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Contents:

Top of Superconductivity Web21

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Bulk high temperature superconducting magnet that traps fields >17T

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High temperature superconductors have significant potential for high field applications since they exhibit extremely high critical current densities in high magnetic fields. Large grain RE-Ba-Cu-O (RE: rare earth elements) superconductors can trap magnetic fields of over 10T at temperatures below 50K, showing that they can function as extremely high field magnets. Once bulk superconductors trap the fields, they behave like permanent magnets as long as they are kept at low temperatures. In other words, they can be run in a persistent current mode.

Despite their high potential, bare bulk superconductors could not be used as high field magnets for engineering applications mainly due to their poor mechanical properties. First of all bulk superconductors must be cooled below their critical temperature to function as magnets. They experience large thermal stresses during thermal cycle, which sometimes causes cracking. RE123 materials must undergo the tetragonal to orthorhombic transformation to be superconducting, which causes the introduction of microcracks along the (001) cleavage planes. They are also fabricated with the melt process during which voids are internally included due to a combination of oxygen gas release and high viscosity in the liquid at the partial melting stage. The presence of these cracks and voids significantly deteriorated mechanical properties.

In addition to the thermal stresses, large electromagnetic forces exert on bulk superconductors when they are magnetized. Almost all the samples were cracked as shown in Fig. 1 when they were activated in high fields at low temperatures. Hence ironically the enhancement of mechanical properties has been the main issue for the development of bulk RE-Ba-Cu-O superconductor magnets rather than the enhancement of superconducting properties.

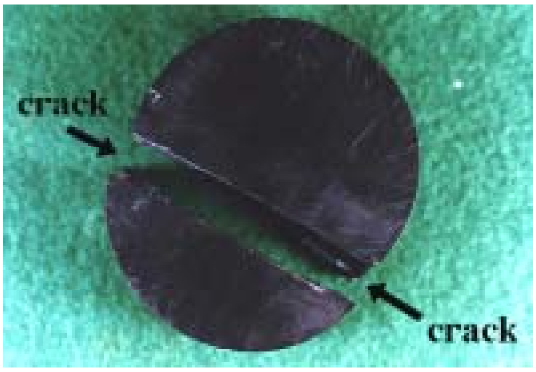

Fig. 1 Bulk Y-Ba-Cu-O sample after field trapping experiment. The sample was broken into two pieces due to a strong electromagnetic force.

An addition of Ag has been found to be effective in improving the mechanical properties, however not sufficient to ensure a 10T magnet. Encapsulation with metal rings was also effective in preventing crack formation or extension. The thermal expansion coefficient of the metal rings is larger than that of an oxide superconductor, and thus the larger thermal contraction of the metal rings impart pre-compression strain, which is beneficial for field trapping, since the tensional force appears in the bulk magnet. However these techniques were not efficient for achieving high field trapped field.

We recently found that the resin impregnation led to a dramatic enhancement of mechanical properties of bulk RE-Ba-Cu-O. As shown in Fig. 2, resin can permeate into the bulk body through the surface cracks when bulk samples are immersed in molten resin with the outer gas being evacuated. Here it is important to note that the voids connected to the cracks were also filled with resin (see Fig. 2). The resin impregnation has another advantage that it greatly enhanced the corrosion resistance of bulk RE-Ba-Cu-O samples against moisture since the surface is coated by resin.

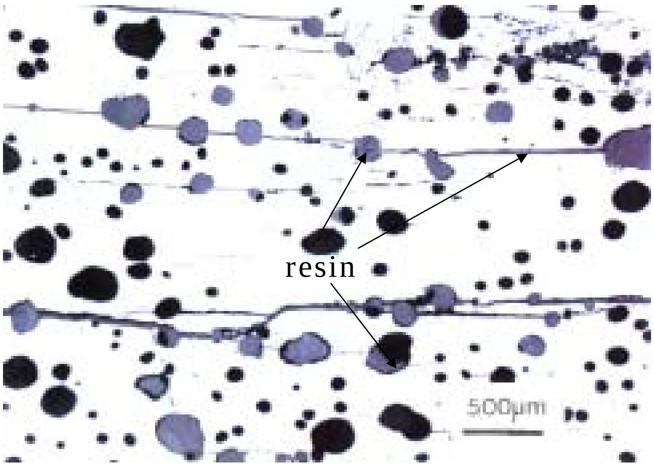

Fig. 2. Cross sectional microstructure of bulk Y-Ba-Cu-O treated with resin impregnation. Note that the resin can permeate into the bulk body through the surface cracks. It is also notable that the voids connected to the cracks are also filled with resin.

These findings motivated us to perform field trapping experiments of resin-impregnated YBCO disk 2.6 cm in diameter and 1.5cm in thickness using 18T superconducting solenoid magnet at Tsukuba Magnet Laboratory of National Institute of Materials Science. First the sample was kept at 100K which is above the critical temperature. Second we activated the magnet at 18T. Third the sample was cooled to the target temperature with a cryo-cooler and finally the external field was reduced to zero. What we found was that all the samples were broken in the field cooling process. We then monitored the temperature of the sample surface. We noticed that the sample temperature rose as soon as the external field was reduced. This is due to the fact that the quantized fluxoids in the sample move when the field distribution changes. When the field sweeping rate was high, a rapid increase in temperature occurred, which often resulted in cracking.

Such instability is known as a cryo-instability. The thermal conductivity of bulk RE-Ba-Cu-O is low, and thus the heat generated in the bulk cannot be removed in a short time. When the temperature is raised locally, the critical current density or flux pinning ability in this region is lowered, which allows more flux to move into the region, finally leading to the flux avalanche. This causes a rapid increase in temperature and a larger electromagnetic force. Even when the sweep rate was carefully controlled, we could not avoid quenching. The improvement of thermal stability is thus required for safety operation of bulk superconducting magnet.

Like resin, Bi-Pb-Sn-Cd alloy with low melting point (~70°C) can permeate into the bulk body, when bulk samples are immersed in molten alloy with the outer gas being evacuated. In order to improve the thermal conductivity of bulk RE-Ba-Cu-O, we drilled a hole about 1mm in diameter at the center. We then impregnated the alloy into the hole. Here we found that the alloy permeates into the interior through the cracks connected to the artificial hole, which did not only improve the thermal conductivity but also

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enhanced the internal mechanical strength. With the aim of further enhancement of thermal conductivity, we inserted an Al rod of 0.9 mm diameter into the hole prior to alloy impregnation. These treatments drastically improved the cryo-stability of bulk RE-Ba-Cu-O magnet. As a result we could trap magnetic fields of over 17 T at 29 K as shown in Fig. 3. One can easily infer from the date presented in Fig. 3 that the field trapping ability at 29K is not saturated. If we can use a larger magnetic source, much higher field can be trapped by the bulk magnet.

For further information, please see Masaru Tomita and Masato Murakami: "High-temperature superconductor bulk magnets that can trap magnetic fields of over 17 tesla at 29K", Nature, vol. 421 (2003) pp517 - 520.

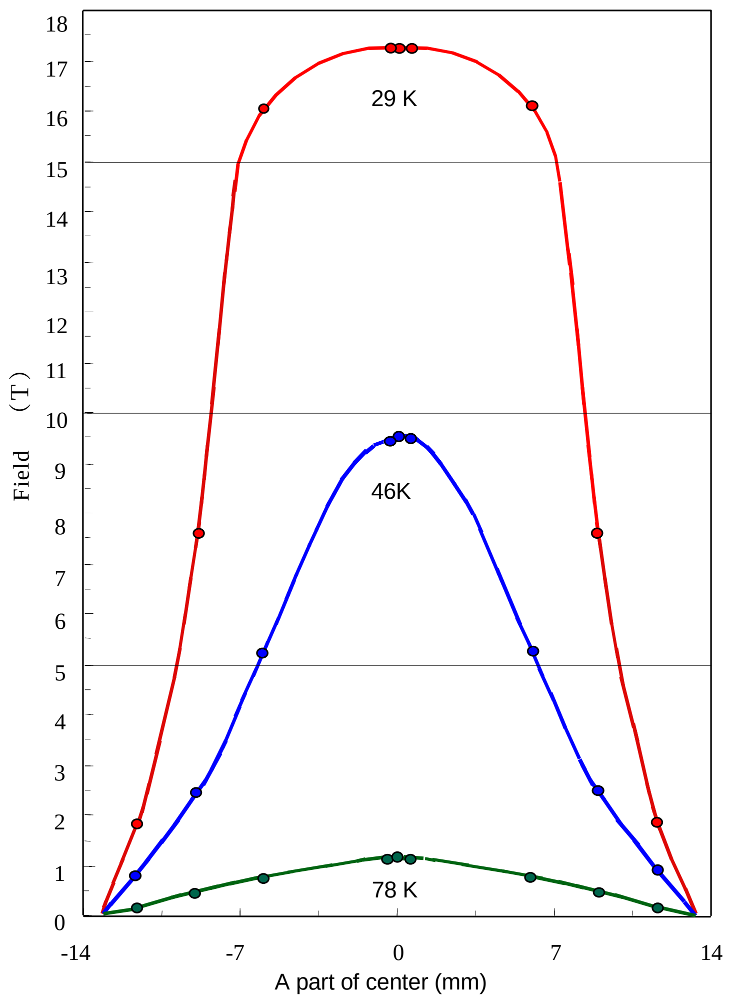

Fig. 3 The distribution of the fields trapped by bulk Y-Ba-Cu-O 2.6cm in diameter and 1.5cm in thickness at 78K, 46K and 29K. The sample was treated with resin impregnation. An artificial hole of 1mm diameter was drilled at the center followed by Bi-Pb-Sn-Cd impregnation with an Al rod inserted into the hole.

