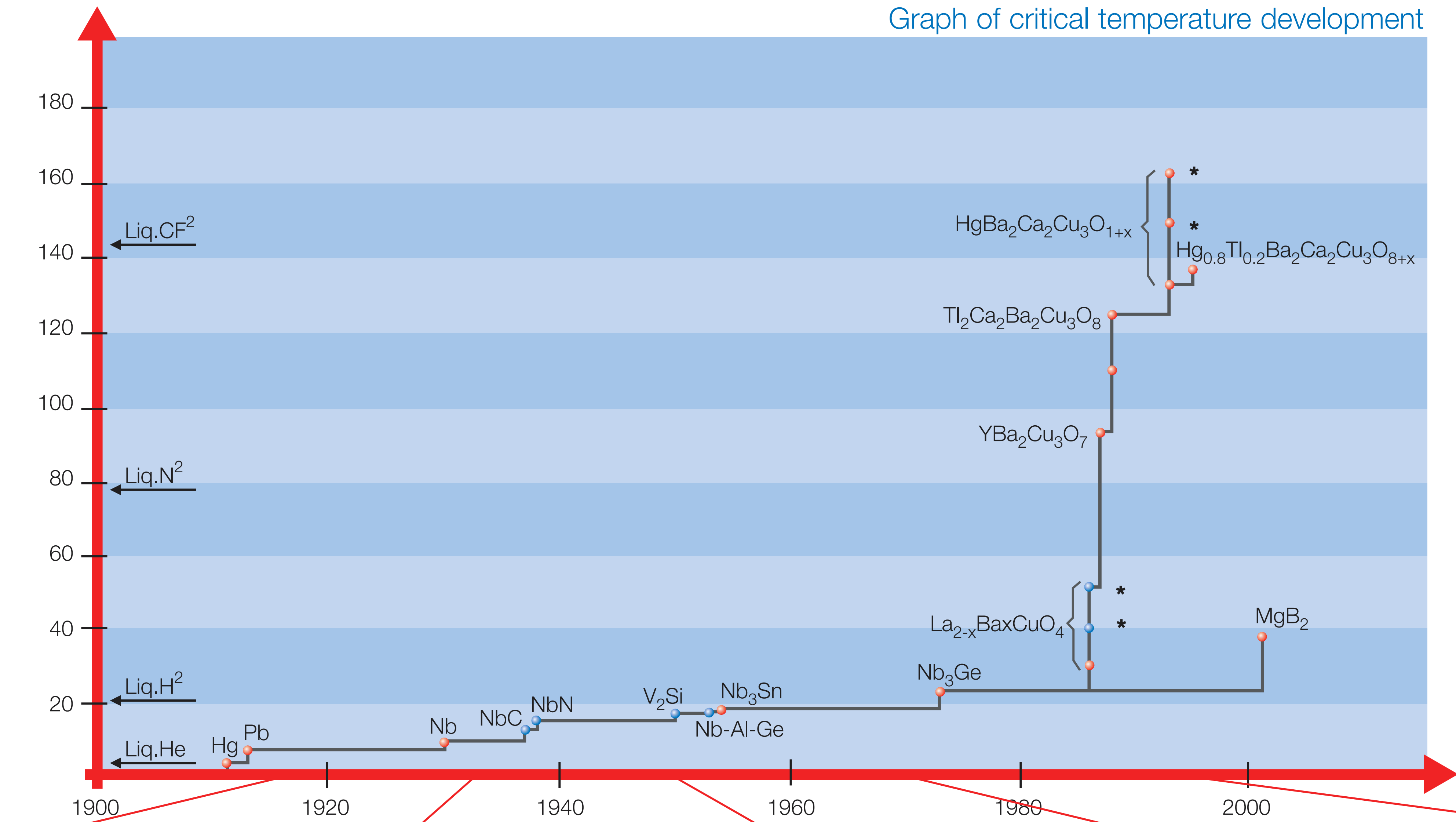
History of Superconductivity

SUPERCOMET
Superconductivity Multimedia Educational Tool

Graph of critical temperature development



On July 10, 1908 professor Heike Kamerlingh Onnes managed for the first time in history to cool down the noble gas of helium (He) to a temperature of 4.2K or -269∝C where it condenses to a liquid. This was the key for discovering superconductivity. Professor Onnes assumed that the electric resistance of metals would steadily decrease with temperature, but some physicists predicted that the resistance of metals would become infinite at 0 K (absolute zero). In 1911 Onnes used liquid helium to cool mercury (Hg), and found that at first the resistance decreased steadily as the temperature dropped just as he had expected, but at about 4 K all electrical resistance suddenly disappeared! This was unexplicable by any existing theory. Onnes had discovered superconductivity, a discovery for which he received the Nobel Prize in 1913.

