ادامه فصل ۱۰

عناوین

۱- مدل دوشاره ای

۲- تئوری BCS مبنای پدیده ابر رسانایی

۳- کاربردهای ابر رسانایی

مدل دوشاره ای

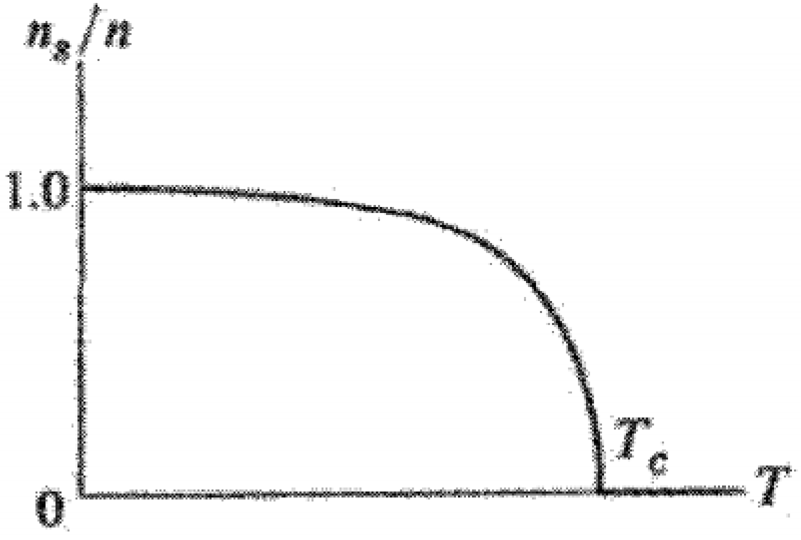
در سال ۱۹۳۴، به منظور توجیه کامل خواص ترمودینامیکی ابررساناها، گورتر و کاسیمیر مدل ابررسانایی دو شاره‌ای را معرفی کردند. بر طبق این مدل، در مواد ابررسانا، الکترون‌های رسانش به دو دسته تقسیم می‌شوند: اَبَرالکترون‌ها[1] و الکترون‌های طبیعی. الکترون‌های طبیعی به همان شیوه‌ی معمول که در فصل ۴ بحث شد رفتار می‌کنند، یعنی همچون ذرات بارداری که در محیط وشکسان جریان می‌یابند، رفتار می‌نمایند. ولی ابرالکترونها خواص عجیبی دارند که باعث خاصیت ابررسانایی ماده می‌شوند. این الکترون‌ها هرگز پراکنده نمی‌شوند، آنتروپی آن‌ها صفر است (نظم کامل) و یک طول همدوسی بسیار بزرگ (در حدود ۱۰۴ A) دارند. این ناحیه، یک گسترش فضایی است که ابرالکترون‌ها در آن گسترده می‌شوند.

1. Superlectron

تعداد ابرالکترون‌ها به دما بستگی دارد. گورتر و کاسیمیر دریافتند که اگر چگالی این الکترون‌ها را با فرمول زیر بیان کنند، سازگاری خوبی با تجربه به‌دست می‌آید.

$$n_S = n[۱ - (\frac{T}{T_c})^۴] \qquad (۱۰-۱۳)$$

چگالی ابرالکترون‌ها بر حسب دما در شکل ۱۱-۱۰ رسم شده است. در $T = 0^\circ K$ همه‌ی الکترون‌ها، ابرالکترون هستند، ولی با افزایش T، تعداد ابرالکترون‌ها کاهش می‌یابد و سرانجام در $T = T_c$ همه به الکترون طبیعی تبدیل می‌شوند.



شکل ۱۱-۱۰ تعداد نسبی ابرالکترون‌ها، $(\frac{n_s}{n})$ ، بر حسب دما

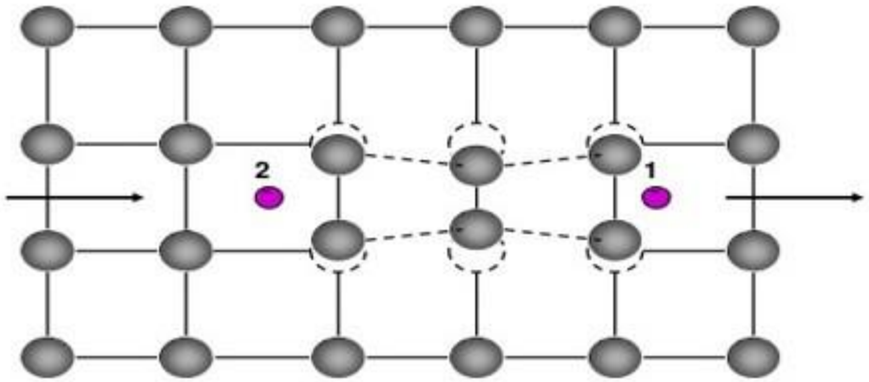
تئوری BCS مبنای پدیده ابر رسانایی

BCS theory, in physics, a comprehensive theory developed in 1957 by the American physicists John Bardeen, Leon N. Cooper, and John R. Schrieffer (their surname initials providing the designation BCS) to explain the behaviour of superconducting materials.