Top of Superconductivity Web21

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The 15th International Symposium on Superconductivity (ISS 2002)

The International Superconductivity Technology Center (ISTEC) held the 15th International Symposium on Superconductivity (ISS 2002) from November 11 through 13, 2002, at the Pacifico Yokohama Convention Center in Yokohama City. The annual symposium, offers precious opportunities to have access to information on the research and development of superconductivity technologies in other nations through exchanges of opinions and research reports. The symposium believes that international exchanges of information lead to enlightenment and practical applications to society and will stimulate and promote the development of superconductivity technologies and industry in the member nations. The ISS 2002 attracted 637 participants including 93 overseas participants from 26 nations. Participants from China, Korea, and other Asia-Pacific regions have increased. A total of 131 oral presentations were presented at the symposium, including 58 invited speakers, and 290 poster presentations were held during the symposium. The proceedings of the ISS 2002 will be published as a special issue of Physica C from Elsevier Science. Twelve Japanese and foreign corporations also exhibited their superconductivity related technologies, materials, and products at the symposium. The ISS 2002 has now grown to be a worldwide event on the science, technology and application of superconductivity.

The first day of the ISS 2002 began with the opening message of Vice President Tanaka of ISTEC, followed by the congratulatory speech by Kanto Bureau of Economy, Trade and Industry Director General Yoshiyasu Nao, who read the message of the Minister of Economy, Trade and Industry Takeo Hiranuma. Afterwards, two special plenary lectures and six plenary lectures presented. The first special plenary lecture was given by Director General Tanaka of SRL on the "Future of IT and PT and Superconductivity Technology." Dr. Tanaka advocated possible applications of high temperature superconducting (HTS) wires at 77K-20K including power cables, motors, generators, and at 4K-20K including nuclear fusion reactors, NMR, SMES. Dr. Tanaka also advocated applications of HTS devices, as post-silicon materials, to routers, servers, and other networking devices. The second special plenary lecture was given by Dr. Heinz-Werner Neumueller of Siemens in Germany on the "Status of Electric Power and Industrial Applications of High Temperature Superconductors in Europe". He introduced the development of power applications, including a power cable, fault current limiter, and power storage system, and the development of industrial applications, including a railway transformer, motor, and generator for 4MW-class ships.

Professor Davis at Berkeley, University of California, gave a plenary lecture, in which he reported new findings on nanoscale inhomogeneity and the quantum interference effect of quasiparticles in Bi-HTS using a scanning tunneling microscope(STM). Professor Hellstrom University of Wisconsin-Madison, reported that in Bi-HTS wiring process, post-anneal and excess pressure were effective in the improvement of micro structure, in the removal of secondary phases, and in increasing of Jc. Director Y. Shiohara of SRL reported on the achievements of Japan's ongoing next generation wire development project, including the successful development of a 30 to 40-meter long IBAD/PLD wire. Director Y. Shiohara also reported that his team had set a target of developing a 300- to 500-meter long wire of a Ic of 300A/cm-W at $100/kAm of cost and 5m/h of production speed. Other speakers included Professor Hayakawa of Nagoya University, who reported on the development and application of an LTS superconducting logic circuit to network devices and Dr. Hammond of Superconductor Technology Inc. in the United States, who introduced the technological development of an HTS microwave receiver and conditions in the US market; Director Murakami, of SRL, introduced the development of a magnetic separation system for water purification, where HTS bulk is applied for the first time in the world, and an application of HTS bulk to a movable water purification system.

On the second and third days, oral sessions were given in four fields, namely physics, chemistry, and flux physics; bulk/system applications; wire/system applications; and thin films and devices. Also, two poster sessions were held. Hot presentations and discussions dominated the sessions.

In the physics and chemistry field, two mini-symposiums were held: "New Materials & New Concept in Superconductivity" and "Anomalies in Superconducting State of High-Tc Cuprates" In particular, participants discussed the latest topics on the analysis of the superconducting mechanism of superconducting materials and high Tc copper oxides. This is partly because superconducting materials have recently seen a number of new findings—high-voltage induced superconductivity, single-dimension superconductivity of a single-phase carbon nano tube, and magnetically induced superconductivity on an organic conductor.

The bulk/system application field saw a number of reports on research and development, including large-size bulk production, which is essential technology for the practical application of superconductivity, high-trapped magnetization technology (15T at 77K), and applications to magnets, motors, generators, magnetic levitation bearings, and magnetron sputtering.

The wire/system application field has seen remarkable developments. Reports on the different processes of the next-generation wires in the IBAD/PLD method, such as a Jc of 10-meter long wire with 2.2MA/cm^2 and a Ic of 1-meter long wire with 200 to 300A/cm - W were presented. American Superconductor Corporation announced four grades of Bi-HTS wires, which were to be marketed in December 2002. Based on 100A or higher levels of Ic on its next generation wires, the company has set a goal of reducing production cost to 1/2 to 1/5 with Bi materials and introduced a projection that the cost-performance would cross over with Bi materials in 3 to 4 years. The company also introduced the development of a 5MW-HTS demonstration motor for US Navy ships, plan for testing an LTS generator demonstration, and demonstrative experiments on applications to cables, SMES, and other electrical energy systems.

The thin film and junction/device field saw a number of technological achievements. These include improvement of the application research of MgB_2 superconductor, found in Japan in 2001, to devices; the development of Y-HTS SQUID and filters which are already at commercial level. Reports were also given on the results of achievements in the development of an AD converter, router, SFQ processor, and other high integration devices, and on the application research of an ultra-high speed low power consumption server. Widespread R&D efforts for the realization of a high integration circuit, aiming for the post-silicon, have accelerated.

In the closing session of the symposium on the third day, the four fields were summed up: Professor Tamegai of The University of Tokyo summarized the discussions in the physics, chemistry, and flux physics field; Director Murakami of SRL, in the bulk/system application field; Director Akiata of the Central Research Institute of Electric Power Industry, in the wire/system application field; and Professor Hayakawa of Nagoya University, in the thin film and junction /device field. Director General Tanaka, of SRL, gave the closing speech as the President of the ISS 2002 Organization and remineded the participants of the opportunity for a reunion at the next ISS 2003, which is scheduled to be held from October 27 through 29, 2003, at Tsukuba City, Ibaragi Prefecture.

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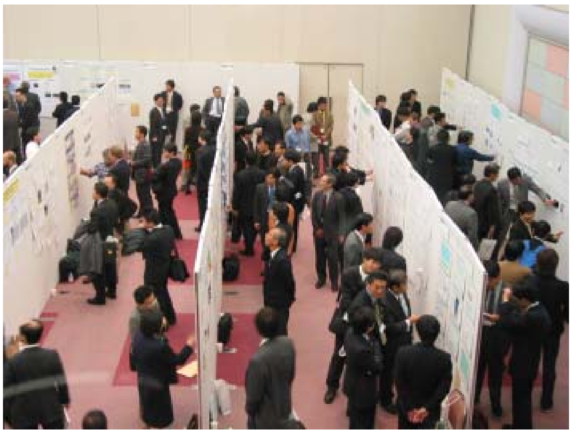

At a Poster Session

Special Plenary Lecture by Director General
Tanaka of SRL/ISTEC

(Yoshinobu Ueba, Director, Research & Planning Dept., ISTEC)

Top of Superconductivity Web21

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ISS 2002 Topics: Physics and Chemistry Field

A mini-symposium on "New Material and New Concept in Superconductivity" included a number of reports on "new types of superconductivity" that contradict with existing common sense on superconductivity. Amaya (Osaka University) reported that iron turned superconductive under ultra-high pressure as a result of the magnetism suppressed and added that the superconducting transition temperature of lithium was 20K which was lower than the theoretical prediction, but it is highest for a single element metal. Amaya concluded his presentation with a very optimistic view that metalizing and superconductorizing of hydrogen, which is predicted to turn superconductors at room temperature, will be realized in the near future. Other reports included the quasi one-dimensional superconductivity that was realized in carbon nano-tube (P. Shen) and a case of organic superconductor which was obtained as a result of metalization under magnetic fields (S. Uji). These reports may suggest that there are still unexplored areas of superconductivity.

