The Science and Significance of Superconductivity

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Superconductivity

• What is it?

• History

• Phase Transitions

• Applications
What is Superconductivity?

• Zero electrical resistance (diamagnetism) and cancelation of magnetic field
• Only certain materials can be Superconductive
• Important for many different modern uses:
  • SQUIDS
  • MagLev Train
  • Hoverboard
  • MRI’s
History of Superconductivity

• Heike Kamerlingh Onnes – April 8, 1911
• Walther Meissner and Robert Ochsenfeld – Meissner Effect
• London Theory
History of Superconductivity

• Material Discoveries

• Electromagnet Advancements

• 1972 Nobel Prize (BCS Theory-1957)
Phase Transitions

• Critical Temperature

• Resistivity
Bardeen, Cooper, Schrieffer (BCS Theory)

- Cooper Pairs
- Isotope Effect
- Mean Free Path
- Flux Quantization
Type-I vs Type-II Superconductors

Diagram showing the difference in behavior of Type-I and Type-II superconductors as a function of temperature and magnetic field.

- **Type I**
  - Region below $B_c$: Superconductor
  - Region above $B_c$: Normal

- **Type II**
  - Region below $B_{c1}$: Mixture of normal and superconducting
  - Region between $B_{c1}$ and $B_{c2}$: Mixture of normal and superconducting
  - Region above $B_{c2}$: Normal
Type-I vs Type-II Superconductors

Type I

\[ \chi_m = -1 \]

\[ B = \mu_0 H \]

Type II

\[ \chi_m = -1 \]

\[ B = \mu_0 H \]

Mixed state
London Equation

\[ j_s = -\frac{n_s e^2}{m} A \]

- \( j_s \) = superconducting current density
- \( n_s \) = constant
- \( e \) = elementary charge
- \( m \) = mass of electron
- \( A \) = magnetic vector potential
Applicability

• Which Materials are Superconductive?
• Why are these superconductive and not others?

• Cost Efficiency and Other Practical Properties
Niobium-titanium or niobium-tin alloy is cooled by liquid helium to 4 K to produce the magnetic field.
Future Uses and Applications

• Military Weapons
• High Temp Superconductors
• Ongoing Research
Superconductivity

• Q&A time
References

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