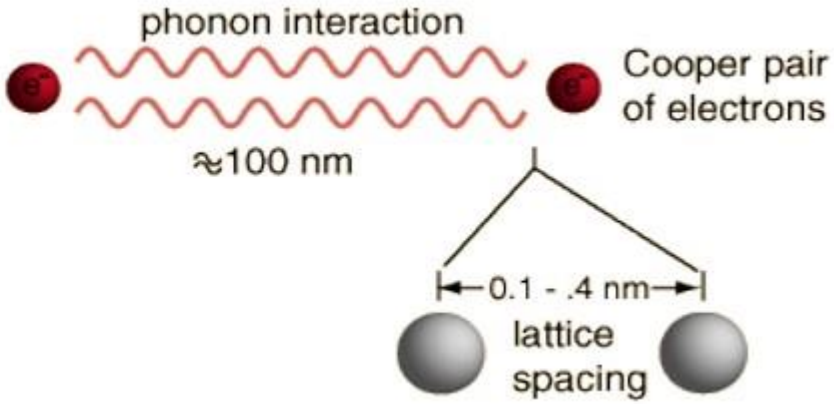
Superconductors abruptly lose all resistance to the flow of an electric current when they are cooled to temperatures near absolute zero. John Bardeen, Leon Cooper, and John Robert Schrieffer shared the Nobel Prize in physics in 1972 for the theory's development.

John Bardeen also won a Nobel prize as one of the principle inventors of the transistor and hence shared in the winning of two Nobel prizes in physics.

A key conceptual element in this theory is the pairing of electrons close to the Fermi level into Cooper pairs through interaction with the crystal lattice. This pairing results from a slight attraction between the electrons related to lattice vibrations; the coupling to the lattice is called a phonon interaction.



Pairs of electrons can behave very differently from single electrons which are fermions and must obey the Pauli exclusion principle. The pairs of electrons act more like bosons which can condense into the same energy level. The theory is also used in nuclear physics to describe the pairing interaction between nucleons in an atomic nucleus



BCS is able to give an approximation for the quantum-mechanical many-body state of the system of (attractively interacting) electrons inside the metal. This state is now known as the BCS state. In the normal state of a metal, electrons move independently, whereas in the BCS state, they are bound into Cooper pairs by the attractive interaction.

Cooper Pairs

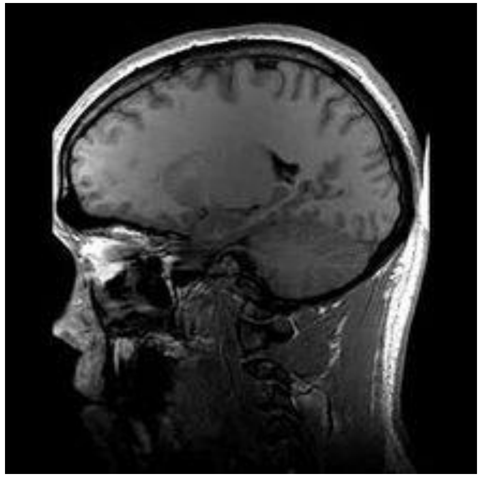
Cooper had discovered that electrons in a superconductor are grouped in pairs, now called Cooper pairs, and that the motions of all of the Cooper pairs within a single superconductor are correlated; they constitute a system that functions as a single entity.