A mini-symposium on "Anomalies in Superconducting State of High-T_c Cuprates" included discussions on experiments and theories of phenomena relating to intrinsically inhomogeneous electronic state. These discussions covered additions of magnetic flux and Zn-impurities to a high-T_c material which induced an antiferromagnetic order co-existing with superconducting state (Lake, Kimura); co-existence of stripe order and superconductivity (Ogata); breaking of time-reversal symmetry in an underdoped regime (Campuzano); and an inhomogeneous charge distribution (Hanaguri). The result of an STM experiment reported by Davis (UC Berkeley) at the plenary session may be considered most advanced in the field of inhomogeneity physics. Meanwhile, a new viewpoint was introduced by Eisaki (AIST), who indicated that crystal inhomogeneity brought about an electronic inhomogeneity. Although these "anomalous" phenomena are intrinsic for high-T_c superconductors, further research is needed to learn whether or not the phenomena contribute to the pair-formation.

In the vortex physics session, visualization of vortices with magneto-optical film reached the ultimate, it is reported that even single flux quantum could be observed. Johansen (University of Oslo) introduced a video that showed the motion of vortices in an Nb superconductor flux quantum. Compared with other flux observation methods, it has a number of advantages, including less expensive, faster time response, and easy zooming-up. Thus, the method will be applied to the research and development of high temperature superconductors in future.

(Setsuko Tajima, SRL/ISTEC)

Top of Superconductivity Web21

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ISS 2002 Topics: Bulk and Its Application Field

The bulk superconductors and system application field included many reports on new processes and applications. First, Muralidhar et al. at ISTEC succeeded in controlling the microstructure of an (Nd, Eu, Gd)-Ba-Cu-O material such that fine RE-rich clusters 3 - 5 nm in size were uniformly distributed in the matrix. As a result, his team achieved the irreversibility field of 15T for fields parallel to the c-axis at 77K. Since the application of high temperature superconductor at high magnetic field is known to have the upper limit regulated by the irreversibility field, the above-mentioned new findings are considered as important achievements for superconductivity community.

In bulk processes, Sawamura of Nippon Steel Corporation reported that his team succeeded in synthesizing an almost-single grain YBCO of 10-cm diameter by using the multi-seeding melt process called the MUSLE method. In this method the precursor has two layers with different chemical composition. Even when multiple seeds are placed on the upper layer, the lower layer could be grown into single grain although the upper layer becomes polycrystalline. Hence this novel method is considered very useful for large-size crystallization.

Iida et al. of ISTEC reported that his team succeeded in joining hetero-type bulk superconductor blocks for the first time in the world, which is a method for fabricating large grain superconductors. They used two mother Y-Ba-Cu-O blocks to be joint and Ag-added Y-Ba-Cu-O material as the solder material. And the joint surface was parallel to the (110) surface. This realized a superconducting joint with no weak links.

Bulk applications also saw new developments. A report was introduced showing that Hitachi had developed a magnetic separation system for water purification that uses the strong magnetic field and magnetic gradient of a bulk superconducting magnet. According to the report, this system is also useful for the purification of seawater contaminated with oil and for the removal of green algae and red tide. In cooperation with Kyushu Electric Power Co., Hitachi has also successfully developed a mobile magnetic separation system, which was loaded on the bed of a truck. Environmental concerns become serious and water recycling has become more and more important in the world. So the magnetic separation technology is considered likely to become increasingly important in the future.

Matsuda et al. of Diax reported the progress in the development of a magnetron sputtering system in which a bulk superconducting magnet, being developed jointly with Nagoya University, was loaded. The Matsuda team reported the successful synthesis of a thin film made of ferromagnetic material, which was considered to be impossible to synthesize with conventional permanent magnets.

As mentioned above, the bulk superconductivity field has exhibited remarkable progress in process and application developments. The moves for new developments seem likely to continue in the future.

(Masato Murakami, SRL/ISTEC)

Top of Superconductivity Web21

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ISS 2002 Topics: Tape and Wire Material and Its Application Field

The following are the major topics on tape and wire field that were reported and discussed at the ISS 2002 held at Yokohama.

Concerning process development of coated conductors, Kakimoto et al. (Fujikura) reported that they succeeded in producing a 46-meter long superconducting tape with texturing structures of both YBCO superconducting layer by PLD on a $Gd_2Zr_2O_7$ layer by IBAD. The tape levealed Jc value of 74A. Freyhardt et al. (Gottingen University) reported a 10-meter long tape with high Ic value of 223A/cm-width in combination of architecture mentioned above. An innovative technological development was reported on the improvement of production speed, which was the major obstacle in IBAD. According to Yamada et al. (SRL), they found highly textured structures in CeO_2 film with short time on the IBAD buffer layer. The film eventually realized high in-plane alignment of 2.6° in $\Delta\Phi$ values, which is almost same as that of single crystals. With this development, the required thickness for IBAD layer becomes thinner, which leads to a shorter production time for the entire process. Concerning the TFA-MOD process, which is expected to realize lower cost, Honjo et al. (SRL) succeeded in achieving high Ic value of 210A (@77K) by maintaining critical current density even with thicker film in a multiple coating method.

Meanwhile, Hellstrom (University of Wisconsin) reviewed recent trends in the development of Bi wire processes in the United States. The successful development of a baking technology under post-anneal and over-pressure has led to the improvement in Jc; the maximum Jc value of 34kA/cm^2 was improved to 59A/cm^2 according to this report. The drastic improvement cannot be explained with an increase in the density alone. It is reasonable to explain that the Jc of the Bi-2223 itself improved. Masur (AMSC) reported the introduction of a new production facilities, which have an improved production capacity to 20,000 km per year. He also reported improvement in Ic-properties to 130A which was realized by the establishment of a production technology.

On the applications using coated conductors, Selvamanickam (IGC) reported a project plan that tests superconducting cables at Alberny in the United States. Unlike the past, the project plans to introduce coated conductors in one section of the test line. Meanwhile, Ueda (Super-GM) explained a project that will fabricate a 500-meter long single-phase transmission cable. Ishiyama (Waseda Univ.) reported the present situations of SMES development where HTS was applied.

The number of research and development reports on the tape and wire field totaled about 100 (30 oral reports, 70 poster reports), which was the largest among all fields in this conference. This means a strong expectations for coated conductors. The levels of technological developments in this field in Japan, Europe, and the United States are similar now. The competition for technological development is expected to promote practical application.

(Teruo Izumi, SRL/ISTEC)

Top of Superconductivity Web21

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Superconductivity Web21

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ISS 2002 Topics: Thin Film, Junction, and Device Field

Some 90 reports including were presented in this field. The major topics are summed up as follows:

Thin film:

It has been thought that high-quality MgB_2 thin films are difficult to produce. However, University of Pennsylvania, etc. reported that they succeeded in producing flat-surfaced MgB_2 film with a critical temperature of 39K or higher by applying the HPCVD (Hybrid Physical-Chemical Vapor Deposition) method that can realize high Mg pressure. NTT and KARC reported that they conducted experiments of making SIS junctions with MgB_2 film. According to the report, they were at the stage of evaluating basic data, including the gap property, etc. Concerning large-area oxide thin films for high frequency filters, THEVA reported that an oxide thin film, where the rare-earth elements in $YBa_2Cu_3O_{7-X}$ was replaced with Dy, made substantial improvement in the stability of properties at a high moisture atmosphere (95%, 40℃).

Ramp-edge Junction:

For the purpose of applying to SFQ circuit and others, discussions were held on issues of production technology when a ground plane is coated under the $YBa_2Cu_3O_{7-X}$ ramp-edge junction. According to Hitachi and SRL, the oxygen content in the ground plane lowered while being layered, leading to the disappearance of superconductivity. To recover superconductivity, the sample was annealed in oxygen atmosphere, which also increased or decreased the Ic of the junction.

SFQ circuit:

Concerning the oxide SFQ circuit, a voltage amplification circuit (SRL) and a ring oscillator (Toshiba) were produced with the Ramp-edge junction. To produce different types of RSFQ circuits for the development of function circuits, improvement in relevant circuit production technologies seem necessary to control the Ic of junctions on the ground plane. Concerning the development of low-temperature SFQ circuits, 2000-junction RSFQ circuits have been produced with, for example, element circuits (Nagoya Univ.) including ALU and registers for processors, 2 x 2 switch circuit (NEC, KARC), a combination of AD modulators and DEMUX (Hitachi); and decimation filters for AD (SRL). The operation of these RSFQ circuits has been confirmed, reflecting the stable Nb-circuit production technology.

