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Topic:

Superconductivity: Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, Applications of superconductor.

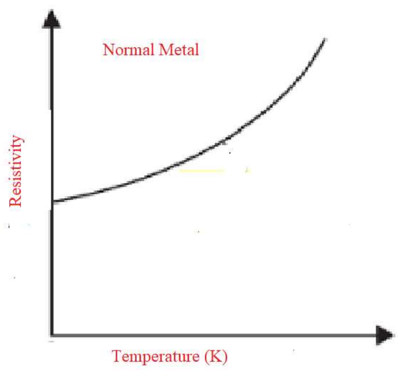
Superconductor:

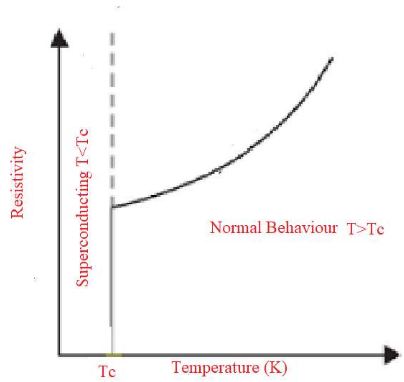
Superconductivity:

Superconductivity is a phenomenon in which the electrical resistivity of certain materials suddenly drops to zero at its transition temperature Tc and magnetic flux fields are expelled from the materials. This phenomena is termed as superconductivity and the materials are typically termed as superconductor.

The superconductor material has two states:

1. Normal state at $T>T_c$. Here, the material reflects the property of normal conductor.
2. Superconducting state at $T<T_c$. Here, the material reflects the property of superconductor.





The superconducting state of the materials will be destroyed by the following causes-

1. At high temperature greater than the critical temperature $(T>T_c)$
2. At high current density $J_c>J_0$, where J_0 is the critical current density at T=0K and J_c is the critical current density.
3. At high magnetic field, $H_c>H_0$, H_0 is the critical field at T=0K and H_c is the critical field.

Isotope Effect:

Impurities added to a pure superconducting material or the lattice imperfections does not stop the transition from normal conducting state to superconducting state but may slow it down. The critical temperature T_c of superconductor is related to its isotopic mass M can be related as-

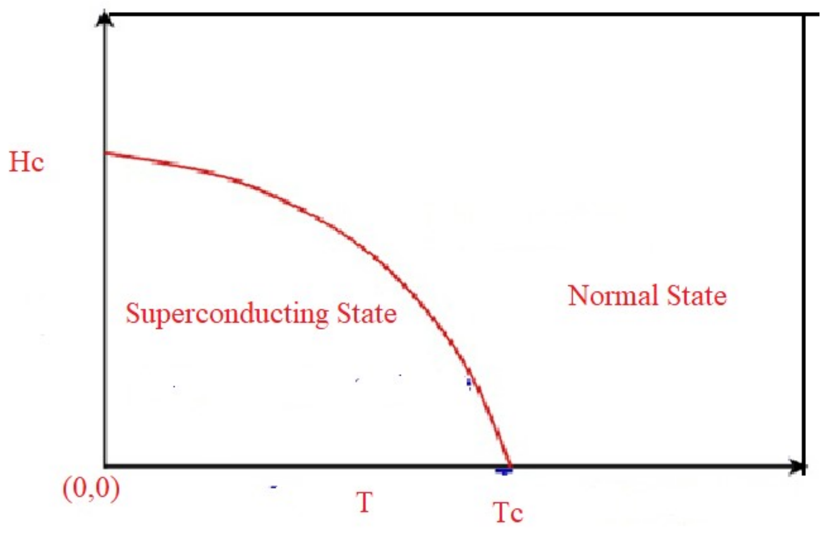
$$T_c \propto \frac{1}{\sqrt{M}}$$

Critical Field:

The normal conducting state can be restored by applying a critical magnetic field H_c that satisfy with temperature T as-

$$H_c(T) = H_0\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

Here H_0 is the critical field at absolute zero with maximum value. The value of magnetic field at which superconductivity becomes destroyed is typically termed as critical field H_c. The critical magnetic field is also a function of temperature. The variation of critical field H_c with temperature T is parabolic in nature. Below the parabolic curve its represent the superconducting state and above the curve it represent normal state.



