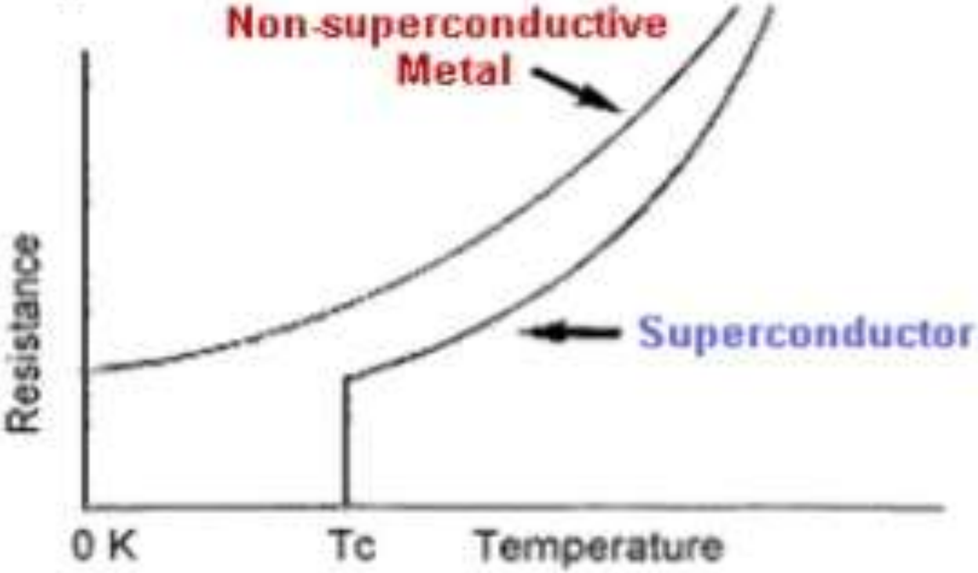
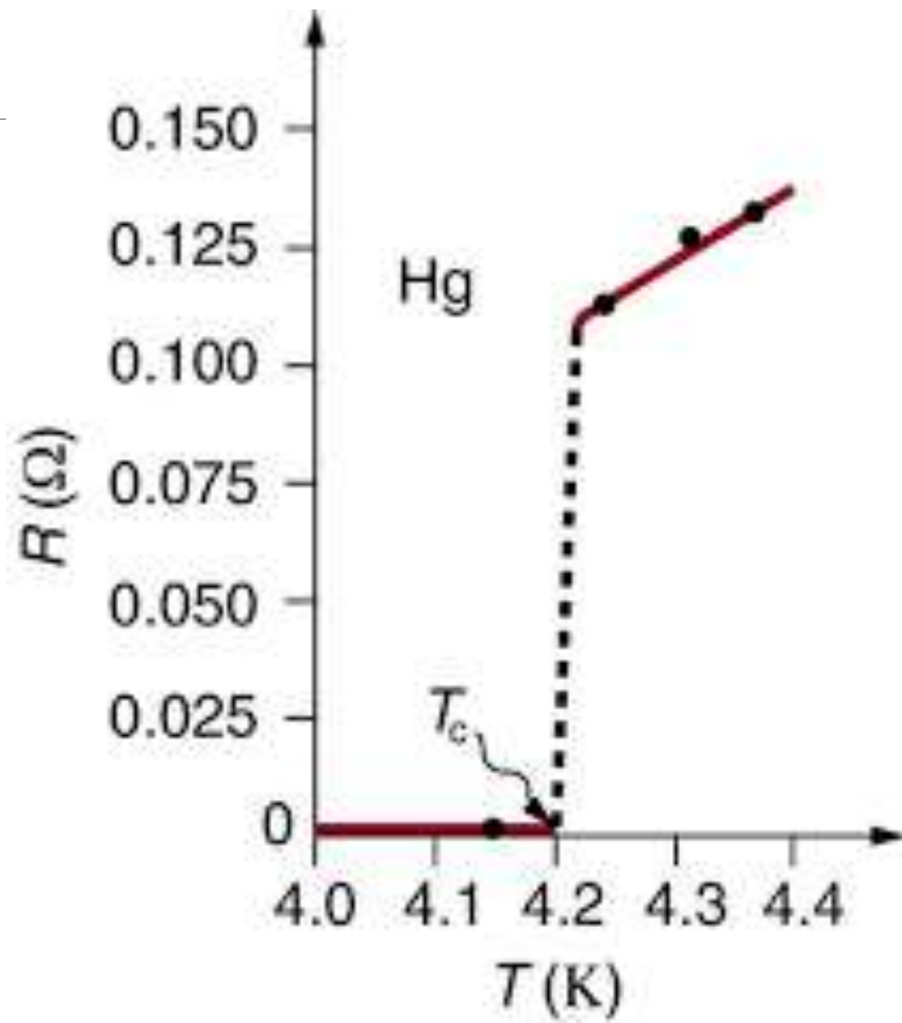
SUPERCONDUCTIVITY

Vhat is superconductivity?