Microwave application:

Superconductor Technologies Inc. (STI) has successfully developed superconducting filter units for marketing. The company also manufactures stirling-type refrigerators, which are running, free of maintenance. At present, over 2000 superconducting filter units are in use in the United States, and the number is steadily increasing. This is seemingly because conditions for linking cellular phones in the United States are not satisfactory.

(Yoshinobu Tarutani, SRL/ISTEC)

Top of Superconductivity Web21

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The 11th International Superconductivity Industry Summit (ISIS-11):

Joint Communiqué

The 11th International Superconductivity Industry Summit (ISIS-11) was held in Tokyo from November 17 through 19, 2002. Some 50 experts, from Japan and other nations, participated in the summit which included three day discussions. A joint communique, to which all of the participants agreed, was completed at the end of December 2002. I believe that the essence of the discussions are reflected very well in this communiqué. Described below is an overview of the communiqué:

Concerning the situation of superconductivity, the industrial application of superconductor technology began with so-called low-temperature superconductors (LTS). Afterward, high temperature superconductors were discovered. These moves accelerated worldwide competition in superconductivity development efforts and brought about steady progress in superconducting technologies. Meanwhile, demand for electrical energy has increased and will continue to grow due to growing industries including expanding telecommunications technologies. On the other hand, however, limits deriving from environmental problems are also becoming increasingly serious. Under these circumstances, superconductivity technology is supposed to be one of the key technologies to meet the demands of the age.

However, to enable this technology to become fully commercialized, reliable superconductor products that address specific market opportunities must be available at a reasonable price. In addition, the products must also be able to deliver value-added benefits to customers. In this regard, efforts are still required to promote various applications of superconductor-based products.

In reaction to these circumstances, the ISIS-11 participants discussed many aspects regarding the facilitation of superconductor technology commercialization and feasible methods for overcoming foreseen obstacles. Specific types of superconductor applications mentioned at the summit included various electric power and electronics applications, such as HTS power cables, transformers, fault current limiters, HTS utility generators, HTS motors and ship propulsion systems, MRI and NMR systems, specialty magnets, filters and network devices. Among others, refrigeration technology is the most important support technology in every superconductor application field. ISIS-11 participants unanimously agreed that the development of cryocoolers must be earnestly pursued, since these components are vital to the future of the superconductor industry.

Based on the discussions mentioned above, the participants in the ISIS-11 have agreed to the following points:

(1) The worldwide demand for electricity is steadily increasing and will likely continue to increase because of economic growth, especially in the information and telecommunication industries and in Asian countries. However, effective energy utilization will also become increasingly important for the protection of the Earth's precious environment. Superconductor technology is one of the most promising and viable solutions for dealing with these issues.
(2) To accelerate the commercialization of superconductor technology, efforts and investments must be focused on specific promising and viable fields of application.

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(3) To realize the expansion of superconductor technology commercialization, the superconductor industry must ensure that customers are thoroughly aware of the benefits of superconductor technology.
(4) The commercialization of superconductor technology should be associated with its standardization. To realize the standardization of superconductor products, international efforts should be centered on presently available commercial products as well as products in the R&D stage.
(5) The role and contribution of CCAS, CONECTUS and ISTEC in promoting international cooperation was widely recognized. The participants urged these organizations to continue their present activities.

The participants agreed that the next ISIS summit be held in Europe, hosted by CONECTUS.

In conclusion, I would like to mention my personal impression of the ISIS-11. One of the features of the ISIS-11 was that we discussed refrigeration technology at the summit. Without refrigeration technology, superconductors cannot work. Thus, refrigeration technology is one of very important and essential supporting technologies for superconductor applications. It is notable that the importance of the refrigerator was reminded and more deeply recognized in this summit. I strongly hope that research activities of the superconductor will be carried out under closer cooperation with refrigeration fields and that development of superconductivity technology will be accelerated toward commercial application.

Note: For further information on the joint communiqué, please refer to "Conferences" at http://www.istec.or.jp/indexE.html.

(Akihiko Tsutai, Director, International Affairs Dept., ISTEC)

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Adoption of the "Research and Development on Evaluating and Lowering AC Loss in HTS Utilization" Relating to the "International Project on Researching the Global Environment" for Fiscal 2002

On October 18, 2002, the Ministry of Economy, Trade and Industry announced their decision to adopt the "International Project on Researching the Global Environment" that the ministry had invited public participation in from June 26, 2002. As part of this public participation, the ministry also decided, on November 7, 2002, to adopt the "Research and Development on Evaluating and Lowering AC Loss in HTS Utilization" proposal of the International Superconductivity Technology Center (ISTEC), which is headed by President Hiroshi Araki.

The "International Project on Researching the Global Environment" for fiscal 2002 was designed to address global environmental problems. Addressing these problems is essential for forming a sustainable economic society and realizing a new Japan in the 21st century. In particular, concerning global warming, the target year that the Kyoto Protocol stipulated for cutting greenhouse gases is approaching. Countries concerned are being urged to take the measures necessary to achieve this goal. Specifically, to solve global warming, the countries concerned have agreed to conduct research and development of technologies to control global warming that cover nine subjects in four fields. These fields are analyzing the climatic change, improving scientific findings on the carbon cycle, developing innovative production processes where biotechnology is applied, and developing innovative technologies in order to separate, collect, isolate, fix, and efficiently use carbon dioxide.

The "Research and Development on Evaluating and Lowering AC Loss in HTS Utilization" focuses on innovative and recyclable energy technologies for cutting greenhouse gases, one of the four fields mentioned above. The research and development period will last for three years from the contract date until March 31, 2005. The budget planned for the three years is ¥400 million. The research and development will concentrate on establishing technology that evaluates AC losses and accordingly contributes to reducing them through simulating appropriate wire structures. The research and development will be conducted in cooperation with Brookhaven National Laboratory under the US Department of Energy along with other institutes for exchanging information. This research and development will encourage introducing SMES and other superconducting equipment as well as using superconducting wires. Improving efficient energy use will result in cutting carbon dioxide emissions.

This research and development, led by Dr. Shiohara (SRL/ISTEC) representing Japan and Dr. Suenaga (Brookhaven National Laboratory) representing the United States, will be implemented by the Japan-US joint research system and will work on establishing technology that evaluates AC losses; simulation research on appropriate wire structures; and comprehensive research. The Japanese project members, centering on SRL, include Fujikura, Kyushu University, and Yokohama National University.

(Yuh Shiohara, SRL/ISTEC)

Top of Superconductivity Web21

Spring, 2003 Date of Issue: April 15, 2003

Superconductivity Web21

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Development of Superconducting Rotating Machine Applications

1. Introduction

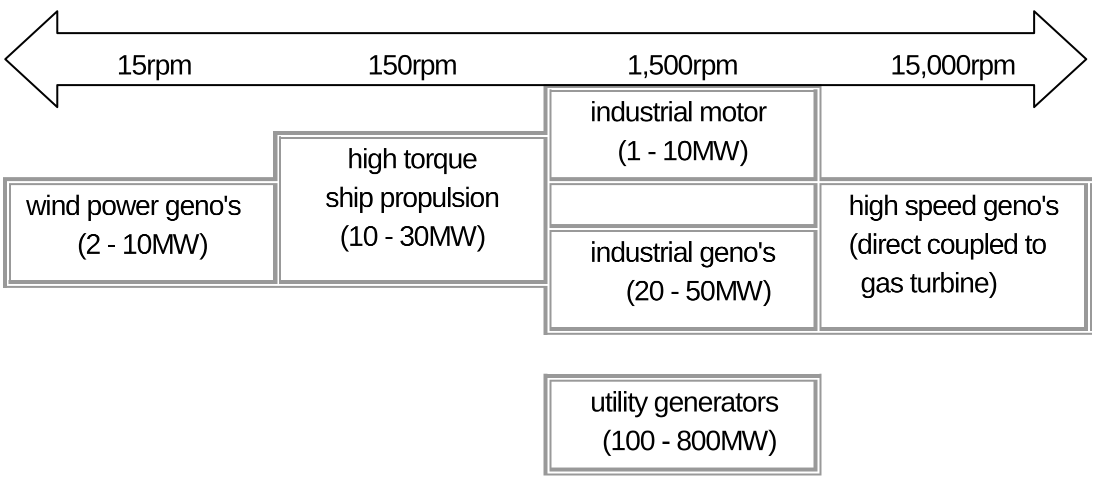
We are interested in development of superconducting rotating machines, which you will expertly find in this issue. In this section, I will focus mainly on development overseas and activities in ISTEC.

2. Overseas topics

Generators and motors have a history of over 100 years since being developed. The entire system, including control subsystems, is fairly mature. Unless superconducting rotating machines show convincing advantages to potential customers, they won't even be accepted in niche markets.

Unless the project or Japan has a definite strategy, the development project may fail to make progress.

