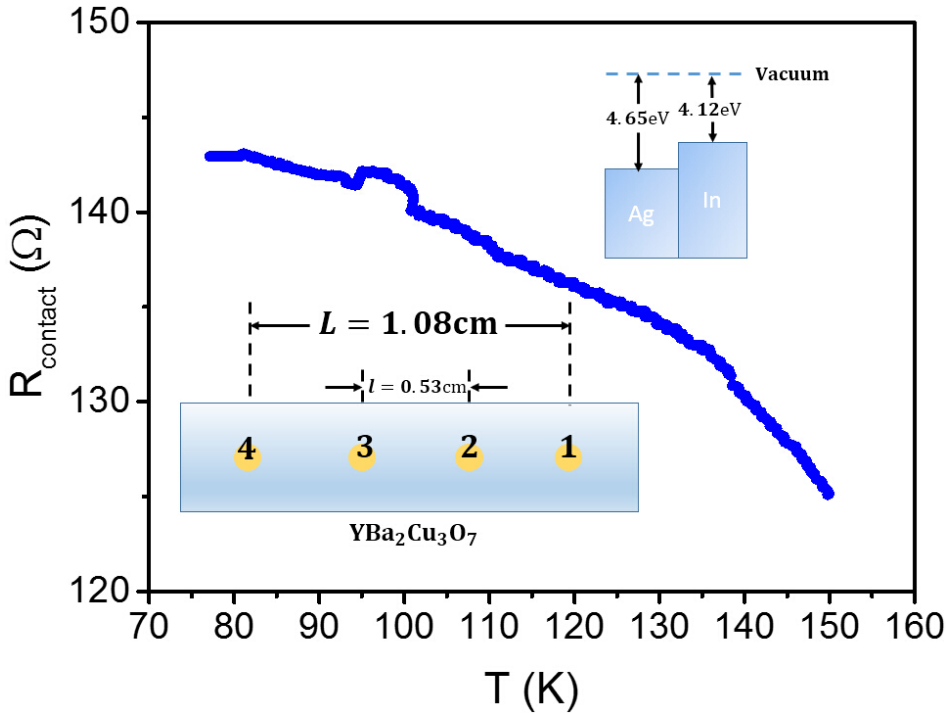

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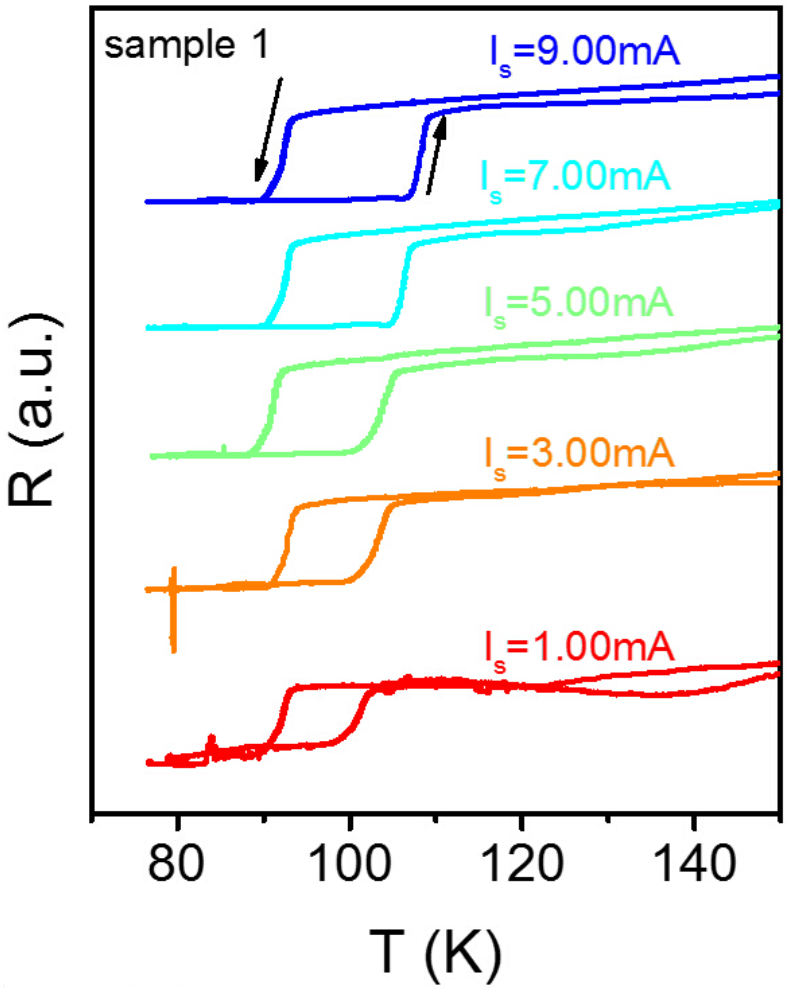
$R - T$ at different current



