Fall, 2007 Date of Issue: October 15, 2007

Superconductivity Web21

Published by International Superconductivity Technology Center
5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan Tel: +81-3-3431-4002, Fax: +81-3-3431-4044

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Published by International Superconductivity Technology Center
5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan
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Top of Superconductivity Web21: http://www.istec.or.jp/Web21/index-E.html

This work was subsidized by the Japan Keirin Association using promotion funds from the KEIRIN RACE
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Verification Test Commencing on Superconducting Magnetic Energy Storage System (SMES) for Electric Power System Control

Tsutomu Tamada
Superconductivity Team, Electric Power R&D Center
Chubu Electric Power Co., Inc.

On June 15, the New Energy and Industrial Technology Development Organization (NEDO) and Chubu Electric Power Co., Inc. held an opening ceremony at the Field Test site in Nikko City, Tochigi Prefecture after preparations were completed for conducting a verification test on SMES for electric power system control.

As part of the Electric Power Technology Program of the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI), NEDO is subcontracting the verification test to Chubu Electric Power as well as Kyushu Electric Power Co., Inc. and the International Superconductivity Technology Center (ISTEC). This four-year project launched in fiscal year 2004 is now in its final year.

The SMES for electric power system control being tested is characterized by the use of a superconducting coil that enables the repeated storage and release of electricity rapidly and with high efficiency; it is able to improve power quality by suppressing fluctuations on the power network.

For this test, we will build an SMES for the control of a power system that outputs 10,000 kW, and then not only conduct performance tests on each piece of equipment at the factory, but also perform comprehensive verifications of its effect by means of a system stability test and load fluctuation compensation repeated at least 20,000 times when it is actually connected to a network. After deciding that a location with a supply line to a metal rolling plant, which is a source of fluctuating load, and a power generating facility would be optimal for the verification test, we obtained the cooperation of Furukawa Electric Co., Ltd. in building the Nikko Superconducting Test Center within the Hosoo Power Plant (Hosoo-machi, Nikko City, Tochigi Prefecture) owned by Furukawa Nikko. Power Generation Inc. Over the course of approximately 6 months, we will verify the items outlined hereafter.

Items to Be Verified

1) Durability and stability after repeated charging and discharging of power
2) Control responsiveness and operating characteristics in response to voltage and frequency fluctuation on the power network
3) System reliability

Effects such as improved power quality on future power networks are expected from this technology.

Table 1 Main specifications of SMES for power system control

Item	Specification
Capacity of converter equipment	10,000 kW
Energy stored on superconducting coil	19 MJ
Type of superconducting coil	Metallic (NbTi)
Operating temperature	4.2 K
Operating current	1,350 A
Operating voltage	1.1 kV
Maximum magnetic field	4.4 T