Superconductors have two remarkable attributes. One is the ability to conduct electric current at zero resistance. The other ability has to do with magnetic fields, and was discovered in 1933 by Walter Meissner and Robert Ochsenfeld in Germany. When a material becomes superconducting, it ejects any magnetic field lines that would normally go straight through it. This property is called the Meissner effect.

In 1950 the Soviet scientists Vitaly Ginzburg and Lev Landau published a theoretical framework for superconductors. Even though the theory is purely phenomenological it has turned out to be extremely useful and applicable to most superconductors, including high-temperature superconductors. The Nobel Prize in Physics for 2003 was awarded to Ginzburg for his work.

A few year later, in 1957 at Illinois University professor John Bardeen together with the young Ph.D. student J. Robert Schrieffer and Leon N. Cooper developed a complete theory for how superconductivity works in metals. The theory is now called the BCS theory. Their theory worked out in great detail how pairs of electrons form Cooper pairs and how they are the foundation of superconductivity. Bardeen, Cooper and Schrieffer received the Nobel Prize in Physics in 1972 for this work.

The same year as the BCS theory was published, a decisive work of Alexei Abrikosov in the Soviet Union was published, where he showed that the magnetic flux in superconductors may be quantized for a certain type of superconductors called type II. It turned out that type II superconductors could be used to make powerful electromagnets. Such electromagnets can be used for many different applications, especially in research laboratories, and in the medical area of MRI (Magnetic Resonance Imaging). In 2003 Alexei Abrikosov shared the Nobel Prize in Physics with Vitaly Ginzburg for his theory on flux quantization.

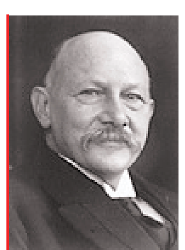
The French scientist D. Jèrome and the Danish scientist Klaus Bechgaard with collaborators discover organic superconductors in their laboratory in Paris in 1979. They combined the organic molecule TMTSF (tetramethyltetraselenafulvalenium) with phosphorus and fluorine to (TMTSF)2PF6 and found it to be superconducting!

In 1986, the German born scientist J. George Bednorz and the Swiss scientist K. Alex Müller working at the IBM Research Laboratory near Zurich discover record breaking high Tc superconductivity in the compound La2-xBaxCuO4, Lanthanum Barium Copper Oxide, with a critical temperature of 30 K. The compound is a ceramic material in a group of compounds called cuprates. Compared to the development during the first 75 years since the discovery of superconductivity, this was a big step forward. The LaBaCuO compound was therefore called a high temperature superconductor. In 1987 Bednorz and Müller receive the Nobel Prize in Physics for this work.

A great European scientific goal was achieved when the Large Electron-Proton Collider (LEP) started up in Genova at CERN in 1989. Particles are accelerated in a 26.67 km main ring and guided by conventional electromagnets. However, at every experimental collision point superconducting magnetic quadrupoles are used to focus the beam. The LEP has proved to be an outstanding tool for understanding the physics of elementary particles.

In 1994 the current world record critical temperature at 164 K was reached with the cuprate HgBa2Ca2Cu3O10+x. To achieve superconductivity at such a high temperature, the sample was put under a pressure of 31 GPa, which is 306.000 times the atmospheric pressure on the surface of the earth.

For many years bottles of powdered magnesium diboride (MgB2) has been common in chemistry labs, but not until January 2001 did Japanese scientists discover it to be superconducting! It proved to have a critical temperature of 39 degrees Kelvin, which is much higher than most metal superconductors. The alloy exhibits rather exotic superconducting characteristic such as two superconducting energy gaps related to two types of Cooper-pairs. The discovery of MgB2 has uncovered a new type of superconductor which may eventually break the record of critical temperature. The compound has turned out to be a very promising material for superconductor applications.

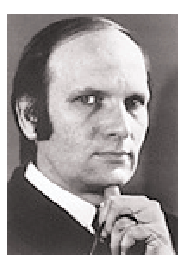


1913

Nobel Prize to Holland

Heike Kamerlingh Onnes received the Nobel Prize in Physics for his work in low temperature physics which culminated in the liquefaction of helium and his discovery of superconductivity in mercury and other materials. Scientists discovered many metals that displayed the same peculiar property as mercury did, such as lead (Pb), tin (Sn), aluminum (Al), indium (In) and Gallium (Ga). However the best conducting metals at room temperature, gold, silver and copper, are not superconductors for any temperature.
The transition from regular electric conductivity to superconductivity in mercury happened at about 4 K, and this temperature was therefore called the critical temperature Tc for mercury.