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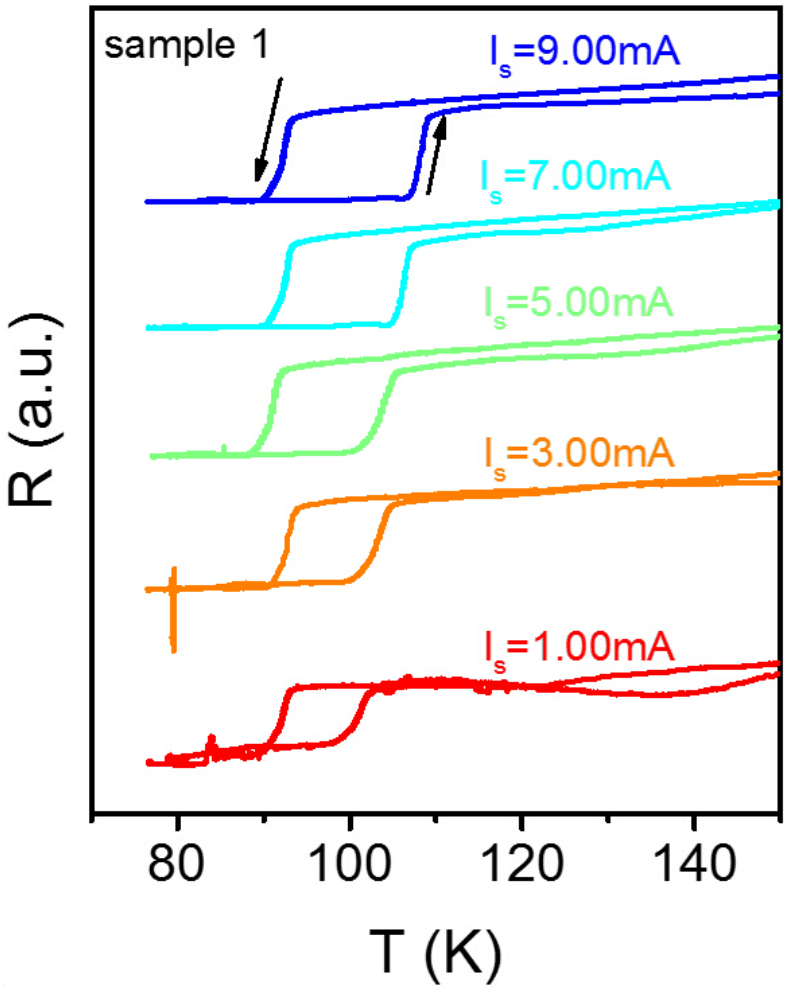
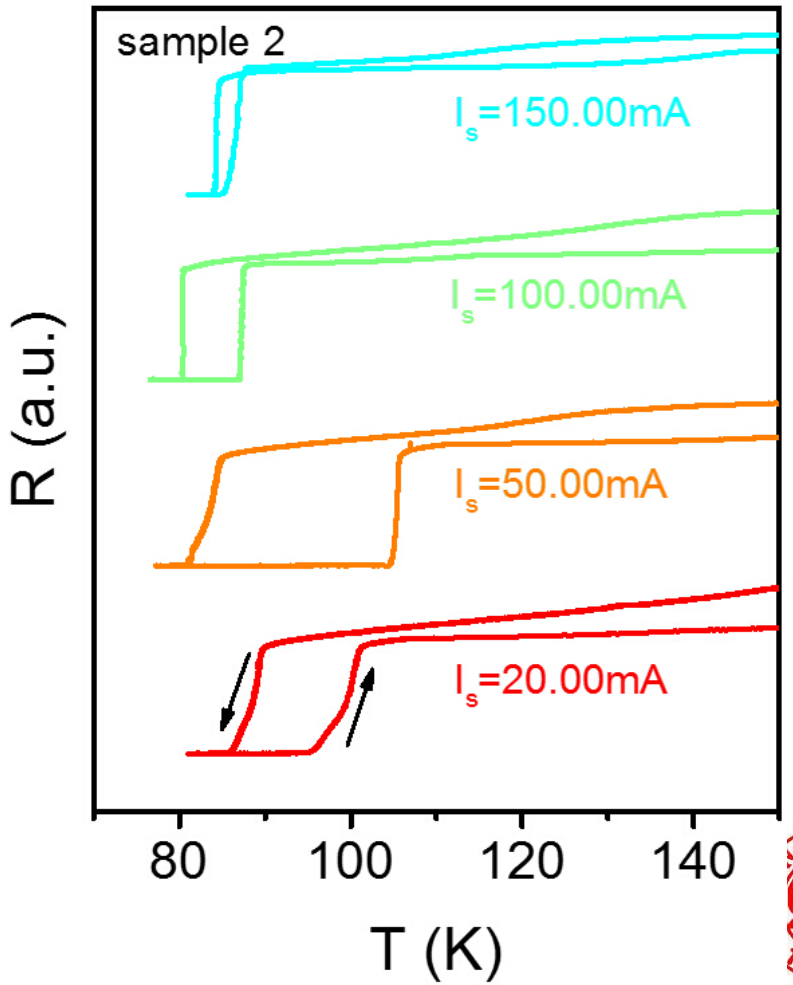
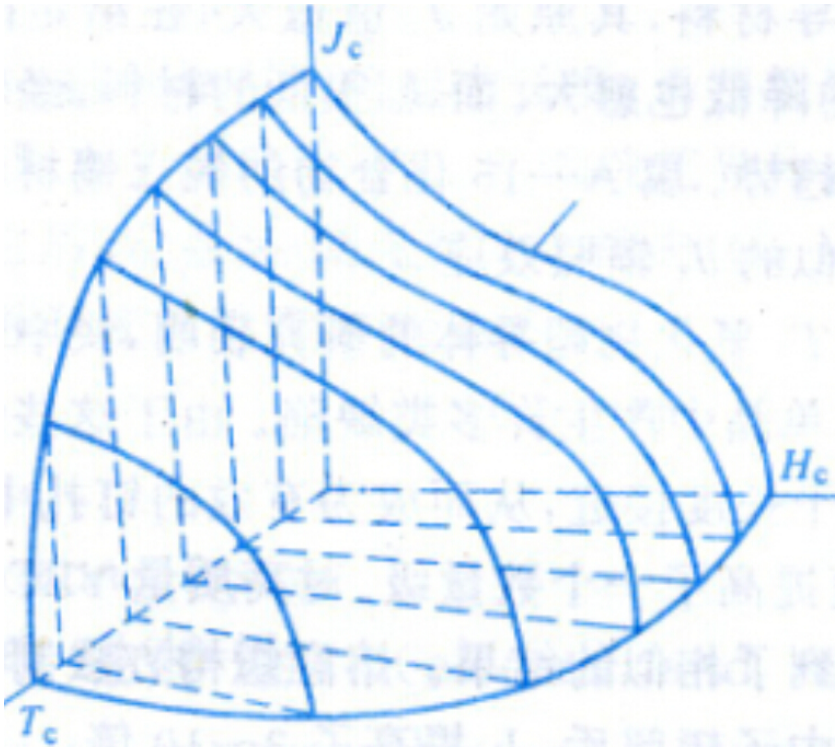




