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The History of Superconductors

Superconductors, materials that have no resistance to the flow of electricity, are one of the last great frontiers of scientific discovery. Not only have the limits of superconductivity not yet been reached, but tl theories that explain superconductor behavior seem to be constantly under review. In 1911 superconduct was first observed in mercury by Dutch physicist Heike Kamerlingh Onnes of Leiden University (shown above). When he cooled it to the temperature of liquid helium, 4 degrees Kelvin, its resistance suddenly disappeared. The Kelvin scale represents an "absolute" scale of temperature. Thus, it was necessary for Onnes to come within 4 degrees of the coldest temperature that is theoretically attainable to witness the phenomenon of superconductivity. Later, in 1913, he won a Nobel Prize in physics for his research in this area.

The next great milestone in understanding how matter behaves at extreme cold temperatures occurre 1933. Walter Meissner and Robert Ochsenfeld discovered that a superconducting material will repel a magnetic field. A magnet moving by a conductor induces currents in the conductor. This is the principle which the electric generator operates. But, in a superconductor the induced currents exactly mirror the f that would have otherwise penetrated the superconducting material - causing the magnet to be repulsed. phenomenon is known as diamagnetism and is today often referred to as the "Meissner effect". The Meis effect is so strong that a magnet can actually be levitated over a superconductive material.

In subsequent decades other superconducting metals, alloys and compounds were discovered. In 1941 Niobium-Nitride was found to superconduct at 16 K. In 1953 Vanadium-Silicon displayed superconducti properties at 17.5 K. And, in 1962 scientists at Westinghouse developed the first commercial superconducting wire, an alloy of Niobium and Titanium. The first use of this wire in high-energy, particle-accelerator electromagnets, however, did not come until 1987 when it was employed at the Ferm Tevatron.

The first widely-accepted theoretical understanding of superconductivity was advanced in 1957 by American physicists John Bardeen, Leon Cooper, and John Schrieffer (above). Their *Theories of Superconductivity* became know as the BCS theory - derived from the first letter of each man's last name - and won them a Nobel prize in 1972. The mathematically-complex BCS theory explained superconductiv at temperatures close to absolute zero for elements and simple alloys. However, at higher temperatures and with different superconductor systems, the BCS theory has subsequently become inadequate to fully expl how superconductivity is occurring.

Another significant theoretical advancement came in 1962 when Brian D. Josephson, a graduate stude Cambridge University, predicted that electrical current would flow between 2 superconducting materials even when they are separated by a non-superconductor or insulator. His prediction was later confirmed a won him a share of the 1973 Nobel Prize in Physics. This tunneling phenomenon is today known as the "Josephson effect" and has been applied to electronic devices such as the SQUID, an instrument capabable of detecting even the weakest magnetic fields.

The 1980's were a decade of unrivaled discovery in the field of superconductivity. In 1964 Bill Little o Stanford University had suggested the possibility of organic (carbon-based) superconductors. The first of these theoretical superconductors was successfully synthesized in 1980 by Danish researcher Klaus Bechgaard of the University of Copenhagen and 3 French team members. $(TMTSF)_2PF_6$ had to be cooled to an incredibly cold 1.2K transition temperature (known as Tc) and subjected to high pressure to superconduct. But, its mere existence proved the possibility of "designer" molecules - molecules fashioned to perform in predictable way.

Then, in 1986, a truly breakthrough discovery was made in the field of superconductivity. Alex Mülle Georg Bednorz (above), researchers at the IBM Research Laboratory in Rüschlikon, Switzerland, create brittle ceramic compound that superconducted at the highest temperature then known: 30 K. What mad discovery so remarkable was that ceramics are normally insulators. They don't conduct electricity well a So, researchers had not considered them as possible high-temperature superconductor candidates. The Lanthanum, Barium, Copper and Oxygen compound that Müller and Bednorz synthesized, behaved in a not-as-yet-understood way. (Original article printed in Zeitschrift für Physik Condensed Matter, April 198 The discovery of this first of the superconducting copper-oxides won the 2 men a Nobel Prize the followin year. It was later found that tiny amounts of this material were actually superconducting at 58 K, due to small amount of lead having been added as a calibration standard - making the discovery even more noteworthy.

Müller and Bednorz' discovery triggered a flurry of activity in the field of superconductivity. Researchers around the world began "cooking" up ceramics of every imaginable combination in a quest higher and higher Tc's. In January of 1987 a research team at the University of Alabama-Huntsville substituted Yttrium for Lanthanum in the Müller and Bednorz molecule and achieved an incredible 92 K For the first time a material (today referred to as YBCO) had been found that would superconduct at temperatures warmer than liquid nitrogen - a commonly available coolant. Additional milestones have si been achieved using exotic - and often toxic - elements in the base perovskite ceramic. The current world record Tc of 138 K is held by a molecule of Mercury, Thallium, Barium, Calcium, Copper and Oxygen. This ceramic superconductor was created in 1995 by the team of Dai, Chakoumakos, (O.R.N.L.) Sun, Wong, (Univ. of Kansas) Xin, and Lu (Midwest Superconductivity Inc.). Under extreme pressure its Tc can be coaxed up even higher - approximately 25 to 30 degrees more at 300,000 atmospheres.

While no significant advancements in superconductor Tc's have been achieved in recent years, other discoveries of equal importance have been made. In 1997 researchers discovered that at a temperature ve near absolute zero an alloy of gold and indium was both a superconductor and a natural magnet. Conventional wisdom held that a material with such properties *could not exist!* Recent years have also seen

the discovery of the first high-temperature superconductor that does NOT contain any copper - and the discovery of the first plastic superconductor !

Startling - and serendipitous - discoveries like these are forcing scientists to continually re-examine longstanding theories on superconductivity and to consider heretofore-unimagined combinations of elem

[Note: For additional, more-esoteric history, visit the "Atypical" page.]

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