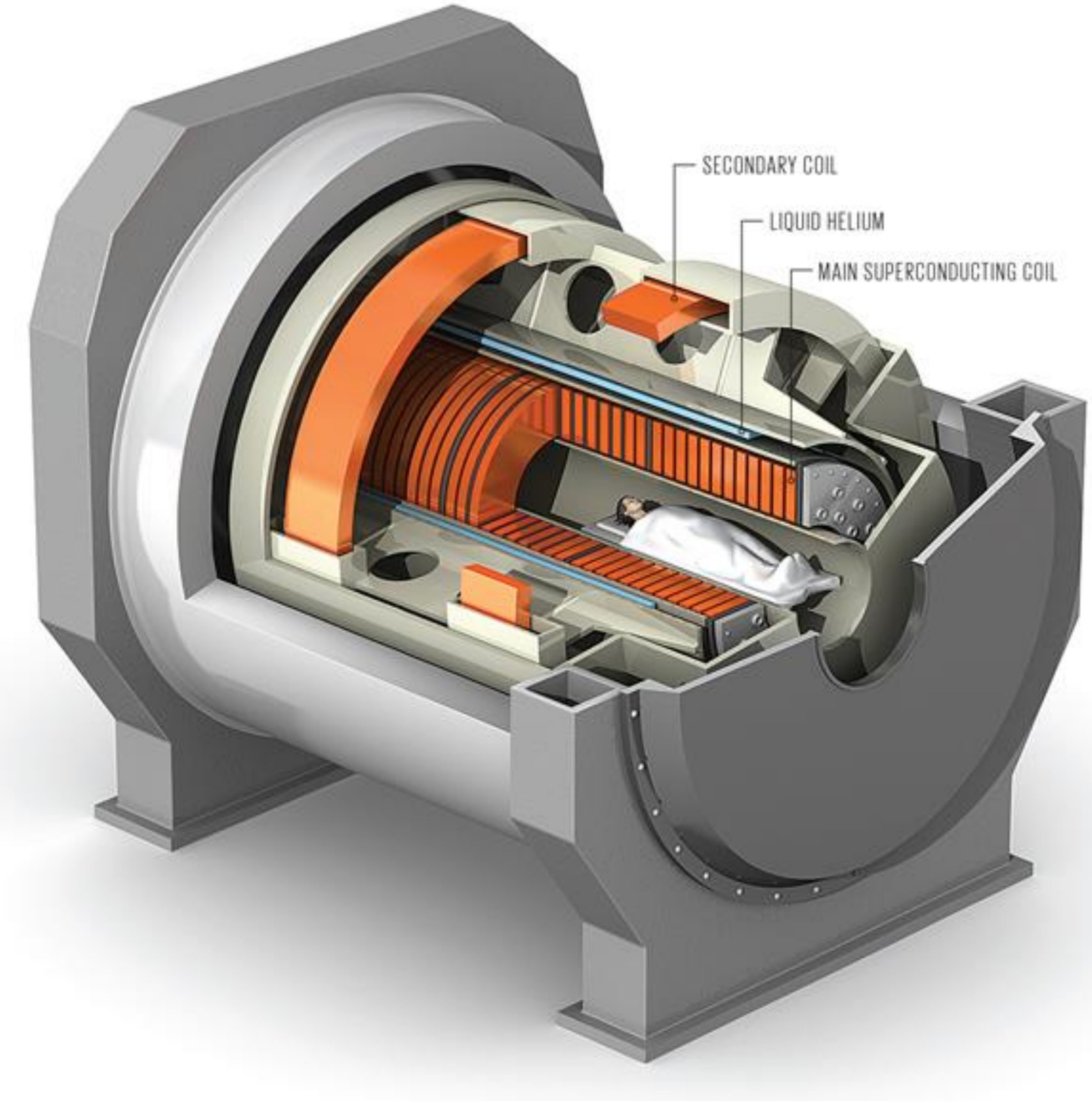
کاربردهای ابر رسانایی

If you set up a current in a loop of superconductor there is nothing to stop it and it will continue flowing forever, forming a very powerful electromagnet, that needs no maintenance other than keeping them cold. The strongest man made permanent magnetic fields are produced using superconductors.

1- MRI (Magentic Resonance Imaging)

Superconducting magnets are used in MRI which is a way of looking at the soft parts of the body.





2- CERN Particle Physics Lab

They are also going to be used in the new 'Large Hadron Collider' experiment at the CERN (THE LARGEST PARTICLE PHYSICS LAB IN THE WORLD). The idea is to accelerate protons and antiprotons to almost the speed of light in a circle and then smash them together. To keep the particles in a circle requires huge magnetic fields which can only be provided by superconductors.

3- levitating train قطار شناور

It is also possible to use superconducting magnets to produce a levitating train. The idea is to put very powerful superconducting on the train, then use copper coils in the track(مسير) which use repulsion to lift the train up to make it levitate.

It is also possible to use the track magnets to push the train along. Because this force is not limited by friction between wheels and a track it is theoretically possible for a maglev train to go much faster and more importantly accelerate and brake(ترمز) faster than a conventional train. Various test maglev trains have been built, in Birmingham, Japan and Germany, although the only one used commercially is a german design built in Shanghi, which uses very strong permanent magnets instead of superconductors.

4- Superconducting Sensors

Due to a subtlety(ظرافت،باریک بینی) of the quantum mechanics of how superconductors interact with magnetic fields, it is possible to make the most sensitive magnetometers possible called SQUIDs (Superconducting Quantum Interference(تداخلی) Devices). These can be used to detect submarines(زیردریایی), measure the magnetic field produced by your brain, find ore(سنگ معدنی) deposits deep underground, sense minute(کوچک) signals from stars etc.

4- Power Cables کابلهای برق

An obvious use of superconductors would be to move power around, huge amounts of electrical energy are wasted(هدر رفتن) just heating up power cables, and superconductors would help. However if you put alternating current(AC) through them they are no longer lossless, and it reqiures a lot of energy to cool them.

So superconductors may not be about to revolutionise(تحول) the world like it looked in 1986, but they are becoming more and more useful in the modern world.