Siemens in Germany succeeded in developing a 400kW-class superconducting synchronous motor in 2002. Although the motor is a proto-type, the company has the following marketing strategy (Figure) because the superconducting motor is characterized as highly efficient, compact, light-weight, and portable. (See Note 1.)



According to the Siemens CEO, they are targeting large-capacity motors with 2MVA or higher capacity, high-speed rotation and lightweight motors for industrial processes, and low speed and high-torque motors for ships. The company expects the superconducting motors will earn fairly good profits instead of their existing motors, which earn little profit today. The CEO believes that technological innovation is a good means to earn more in the future and accordingly invests in technology with a long-term view.

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The development of a high temperature superconducting motor by AMSC in the United States is an example of technological development at the national level. The company set a goal of holding tests in the summer of 2003 and is now developing a 5MW and 230 rpm motor. In cooperation with GE, AMSC is also developing a 100MW class high temperature superconducting generator. AMSC estimates that the annual worldwide market reaches $1.5 billion for high temperature superconducting generators with high efficiency and low-operation costs. The company is planning to develop 100 to 1,200 MVA-class high-temperature superconducting generators for electric power industries in the world. GE is known well for their attitudes of only doing things that quickly bring profits and of only participating if they can get the largest or second largest market share. Profit-oriented GE's involvement in the superconducting generator business seems promising.

3. Domestic activities

After phase 1 of the 7MW-class generator was completed, phase 2 of the superconducting generator project under the Ministry of Economy, Trade and Industry went underway through NEDO. NEDO is basically examining expanding capacity with low temperature superconducting wires. The Japanese government is not involved with any development projects on superconducting motors for applying them to electric power, general industry, or ships. It seems that manufacturers lack the courage and funding to develop projects by themselves. Nor have any efforts been made to appeal to the interests of users.

4. Activities in ISTEC

ISTEC has played a major role in holding International Superconductivity Industry Summits (ISIS) where Japan, Europe, and the United States have participated for forming the superconductivity industry. ISTEC has also held an International Superconductivity Industry Summit (ISIS) every year to promote the enlightenment, propagation, and exchange of superconductivity information. The Superconductivity Research Laboratory (SRL) is also engaging in developing Y based wire, which is the next generation superconducting wire, in cooperation with the industrial circles concerned. Japan is ahead of other competitors in the world in terms of Y based wire development. Given that material is not of any use unless it is actually used, development activities must be promoted in anticipation of applying them. Research on applying high temperature superconductivity to electrical energy is already underway. ISTEC carried out research in "Applying High Temperature Superconductivity to Industrial Magnets" in fiscal 2002. (See Note 2.) The research covered the possible consumption volume, performance, efficiency, energy-saving effects, and convenience of high temperature superconducting wires when they are applied to motors, electromagnetic brakes, single-crystal pulling systems, magnetic separation systems, and magnet-levitated railways. The research also concluded that the high temperature superconductivity-applied motor market is the largest in terms of sales among these applications. Accordingly, SRL set up the "Research Committee on Moves for Practical Applications of High Temperature Superconducting Motors" in fiscal 2003 and has been discussing steps that will lead to the market accepting superconducting motors. The committee members include experts on ordinary motors and their control systems. These members are expected to present views that may contradict experts on superconductivity, and they will prevent discussions from being dominated by narrow views from the sole standpoint of superconductivity. More specifically, the committee is trying to identify the areas of needs and classes of capacities of superconducting motors that are the most appropriate to introduce. Experience of over 100 years in motors and related equipment will be very instrumental in forming the superconducting equipment market.

We also hope that experts on superconducting equipment (systems) will devise new types of superconducting equipment based on new mechanisms that make the most of superconductivity. Such equipment types should not merely replace existing equipment. When new equipment-based mechanisms are devised, they will broaden the applications for superconductivity. When specifications of the materials needed for producing the equipment are defined, application development will be encouraged even more than before.

5. Conclusion

In addition to merely replacing existing equipment, some people concerned frequently say that there could be some niche markets where superconducting equipment fits well.

Although ISTEC has played a major role in researching and developing superconductivity in the world, ISTEC should contribute further to the niche markets such as superconducting rotating machines, and to R&D activities related to these applications.

(Note 1)
Dag W.A. Willen, NKT Research & Innovation A/S.
At the 11th International Superconductivity Industry Summit (ISIS-11, Tokyo, November 2002, hosted by ISTEC).
(Note 2)
"Research Report on High Temperature Superconductivity for Industrial Magnet Application"
International Superconductivity Technology Center, March 2002

(Osamu Horigami, Director, SRL/ISTEC)

Top of Superconductivity Web21

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Trends in Superconducting Rotating Machine Technology

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Electrical rotating machines are classified into generators and motors. Although motors with supersonic waves are also devised, most of electrical rotating machines use the magnetic field, where moving conductor generates electromotive force (generators) or current through conductors makes electromagnetic force (motors). This is where superconductivity application can be promising, effective, and worthwhile.

The generator uses the basic principle of voltage generation taking place when a conductor in the magnetic field moves. The motor uses electromagnetic force generated by current or changes of the magnetic permeability in the magnetic field. The former has the same structure as the generator.

When such an electromagnet is replaced with a superconducting magnet or bulk superconductor, or when bulk superconductor is used for changing magnetic permeability, it turns into a superconducting rotating machine. Some engineers are also discussing the possibility of using superconducting wire for a voltage generation conductor for generators and for a current conductor for motors, which is referred to as an armature conductor.

This section reports general technological trends in systems for making rotors superconductive.

Depending on the power source, rotating machines are classified into DC and AC ones. DC ones are subdivided into DC ones with commutators, which account for the majority of rotors on the market, and monopolars (homopolars) for special purposes. Although a number of ideas have been presented to make superconducting heteropolars , no definite technological development activities have been reported so far. The application of homopolars has been limited to special purposes because it requires generating a high magnetic field in a large air space. Copper and iron magnets cannot satisfy this requirement. Thus, people have begun to realize the usefulness of superconducting magnets that can generate high magnetic fields in air space, especially for ship motors requiring large-capacity electrical propulsion, which cannot be realized with existing DC rotating machines. Development of such magnets is underway, including development for military applications. Since stationary superconducting magnets can be used and cannot be influenced by magnetic field due to r armature current (armature reactions), excellent features are supposed to be available for superconducting application. In reality, however, a number of problems remain unsolved on the armature current collectors .

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AC rotating machines are classified into synchronous machines and induction ones. Alternative current runs on stator and rotator of an induction machines. Research and development depend on improving the alternative current of superconducting wire. Since low-frequency alternative current runs on the rotor, one idea for a superconducting induction motor has been presented to use the flux flow state of bulk superconductor.

Synchronous machines are subdivided into those used for generators for power systems, where alternative current runs on the stator and the rotator is an electromagnet, and into reluctance-type and hysteresis-type synchronous machines, which use changes in the magnetic rotor permeability. The speed of rotations of the latter machines depends on the AC frequency of the stator. Therefore, both machines are used for motors in variable-speed operations in combination with invertors. In the former machines, since a superconducting magnet is used for the electromagnet, high-efficiency machines smaller than conventional machines can be manufactured. In addition, as no magnetic material is needed for magnetic circuits, stability in the power system will improve. When the former machines are used as motors, inverter operation is easily available. The development of a superconducting generator, where low-temperature superconductivity is applied, has now advanced close to practical application. Although the advantages of high temperature superconductivity in generators are limited, application to motors is expected to bring about considerable advantages----changes in the rotator speed requests margins in the rotator temperature of a motor, which will bring about advantages of high temperature superconductivity. Thus, efforts for the research and development of such a motor are underway. By applying superconducting bulk to a rotator, research is underway to develop a reluctance motor, where changes in magnetic permeability are used, and a hysteresis motor, where magnetic hysteresis is applied.

In addition to homopolars and large-type synchronous generators, where low temperature superconductors are advantageous, the development of a high temperature superconducting motor is expected. The development of rotating machines is also expected, which applies high temperature superconductivity.

Top of Superconductivity Web21

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Superconductivity Web21

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Development Status of Key Technology for Superconducting Generators by Super-GM Project

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Engineering Research Association for Superconductive Generation Equipment and Materials

The Ministry of Economy, Trade and Industry, through the New Energy and Industrial Technology Development Organization (NEDO), commissioned us to research and develop three types of 70MW-class low-temperature superconducting generators for 12 years starting in fiscal 1988. As a result, the project obtained the design and manufacturing technologies of a 200MW-class superconducting generator. In addition, since fiscal 2000, we have been implementing a four-year project in order to improve economic efficiency, which aims to achieve key technologies for a higher density and a larger capacity generator for greater economy.

