Periodic Graphics

A collaboration between C&EN and Andy Brunning, author of the popular graphics blog *Compound Interest*

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To see more of Brunning's work, go to **compoundchem.com.** To see all of C&EN's Periodic Graphics, visit **cenm.ag/periodicgraphics.**

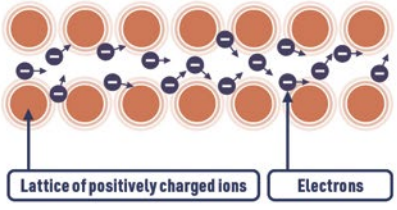
The science of superconductors

PERIODIC GRAPHICS

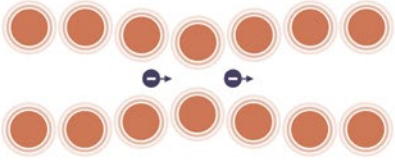
Superconducting materials, capable of conducting electricity without resistance, have fascinated scientists for over a century. Here we examine what they are, how they've been found, and how we use them.

What are superconductors?

When we pass electrical current through a conducting solid, electrons collide with themselves and the lattice of ions in the solid, causing resistance. At low temperatures, there are fewer vibrations, fewer collisions, and lower resistance.



In superconducting materials, electrical resistance drops to zero if they are cooled below a critical temperature (T_c) that is far below room temperature. In some superconductors, this resistance drop happens because electrons pair up and flow together, overcoming resistance. Scientists still don't know exactly how superconductivity happens in some types of superconductors.



The lattice is distorted by the first electron, creating a region of positive charge that pulls the second electron through.

A short history of superconductors

1911 The first superconductor

Physicist Heike Kamerlingh Onnes discovers superconductivity in mercury in 1911 by cooling it with liquid helium. Other scientists find superconductivity in other metals in subsequent years.

Name		Mercury		Lead
T_c	Hg	-269.2 °C	Pb	-265.9 °C

1986 High-temperature superconductors

J. Georg Bednorz and K. Alex Müller discover superconductivity in a copper oxide ceramic. C. W. Chu modifies this copper oxide to make a superconductor with a critical temperature achievable using liquid nitrogen as a coolant.

LaBaCuO	Lanthanum barium copper oxide	-243.1 °C
YBaCuO	Yttrium barium copper oxide	-180.1 °C

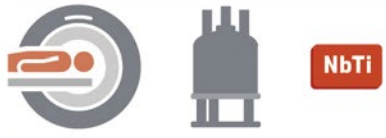
1993 Current record holder

Scientists make the highest-temperature superconductor at ambient pressure to date. Room-temperature superconductors remain elusive.

HgBaCaCuO	Mercury barium calcium copper oxide	-140.1 °C

Superconductor applications

MRI scanners and NMR machines



Magnetic resonance imaging (MRI) machines in hospitals use electromagnets made from superconducting niobium-titanium (Nb-Ti) wire. Liquid helium cools the wire to superconducting temperatures. Nuclear magnetic resonance machines, which analyze organic compounds, work similarly.

Superconducting maglev trains

Superconducting magnetic levitation railways in Japan use Nb-Ti magnets on trains to induce a current in the metal coils positioned under the tracks and drive the train forward.

Particle accelerators

Superconducting Nb-Ti or niobium-tin magnets in particle accelerators such as the Large Hadron Collider generate the magnetic fields and electric fields needed to steer and accelerate particles.