Variation of critical field H_c with temperature T

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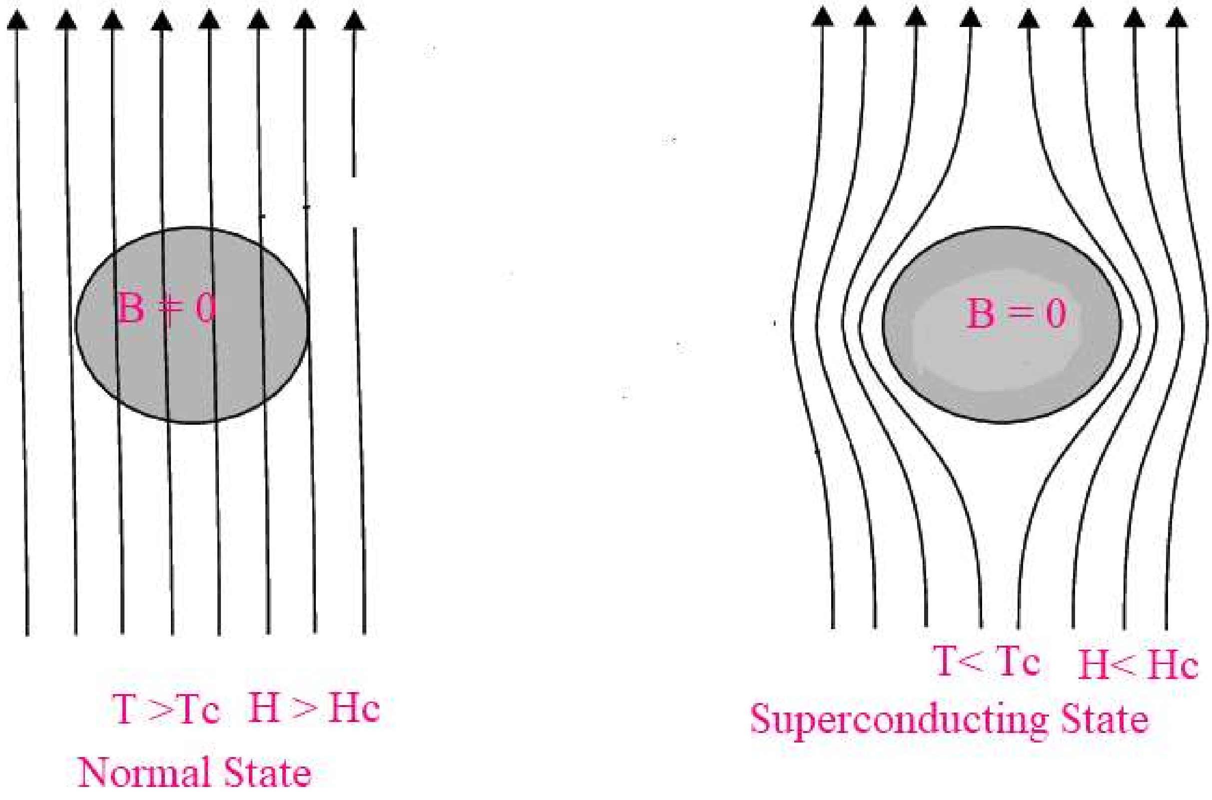
Meissner Effect:



Meissner Effect in Superconductor

A superconductor in the superconducting state shows perfect diamagnetism. Therefore, externally applied magnetic field cannot penetrate inside the superconducting materials. When, a material becomes superconducting state to normal state, the magnetic lines of forces/flux are pushed out from the interior of the material and the material behaves like perfect diamagnetic. This phenomenon is known as Meissner Effect.

$$\overrightarrow{\boldsymbol{B} = \boldsymbol{0}}$$

$\boldsymbol{\mu_0}\,(\overrightarrow{\boldsymbol{H}} + \overrightarrow{\boldsymbol{M}}) = 0$

Therefore, $\overrightarrow{M} = -\vec{H}$

Therefore, $\chi = -\frac{M}{H} = -1$

Type-I & Type-II superconductor:

In the type-I superconductor, superconducting state to normal state transition is sharp, well defined and sudden and occurs at H_c. In this type of superconductor,

$H < H_c$ denotes the superconducting state.