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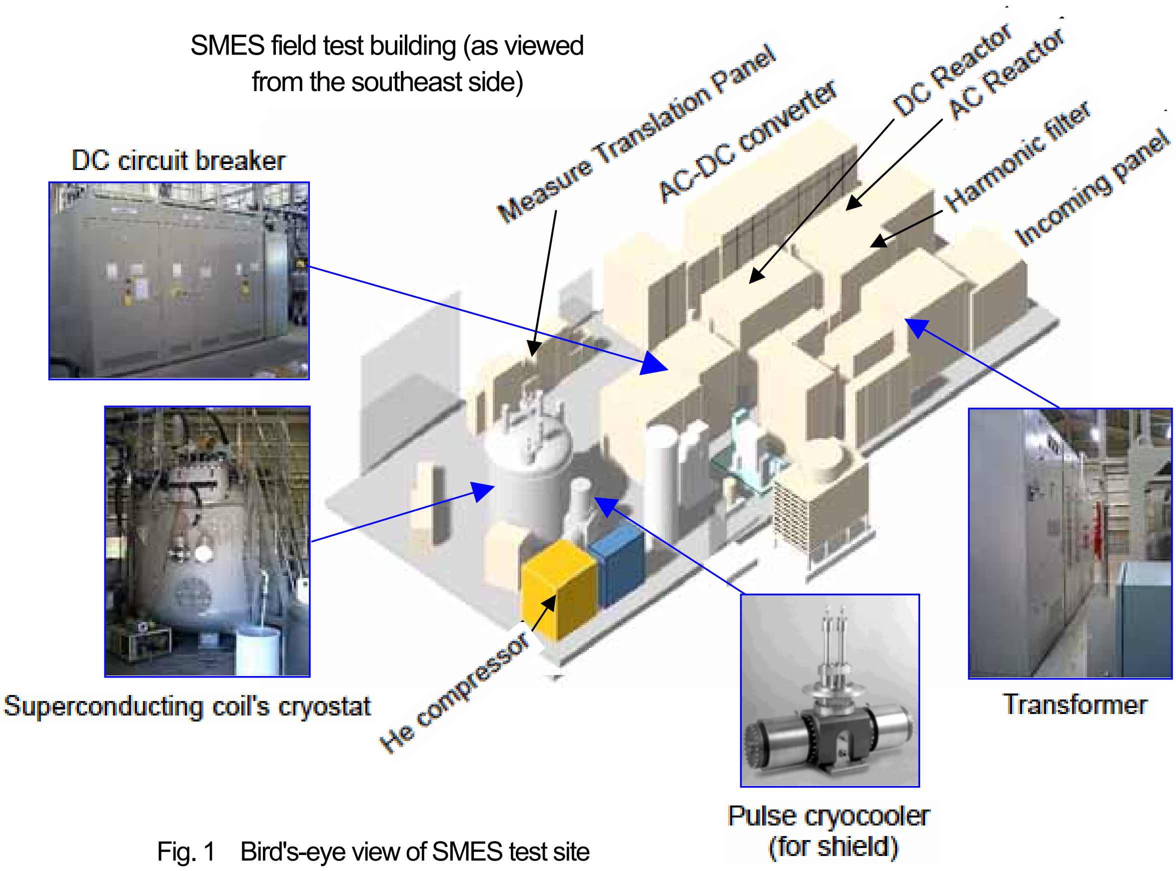

Fig. 1 Bird's-eye view of SMES test site

Fig. 2 Opening Ceremony

(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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

Power

SuperPower, Inc. (August 7, 2007)

SuperPower, Inc., a subsidiary of Philips Holdings USA, reported several new achievements and a new world record in superconducting magnet performance at the 2007 U.S. Department of Energy Annual Peer Review in Superconductivity for Electric Systems. First, SuperPower reported the production of the world's longest buffered wire to date. Several wires in lengths of 1,350 meters and including a complete buffer template stack with five nano-scale layers have been produced, with an average in-plane texture of 6 to 7 degrees and a uniformity of 2 to 3%. The 4-mm-wide wires were produced at a speed of 350 meters/hour, demonstrating the long-length, high-throughput capability of SuperPower's pilot-scale wire manufacturing process. Philip J. Pellegrino, president of SuperPower, Inc., commented, "In addition to our achievements in wire performance and production lengths, further improvements in the areas of process speed, product throughput and materials cost reduction have enabled us to steadily reduce our pricing, with the goal of achieving price parity with copper by the end of this decade. We are well on the way toward achieving that goal." In addition to the delivery of 9.7 kilometers of second-generation (2G) HTS wire to Sumitomo Electric Industries in December 2006 for use in the Albany HTS Cable Project and the use of 2G wire for a variety of in-house device demonstrations, SuperPower has also sold more than 6.4 km of its 4-mm-wide equivalent 2G HTS wire to 25 research organizations, universities, and commercial firms around the world since July 2006. This wire will be used in a wide variety of applications including cables, fault current limiters, and magnets.

SuperPower and its project partner, Sumitomo Electric Industries (Japan), also reported the successful installation of the world's first 2G HTS cable in National Grid's utility system. The installation marks the completion of a critical element of the Albany HTS Cable Project. Using the 9.7 km of 2G HTS wire provided by SuperPower, Sumitomo fabricated a 30-m long, 3-phase, fully shielded cable. Cable installation is presently ongoing and will be followed by a period of testing, with re-energization of the entire system planned for November 2007. The cable will then be operated for approximately 6 months. In the previous phase of the cable project, the two first-generation HTS cable sections were operated without incident for about 9 months.

Also at the Peer Review, SuperPower and the National High Magnetic Field Laboratory (NHMFL) reported a new world record of 26.8 Tesla, the highest magnetic field ever to be created by any superconducting magnet (see below summary for NHMFL, Aug. 7, 2007).