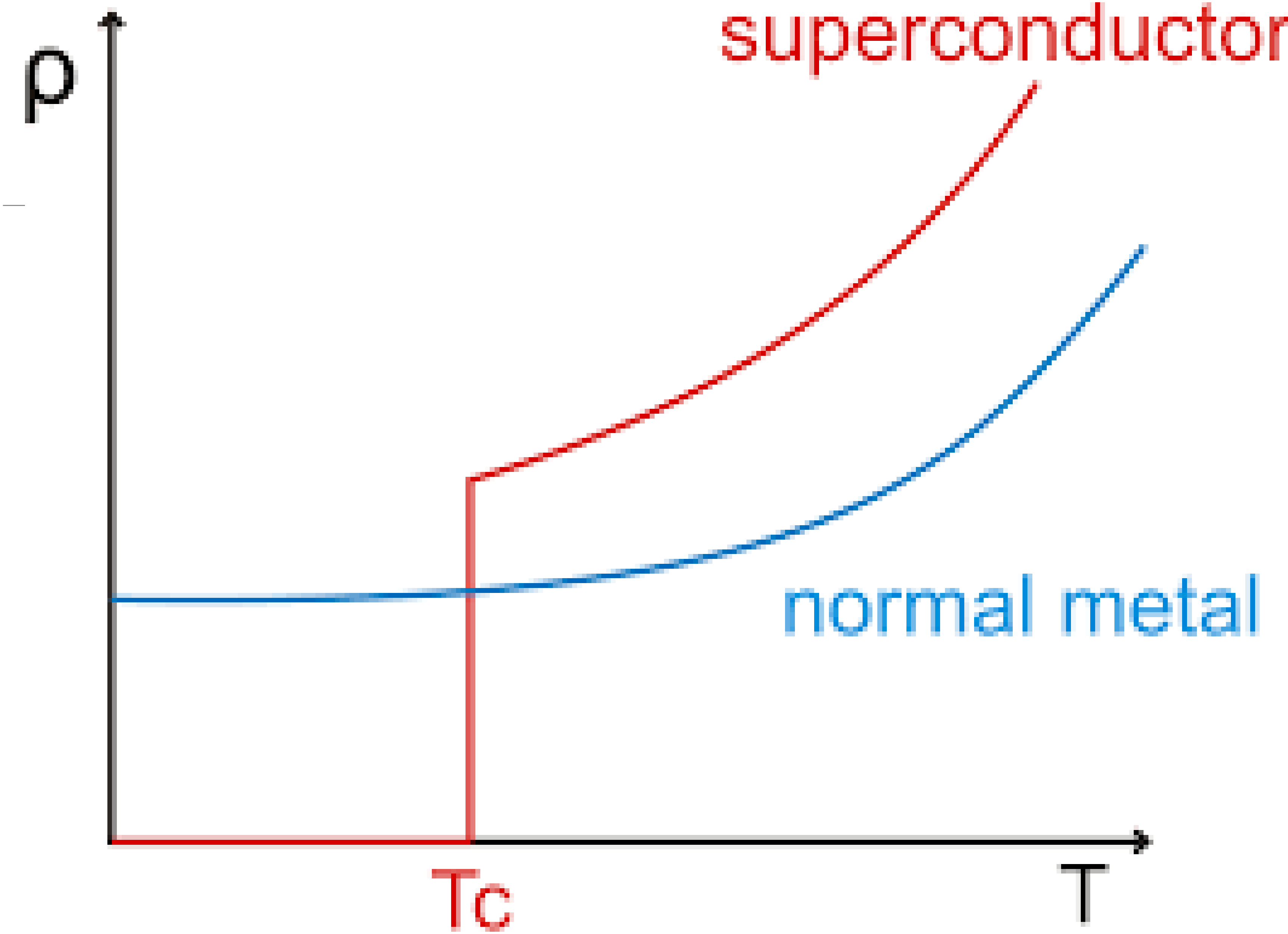
Superconductivity is a phenomenon of exactly
ero electrical resistance and expulsion
f magnetic fields occurring in
ertain materials when cooled below a
haracteristic critical temperature.

was discovered by Dut
hysicist Heike Kamerli
Onnes on April 8,1911 ir
eiden.





