

Historical Survey

Sadao NAKAJIMA

Project leader

Motivation

The Special Project Research on New Superconducting Materials supported by the Grant-in-Aid of Scientific Research from the Ministry of Education, Science, and Culture Japan was organized on the basis of two preceding workshops also supported by the Grant-in-Aid of Scientific Research, one titled Novel Types of Superconductivity held in 1981 and the other titled New Superconducting Materials held in 1982.

The late K. Yasukochi, Professor of Nihon University and a leader of large scale applications of superconductivity in Japan, was seriously interested in observations suggesting non-reproducible high temperature superconductivity and felt the time was perhaps ripe to start a systematic program of basic research into high- T_c materials, without which further development in large scale applications would not be possible either. He invited S. Nakajima, then director of the Institute for Solid State Physics at University of Tokyo, to organize a team of scientists to work together toward higher T_c . S. Tanaka and H. Fukuyama from University of Tokyo joined the team at an early stage and collaborated with Nakajima and Yasukochi in planning the above mentioned workshops. Tanaka was invited because of the potential importance of oxides, though not popular superconducting materials then.

Underlying Physics

At the first workshop, global trends of basis research on superconductivity was critically reviewed mainly by theorists. The most important outcome was the recognition that development of new superconducting materials in the preceding decade, ternary compounds, inorganics, organics, and amorphous films, had almost always raised fundamental problems concerning the mechanisms of superconductivity. It was concluded that the search for higher T_c materials should also go hand in hand with the investigation of mechanisms.

At the second workshop, the key experimenters talked about their future plans along that line and the team of scientists, mostly from universities and some from the Electrotechnical Laboratory and Nippon Telephone and Telegram Laboratories, was organized to start a three-year program titled the Special Project Research on New Superconducting Materials. The proposal was made in 1983 and the program started in 1984.

Organization

The three-year program was divided into five groups to focus on

1. theory
2. intermetallic compounds and magnetic superconductors
3. inorganic superconductors
4. organic materials and salts
5. development of new technologies for synthesis of superconducting materials.

Member scientists are listed in a separate table. Note that the fifth group was to be headed by Yasukochi who unfortunately passed away at the very beginning of the program. Note also that, in addition to the five standing groups mentioned above, 19 one-year proposals in 1984 and 14 one-year proposals in 1985 were adopted from public applications. In 1986, 16 of them were transferred to the standing groups.

The total amount of the Grant-in-Aid of Scientific Research for the three-year term was ¥606,300,000. About 80% of money went to university laboratories working on superconducting materials and mechanisms to provide them with modern equipment.

The rest of money went to organization of workshops and annual symposium, publications, and other activities. Each of the five groups held workshops once or twice a year. Scientists from other groups and even from outside were invited if necessary. There was an administrative committee to keep the integrity of the program. It organized the annual symposium at the end of each fiscal year to review the whole activity. The symposium was attended by all the member scientists with their collaborators and open to public. The symposium report titled Research Report on New Superconducting Materials was published in English.

Outcome and Extension

The outcome of the program as a whole will briefly be discussed here since individual activities may be seen from summary reports of group leaders and papers contributed by member scientists and collaborators.

As was mentioned before, the most characteristic feature of the recent advancement in basic research on superconductivity is development of new superconducting materials closely related with the problems of mechanisms. The discovery of high- T_c oxides by Bednorz and Müller in 1986, which has brought a serious challenge to the BCS mechanism, is a highlight of this trend.

In order to match such a trend, we need to promote systematic studies by scientists of diverse disciplines with modern equipment. The program on New Superconducting Materials was very effective and timely in bringing up such a strong team of scientists in Japan. In fact it was Tanaka's group at University of Tokyo who succeeded in identifying the crystal structure of the superconducting phase in La-Ba-Cu-O discovered by Bednorz and Müller in early 1986. This research at Tokyo was done independently of the ongoing work at Zürich. The group also independently obtained superconductivity at 40 K in La-Sr-Cu-O. These results, together with results obtained at Tohoku University, the Electrotechnical Laboratory, the Institute for Molecular Science, and Hiroshima University, were reported at a special session of the third annual symposium of the Special Project Research held on 19 January 1987. This was probably the first meeting at which the so-called superconductivity fever prevailed.

In view of our participation in this dramatic breakthrough, the Ministry of Education, Science, and Culture decided to extend the program for one year from April 1987 through March 1988 with the Grant-in-Aid of Scientific Research ¥169,000,000 for 15 selected members under the more specific title: High Temperature Oxide Superconductors. The aim is to produce high quality single crystals and powder samples and to perform precise measurements of their properties.

The extensive study of high- T_c oxides is of course most important, but we should not forget the fact that there remain some other basic problems unsettled. For instance, another problem of strong correlation in heavy Fermion superconductors was studied actively in our three-year program with use of NMR and other experimental means and with the theoretical idea of anisotropic Cooper pairs.

The theory of the effect of Anderson localization upon T_c and H_{c2} in thin films was fully developed, but the experimental study is not satisfactory.

The remarkable progress made in the study of organic superconductors was reported at every annual symposium: T_c has grown up from 1 K to 10 K within the short period after the discovery in 1980.

The application of such semiconductor technologies as MBE and MOCVD to the syntheses of new superconducting materials, *e.g.* the metal-semiconductor interface to check Ginzburg's idea, was initiated in our three-year program, but awaits future development.

An interesting theoretical idea of novel mechanism was proposed even for A15 compounds, but we need again to wait for the experimental checks.

Finally the three-year program also trained many young researchers in the theoretical aspects of superconductivity.

International Exchange

At an early stage of organization, we were aware of the importance of international collaboration, particularly with US. Thus, in 1983, we sent the English translation of our proposal submitted to the Ministry of Education to about 15 eminent US scientists including Professor J. Bardeen and Professor T. Geballe. The response was favorable and encouraging. At the 6th Taniguchi International Symposium, Nakajima gave a talk about the program.

In 1985, at the International Conference on Materials and Mechanisms of Superconductivity held at University of Iowa in May, Professor M. Beasley invited Nakajima to talk at luncheon about the Japanese program and also suggested the possibility of sending US scientists to Japan. In November of the same year, Nakajima discussed the problems of higher T_c materials with Chinese scientists at the Institute of Physics in Beijing.

In 1986, with financial support from the National Science Foundation, six US scientists, M. Beasley, D. Finnemore, T. Geballe, B. Maple, L. Sham and C. Varma, together with D. Liebenberg, NSF Program Director, attended the second annual symposium of the Special Project Research held in Tokyo in January. They also visited a few Japanese laboratories working on superconducting materials. In December of the same year, when Tanaka's group confirmed superconductivity of La-Ba-Cu-O, K. Kitazawa was in US to attend a Material Research Society meeting and announced the result obtained at Tokyo to US scientists. The superconductivity fever started from then.

On 8 January 1988, the public Symposium commemorating the great discovery of high- T_c oxides was held in Tokyo under the auspices of the Ministry of Education, Science, and Culture. In addition to Japanese speakers, Professor C. W. Chu and Dr. B. Batlogg were invited to deliver lectures with financial support from the Grant-in-Aid of Scientific Research for High Temperature Oxide Superconductors.

References

1. S. Nakajima: Proc. 6th Taniguchi Int. Symposium, Springer-Verlag, (1984) 206.
2. S. Tanaka: Physics Today Vol. 40, No. 12 (1987) 53; S. Nakajima: *ibid* 57.