In a final announcement, SuperPower announced that together with the Oak Ridge National Laboratory, SuperPower has received the 2007 R&D 100 Award for its 2G HTS wire. The award was given to SuperPower for its High Performance LMO-enabled HTS wire, selected as one of the 100 most technologically significant products to be introduced into the marketplace over the past year. This wire has the unique combination of strength, flexibility, fabricability, throughput, and low cost needed for power grid applications, including coils and motors. The award will be presented to the inventors of the wire at a ceremony to be held later this fall.

Source:
"SuperPower Announces New World Records in Wire and Magnet Technologies"
SuperPower, Inc. press release (August 7, 2007)
http://www.superpower-inc.com/20070807.aspx

American Superconductor Corporation (August 9, 2007)

American Superconductor Corporation (AMSC) reported its first quarter financial results for the period ending June 30, 2007. Revenues for the first quarter increased by 41% to U.S. $19.8 million, from $14.0 million for the same period in the previous fiscal year. In particular, revenue for AMSC Power Systems increased by 305%, compared with the revenue for the same period in the previous fiscal year. The net loss was $9.7 million, compared with $6.7 million for the same period in the previous fiscal year. The net loss included several unusual items, including approximately $2.9 million in charges related to a higher adjustment on an outstanding warrant because of an increase in the company's stock price, restructuring and impairment charges for the AMSC Superconductors business unit, and the write off of a SuperVAR ® synchronous condenser that AMSC had planned to ship to a customer. The company ended the first quarter with $30.5 million in cash, cash equivalents, and short-term investments. AMSC has since completed a follow-on stock offering yielding approximately $94 million in net proceeds. As of June 30, 2007, the company's total backlog of orders and contracts was valued at $75 million. AMSC has also received a record commercial order from Sinovel Wind (China), increasing their backlog to approximately $140 million, in addition to awards of up to $24 million and $21.7 million from the Department of Homeland Security and the Department of Energy, respectively. David Henry, Senior Vice President and Chief Financial Officer, commented, "With the resources to fully capitalize on our growth opportunities now available as a result of our recently completed stock offering, we are driving hard to achieve our profitability objectives. Based on the momentum we continued to build in the first quarter, we are now anticipating revenues for fiscal 2007 to increase approximately 67 percent year-over-year to a range of $85 million to $90 million, up from our previous forecast of $75 million to $80 million. We expect our net loss for the fiscal year will be in the range of $21 million to $24 million. This compares with our previous forecast of $22 million to $25 million. We believe we will approach positive EBITDAS in the fourth quarter of fiscal 2007, and we remain on track to be EBITDAS positive in fiscal 2008."

Source:
"AMSC Reports First Quarter Fiscal 2007 Financial Results"
American Superconductor Corporation press release (August 9, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1038763&highlight

Zenergy Power plc (August 9, 2007)

Zenergy Power plc has been granted a core patent for HTS coils in Germany. This patent is of particular importance as it represents the central component of a new class of highly energy efficient, compact, and lightweight electricity generators. These generators will be sold to industrial players within the renewable energy sector to improve the efficiency of electricity production and are expected to reduce overall costs associated with the production of renewable energy, including a reduction of up to 25% in offshore wind power costs. The HTS coils are being developed by the Zenergy Power Group and its partners, with the backing of several governmental and public bodies including the European Commission, the German Ministry of Economics and Technology, and the United Kingdom's Department of Trade and Industry. The annual market for HTS components within the wind power and hydropower markets is expected to be in excess of 2.6 billion euros. At present, the Group is in the process of installing the world's first HTS hydrogenerator into a commercial hydroelectric power station in Germany. After testing, the 1.25-MVA superconductor generator is expected to power approximately 2,000 households. Zenergy's components have already been shown to have an efficiency level of greater than 98% for the generation of hydroelectric power.