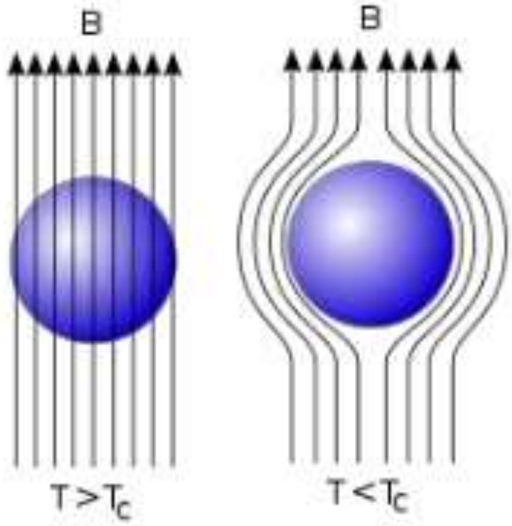
0.150
0.125
0.100
0.075
0.050
0.025
0
R (Ω)
Hg
T_c
4.0
4.1
4.2
4.3
4.4
T (K)



superconductor
ρ
normal metal
Tc
T

Meissner Effect

- When a material makes the transition from the normal to superconducting state, it actively excludes magnetic fields from its interior.
- It was discovered by German physicists Walther Meissner and Robert Ochsenfeld .



A magnet levitating above a superconductor cooled by liquid nitrogen.

TYPE I SUPERCONDUCTORS

- It loose their superconductivity very easily and abruptly when placed in a magnetic field.
- known as soft superconductors
- It obey Meissner effect.
- Eg: Most of pure metals, tin , Indium

