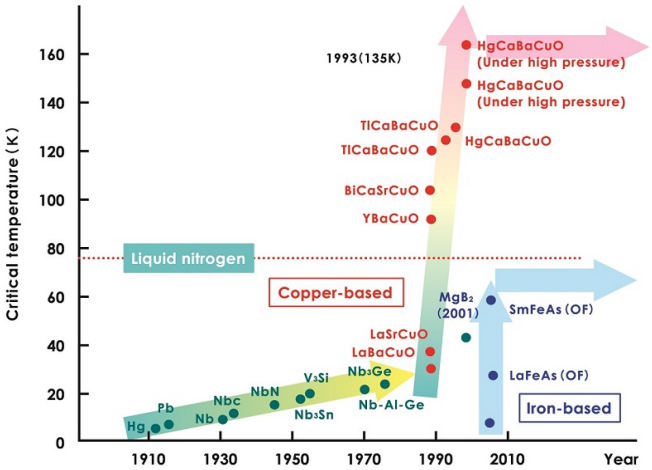
What are superconductors

Superconductivity is a phenomenon in certain materials when cooled to temperatures below a critical temperature T_c : for temperatures below the critical temperature the electrical resistance vanishes, unlike ordinary metallic conductors, whose resistance decreases linearly with temperature. A current in a loop formed with a superconducting wire can hence persist indefinitely with no power source. Shortly after the discovery new effects of superconductive materials were described for materials in the superconductive phase

- the resistivity becomes finite if a critical current density is exceeded,
- the resistivity becomes finite if a critical magnetic field is exceeded,
- the magnetic flux is expulsed from the superconductive material, this effect is called (Meissner-Ochsenfeld effect).

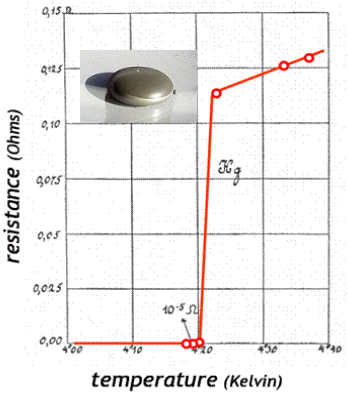
In subsequent decades other superconducting metals, alloys and compounds were discovered. During the 1980s, scientists discovered new ceramic materials that become superconductive at much higher temperatures, so called high-temperature superconducters. Although cooling would be much cheaper, these high-temperature superconductors are difficult to manufacture and too expensive for use over long distances. But in 2001, researchers in Japan discovered that a quite simple compound, magnesium diboride (MgB_2), becomes superconductive at a temperature of 39 K.



Discovery

Superconductivity was discovered on April 8, 1911. At that time the Duch physicist Heike Kamerlingh Onnes was studying the resistance of solid mercury at very low temperatures using liquid helium as refrigerant. At the temperature of 4.2 K, he observed that the resistance abruptly disappeared – or more precisely was lower than the measurement uncertainty. This behaviour was absolutely unexpected and later explained as a new phase: superconductivity. 1913 Onnes was awarded the Nobelprice for this discovery.

Heike Kamerlingh Onnes
University of Leiden (1908)
Museum Boerhaave, Leiden



1911: discovery of superconductivity in Mercury. H.K. Onnes, Commun. Leiden 120b (1911)

High temperature superconductors

In 1986 Alex Müller and Georg Bednorz, researchers at the IBM Research Laboratory in Rüschlikon, Switzerland, created a superconducting ceramic compound with a critical temperature of 30 K, the highest temperature then known. This was a real surprise and a breakthrough as contrary to the other superconducting materialls, ceramics are isolators. Bednorz and Müller were awarded the Nobel prize for the discovery of the copper-oxides the following year. The sentence from Müller and Bednorz that stays in mind is: Es ging uns um den Spass an der Sache -it was all about having fun.
The discovery triggered a lot of research on superconductivity all around the world..

https://www.higgs.ch/es-ging-uns-um-den-spass-an-der-sache/7529/
http://www.superconductors.org/condmatt.htm

Karl Alex Müller and Klaus Bednorz in Zurich. https://www.higgs.ch/es-ging-uns-um-den-spass-an-der-sache/7529/

Applications
Medicine

Energy transport

With more and more renewable energy produced at remote places the problem of efficient, cheap and environment friendly transport of electric energy over large distances becomes needs to be solved. High-voltage DC overhead lines are currently the cheapest option, an alternative is to bury copper or aluminium high-voltage lines underground, a solution that is very expensive and therefore only applied in highly populated regions. Using conventional wires for transmission however causes a loss of energy due to heating of wires. For long lines, energy loss can be as much as 10 percent of the transmitted energy, being equivalent for Europe to the output of 3 to 5 large power plants.
Research is ongoing to use new, cheap superconductive wires made from magnesium diboride (MgD_2) for long-distance energy transmission with no loss of energy. In 2014, a first test of the MgB_2 wire with up to 20 000 amperes at CERN, confirmed that the material would be a good choice.

https://cds.cern.ch/journal/CERNBulletin/2014/16/News%20Articles/1693853?ln=en
https://www.youris.com/Energy/Energy-Grid/New-Superconductive-Material-For-Long-Distance-Energy-Transmission.kl

The 20-metre long electrical transmission line containing the two 20 kA MgB2 cables. https://cds.cern.ch/journal/CERNBulletin/2014/16/News%20Articles/1693853?ln=en

High magnetig fields

CERN, medicine

https://phys.org/news/2014-04-cern-world-record-current-superconductor.html
http://www.bestpaths-project.eu/en/demonstration/demo-5

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Volume 55, March 2016, Pages 59-72

https://phys.org/news/2016-09-superconductive-material-long-distance-energy-transmission.html

https://scx2.b-cdn.net/gfx/news/hires/2014/worldrecordc.jpg