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SUPERCONDUCTOR PROGRESS IS ELECTRIFYING RESEARCHERS

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Caption: John Trotter -- Mercury News
SUPER CERAMIC -- Edward Engler, left, and Paul Grant show new superconductor they've made at IBM in San Jose.
CHART: Record-setting superconductors. Mercury News

In a San Jose IBM lab last Sunday afternoon stood a shiny tank of intensely cold liquid helium. Suspended inside was a gritty black ceramic sliver, trailing four wires. The other ends of the wires were connected to a meter that measured the sliver's resistance to electric current.

Paul Grant, directing the experiment, stood nearby at the telephone, telling a colleague in New York what the needle on the meter was doing as the ceramic sliver got colder.
The needle suddenly dropped to zero.
"We both went into hysterical laughter," Grant says.
He had just duplicated a novel new superconductor, a material that, when cold, can transmit an electrical current forever.
The practical results -- although several years of hard work away -- could be stunning, researchers say.
"If the results . . . hold up and can be translated into productive devices, it will revolutionize both the electrical industry and the electronics industry," said Carl Rosner, president of the country's largest superconductor company.
"The amount of energy to be saved would go into the billions of dollars."
The study of superconductors, a nearly stagnant corner of science, has been hopping for the past two months. Scenes like that at IBM are occurring in a dozen labs around the world as exuberant physicists cook up and test samples of a fantastic substance they can scarcely believe and don't really understand.
Unlike previous superconductors, the new one works at a temperature that's easy and inexpensive to maintain. That suddenly makes possible a myriad of applications:
(check) More efficient transmission lines that would let utilities build power plants hundreds of miles away from cities.
(check) Smaller, faster computers and other electronic devices.
(check) Trains zipping nearly frictionless down their tracks, supporting themselves with powerful magnets maintained by endlessly circulating electricity.

(check) More efficient electric motors and generators.
(check) Inexpensive medical diagnostic instruments that can provide vivid images of the body's interior without the invasive effects of X-rays.

"I think that these developments are potentially as important as the discovery of the transistor and laser," said Mario Rabinowitz, a senior scientist investigating advanced projects at the Electric Power Research Institute in Palo Alto. Many of his colleagues around the country echoed his sentiments.

Superconductivity overturns a fundamental constraint that we take for granted: Electric current is hindered by small amounts of subatomic friction, even in the best conductors, at normal temperatures. That friction keeps electrons from flowing at top efficiency. A typical electric circuit has been compared to a garden hose with a lot of holes in it.

But maybe it doesn't have to be this way. What if electrons could skate down their wires without encountering resistance?

That's what a Dutch physicist, Heike Onnes, discovered in 1911, when he found that the element mercury offers no resistance to current when cooled to 4.2 degrees Kelvin.

(Scientists measure extremely cold temperatures in degrees Kelvin. For convenience, zero Kelvin is set at absolute zero, the hypothetical temperature at which all molecular motion ceases. On the Fahrenheit scale, that's minus 459 degrees.)

It took 40 years for theorists to explain what Onnes had found. They believe that the vibrating "lattice" of molecules in certain substances, when sufficiently cooled, allows pairs of electrons to slip through without hindrance.

Experimenters went on to find hundreds of compounds that are superconductive when cooled nearly to absolute zero.

But these substances are of little use, since the only coolant capable of reaching 4 degrees Kelvin, liquid helium, is difficult to maintain and rarely worth the cost. The major superconductor uses today are in the powerful magnetic resonance imaging instruments, which use magnetic fields to probe tissue, bones and organs in the body, and in the magnets used to confine subatomic particles in particle accelerators and nuclear fusion experiments.

Instead, "it has long been the dream of visionaries that room-temperature **superconductivity** would be possible," Rabinowitz said.

In 1973, researchers took a small step in that direction, when they found an alloy of the elements niobium and germanium that was superconductive at 23 degrees Kelvin. That prompted a flurry of interest, but no one could improve on it.

By the early 1980s, government and private research funds for **superconductivity** started drying up and the field became "dormant," said Earl Skelton, a physicist at the U.S. Naval Research Laboratory in Washington, D.C. Then last year, two researchers at an IBM laboratory in Zurich, Switzerland, following up on a hunch, made a mixture of several oxides -- materials better known as insulators than conductors.

They published a cautious report in September, telling their colleagues that the substance had passed one of the two standard tests for **superconductivity**, when cooled to about 30 degrees Kelvin.

And they gave the recipe: barium, lanthanum, copper and oxygen.

Within weeks, they and labs in Houston and Tokyo got the substance to pass the second test. It was the first record- setting superconductor in 13 years.