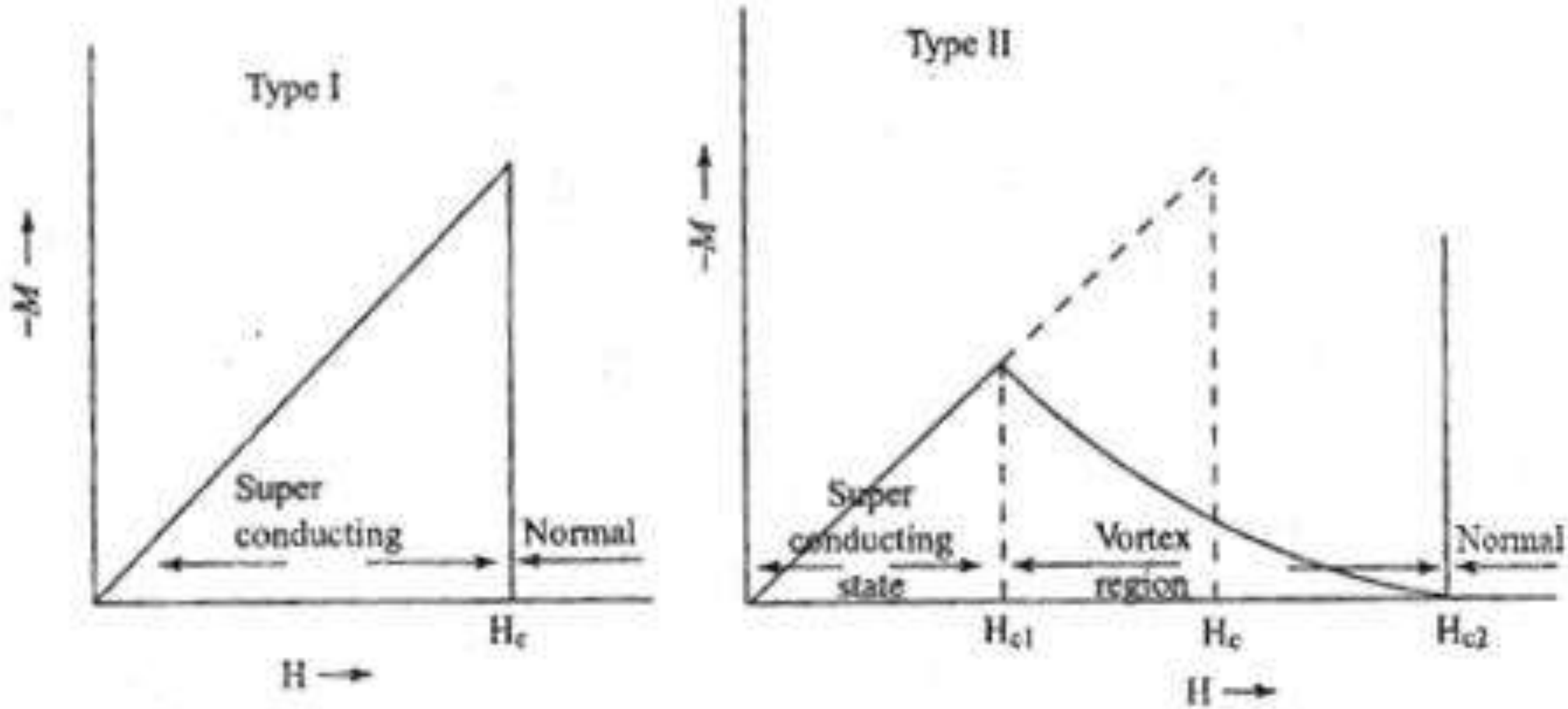
TYPE II SUPERCONDUCTORS

- It loose their superconductivity gradually but not easily or abruptly when placed in the external magnetic field.
- The state between the lower critical magnetic field (Hc1) and upper critical magnetic field (Hc2) is known as vortex state or intermediate state.

- It is known as hard superconductors .

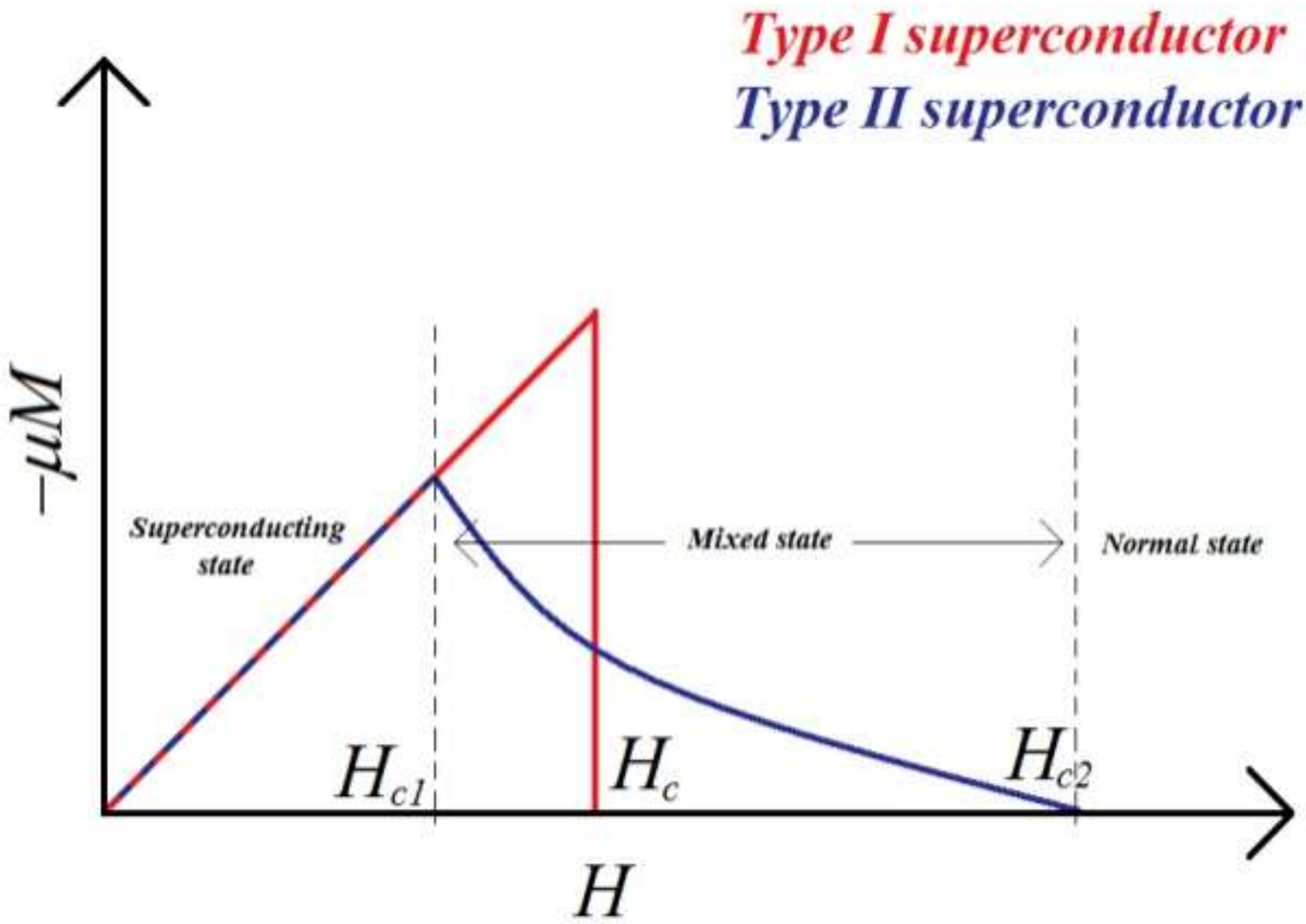
It obey Meissner effect but not completely.

