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A Sudden Host of Questions On Bell Labs Breakthroughs

By KENNETH CHANG MAY 28, 2002

Correction Appended

On a ski slope in Utah in March, Paul Grant and Rick Greene made a bet -- about superconductors.

Dr. Grant and Dr. Greene, who had been longtime colleagues at the I.B.M. Almaden Research Center in San Jose, Calif., had debated all day a sensational scientific report that molecules of carbon shaped like soccer balls had been turned into superconductors -- materials that carry electricity with virtually no resistance -- at surprisingly warm temperatures.

Dr. Grant doubts the findings. Dr. Greene said he thought that they they would be verified.

Last week, Dr. Grant sent an e-mail message reminding Dr. Greene of the wager, because the lead researcher of the experiment was Dr. J. Hendrik Schön, the Bell Labs scientist who is now the center of a scientific misconduct investigation. Nearly identical graphs appear in several of Dr. Schön's scientific papers, even though the graphs represent different data from different experiments. Bell Labs, part of Lucent Technologies, has convened an independent panel to investigate.

But even before the two main papers cited in the investigation were published, a debate had arisen over the superconductor claims.

"There's been a lot of buzz for well over a year," said Dr. Grant, now a science fellow at the Electric Power Research Institute in Palo Alto, Calif.

Dr. Schön and his collaborators have developed a revolutionary technique that allows them to explore systematically the electronic properties of various materials. Dr. Grant had called the team's "buckyball" work paper "a tour de force of physics" when it was announced. Other scientists said it might be worthy of a Nobel Prize.

The superconductor work is not among the seven papers that include the suspect graphs, which report advances in organic transistors and molecular electronics. But the investigation casts a pall over all of Dr. Schön's research. He has been an author on more than 70 scientific papers in the last two and a half years -- a remarkably prodigious output -- and some people wonder whether there might be undiscovered problems with other papers.

"That has to be the question on everybody's minds," said Dr. Arthur Hebard, a professor of physics at the University of Florida and a former Bell Labs scientist. "I have more skepticism about the data."

Dr. Schön's collaborators on the superconductor work -- Dr. Christian Kloc, a chemist at Bell Labs, and Dr. Bertram Batlogg, ex-director of solid state physics research at Bell Labs and now a professor of physics at the Swiss Federal Institute of Technology in Zurich -- are also co-authors of several of the questioned papers. Some researchers are increasingly disturbed that no one has reproduced the superconducting results since they were reported a year and a half ago.

"Good stuff will repeat itself in other laboratories," Dr. Hebard said.

Dr. Schön has declined to comment on the questions about his work other than that he stands by his results and that he will cooperate with the panel. Dr. Kloc also declined to comment, and efforts to reach Dr. Batlogg have been unsuccessful.

Bell Labs officials have said that the panel will investigate those questions and that Lucent will act on its recommendations.

Dr. Hebard was on a Bell Labs team that discovered in 1991 that buckyballs, molecules made of 60 carbon atoms arrayed in the shape of a soccer ball, could be

turned into superconductors when mixed with potassium, a process that adds electrons to carry the electrical current. Buckyballs are named after R. Buckminster Fuller, designer of the geodesic dome that they resemble.

But the buckyballs switched back into insulators at temperatures above minus 427 degrees Fahrenheit. Other researchers verified that work. But because so-called high-temperature superconductors work at considerably warmer temperatures, most researchers in the field soon lost interest.

The new team at Bell Labs, Drs. Schön, Kloc and Batlogg, took a radically different approach to making buckyball superconductors. In Nature on Nov. 30, 2000, the researchers reported that they had essentially built a transistor out of buckyballs. They placed a layer of aluminum oxide on top a neatly stacked crystal of buckyballs and then gold electrodes on the aluminum oxide.

The electrodes, the team reported, generated an electric field strong enough to yank an average of three electrons away from each buckyball. The "holes" left behind by the missing electrons were then able to condense into a superconducting current. The electron-depleted buckyballs were superconducting up to a temperature of minus 366 degrees, the scientists said.

In the paper, they also wrote that calculations indicated that if the buckyballs could be moved farther apart from one another, the superconducting temperature could be pushed up even more.

A year later, they reported in Science that they had achieved just that. By wedging bromoform, a molecule containing bromine, between the buckyballs, the team said it had raised the superconducting temperature to minus 249 degrees, warmer than most high-temperature superconductors.

But scientists who tried to reproduce the experiment have been stymied at the first step of the first experiment, making the layer of aluminum oxide, which acts as an insulator to prevent electric charge on the gold electrodes from arcing across to the buckyballs.

Because buckyballs hold their electrons tightly, pulling off one electron requires a strong electric field. Pulling three off requires a very strong electric field. But for

everyone else, the oxide layer failed at electric fields far weaker than those reported in the Bell Labs papers.

"We're off almost by a factor of 10," Dr. Hebard said, adding that it was possible that the Bell Labs researchers used special techniques not yet discovered by others.

"If it's correct," Dr. Hebard said, "it's a wonderful challenge. If it's not correct, it's very troubling."

Dr. Arthur P. Ramirez, a scientist at the Lawrence Livermore National Laboratory who was on the 1991 team that discovered buckyball superconductivity, said he believed that the researchers had achieved what they claimed -- superconducting buckyballs at minus 249 degrees. "It seems to hold together with previous work we did," he said.

Dr. Ramirez has also come closest to reproducing the work.

Using buckyball crystals provided by Dr. Kloc, Dr. Ramirez has produced transistors with aluminum oxide layers that withstand electric fields three times as strong as Dr. Hebard's, although it still needs to be three times as great as it is now to achieve superconductivity.

"It requires a combination of different expertises that is not commonly found in one place," Dr. Ramirez said. "We've been working on this for half a year, and it's pretty difficult."

The field of superconductivity is littered with remarkable claims that never reappeared in other laboratories. "When there's a real event, it reproduced relatively quickly," said Dr. Greene.

Even though the buckyball experiment has not been reproduced, Dr. Greene, director of the Center for Superconductivity at the University of Maryland, took the side of the Bell Labs researchers in his bet with Dr. Grant because of the credibility of Dr. Batlogg, a well-respected researcher in the field.

"On the other hand," Dr. Greene said, "there are some competent groups that have been working on this. I'm a little surprised it hasn't been reproduced."

Dr. Grant said the Bell Labs researchers should have gone out of their way to have someone else reproduce the experiment. "You want the greatest credibility you can gather," he said.

After protecting any potential commercial applications with patent applications, the researchers should have invited other scientists into their laboratory and provided a hands-on demonstration or gone to another lab and reproduced the experiment there, Dr. Grant said.

Although the first task of the investigating panel, headed by Dr. Malcolm Beasley, a professor of applied physics at Stanford, is to examine the issues raised so far, it has free rein to look at other areas of Dr. Schön's research, including the buckyball superconductors.

Correction: *May 29, 2002, Wednesday An article in Science Times on Tuesday about a debate over superconductor research at Bell Labs misstated the affiliation of Dr. Arthur P. Ramirez, a researcher who has reproduced part of the work. He is a scientist at Los Alamos National Laboratory, not Lawrence Livermore National Laboratory.*