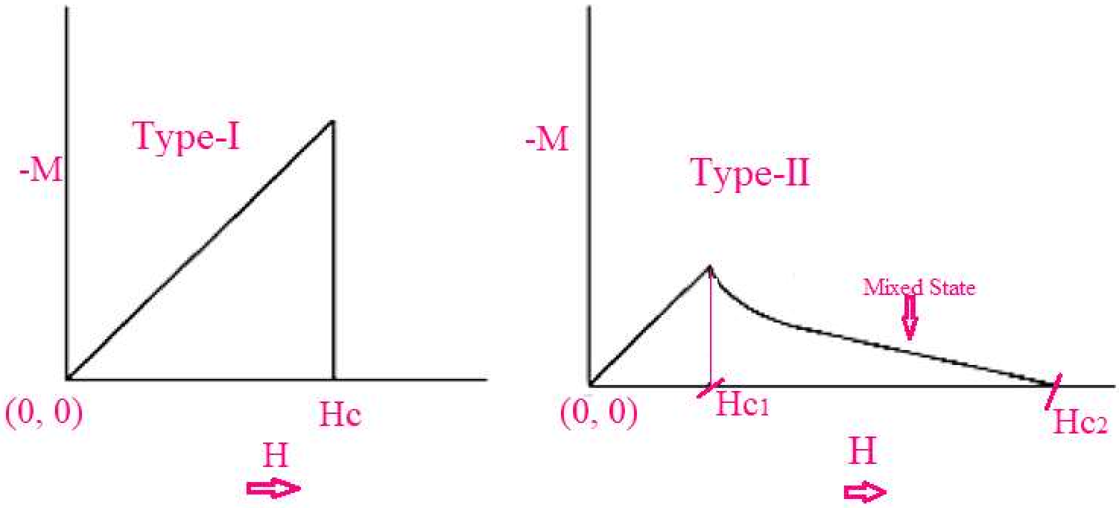
$H > Hc$ denotes the Normal state.

In the type-II superconductor, superconducting state to normal state transition is not sharp and well defined. The transition occurs gradually. Here, we found two critical field, H_{c1} and H_{c2}. The transition starts at H_{c1} and finishes at H_{c2}. Here we can found,

$H < H_{c1}$ denotes the superconducting state.

$H_{c1} < H < H_{c2}$ denotes the mixed state.

$H > Hc_2$ denotes the Normal state.



Type-I and Type-II Superconductor

Applications of superconductor:

1. It has uses in MRI scan and NMR imaging.
2. Superconductors have applications in high speed trains, ships as well as in various driving system.
3. Superconductors have applications in particle accelerators.
4. It has application in switching device.

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Frequently Asked Questions:

1. What do you mean by superconductivity?
2. What do you mean by critical temperature and critical field?
3. What is isotope effect in superconductor?
4. Explain Meissner effect.
5. What are Type-I and Type-II superconductor?
6. Compare Type-I and Type-II superconductor.
7. State London's Equation and penetration depth.
8. Derive London's Equation and penetration depth.
9. State the BCS theory of superconductivity?
10. What are Cooper pairs?

References:

(i) *Introduction to Solid State Physics*, ***Global Author-Charles Kittel, Published by WILEY (Global Ed.).***

(ii) *Solid State Physics (Theory, Problems and solutions)*, ***Author- Jyotirmoy Guha, Published by Books and Allied Pvt. Ltd. (2nd Ed.).***

(iii) *Solid State Physics*- ***Author- S. O. Pillai, Published by New Age International Publishers. (7th Ed.).***

Link to Audio visual Lectures (e-Lectures) and NPTEL lectures on this topic given by Distinguish Professors of Indian & Foreign Universities:

(1) *https://www.digimat.in/nptel/courses/video/115103108/L01.html*

(2) *https://www.youtube.com/watch?v=GglT1RoBPzg*

(3) *https://www.youtube.com/watch?v=D-9M3GWoBrw*