- Eg:Niobium, Vanadium
- They are used for strong field superconducting magnets.


Type I
−M →
Super
conducting
Normal
H_c
H →
Type II
−M →
Super
conducting
state
Vortex
region
Normal
H_{c1}
H_c
H_{c2}
H →

(a)

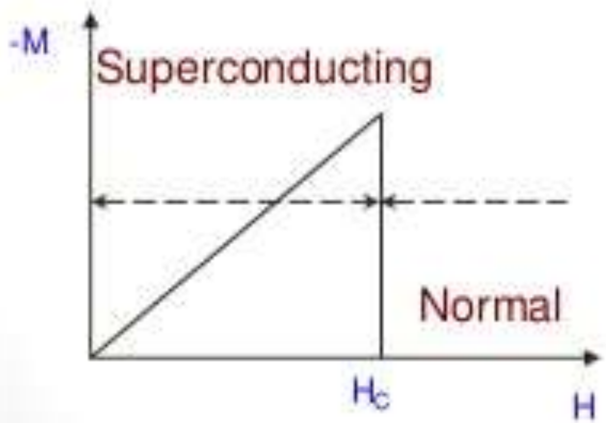
(b)


Type I superconductor
Type II superconductor
$-\mu M$
Superconducting state
Mixed state
Normal state
H_{c1}
H_c
H_{c2}
H

Types of Superconductors

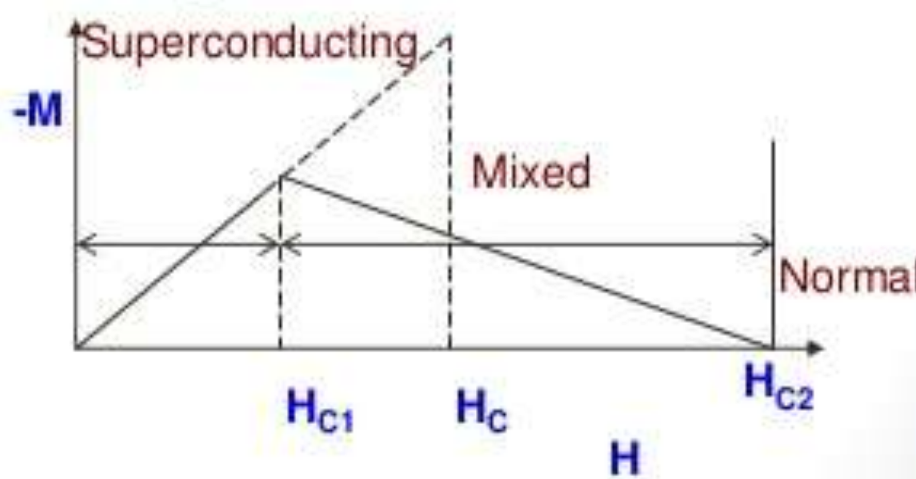
Type I

- Sudden loss of magnetization
- Exhibit Meissner Effect
- One $H_C = 0.1$ tesla
- No mixed state
- Soft superconductor
- Eg.s – Pb, Sn, Hg



