Race to Find the Key to Superconductivity

By Tsukasa Fukuma

Japan, the United States and other countries are racing to develop high-performance superconducting materials, which are being hailed as revolutionary new industrial materials that could transform society in the 21st century.

While the emphasis of research and development efforts differs from country to country, there is general agreement that superconductivity technology will have an enormous impact on industry. All are striving for a technological breakthrough, in many cases as a national undertaking. Active exchanges of personnel and information through international conferences and other channels further distinguish this unprecedented development drive.

The current fever over superconductivity research really began with a January 1986 paper by Dr. K. Alex Muller and Dr. J. Bednorz of IBM's research laboratories in Zurich that indicated the possibility of achieving superconductivity at relatively high temperatures using lanthanum ceramics. But it remained for Prof. Shoji Tanaka of the University of Tokyo and his research team to give the discovery the publicity it deserved. In November 1986, Tanaka's team conducted a series of tests confirming the conclusions of the IBM researchers' paper. The tests got wide publicity in the mass media, and the superconductivity race was on.

The theory of superconductivity has a long history. In 1911, the Dutch physicist Heike Kamerlingh Onnes demonstrated that resistance to electrical currents disappeared in mercury when it was cooled to extremely low temperatures.

Research and development efforts since then have concentrated mainly on harnessing superconductivity for use in nuclear fusion and MHD (magnetohydrodynamics) power generation and magnetically levitated trains. But the reliance on expensive liquid helium in existing superconductivity technology hindered commercial applications.

Therein lay the significance of the Zurich discoveries. Muller and Bednorz found that lanthanum ceramics became superconducting at 30K (243.16 degrees C below zero), using liquid nitrogen as a coolant instead of liquid helium. Liquid nitrogen costs only a twentieth as much as liquid helium. Suddenly commercially reasonable costs seemed within reach.

Crucial test

Tanaka's University of Tokyo team had been conducting research on oxide superconductors for nearly a decade. Checking out the IBM paper's hypothesis only required changing the chemicals and materials, explains Tanaka, who says the experiments were conducted with relative ease. The IBM paper said that no experiment had been conducted to confirm the crucial Meissner effect, a precondition of true superconductivity, in lanthanum ceramics. Within a week, Tanaka recalls, his team's experiments

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The 18th International Conference on Low Temperature Physics held in Kyoto in August 1987 were done and the presence of the effect confirmed. The ceramic compound really was a new high-temperature conductor. It took another month to confirm the material's crystal structure.

This work was followed by the discovery by University of Houston Prof. Paul Chu that a yttrium-bearing compound went into superconductivity when cooled in liquid nitrogen to 57K. On January 29, 1987, his team developed another yttrium-bearing compound that became superconducting at 90K, a temperature easily achieved using liquid nitrogen. Like Tanaka, Chu had confirmed the results of the IBM experiments soon after their announcement. He quickly found that the transition temperature for superconducting effects could be raised by increasing pressure on the material. But he reached the conclusion that it would be impossible to achieve a transition temperature of 60K or beyond with lanthanum-bearing materials.

Since then, researchers in various countries have rushed to develop materials that will become superconductors at ever higher temperatures. There were high hopes that the 18th International Conference on Low Temperature Physics, held in Kyoto in August 1987, would bring news of superconductors that worked at temperatures higher than 90K. But no clear-cut conclusions emerged, slowing the race on higher temperatures.

Prof. Shoji Tanaka of the University of Tokyo

The question of why some compounds become superconductors at certain temperature and others do not remains unanswered, and it is strongly felt that more basic research is needed. Many conference participants felt that superconductivity research has now entered a foundation-consolidating phase after several months of frenzied competition.

Worldwide effort

Nonetheless, the Kyoto sessions were instructive. The active exchange of information among front-line researchers shed light on the current state of research around the world. It was obvious that Japanese and U.S. universities, national research institutes and private enterprises are conducting research across a broad spectrum, ranging from fundamentals to applications. India, China and the Soviet Union, too, were found to be making active investments in research on superconductivity technology.

The United States has drawn special attention with a superconductivity research and development program announced by U.S. President Ronald Reagan. The U.S. government sponsored a conference in Washington D.C. last July on commercial applications for superconductors that was attended by Reagan, Energy Secretary John S. Herrington and U.S. Trade Representative Clayton Yeutter.

In his remarks at the meeting, Reagan stressed the massive impact superconductivity will have on scientific and technological development. His superconductivity research and development program calls for the federal government to revise pertinent laws to facilitate joint research and joint production of superconductors and superconductor products. It also expands the Defense Department's superconductivity-related budget, and calls for U.S. participation in Japan's superconductivity R&D program. It is the first time the United States has shown a national interest in developing a specific technology since the space program.