Source:

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"Core Patent in Key Renewable Energy Markets"
Zenergy Power plc press release (August 9, 2007)
http://www.trithor.com/pdf/press-en/2007-08-09-Core-Patent-Coils.pdf

American Superconductor Corporation (August 28, 2007)

American Superconductor Corporation (AMSC) has received two additional orders for its D-VAR ® voltage control solution to enable 60-MW and 48-MW wind farms under construction in the United States and Scotland, respectively, to meet local power grid interconnection requirements. The installation of the D-VAR systems is scheduled for early 2008, and both wind farms are expected to begin operation within the next 12 months. The orders mark the 32nd and 33rd wind farms worldwide to purchase AMSC's D-VAR systems; with the addition of these orders, AMSC products will be utilized in the generation of more than 5.7 gigawatts of wind power worldwide, or triple the value as of September 2006.
Source:
"AMSC Receive New D-VAR® Orders for Wind Farms in the U.S. and Scotland"
American Superconductor Corporation press release (August 28, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1045380&highlight

U.S. Department of Energy (August 28, 2007)

In a visit to the Energy Louisiana Operations Center in Gretna, Louisiana, the new Assistant Secretary for the U.S. Department of Energy (DOE)'s Office of Electricity Delivery and Energy Reliability, Kevin M. Kolevar, highlighted the Bush Administration's efforts to increase the use of advanced technologies for power delivery in the U.S. as well as the DOE's recent announcement to invest up to U.S. $51.8 million to modernize and secure the U.S. electric grid. Entergy Corporation, the Oak Ridge National Laboratory, and nkt cables (Germany) have joined the project led by Southwire Company to install a 13.8-kV HTS cable to solve real-world electrical congestion near downtown New Orleans. The DOE has awarded this project up to $13.3 million.

As previously reported, four other consortia have been selected by the DOE to receive up to $51.8 million for cost-shared projects to modernize the U.S. electrical grid. Two of these consortia will be led by American Superconductor (receiving $9 million and $12.7 million), one will be led by SC Power Systems (receiving $11 million), and one will be led by SuperPower Inc. (receiving $5.8 million). The projects are expected to last two to five years.
Source:
"Department of Energy Official Touts Bush Administration's Efforts to Modernize our Nation's Electric Grid"
U.S. Department of Energy press release (August 28, 2007)
http://home.doe.gov/news/5342.htm

Magnet

National High Magnetic Field Laboratory (August 7, 2007)

The National High Magnetic Field Laboratory (NHMFL) and SuperPower, Inc., a subsidiary of Philips Holdings USA, have reported a new world record of 26.8 Tesla, the highest magnetic field ever to be created by any superconducting magnet (including low-temperature superconducting magnets). The HTS magnet coil was fabricated by SuperPower using SuperPower's second-generation HTS Wire™ and was tested by NHMFL researchers. In late July, the magnet generated a field of 26.8 Tesla in a background field

of 19 Tesla at 4.2 Kelvin. Without the background field, the coil generated a field of 9.5 Tesla at 4.2 Kelvin. This new world record was more than 1.8 Tesla higher than the previous world record attained using a first-generation coil in 2003. David Larbalestier, Director of the Applied Superconductivity Center and Chief Materials Scientist at NHMFL, commented, "This test demonstrates what we had long hoped - that YBCO high-temperature superconductors being made now for electric utility applications also have great potential for high magnetic-field technology. It seems likely that this conductor technology can be used to make all-superconducting magnets with fields that will soon exceed 30 Tesla. This far exceeds the 22 to 23 Tesla limit of all previous niobium-based superconducting magnets." The new record brings researchers a step closer to realizing the National Research Council's goal of creating a 30-Tesla superconducting magnet, which would enable considerable advances in physics, biology, and chemistry.
Source:
"New Mag Lab Record Promises More to Come"
National High Magnetic Field Laboratory press release (August 7, 2007)
http://www.magnet.fsu.edu/mediacenter/news/pressreleases/2007august7.html

Mass spectroscopy

Carnegie Mellon University (August 23, 2007)

Researchers at Carnegie Mellon University have utilized a novel mass spectrometer to characterize large viral particles and bulky von Willebrand factors. Using a Macromizer™ mass spectrometer, the group successfully analyzed the outer mature protein shell of the HK97 virus, weighing 12,900 kDa, and the uncleaved protein shell, weighing 17,700 kDa (conventional mass spectrometers are unable to sensitively characterize molecules over 150 kDa at a low-charge state). The resulting spectra revealed an unprecedented 30+ positive charges. The group also collected an improved mass spectrum of a von Willebrand factor (200 to 1,100 kDa), a protein complex in blood that is necessary for proper coagulation. The direct mass analysis of these heavy, intact biological molecules at a low-charge state represents a new level of analysis previously unattainable using conventional detectors.