Type II

- Gradual loss of magnetization
- Does not exhibit complete Meissner Effect
- Two H_Cs – H_{C1} & H_{C2} (≈30 tesla)
- Mixed state present
- Hard superconductor
- Eg.s – Nb-Sn, Nb-Ti



Superconducting Materials

Class of materials	Example	T_c (K)
Metal and alloys	Al, Pb, Nb_3Sn, NbTi, MgB_2	≤ 39
Organic Superconductor	K_3C_{60}, $[BEDT\text{-}TTF]_2X$	< 42
Heavy Fermions	$CeCu_2Si_2$	< 1
Borocarbide & boronitride	$LuNi_2B_2C$	< 23
Oxides base (Bi, Ti, Sr)	$Ba_{0.63}K_{0.37}BiO_3$, $SrTiO_{3\text{-}d}$	< 30
Copper oxide base	YBCO, BSCCO, HBCCO	≤ 164
Iron-arsenide	RFeAsOF	≤ 50

BCS THEORY OF SUPER CONDUCTORS

- A microscopic theory of the electronic structure of superconductor was given by
- J. Bardeen, L.N. Cooper and J.R. Schrieffer and is known as BCS theory.
- It is based on the formation of cooper pair of electrons.

- During the flow of current in a superconductor, when an electron approaches a positive ion of the metal lattice, there is a coulomb attraction between the electron and the lattice ion.
- This produces a distortion in the lattice. ie., the positive ion gets displaced from its mean position.
- Smaller the mass of the positive ion core, the greater will be the distortion.

- This interaction called the electron-phonon interaction leads to scattering of the electron and causes electrical resistivity.
- Now a second electron which approaches the distorted positive ion also experiences coulomb attractive force.
- Thus an apparent force of attraction develops between the two electrons via the lattice and they tend to move in pairs.

- At normal temperatures the attractive force is too small and pairing of electrons does not take place.
- Below the transition temperature, the apparent force of attraction reaches a maximum value for any two electrons of equal and opposite spin.
- This force of attraction exceeds the coulomb force of repulsion between two electrons and the electrons move as pairs.
- These pairs of electrons formed by the interaction between the electrons with opposite spin and momenta in a phonon field are called cooper pairs.

- Phonons are quanta of lattice vibrations.
- The pair has a total spin of zero. As a result, the electron pairs in a superconductor are bosons.
- The dense cloud of cooper pairs form a collective state and they drift co-operatively through the material.
- Thus the superconducting state is an ordered state of conduction electrons.
- They drift with identical velocity, without collisions.
- Thus the substance possess infinite electrical conductivity.

HIGH –TEMPERATURE SUPERCONDUCTORS

- Superconductors having transition temperature above 20K are called high Tc superconductors
- Eg.Yttrium Barium Copper Oxide(YBa2Cu3O7) with Tc 90K
- Mercury Thallium Barium Calcium Copper Oxide(Hg12Tl3Ba30Ca30Cu45O125) with Tc 138K

APPLICATIONS OF SUPER CONDUCTORS

- 1. Low loss transmission lines and transformers can be made with superconductors.
- 2. Superconductors are used to perform logic and store function in computers.
- 3. Small size electric generators are developed with superconducting coils.
- 4. High capacity and high speed computer chips can be developed with superconductors.
- 5. Cryotron, a fast electrical switching system utilises superconductivity for its operation.
- 6. SQUID, a superconducting device has many applications in scientific, industrial medical and communication fields.

Applications

- **Superconducting levitation:**

Maglev Trains (On Track with superconductivity)

Medical Diagnosis

Power Cables

- Superconducting wires carry up to five times the current carried by copper wires with the same cross section

- Large hadron collider or particle accelerator. The latest and biggest largehadron collider is currently being built in Switzerland by a coalition of scientific organisations from several countries. Superconductors are used to make extremely powerful electromagnets to accelerate charged particles very fast.
- SQUIDs (Superconducting QUantum Interference Devices) are used to detect even the weakest magnetic field. They are used in mine detection equipment to help in the removal of land mines.

- The USA is developing “E-bombs”. These are devices that make use of strong, superconductor derived magnetic fields to create a fast, high-intensity electromagnetic pulse that can disable an enemy’s electronic equipment. These devices were first used in wartime in March 2003 when USA forces attacked an Iraqi broadcast facility. They can release two billion watts of energy at once.