Superconductivity phase transition

i) Thermal disturbance destroys the Cooperelectronpair.

ii) Surface current produce a magnetic field.



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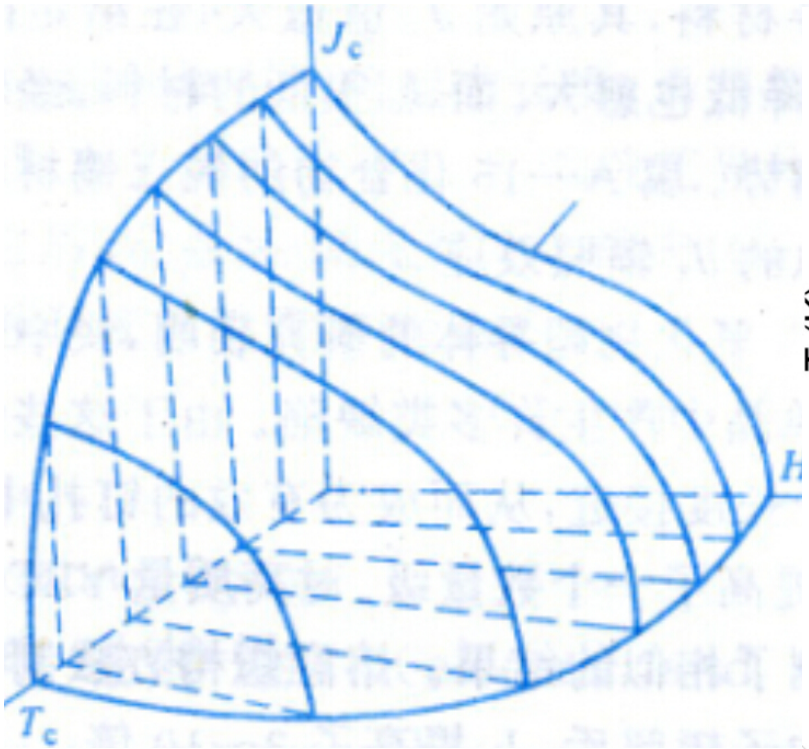