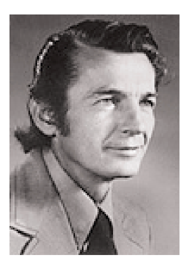




1972

Nobel Prize to USA

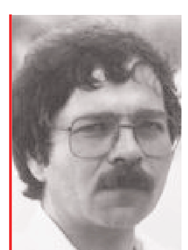
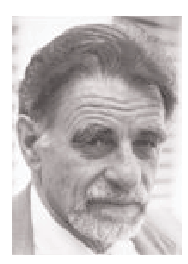
The American physicists **John Bardeen**, **Leon N. Cooper** and **J. Robert Schrieffer** share the Nobel Prize in Physics for publishing the BCS theory of superconductivity in 1957. It was the second time Bardeen was awarded the Nobel Prize in Physics – he received the first one in 1956 (together with William B. Shockley and Walter H. Brattain) for the invention of the transistor. Therefore, Bardeen was called “the great one” by his colleagues.


1973

Nobel Prize to Japan, Norway and UK

Leo Esaki from Japan, **Ivar Giaever** from Norway (now a US citizen) and **Brian D. Josephson** from England share the Nobel Prize in Physics. Giaever and Esaki received the prize for their experimental discoveries regarding tunneling phenomena in superconductors and semiconductors respectively, while Josephson was awarded for the theoretical prediction of the Josephson effect. Leo Esaki was awarded the prize for his pioneering work on tunneling processes in solids conducted in 1958, while Giaever had taken the next important step in 1960 by probing the superconductor energy gap through a tunneling experiment. This inspired Josephson to work on a theory for the supercurrent between two superconductors which was published in 1962.

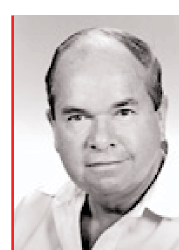
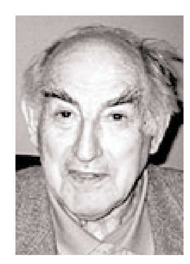



1987

Nobel Prize to Switzerland

J. George Bednorz and **K. Alex Müller** from the IBM laboratories in Switzerland share the Nobel Prize in Physics for their discovery of superconductivity in ceramic materials, heralding a new era of research and discoveries of new superconducting materials, and an explosive effort to develop new superconductivity applications. These high temperature superconducting ceramic materials all contain layers of copper and oxygen and are therefore called cuprates. They all belong to a family of crystalline ceramics called perovskites. It has turned out that the physical properties of these superconductors cannot be explained by the BCS theory. A lot of work has been invested in understanding the quantum mechanical theory, and the matter is still unsolved.

The discovery of these superconductors opened up new possibilities for applications of superconductivity because most high temperature superconductors can be cooled down using liquid nitrogen (N2), which is a lot cheaper than liquid helium (He). Liquid nitrogen has a boiling point of 77K, much higher than the boiling point of liquid helium at 4.2K. Thus it is much cheaper to use high temperature superconductors than it is to use low temperature superconductors since cooling to 77 K is much simpler than cooling helium to 4.2 K.


2003

2003 Nobel Prize for superconductor theory

Alexei A. Abrikosov, **Vitaly L. Ginzburg** and **Anthony J. Legget** are awarded the Nobel Prize in Physics for their work concerning superconductivity and superfluidity. Vitaly Ginzburg contributed to the development of the Landau-Ginzburg theory for superconductors published in 1950. In 1957 Alexei Abrikosov applied this theory for superconductors in the presence of magnetic fields, and found that the magnetic field penetrates the superconductor in the form of flux tubes with a unitary magnetic flux. We call this a flux quantum or a vortex. Abrikosov's work established the defining criterion for the distinction between type I and type II superconductors. Anthony Legget has worked on a phenomenon closely related to superconductivity called superfluidity.

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The SUPERCOMET Project aimed to:
- **Set up an international partnership with competence related to the renewal of physics teaching across Europe.**
- **Establish firm connections with existing organizations for physics educators, researchers in physics education, as well as curriculum authorities and policy makers.**
- **Develop a concept for products related to physics education that may be put to use immediately, simultaneously allowing for expansion with regard to subject and scope.**

The project partners are:
- **Norwegian University of Science and Technology (NTNU)**
- **Simplicatus AS, Norway**
- **Istituto Tecnico Commerciale Statale ‘Enrico Tosi’, Italy**
- **Zanichelli Editore S.p.a, Italy**
- **Katedralskolen i Trondheim, Norway**
- **Faculty of Education, University of Ljubljana, Slovenia**
- **Institute of Education, University of London, UK**