Superconductors continue to give up their secrets

It has been less than a decade since the first breakthrough in achieving superconductivity at high temperatures. Mark Wilsey reports on some of the latest results in research.

In the past hundred years, the use of electricity has revolutionized both industry and society. The worldwide demand for electricity is expected to at least triple by the middle of the next century. Superconductivity holds the promise of revolutionizing our use of electricity. Magnetically levitated trains, advanced energy storage systems, and high-performance supercomputers are but a few of the applications that will come out of the continuing development of superconductor technologies.

The key is that a superconductor can transmit electricity with no energy loss, because it offers no resistance to the flow of electricity. In conventional conductors, electrical resistance converts the energy loss into heat, which hurts the efficiency of electrical devices. The drawback with applying superconductors to technology has been that, so far, extremely low temperatures are required for them to achieve zero resistance.

For decades, only a handful of metals and alloys were known to act as superconductors at temperatures just a few degrees above absolute zero, 0 Kelvin, or −273°C. Obtaining such low temperatures has made the application of superconductivity difficult and expensive. However, in recent years, researchers have discovered materials which are superconducting at the more moderate temperature of liquid nitrogen, 77 K. The cost of liquid nitrogen as a coolant is a small fraction of that of liquid helium at 4 K. With these discoveries in hand, it would seem that practical uses of superconductivity are more feasible.

Superconducting at high temperatures

It was in 1986 when a team of researchers at an IBM laboratory in Zurich, Switzerland announced that they had achieved superconductivity in a ceramic-like material at a record temperature of 30 K (see *EIR*, Vol. 14, No. 25, 1987, "What High-Temperature Superconductors Promise"). This set off a flurry of activity worldwide. By early 1987 Paul Chu at the University of Houston reported the development of a superconductor with a critical temperature of 95 K. (The critical temperature, or T_c, is the temperature at which a material becomes superconductive.) The era of high-temperature superconductors was born.

Chu's compound was composed of yttrium, barium, copper, and oxygen, and was dubbed YBCO. Other copper-oxide superconductors soon followed based on thallium or bismuth, with calcium and strontium and other elements mixed in. From 1986 to 1988 the record T_c for superconductors rose by 100°. However, these materials are brittle, and have therefore proven difficult to form into useful shapes, such as the wires shown in the picture on the opposite page. Nonetheless commercialization of high-temperature superconducting is moving steadily ahead.

In the early 1990s the economic potential of these materials was recognized by technology analysts, and HTSC was declared a critical technology. Today there is a $1.5 billion market for superconductors. It is estimated that this will grow to $8-12 billion by 2000 and $150-200 billion by 2020. The Department of Energy formed High-Temperature Superconductivity Pilot Centers at Argonne, Los Alamos and Oak Ridge National Laboratories to aid industry in developing this technology. The Defense Department, through the Advanced Research Projects Agency (ARPA) and the Ballistic Missile Defense Organization (BMDO), also funds superconductivity research, as well as other government agencies.