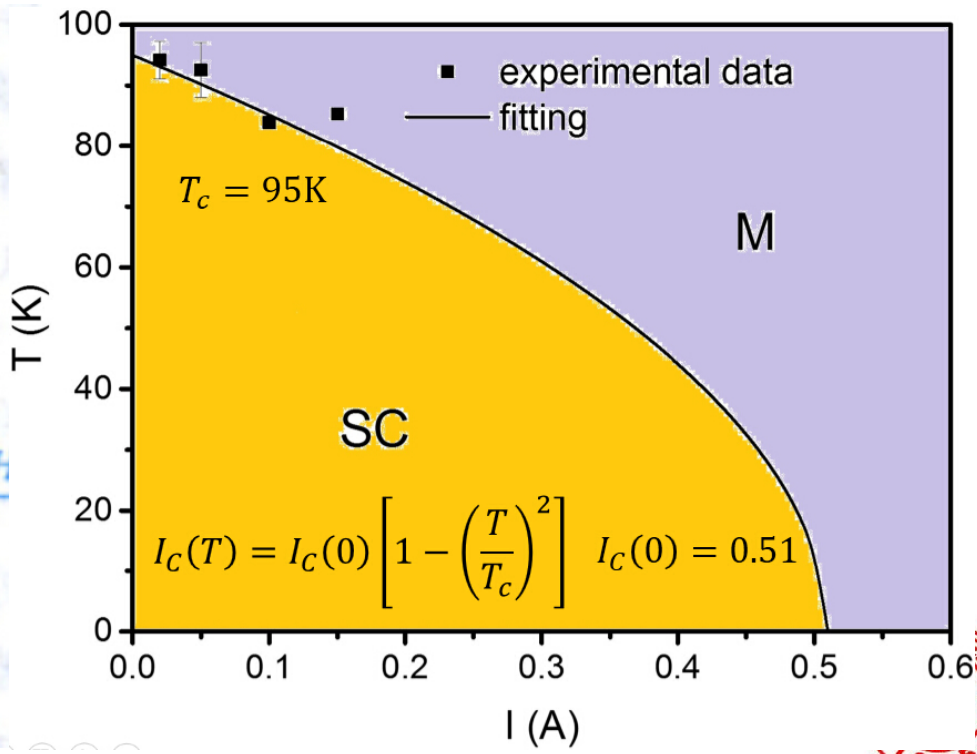

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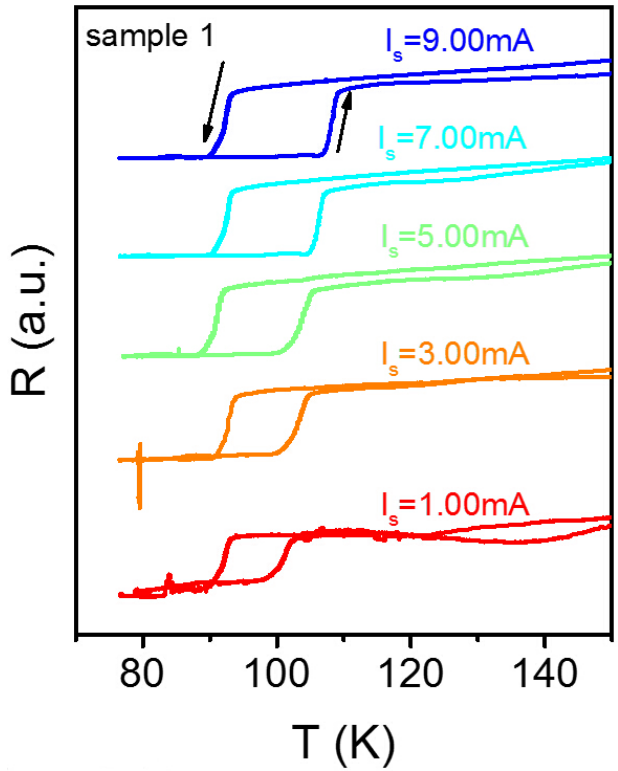