With no sure theory to explain how it worked, and thus no theoretical limit to how warm they might go, researchers in a dozen labs tried to imitate, and then improve upon, the Zurich

superconductor, with remarkable success.
In their search, they substituted similar elements and tinkered with the proportions.
It's like "being in the kitchen and trying various seasonings," Skelton said. Since then, "the progress has been phenomenal," said Grant of IBM. "It's a real footrace now."
Late last month came the most astounding news so far, that Paul Chu of the University of Houston had substituted the element yttrium for the lanthanum and invented a compound that was superconducting at 98 degrees Kelvin.
That was a breakthrough because anything above 77 degrees Kelvin can be maintained with liquid nitrogen, a refrigerant far cheaper and more efficient than liquid helium. "Nitrogen is easy to obtain. You can get it out of the air," Rosner said.
Within the past week, teams in Japan and all over the United States reported duplicating Chu's work, making samples that look like small chips of asphalt. Grant's team learned the formula on a Friday, went to work that evening and got it to work on Sunday.
"I never thought I would see that in my lifetime," Grant said.
Some expect more amazing reports any day.
Chu's 98-degree mark is the current confirmed record, but his and at least three other labs are rumored to have seen promising hints last week of **superconductivity** in materials as warm as 240 degrees Kelvin, which is just 40 degrees below zero Fahrenheit -- a cold winter day in Wyoming.
"I wouldn't be surprised to find that by July we have a room-temperature superconductor," Skelton said.
Even if no one improves on Chu's record, scientists and engineers in many industries are envisioning big changes if his compound can be transplanted from the lab to the rest of the world.
Power transmission: Rabinowitz of EPRI, who a decade ago helped design transmission wires made with superconductors and liquid helium, believes a similar design might work now. Lines could carry current, with little loss, from hydroelectric plants in rainy regions or from solar-power plants in deserts, to people hundreds of miles away.
Thin tubes containing a copper wire wrapped or coated with a superconducting material would be buried in the ground. Liquid nitrogen would fill the tube; small refrigerators spaced along the line would keep the nitrogen cold.
EPRI, which is the research lab serving the country's electric utilities, is considering financing research into such a project.
Transportation: Skelton believes another important application might be trains carrying powerful electromagnets whose magnetic fields would be generated by a current circling endlessly through them. The magnets would repel the train's tracks, lifting it slightly into the air.
"It would make high-speed transportation significantly cheaper than it is today," Skelton said.
Electronics: "We are certainly very interested in the possibilities," said Robert Burmeister, a laboratory director at Hewlett-Packard.
One effect of zero resistance would be to reduce the time electrons take to get from chip to chip along the connecting lines, which in today's advanced electronics is a factor limiting their performance, an IBM spokeswoman said.
Another advantage would be in reducing the amount of waste heat emitted by those circuits, which now keeps engineers from packing components as densely as they otherwise could, said a spokesman for Hypres Inc., a company that already employs **superconductivity** in a computer it sells.

Most computer companies abandoned their efforts to develop superconducting computers several years ago because the cost of cooling outweighed the electronic advantages, said Mike Jacobs, a spokesman for Bell Laboratories in New Jersey.

"There's going to be a renewed interest in these devices," Jacobs said.

Motors and generators: "Everybody will re-look at every single electrical application" to try to improve performance, reduce power loss and further miniaturize circuits, Rosner said. "Motors, generators, every single electrical device would certainly be looked at very carefully and redesigned."

Medical imaging: It now costs $50,000 to $100,000 a year to cool the magnets in these instruments. If the magnets were made of higher-temperature superconductors, they could be refrigerated for just $1,000 per year, estimated Rosner, president of Intermagnetics General in Guilderland, N.Y.

Large questions remain about the ceramic substance's suitability for all these applications, however.

"There may be a long way to go from the lab to the circuit," Burmeister of HP said. "It's a little early to judge the full impact."

The two biggest questions are whether the substance might prove too brittle or unable to carry enough current to make it worthwhile.

Already, however, a ceramics expert at Argonne National Laboratories in Illinois has tried his hand at fabrication, with some success.

"We can make sheets and rods, tubes, bars, even cups," Roger Poeppel said. Although the substance is stiff after it's fired, sufficiently narrow strands might be flexible. Poeppel intends to make a strand a few thousandths of an inch thick. "We think it would be flexible enough to wrap around your finger," he said.

A group at Stanford University is taking another approach, working on ways to make the ceramic in thin films, which would be necessary for use in many electronic devices.

These efforts, and others in Japan, are just the first steps toward deciding how workable the substance is.

"It will take some pretty strong efforts in materials science," Grant said. "But the prospect is really exciting."