Cryogenics: New Superconducting Materials Announced at Dallas

The property of some metals to carry an electric current without resistance when cooled to sufficiently low temperatures was first demonstrated in 1911, and it was soon shown that this property of superconductivity could be suppressed if a strong enough magnetic field penetrated the metal. Advances in superconductivity since that time have been sporadic and infrequent. It was 1957 before a theory of superconductivity was developed (the theory still does not explain many experimental observations), and the first practical application—a superconducting magnet—was not developed until 1961. The announcement of two developments in superconductivity at the American Physical Society meeting in Dallas last week, therefore, represents an unusual advance in this field of science.

One of the announcements was of a compound that has been developed over the past few years with the object of making a substance that becomes superconducting at a relatively high temperature—that is, the substance has a high transition temperature. This substance has now been prepared so that it remains superconducting in magnetic fields that are almost twice as strong as fields previously required to suppress superconductivity.

The other announcement was that a class of compounds consisting of organic molecules sandwiched between metallic layers display superconductivity. These are the first superconductors containing organic molecules and may be the first substances that restrict the conducting electrons to two dimensions.

For just about any application of superconductors — including transmission of electric power — a high transition temperature is desirable because the cost of cooling is a major expense. An important point in transition temperatures is 20.38 kelvins—the boiling point of hydrogen—because such a transition temperature makes it possible to cool the superconductor with hydrogen rather than with helium.

The only superconducting devices now in commercial production are magnets, which are likely to be the main use for superconductors in the near future. The need for substances capable of withstanding high magnetic fields is therefore obvious.

In 1954 Brend Matthias (University of California, San Diego, and Bell Telephone Laboratories) found that a compound of niobium and tin (Nb_3Sn) became superconducting at 18 kelvins. For the next 13 years, trials with thousands of compounds failed to yield one with a substantially higher transition temperature. In 1967 Matthias reported that a mixture of Nb_3Al and Nb_3Ge (niobium with aluminum and with germanium) became superconducting at about 20 kelvins, and in the fall of 1968 he reported that a mixture with the ratio of $Nb_{0.79}(Al_{0.75}Ge_{0.25})_{0.21}$ became superconducting at 20.98 kelvins —a narrow but significant margin over the boiling point of hydrogen.

This substance could withstand a magnetic field of about 220,000 gauss. For several years Matthias has worked with Ernest Corenzwit (Bell Telephone Laboratories) on different methods of preparing the alloy—primarily changes in annealing techniques—in an effort to increase its resistance to magnetic fields. At the Dallas meeting it was reported that the substance could remain superconducting at 4.2 kelvins in the presence of a field of 410,000 gauss (about 10^6 times the strength of the earth's field).

To test the new material it was necessary to construct a special pulsed magnet capable of generating the required field. This was done by Simon Foner (who reported the results at Dallas) and Edward McNiff, both from the Francis Bitter National Magnetic Laboratory of Massachusetts Institute of Technology.

Commercial use of the new superconductors will be at least several years away because of the difficulty of fabricating wires from the material. The alloy that becomes superconducting at 18 kelvins—Nb_3Sn—has been produced commercially in wire form since 1961 —7 years after it was discovered. It will undoubtedly be more difficult to prepare the new substance in wire form; but if an intensive development effort were directed toward the problem, it would not necessarily take longer.

For the development of the niobium-aluminum-germanium alloy and related compounds, Theodore Geballe (Stanford University and Bell Telephone Laboratories) and Matthias were awarded this year's Oliver E. Buckley Solid State Physics prize. At the award ceremonies in Dallas, Geballe announced the discovery of a new class of superconducting substances.

A little less than a year ago, Geballe, Frederick Gamble (Synvar Associates in Palo Alto, California), and two students, Francis Di Salvo and Richard Klemm, began investigating a class of compounds called dichalcogenides. These compounds have a layered structure somewhat like graphite and are capable of holding organic molecules between the layers. Examples are niobium sulfide and tantalum sulfide (NbS_2 and TaS_2) crystallized with a variety of organic compounds such as pyridine and aniline. About 20 such compounds have been found to be superconducting, typically at temperatures of a few kelvins.

There seems to be no clear correlation between the nature of the layered metals, the types of organic compounds used, and the transition temperatures. In most cases the transition temperature rises somewhat after the addition of organic molecules, and in no case does the addition destroy superconductivity.

Geballe and Gamble believe that they have demonstrated that superconductivity can take place in structures that are two-dimensional. That is, they think that the electrons can move only in the metallic layers that are about 6×10^{-8} centimeters thick and that they are separated by layers of organic molecules up to 18×10^{-8} centimeters thick. Geballe says that the new compounds offer an opportunity to examine present theories of two-dimensional electronic systems. In addition, there have been ideas about the possibility of superconductivity resulting from the interaction between electrons and organic molecules, but until now there have been no superconducting systems on which to test these ideas.

The new superconducting compounds will undoubtedly stimulate further theoretical and experimental studies, but at the present time there is no obvious practical use for them.

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