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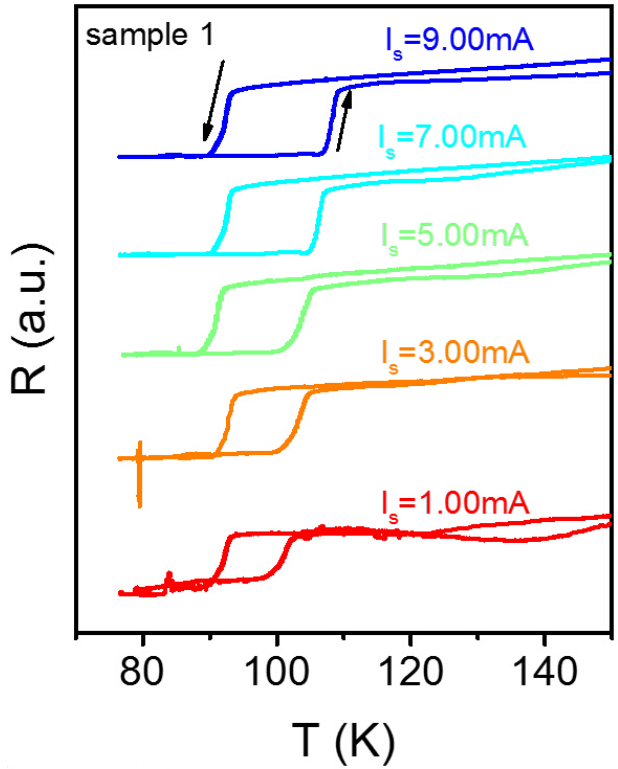
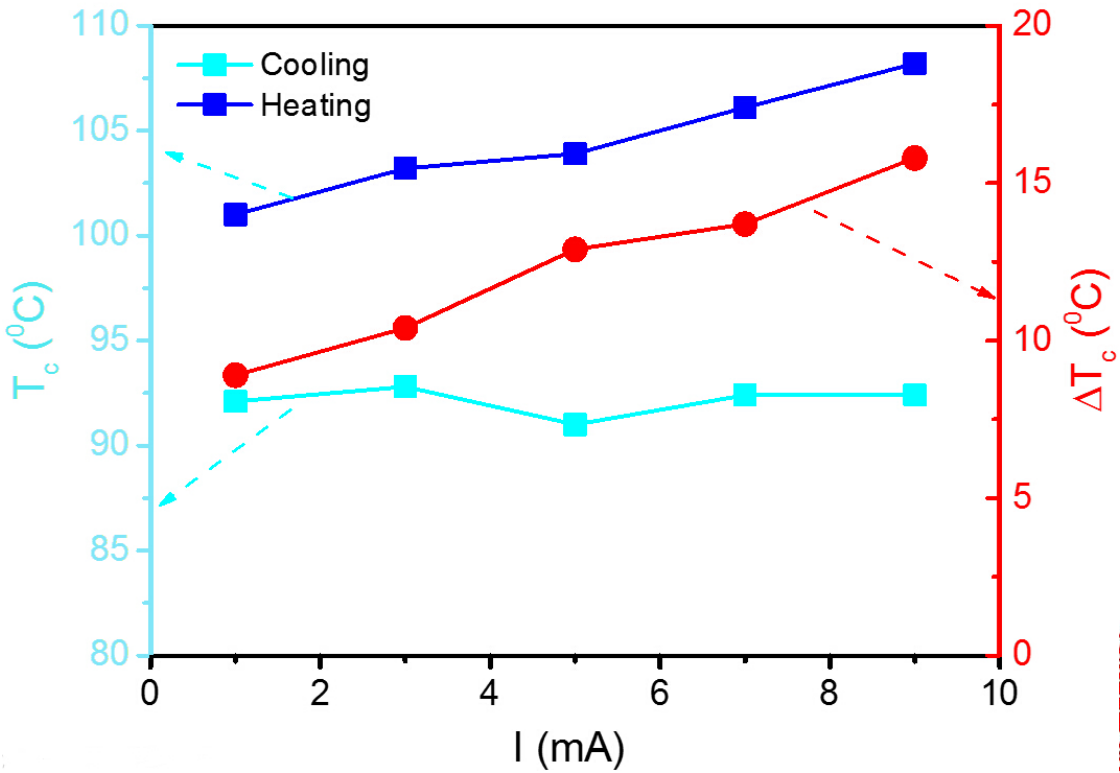
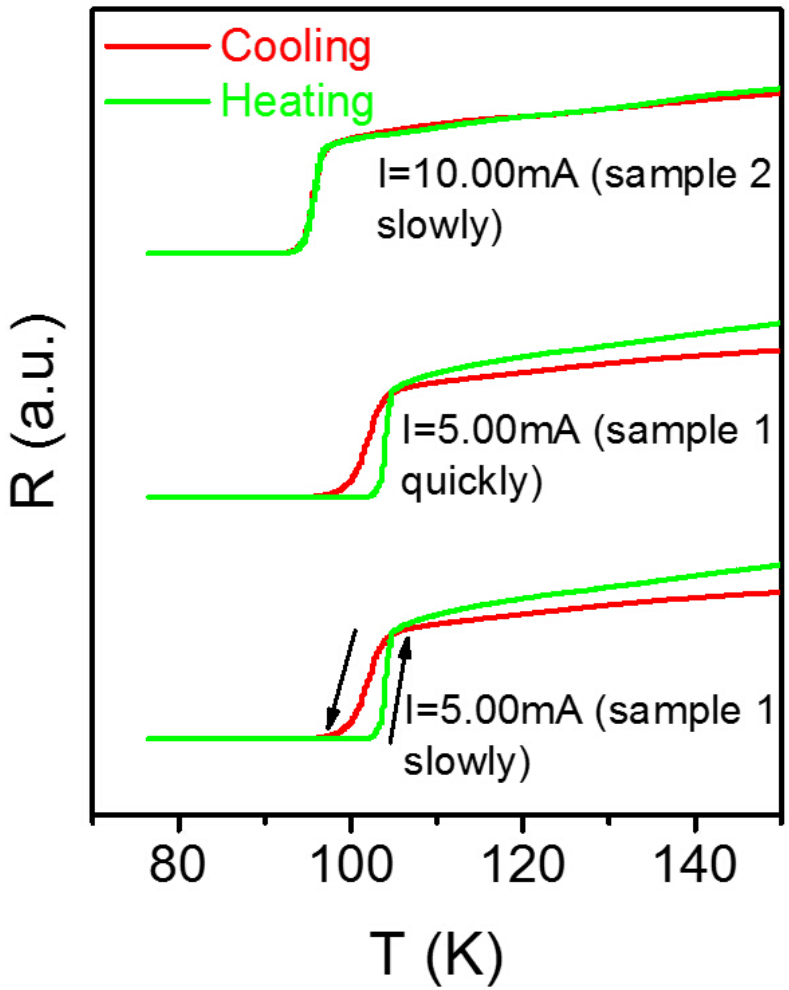




F Doping: $YBa_2Cu_3F_2O_6$

Y_2O_3: 0.78g $BaCO_3$: 1.36g
CuO: 1.65g BaF_2: 1.21g

i) $T_c = 103K$, higher than YBCO about 8K.
ii) The speed of cooling and heating do not effect the temperature-hysteresis.
iii) Temperature-hysteresis may depend on sample itself.