1. Development Targets

The development for higher density targets 200MW-class generators and the development for larger capacity targets 600MW-class generators. Table 1 lists the targets of these development projects as follows:

Table 1 Project Development Targets

Item		Ongoing Project	Preceding Project
High-density key technology	Current density of armature winding * 1	$140A/cm^2$	$110A/cm^2$
	Current density of field winding * 2	$80A/mm^2$	$60A/mm^2$
	Output density	1.5	1
Large-capacity key technology	Armature current	15kA - class	6.5kA - class
	Field winding current	6kA - class	3kA – class
	Outer rotator diameter	1,100mm	900mm

Note* 1
Average current density on cross section of ring, which is made of armature winding including insulation and support teeth.
Note* 2
Average current density on cross section of the field winding support shaft slot.

2. Development Status

The primary basic designs have been carried out in order to determine the development targets of the individual element technologies. As a result, we have obtained perspective of development for the high-density 200MW generator and the large-capacity 600MW generator. We are now verifying these designs with element models and detailed computer analysis.

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The project details are as follows:

(1) Developing high-density key technology (200MW-class generator)

- Superconducting field winding
Based on the wire with three-component-composite structure of Cu/CuNi/NbTi, which was successfully developed in the previous project, we are developing ffield winding of current density 1.5 times higher.

We have manufactured successfully different prototype wires and almost achieved the development targets of critical current density, Jc = 3.3 kA/mm^2 at 5T and 1.3 kA/mm^2 at 8T.

- Field winding support shaft
In the previous project, A286 or Inconel was used for the field winding support shaft because extremely high mechanical strength are required at room and low temperatures. Low productivity with these materials, however, results in increased production costs. In this project, we examined a number of other materials and found that 13% Ni steel where the Ni quantity is reduced to half is quite possible to be applied. This will contribute to reducing material costs and the number of processing steps. In addition, 13% Ni steel is ferromagnetic material, which enables higher magnetic flux density compared to nonmagnetic material.

- Armature winding
Cross section of a bar of armature winding consists of internally transposed strand groups and cooling tubes. The cooling tubes are divided into two structures to reduce loss. Through analyzing the temperature on the cross section of the winding, it was confirmed that the highest temperature is under the class B limitation. We are going to carry out verification tests using element models.

- Teeth
We changed the tooth material from FRP that was applied in the previous project to lower-price stainless steel. We have confirmed the teeth have no problems according to our analyses including characteristic vibration analysis and more. We are going to carry out verification tests using element models.

- Armature winding structure
We are going to make a partial model of the armature winding to verify if the results obtained by element models and analyses are reasonable. In the structure of the partial model, the end portion will be equal to the real machine, while the straight portion size will be one-half of the real machine. We have scheduled conductivity, vibration, and other tests on the armature winding structure with the partial model.

(2) Development of Large-Capacity Key Technology (600MA-class generator)

- Field winding
Based on 1.6 mm diameter wire in three-component-composite structure of Cu/CuNi/NbTi, which was successfully developed in the previous project, we set targets of improving the NbTi critical current density (Jc) to 1.3 times (3.3kA/mm^2 at 5T), and of enlarging the wire diameter to 2 mm for 6000A class large current field winding. The research and development are now underway. We have completed examinations of heat treatment conditions at production and made a prototype wire for experiment. In our test, the prototype wire with 2 mm target diameter almost achieved the critical current density that we set as our target. We also made a prototype Rutherford-cable-like conductor with 9 strands and a large section and

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measured AC loss. We confirmed that the measured AC loss is sufficiently smaller than the target value of 200kW/m^3.

- Field winding structure

We are going to make single winding model and field winding partial model, which has saddle type winding of one fifth the length of straight portion and same winding cross section and almost same end portion structure with the real 600MW class machine. These will be experimented with for verification.

- Teeth

Since a large-capacity generator will substantially increase the armature current, the electromagnetic force on the teeth will also increase. For this reason, we examined connected wedge structure. According to our analysis, the connected wedge structure shows approximately only one-half maximum stress compared to independent wedge at sudden short-circuit.
We are also planning to examine the connected structure with models.

As mentioned above, this project will use a variety of models during fiscal 2003 to carry out experiments for verification and try to establish the relevant fundamental technology.

Top of Superconductivity Web21

Superconductivity Web21

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Technological Development for Superconducting Motors Today

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The 1MW or higher class high-temperature superconducting synchronous motor is characterized as having the following advantages over current motors:

1. improvement in efficiency (several percent)
2. small and light-weight (approximately 2/3 of current motors)
3. low noise (because of small harmonic flux)
4. fit for inverter-driven operation (harmonic control with a heavy-duty damper)
5. large overload capacity (because the load-angle is extremely small)
6. almost no decrease in efficiency upon partial load
7. self-start is available (with a damper)
8. condenser and inductive operations are available (with field current control during no load operation)

The following advantages are also available by applying high-temperature superconductors to NbTi wire and other low-temperature superconductors:

1. a large reduction in the refrigerator capacity is available (1/10 or less of current motors)
2. reduction in the vacuum degree inside the rotor (absorbent instead of vacuum drawing) is available
3. the margin for transient field current is unnecessary (due to overload capacity of the high-temperature superconductor in a short time)

Meanwhile, the following major technological issues must be cleared in order to succeed in developing the high-temperature superconducting motor mentioned above:

- Improving the performance of the high-temperature superconducting magnet: developing high-performance superconductors, coils, supports, and cooling technologies, and improving economy.
- Optimizing the structure of the cryogenic rotor: reduction in the capacity of the refrigerator by reducing the volume of heat penetration into the cryogenic rotor.
- Developing a refrigerator in which a cryogenic rotor is built: for a smaller and more reliable refrigerator.
- Demonstrating performance and economy by using key components and a prototype model machine.

We implemented the basic design of a superconducting motor with a capacity of over 10MW in which Bi-2223 is applied at 30K. We examined the effects that the machine parameters had on the characteristics. As listed in Table 1, we obtained the field magnetomotive force, electric loading, motor weight, and motor efficiency for a superconducting motor with a capacity of 10MW.

Table 1 Basic Design Example of a 10MW-class High-Temperature Superconducting Motor

Synchronous reactance [pu]	0.3	Field winding magnetomotive force [MA/pole]	0.50
Outer rotor diameter [m]	0.43	Electric loading [A/cm]	1280
Built-up of stator magnet core [m]	1.03	Motor weight [ton]	13.6
Rotor build [m^3]	0.19	Motor efficiency [%]	98.9

In addition, we evaluated the heat penetration volume into the cryogenic rotor, which is fixed in the superconducting field winding. As a result, the heat penetration indicated (1) 35 to 40 [W] when a multilayer heat insulator was used without a low-temperature damper and (2) 20 to 30 [W] when a low-temperature damper was used to substantially reduce the penetration of radiation heat. These figures also indicate the necessary refrigerator capacity.

As described above, the high-temperature superconducting motor is characterized as having many advantages such as improved efficiency, lightweight, low noise, and improved capacity for overloading and partial loading. Thus, we need to work on developing a high-temperature superconducting motor as soon as possible. At that time, key technologies will be those that can improve the performance and economy of a high-temperature superconducting magnet; that can make a smaller refrigerator; and that can build a refrigerator in the rotor.

Top of Superconductivity Web21

Superconductivity Related Product Guide

-- Superconductivity Related Gases, Coolants, and Related Equipment --

Iwatani Industrial Gas Corp.
Every kind of industrial gases (oxygen, nitrogen, argon, helium, etc.), liquid nitrogen, liquid argon, and liquid helium
Contact: Kanto Branch (Low-Temperature Equipment Dept.)
Tel: 03-5405-5795 Fax:03-5405-5985

Osaka Sanso Industries Co., Ltd.
Helium (pure gas) unit and helium liquefiers, compressors for helium liquefaction, liquid helium storage, collection compressors, and gas refiners
Contact: Gas Equipment Sales Group
Tel: 03-3434-0199 Fax: 03-5472-8728

Koike Oxygen Industries Co., Ltd.
Helium liquefiers and refrigerator made by Inde, Inc.
Contact: Advanced Equipment Office
Tel: 0473-76-3633 Fax: 0473-76-7020

Suzuki Shokan Co., Ltd.
Liquid helium Dewar, continuous liquid helium level indicators, and transfer tubes
Contact: Low-Temperature Equipment Dept.
Tel: 0492-25-7511 Fax: 0492-26-8971
e-mail: teion@suzukishokan.co.jp

JECTRI Co., Ltd.
Liquid gas level indicators, transfer tubes, liquid helium containers, liquid nitrogen automatic suppliers, liquid helium automatic suppliers, liquid nitrogen containers, liquid gas vacuum insulation pipes, subcool LN2 cycle cooling systems, and liquid nitrogen gas-liquid separators
Contact: Sales Dept.
Tel: 049-225-7555 Fax: 049-225-7558
e-mail: t_makino@jecctorisha.com