The Macromizer is a cryodetector-based MALDI TOF mass spectrometer equipped with 16 superconducting tunnel junctions. Carnegie Mellon University houses the only two of these instruments in the U.S. The instruments can be used to measure the molecular weight of large, intact proteins or protein complexes in a matter of seconds, as opposed to the several days that are required using the "bottom-up" approach of conventional mass spectrometry. The group's results represent a step toward the realization of rapid disease diagnosis using mass spectrometry. Professor Mark Bier, Associate Research Professor and Director of the Center for Molecular Analysis at Carnegie Mellon University, elaborated: "This is a new frontier in mass spectrometry research. We anticipate that this work will help to advance research in proteomics, virology, molecular biology and nanotechnology."

The research is funded by a grant from the National Science Foundation's Biological Infrastructure program. Using this support, the group is also building a next-generation heavy ion mass spectrometer.
Source:
"Carnegie Mellon scientist uses mass spectrometer to weigh virus particle, von Willebrand factor"
Carnegie Mellon University press release (August 23, 2007)
http://www.cmu.edu/news/archive/2007/August/aug23_massspec.shtml

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Cryocooler

Oxford Instruments plc (August 20, 2007)

Oxford Instruments plc has acquired VeriCold Technologies GmbH, a manufacturer of cryogen-free products utilizing pulse tube cooler technology. VeriCold's range of Cryofree® products will complement and broaden Oxford Instruments' extensive range of low-temperature and high magnetic field instruments for both existing academic research and new markets. The acquisition is part of Oxford Instruments' five-year plan to double the size of the company through the acquisition of complementary technologies. VeriCold will remain at its location in Germany but will significantly expand its research and development group in response to the growing demand for cryogen-free technologies, particularly in the areas of quantum computing and airport security.

Source:
"Oxford Instruments plc acquires VeriCold Technologies GmbH"
Oxford Instruments plc press release (August 20, 2007)
http://www.oxinst.com/wps/wcm/connect/Oxford+Instruments/Internet/Press/Current+News/Oxford+Instruments+plc+acquires+VeriCold+Technologies+GmbH

Materials

Superconductive Components, Inc. (August 7, 2007)

Superconductive Components, Inc. (SCCI) reported its second-quarter financial results for the period ending June 30, 2007. Total revenues amounted to U.S. $3.4 million, an increase of 194% compared with the results for the same period in the previous fiscal year. The increase in total revenue was driven by strong sales growth in the company's photonics/optical sector. Gross profit increased to $0.5 million, compared with $0.3 million for the same period in the previous fiscal year. As of June 30, 2007, SCCI's backlog was $2.0 million. Dan Rooney, Chairman, President and Chief Executive Officer of SCCI, commented, "We are pleased with our results for the second quarter of 2007, which marked the fourth consecutive quarter of profitability. Specific strategies continue to be pursued in markets that offer long-term, profitable growth opportunities and also contribute to further diversification of the company's business."

Source:
"Superconductive Components, Inc. Reports Strong Second Quarter 2007 Results"
Superconductive Components, Inc. press release (August 7, 2007)
http://www.sciengineeredmaterials.com/investors/ne/earnings/scci27.htm

Communication

Superconductor Technologies Inc. (August 2, 2007)

Superconductor Technologies Inc. (STI) reported its second-quarter financial results for the period ending June 30, 2007. Total net revenues amounted to U.S. $4.7 million, compared with $5 million for the same period in the previous fiscal year. Net commercial product revenues totaled $3.7 million, compared with $3.9 million for the same period in the previous fiscal year. Government and other contract revenue

totaled $1.0 million, compared with $1.1 million for the same period in the previous fiscal year. Net loss for the quarter totaled $2.0 million, compared with $22.7 million for the same period in the previous fiscal year (which included a $20.1 million non-cash goodwill impairment charge). Jeff Quiram, STI's President and Chief Executive Officer, reported, "We are pleased to add three new customers, each contributing 10% or more of our revenues in the second quarter as they moved beyond the technical evaluation stage to commercial deployment. Our government business grew sequentially in the second quarter, and we expect government revenue to continue to increase in the future as we deliver on the initial $4.7-million Air Force contract we signed in April. Finally, as we face the challenges of growing our revenues, by continuing to effectively manage our current assets and operating expenses we have succeeded in further reducing our quarterly breakeven level to approximately $8.3 million." As of June 30, 2007, STI had a commercial product backlog of $143,000, compared with $800,000 as of June 30, 2006.
Source:
"Superconductor Technologies Inc. Announces Second Quarter 2007 Results"
Superconductor Technologies Inc. press release (August 2, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1036133&highlight