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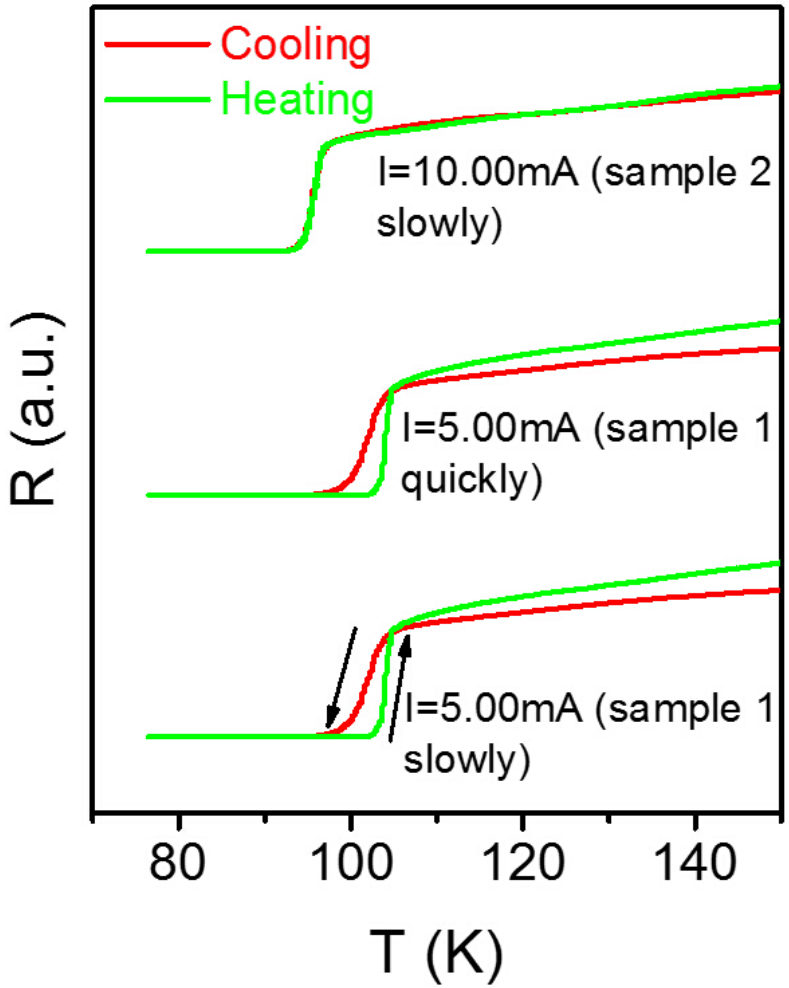

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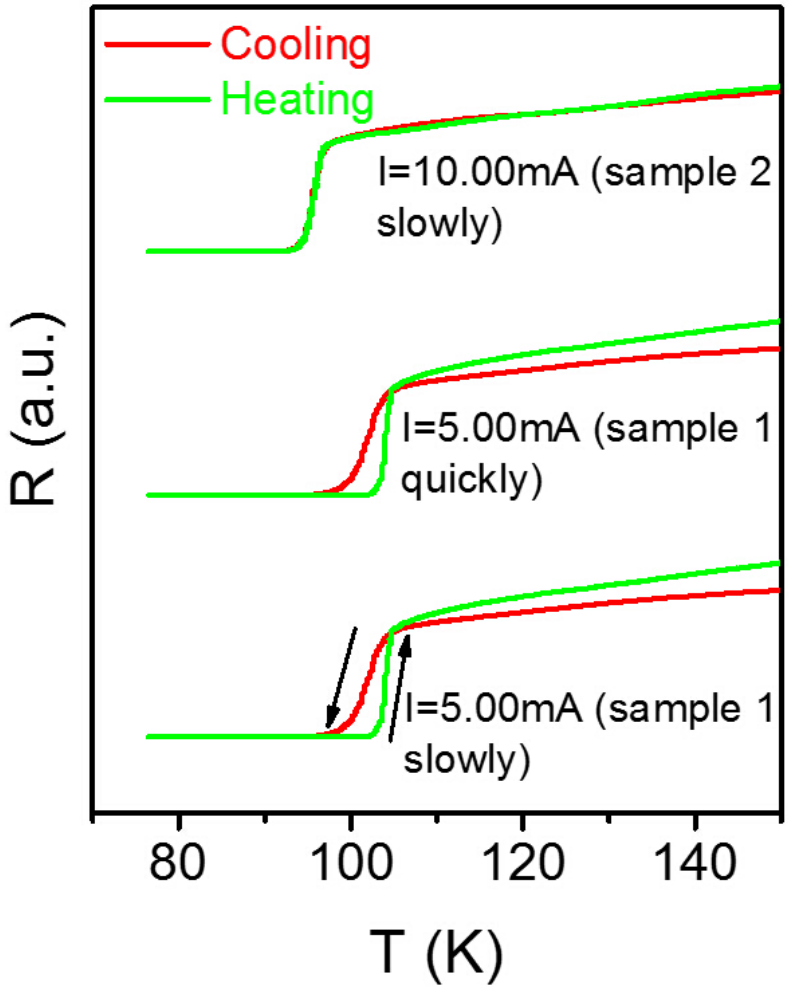