Taiyo Toyo Sanso Co., Ltd.
Helium re-concentration systems, dilution freezers, LHe automatic pressure control, liquid nitrogen generators, and LN2 storage and transport containers
Contact: Cryogenic Dept., Industrial Gas Business Dept.
Gas Business Division
Tel: 03-3231-9845 Fax: 03-3271-3270
e-mail: cryo@saan.co.jp

Air Liquide Japan, Ltd.
Industrial gases, medical gases, and technical services
Contact: Keiji Miyazaki, Plant Engineering Service Division
Tel: 0794-37-2811 Fax: 0794-37-7315

Nippon Sanso Corporation
Full automatic helium refrigeration and liquefaction systems, and full automatic liquid nitrogen production systems
Contact: Sales Dept., Space and Cryogenic Equipment Division
Tel: 044-288-6937

----Bulk and Applications----

[Synthetic powder]
Superconducting Material Group, FTP Division, Dowa Mining Co., Ltd.
Bi systems
Contact: Mr. Nakamura
Tel: 03-3201-1086 Fax: 03-3201-1036

[Bulk material]
- Polycrystals (target material, etc.)
Superconducting Material Group, FTP Division, Dowa Mining Co., Ltd.
Y & Bi systems
Contact: Mr. Nakamura
Tel: 03-3201-1086 Fax: 03-3201-1036

-Melts (single domain crystal)
Superconductivity Group, New Material Research Dept.
Advanced Technology Laboratory, Nippon Steel Corporation
Trade name: QMG
Contact: Oxide Material
Tel: 0439-80-2714 Fax: 0439-80-2746
e-mail:hirano@re.nsc.co.jp

Superconducting Material Group, FTP Division
Dowa Mining Co., Ltd.
Contact: Mr. Nakamura of RE materials
Tel: 03-3201-1086 Fax: 03-3201-1036

- Thick Film
Superconducting Material Group, FTP Division
Dowa Mining Co., Ltd.
Contact: Mr. Nakamura of Bi materials
Tel: 03-3201-1086 Fax: 03-3201-1036

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[Application products and assemblies of bulk materials]

- Magnetic shield
Superconducting Material Group, FTP Division
Dowa Mining Co., Ltd.
Y & Bi systems
Contact: Mr. Nakamura and Mr. Wada
Tel: 03-3201-1086 Fax: 03-3201-1036

- Current lead
Superconductivity Group, New Material Research Dept.
Advanced Technology Laboratory, Nippon Steel Corporation
Contact: Oxide Material
Tel: 0439-80-2714 Fax: 0439-80-2746
e-mail:hirano@re.nsc.co.jp

- Magnetic field generator using bulk superconducting magnet (3T in free space)
Aisin Seiki Co., Ltd.
Sales: Mr. Okubo Tel: 0566-24-8865 Fax: 0566-24-8859
R&D: Mr. Oka Tel: 0566-24-8423 Fax: 0566-24-9391

Imura Material Development Laboratory Co., Ltd.
Contact: Mr. Ito
Tel: 0566-24-9382 Fax: 0566-24-9370

(Yasuzo Tanaka, Editor)

Top of Superconductivity Web21

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Superconductivity Web21

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What's New in the World of Superconductivity (February)

Power

American Superconductor Corporation (February 4, 2003)

American Superconductor Corporation (AMSC) announced their third quarter fiscal 2003 results for the period ending December 31, 2002. Net revenues decreased from US $ 3.53 million for the third quarter of 2002 to $ 2.75 for the presently reported quarter. The net loss increased from $10.88 million for the third quarter of 2002 to $ 12.61 million for the presently reported quarter. However, the net revenues for the nine-month period ending December 31, 2002, totaled $10.09 million, while the net revenues for the first nine months of fiscal 2002 totaled $8.45 million. The net loss for the first three quarters of fiscal 2003 was $ 33.67 million, compared with $ 29.04 million for the first three quarters of fiscal 2002. The operating loss for the first nine months of fiscal 2003 was $34.49 million, compared with $ 33.09 million for the first nine months of fiscal 2002. The operating loss for the Electric Motors and Generators business segment remained about the same for these two periods, while the operating loss for the Power Electronic Systems segment decreased by 42% due to higher revenues and cost control measures. The operating loss for the HTS wire segment increased significantly because of the impact of depreciation and the cost of operating AMSC's new HTS wire manufacturing plant. The cash burn rate for the third quarter of 2003 was higher than anticipated because of delays in expected commercial orders and government contracts. The cash burn rate is expected to decrease in the fourth quarter thanks to the receipt of the delayed product orders; new product orders and commitments as well as new development contracts are also anticipated. AMSC expects to have a total fiscal 2003 revenue of approximately $ 19.5 to 20.5 million.
Source:
"American Superconductor Reports Third Quarter Results and Updated Outlook for Fiscal Fourth Quarter"
American Superconductor Corporation Press Release (February 4, 2003)
http://www.amsuper.com/html/newsEvents/news/104429731361.html

American Superconductor Corporation and GE Industrial Systems (February 4, 2003)

American Superconductor Corporation (AMSC) and GE Industrial Systems have sold two D-VAR ™ dynamic voltage compensation systems to Rayburn Country Electric Cooperative. The D-VAR systems will be used to improve power reliability by mitigating voltage stability problems on a 138 kV transmission grid serving 26,000 customers. The electrical demand in the region served by this grid has been growing at a rate of 6% per year; this growth rate has increased the potential for widespread low voltage and voltage collapse. The D-VAR systems will enable these problems to be avoided and will delay the need for expensive alternative solutions. The D-VAR systems are expected to become operational by June 1, 2003.
Source:
"AMSC and GE Sell Two D-VAR™ Systems to Texas Utility"
American Superconductor Corporation Press Release (February 4, 2003)
http://www.amsuper.com/html/newsEvents/news/104429743601.html

American Superconductor Corporation (February 24, 2003)

American Superconductor Corporation (AMSC) and GE Industrial Systems have sold a new,

advanced transmission reliability system, consisting of three D-VAR ™ units and related GE equipment, to Connecticut Light & Power Company, a subsidiary of Northeast Utilities. The system will be used to increase the reliability and flow of electricity in a chronically congested power grid. By monitoring the variations in voltage, the system will immediately allow an additional 100 megawatts of power to flow through the existing transmission lines. The system is expected to be installed and operational by the summer of 2003. Commented David Boguslawski, Vice President of Northeast Utility's Transmission Business Unit, "Our in-depth review found that the D-VAR technology represents a flexible and affordable solution that will help us with reliability in southwest Connecticut in the near term while we continue to work with local communities to meet the long-term needs of this region."
Source:
"Northeast Utilities Boosts Electricity Flow Into Chronically Congested Section of Power Grid with Advanced Transmission Reliability System"
American Superconductor Corporation Press Release (February 24, 2003)
http://www.amsuper.com/html/newsEvents/news/104609398101.html

Sensor

Bruker Daltonics, Inc. (February 27, 2003)

Bruker Daltonics, Inc. has announced a collaboration with the Mayo Clinic in the field of proteomics, focusing on the development of novel, efficient methods of protein analysis using Fourier transform mass spectrometry (FTMS). As part of the collaboration, Bruker Daltonics will provide the Mayo clinic with a 12 Tesla commercial FTMS system that has been optimized for proteome-wide measurements. The system has an ultra-high mass accuracy (less than 1 ppm mass errors) and resolving power, a wider dynamic range, and an automated data-dependent MS/MS, enabling detailed proteome characterization when combined with on-line multidimensional liquid chromatography. The installation of the FTMS system, including the 12 Tesla superconducting magnet, is expected to be completed by March 2003
Source:
"Advancing High-Throughput Proteomics with FTMS: Bruker Daltonics Announces Collaboration to Develop Highly Sensitive Protein Analysis Methods with Ultra-high Field FTMS"
Bruker Daltonics, Inc. Press Release (February 27, 2003)
http://ir.bdal.com/ireye/ir_site.zhtml?ticker=bdal&script=412&layout=-6&item_id=386496

Communication

Superconductor Technologies Inc. (February 11, 2003)

Superconductor Technologies Inc. (STI) announced that it expects to achieve commercial product sales amounting to US $ 40 million in 2003, in addition to approximately $ 10 million in government revenue for a total revenue of $50 million. This expectation is more than double the preliminary net revenue of $22 million for fiscal 2002, which was nearly double the net revenue of $ 12.4 million for 2001. STI plans to pursue growth by focusing on key wireless carriers, satisfying existing customer needs, adding new customers, and penetrating select international markets. STI expects to announce its final year-end results in early March.