Imaging and detection uses

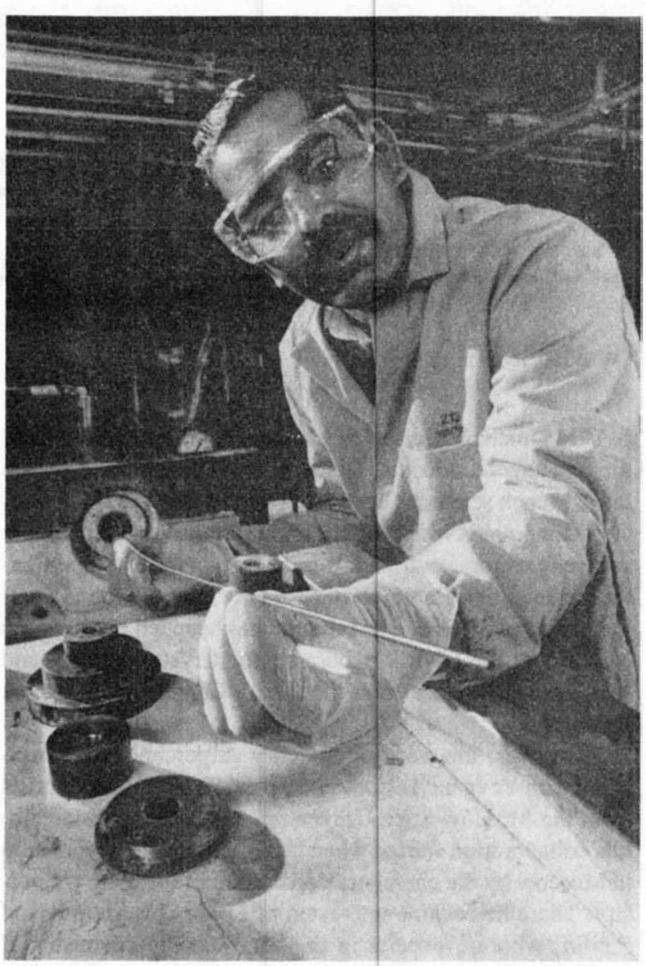
One area where high-temperature superconductors are beginning to come into commercial use is in microelectronics and sensor applications. Making use of advances in thin film technology, manufacturers are finding ways to fashion products from thin layers of superconducting material applied to a surface. Superconducting thin films have been used in components of microwave systems to improve the performance of communications devices and radar equipment a hundredfold.

A magnetic-sensing device called a superconducting quantum interference device (SQUID) is another application for high-temperature superconductors. A SQUID is a circuit of superconductor on silicon with a small section that is not strongly superconducting. The flow of electrons through that section is extremely sensitive to magnetic fields, which can be measured as a change in voltage in the SQUID. Such devices can aid engineers in discovering defects in structures or geologists in prospecting for petroleum. In the field of medicine, using high-temperature superconductors, SQUIDs may soon be sensitive enough to detect the electromagnetic signals of the heart and brain. High-temperature superconductors can also be used in magnetic resonance imaging system coils, where they would improve the images, although they would not reduce the size and cost of the equipment.

Superconducting power transmission?

Progress is also being made in the production of electrical wires: Ductile high-temperature superconducting wire of several hundred meter lengths are being produced routinely by what is called the powder-in-the-tube method. Typically a silver tube is packed with a precursor powder, perhaps the components for bismuth-strontium-calcium-copper oxide (BSCCO), a high-temperature superconductor with which this process works well. Then the tube is rolled and heated to turn the powder into BSCCO. The silver sheath gives the wire flexibility and provides an alternative pathway for the current if superconductivity is lost.

Once the manufacturing of high-temperature superconducting wires in kilometer lengths is perfected, we can begin imagining how they could be used to improve the tranmission of power itself: A superconducting powerline could carry three to five times more electricity than a copper line. Utilities could also use high-temperature superconductors in devices called fault-current limiters, which shunt power surges to prevent damage to substations, thereby eliminating circuit breakers and fuses. Further on, we can envision the development of superconducting magnetic energy storage (SMES) systems. Energy is stored in the SMES coils, and, since there is no resistance, the current could circulate forever, to be tapped when needed.



Balu Balachandran of Argonne National Laboratory in Illinois stretches silver-clad high-temperature superconductor (HTSC) wire as part of joint research with Intermagnetics General Corp. The goal of the project is to develop practical lengths of wire 100 feet long using HTSCs, which offer no resistance to electrical flow.

The next couple of years will see many advances in the commercialization of high-temperature superconductors, particularly in electronics. However, the basic science of superconductivity will continue to see advances as well. Theorists tell us that there is no basis to assume there is an upper limit to superconductivity and a room-temperature superconductor is not out of the question.

In our two reports below, we take a look at some of discoveries being made in France and elsewhere in superconducting mercury compounds. Our interview with Dr. Masato Murakami about his research into superconducting magnets, includes the exciting possibilities of applying trapped magnetic fields for development of new magnetic levitation systems in transportation. The confidence of Dr. Murakami and his associates is such that, although they continue to conduct research in its embryonic stage, he is already reporting on a nine-year program to develop prototype trains.