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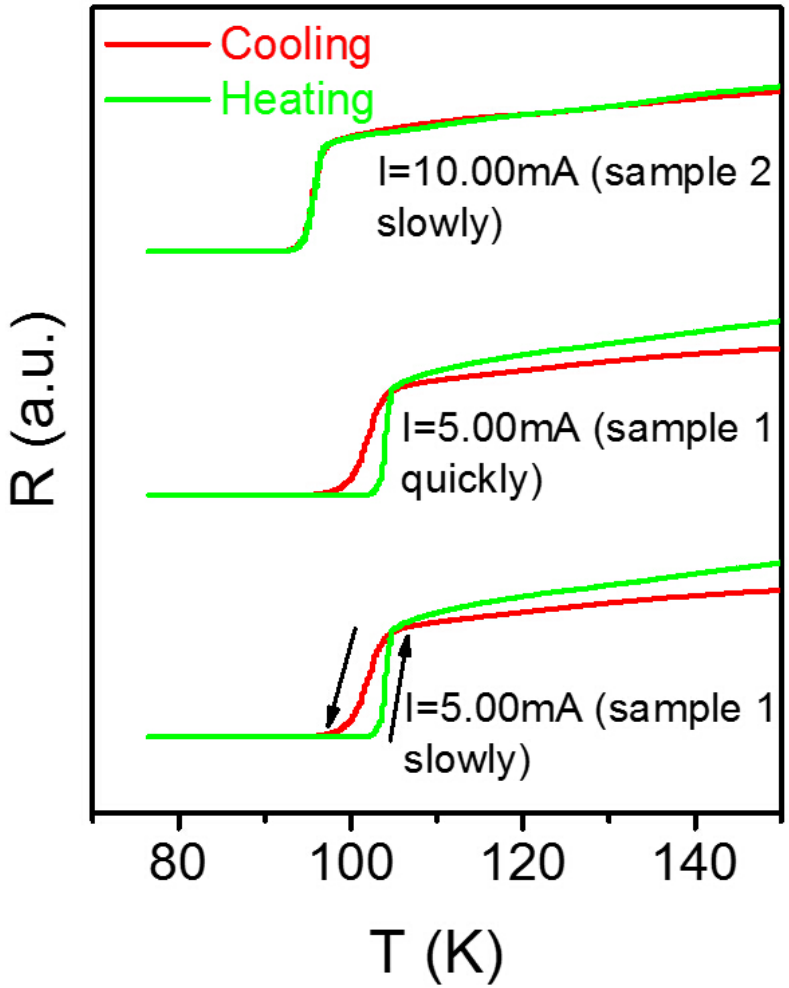

Conclusion

- YBCO has superconductivity at 95K
- Temperature-hysteresis depend on sample itself rather than the speed of cooling and heating or thermometer delay or temperature gradient.
- The seebeck coefficient of YBCO is about $S = 0.3\mathrm{mV/K}$.
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Reference

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Acknowledgement

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