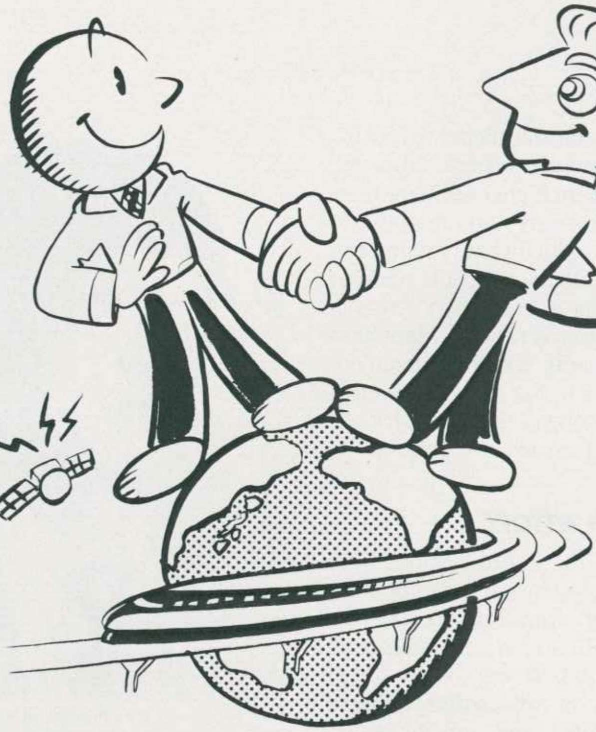
Prof. Paul Chu of the University of Houston

Chu, who visited Japan in August to attend the Kyoto conference, says the Washington gathering was intended to introduce scientists in this field to U.S. business executives and to bring them up to date on the present state of research and the potential of high-temperature superconductors. The federal government, however, has yet to lay out a clear-cut policy on aid for superconductivity research, Chu adds. He also points out that the U.S. president used the meeting to underline the need for more coordinated efforts by industry, the government and the academic community.

Great strides

One example of the seriousness with which the new technology is viewed in the U.S. is a decision by the State of Texas to set up a new superconductivity research center in the University of Houston. According to Chu, the center will primarily promote the application of superconductivity technology, and will eventually have a staff of some 200 researchers.

In Japan, too, preparations are under way to establish a framework for superconductivity development. According to Kozo Iizuka, director general of the Agency of Industrial Science and Tech-



nology of the Ministry of International Trade and Industry (MITI), a council for the development of superconductivity technology launched in April 1987 has already made suggestions on the appropriate course of future research. A proposal has been made for establishing an international research center on superconductivity technology, to be run as a private organization. Meanwhile, MITI has already set up an association for research on superconductivity applications for power generation equipment and materials which will begin full-scale activities in fiscal 1988. The Science and Technology Agency and the Education Ministry are also taking steps to facilitate research.

After the Kyoto conference, Tanaka, Chu and Iizuka discussed where things stand in this important field. The Kyoto conference, Tanaka said, made it clear that there are two courses for future research. One is to trace the basic physical properties of superconducting material, an area in which the U.S. in particular has made great strides. The other course is theoretical studies.

Tanaka said that superconducting materials must meet the four conditions of having no electrical resistance whatever, possessing recognizable Meissner effects, being experimentally reproducible and being stable as a material.

"Considerable efforts have so far been made to trace the physics or the physical properties of superconductors," said Chu. "Good-quality superconductors can be synthesized. In this sense, appreciable efforts have thus far been made to synthesize and coordinate such superconductors. Superconducting temperatures are now in the 40K–100K range, on the assumption that all four conditions for superconductors are met. There is potential for higher-temperature superconductors."

Another revelation of the Kyoto conference was the keen interest of private enterprises in commercial applications for superconductors. It is said that superconductivity technology will have almost as great an impact on industry and society as did the invention of the transistor. Some speculate that superconductivity will be harnessed for use in levitating trains, electromagnetic-propulsion ships, electricity storage equipment or still unimagined new devices that will be developed by fusing electronics and superconductivity technologies.

Chu forecast that superconductivity applications would probably start in the field of microelectronics. He said transistors have contributed greatly in the field of small-capacity current. Superconductivity, in contrast, would impact all areas where electricity is used, including large-capacity currents. In fact, he predicted, it is commercial applications in the large-capacity current field that will have the greatest social impact.

Tanaka said future superconductivity research should first of all trace the physical properties of established superconductors, and offer accurate experimental data. The next step is to conduct research on practical applications for such superconductors. The last, and the one he termed most risky and difficult, is to discover new materials with very high critical temperatures.

Chu agreed that it is first essential to accurately trace the physical properties of a group of superconductors, then seek new higher-temperature superconductors. Further, research must continue on applications. All three approaches will be closely interlocked, Chu said, adding that new materials should also be studied when tracing the physical properties of the superconductors developed so far. On high-temperature superconductors, he stressed that research should proceed very cautiously while confirming the stability and reproducibility of the new materials.

MITI's Iizuka said superconductivity research would increasingly require international exchange. The two professors agreed, with Tanaka observing that in today's information-oriented society it is impossible for a single country or enterprise to monopolize a new technology. He urged that efforts be made to ensure that international exchange be conducted at the basic research stage. Chu praised Japan's research posture as "very open," adding that openness is the foundation of international cooperation. No enterprise or country should be allowed to hoard information on superconductivity in secret, he said.

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