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5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan Tel: 03-3431-4002, Fax: 03-3431-4044

Source:
"Superconductor Technologies Inc. Supplies Guidance for Fiscal 2003"
Superconductor Technologies Inc. Press Release (February 11, 2003)
http://ir.thomsonfn.com/InvestorRelations/PubNewsStory.aspx?partner=Mzg0TlRrMU1RPT1QJFkEQUALSTO&product=MzgwU1ZJPVAkWQEQUALSTOEQUALSTO&storyId=81015

Superconductor Technologies Inc. (February 26, 2003)

Neal O. Fenzi, Vice President of Product Management at Superconductor Technologies, Inc., recently gave a presentation at the Wireless Systems Design Conference and Expo, in San Jose, California, in which he commented that wireless carriers must embrace alternative technologies to achieve network performance optimization and continued growth. According to a recent issue of Consumer Reports, the overall satisfaction rating for wireless companies was lower than that of most other companies rated by the survey. The main source of dissatisfaction appeared to be the high rate of dropped calls, with one-third of respondents stating that they were considering changing their providers. Fenzi went on to explain how HTS filters can provide both sensitivity and selectivity to networks, helping to eliminate out-of-band interference. Recent field trials in urban and suburban clusters have shown that sites where STI's SuperLink Rx 850 cryogenic receiver front-end has been installed a more than 40% improvement in dropped and failed calls during periods of heavy usage, providing a cost-effective solution for carriers with tight budgets. Fenzi stated that even using conservative estimates, the SuperLink solution would pay for itself in six months.
Source:
"Wireless Carriers Must Learn to 'Do More With Less' If They Are to Continue to Grow in 2003, Says STI Executive"
Superconductor Technologies Inc. Press Release (February 26, 2003)
http://ir.thomsonfn.com/InvestorRelations/PubNewsStory.aspx?partner=Mzg0TlRrMU1RPT1QJFkEQUALSTO&product=MzgwU1ZJPVAkWQEQUALSTOEQUALSTO&storyId=82186

(Akihiko Tsutai, International Affairs Department, ISTEC)

Top of Superconductivity Web21

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Patent Information

Introducing Approved Patents

Patents approved recently are introduced below.

Patent No. 332554, "Superconducting Sigma Delta Modulator", Publication No. 2001-119300 (applied in 1999)

This patent is related to the AD converter of a sigma delta modulation system. This system converts an analog input signal into a series of high-speed pulse signals (1-bit digital signals) and then into high-accurate digital signals (multiple bits) through digital processing.

This system is based on the configuration of an integrator circuit (sigma) of input signals and a comparison and difference circuit (delta) of 1-bit signal. When a high-speed superconducting circuit of single flux quantum (SFQ) is applied to this system, high-speed and high-accuracy AD conversion is available. This invention used the fact where Josephson junctions with specified parameters can generate n pieces of SFQ pulses for an input SFQ pulse. Through the differential processing for the integrated signal by (n+1) pulses, more multiple bit code of digital signal are available at the same sampling frequency, and more wide bandwidth is also available at the same bit accuracy. This realizes a high-speed and high-bit AD converter, which improves the performance of receivers of the base stations in wireless communications and the performance of measurement instruments.

For more information about this invention, access the homepage of the Patent Office of Japan and visit the Intellectual Property Digital Library (IPDL).

Marked MgB_2 Patent

Described below is a summary of the patent for the new superconducting material MgB_2, found by Professor Akimitsu et al. at Aoyama Gakuin University in January 2001.

"Intermetallic Compound Superconductor Comprising Magnesium and Boron, Alloy Superconductor Containing the Intermetallic Compound and Method for Producing These," Publication No.2002-211916 (applied for on January 9, 2001).

This patent aims to provide an intermetallic compound superconductor with a high superconducting transient temperature (Tc), an alloy superconductor having a high Tc and excellent in malleability and ductility, and a production method with good reproducibility at a low production cost.

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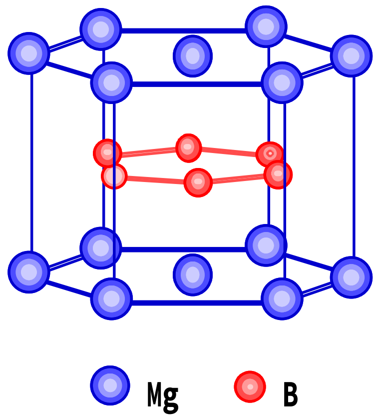
This new intermetallic compound superconductor, consisting of magnesium (Mg) and boron (B), is expressed as MgB_2 and has a hexagonal AlB_2 crystal structure and Tc of 39K, the highest among the existing metallic superconductors. An alloy containing this intermetallic compound will turn to the alloy superconductor excellent in malleability and ductility and with high Tc of 39K.



Hexagonal AlB_2-type Crystal Structure

In the production, a mixture of Mg and B powders is used as the starting material. The mixture is hot-pressed in a vacuum or inactive gases. When a mixture of Mg and B powders at a 1:2 chemical composition ratio is heated, it will turn into an intermetallic compound superconductor. When Mg and B powders are mixed at Mg: B = 1 -x: 2+y, (0<x<1, -2<y<0, and 0<y<2), it will turn into an alloy superconductor.

(Katsuo Nakazato, Director, Development Promotion Dept., SRL/ISTEC)

Top of Superconductivity Web21

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Standardization Activities

---- IEC/TC90-VAMAS Joint Conference Held ----

The IEC/TC90 Superconductivity Committee and VAMAS/TWA16 held an IEC/TC90 (Superconductivity)-VAMAS Joint Conference relevant to standardization of the superconductivity at the Pacifico Yokohama Convention Center on November 12, 2002. The joint conference had 17 participants from Germany, Austria, United Kingdom, Korea, and Japan.

This joint conference, held in Yokohama, is meeting for the fifth time, following Gifu, Morioka, Tokyo, and Kobe conferences in the past. VAMAS/TWA16 is an international research project, set up in 1993, aiming to standardize superconducting material measurements and evaluation technologies. IEC/TC90 exchanged a memorandum on cooperation for standardization with VAMAS (Versailles Project on Advanced Materials and Standards) in 1995. IEC/TC90 has a liaison with VAMAS.

The Yokohama joint conference proceeded with the following agenda:

1. TWA Office Report
2. Project Reports and Discussions
(1) Project number WG1-1 (Bending strain effects on critical current in oxide superconductors, and some round robin test results)
(2) Project number WG1-3 (Measurement method of irreversibility field in oxide superconductors)
(3) Project number WG1-4 (Coupling loss measurement in multi-filamentary HTS superconductors)
(4) Project number WG2-1 (Measurement methods of trapped field and levitation force in bulk oxide superconductors, and some round robin test results)
(5) Project number WG3-1 (Measurement methods of surface resistance in thin film superconductors)
(6) Project number WG4-1 (Measurement method for the mechanical properties of oxide superconductors)
3. New Proposal on Strain Effects
4. Related Activities in IEC/TC90
5. Feature Schedule

The next conference, which is regarded as a satellite meeting of ISS 2003 (October 27-29, 2003), is scheduled for Tsukuba City, Japan.

---- Attention to Integrated Promotion with R&D Projects ----

It is necessary to promote superconductivity standardization activities in close cooperation with research and development in order to create superconductivity technologies and implement their practical application. In particular, since November 2001, superconductivity standardization activities have been attached importance to an integrated effort with superconductivity related research and development projects.

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The EU has been carrying out an integrated promotion policy for standardization efforts and research and development since October 1999. North America has been promoting this policy since September 2000, and Japan implemented the same policy starting in September 2001. The EU and the United States have been providing financial support for some research and development projects that aim at standardization. Thus, Japan has also been strengthening standardization activities to compete with the EU and the United States.

When researching actual superconductivity related R&D projects, however, we will notice a fairly large difference between the reality and the integrated promotion policy. More specifically, researchers and engineers have very different levels of recognition and understanding towards standardization. We cannot disregard these differences when implementing a uniform integrated promotion policy. That is to say there are following significant problems. The advanced research and technological development, whose standardization cannot be imagined during research and technological development stages, are different from product commercialization. It is against national interests to standardize formation technologies that are full of know-how. The de facto standard is the right way while the de jure standard is weak. To standardize a product under development could bring about confusion in the industry. Targets for standardization lie only in mass-volume products manufactured with an advanced quality control system. Thus, the policy of integrated promotion is urged to classify R&D subjects and to enlighten researchers and engineers.

At present, Japan has six electric energy and electric equipment related projects as superconductivity related R&D projects under the Ministry of Economy, Trade and Industry. Based on the research and development reports, and the development product specifications of these projects, publicly available specifications (PAS) and technical specifications (TS) as pre-standard can be prepared and issued. Setting a course for globalization and internationalization is essential for Japan's superconductive technological capabilities. Japan's successful globalization and internationalization of its superconductivity technologies will considerably strengthen the international competitiveness of the nation's superconductivity industry and other general industries as well. This recognition and understanding must be steadily promoted to researchers and engineers as part of Japan's standardization efforts.

(Yasuzo Tanaka, Standardization Dept., ISTEC)

Top of Superconductivity Web21