The Solid State
WS 2013/14

Lectures (Tuesday & Friday)

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Last time:
Semiconductor devices

Today:
Superconductivity
Your questions
Superconductivity

1911, Leiden
Discovery of
Superconductivity

1912: disappears
at high currents or
applied magn. fields

Heike Kamerlingh Onnes
Nobel prize 1913 (Low T research including liquid He)
PhD RUG on ‘new proof for the rotation of the earth’
Is zero resistance enough?

Ideal metal has zero resistance at T=0K (no xtal imperfections, impurities or phonons)

Also in shubnikov-de haas effect
Zero resistance (no scattering possible)


GaAs/AlGaAs Heterostructure
Meissner Ochsenfeld effect (1933)

Superconductor is also a perfect diamagnet.
Type I and II

Type I: destruction of superconductivity upon applied magnetic field by first order phase transition

Type II: At first critical field: flux penetration, superconductivity destroyed at second critical field

YBCO vortex state (decorated)
BCS Theory (1957)

Bardeen, Cooper & Schrieffer: condensation of Cooper pairs

Electrons ‘bind’ together through lattice polarization

→ bosons → condensation → energy gap for excitations

Nobel prize 1974
Flux quantization

\[ \Phi = \int \mathbf{B} \cdot d\mathbf{A} = n\varphi_0 \]

\[ \varphi_0 = \frac{h}{2e} \sim 2 \times 10^{-15} \text{ V} \cdot \text{s} \]

Earth’s magnetic field \( \sim 500 \text{ mG} \), so in 1 cm\(^2\) of \( \mathbf{B}_{\text{Earth}} \) there are \( \sim 2 \) million \( \varphi_0 \)’s.

Total flux (field\( \times \)area) \( \Phi \) is integer multiple of \( \varphi_0 \)

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**EXPERIMENTAL EVIDENCE FOR QUANTIZED FLUX IN SUPERCONDUCTING CYLINDERS**

Bascom S. Deaver, Jr., and William M. Fairbank
Department of Physics, Stanford University, Stanford, California
(Received June 16, 1961)
Δφ(B) + Δφ(I) = n \cdot 2\pi
1986, start of a new era on superconductivity

Possible High $T_c$ Superconductivity in the Ba–La–Cu–O System

J.G. Bednorz and K.A. Müller
IBM Zürich Research Laboratory, Rüschlikon, Switzerland

Received April 17, 1986

Bednorz & Muller, nobel prize 1987
High Tc superconductors
The perovskite superconductors

(La,Ba)$_2$CuO$_4$ ($T_c$=38 K)

TlBa$_2$Ca$_2$Cu$_3$O$_{9+d}$ ($T_c$=123 K)
Applications

- Yamanashi XML01 train
  581 km/h

Medical imaging (soft tissue, MRI)
Applications

Power transmission lines

Telecommunication filters

Accelerators