Superconductor Technologies Inc. (August 22 and 27, 2007)

Superconductor Technologies Inc. (STI) has entered into an agreement with Hunchun BaoLi Communication Co. Ltd. ("BAOLI", China) under which BAOLI will invest $15.0 million in the company in exchange for 9,216,590 shares of STI's common stock at a purchase price of $1.6275 per share. The investment will be made in four installments, with the first installment of $1.0 million available as of August 31, 2007, the second installment of $3.0 million available as of September 30, 2007, the third installment of $2.0 million available as of October 22, 2007, and the fourth and final installment of $9.0 million available as of December 30, 2007. According to the agreement, BAOLI has agreed to vote all but 2,148,296 of its shares, in proportion to the votes of STI's other shareholders, on any matters that may require a shareholder vote in the future.

In related news, STI initiated negotiations to form a joint venture with BAOLI, which manufactures push-to-talk (PTT) handsets and associated battery technology for the Chinese market. The proposed joint venture would focus on the manufacturing and marketing of STI's SuperLink® interference elimination solution for the Chinese market. QiangHua Shao, president of BAOLI, stated, "STI is the world leader for interference elimination with its SuperLink® product, and we see significant opportunities for this solution in China and other Asian markets. By combining BAOLI's manufacturing and supply chain capabilities with STI's technology, we believe the proposed joint venture would be positioned for success in China, the country with the world's largest wireless network. Our goal is to form this joint venture by the end of 2007."
Source:
"Superconductor Technologies Enters Into $15.0 Million Investment Agreement"
Superconductor Technologies Inc. press release (August 22, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1042612&highlight
"Superconductor Technologies in Negotiation to Enter Joint Venture With Hunchun BaoLi Communications"
Superconductor Technologies Inc. press release (August 27, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1044929&highlight

Basic

European Science Foundation (August 7, 2007)

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Dr. Masaki Hori (University of Tokyo) has received a valuable EURYI Award for his project on the handling and storage of anti-protons. In cooperation with the Max-Planck Institute in Germany, Hori has been studying the storage of anti-protons using radiofrequency, rather than magnetic fields. Using this approach, Hori intends to construct a “superconducting radiofrequency quadrupole trap” that will be very compact – about the size of an office wastebasket. Hori then plans to utilize this device to create complete atoms of anti-matter and to conduct experiments that should confirm the predicted behavior of anti-matter. Hori has already shown that antiprotons have exactly the same mass of protons as well as an equal, but opposite, charge.

The EURYI Award is given by the European Science Foundation and the European Heads of Research Councils with the goal of attracting young researchers from anywhere in the world to work in Europe for the further development of European sciences. The award is valued at between €1,000,000 and €1,250,000.

Source:
“EURYI award project to store antimatter in box like ‘office bin’”
European Science Foundation press release (August 7, 2007)
http://www.esf.org/ext-ceo-news-singleview/article/euryi-award-project-to-store-antimatter-in-box-like-office-bin-301.html

(Akihiko Tsutai, Director, International Affairs Department, ISTEC)

(Published in a Japanese version in the August 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Advances in Cooling / Thermal Technology
- Advances in Large Stirling Pulse Tube Cryocoolers -

Yoshimasa Ohashi
Vacuum and Cryogenic Group, Energy Planning Dept.
Aisin Seiki Co., Ltd.

Stirling type pulse tube cryocoolers are being developed in an attempt to increase cryocooler lifetime and efficiency. These cryocoolers are comprised of a compressor without wearing parts and pulse tube cryocooler without any moving parts. Reliability beyond similar cryocoolers developed thus far can be expected due to the lack of wearing parts and few causes of contamination. Aishin Seiki Co., Ltd. has already verified durability performance for more than 50,000 hours using a small Stirling type pulse tube cryocooler (SPR-05) to cool superconducting equipments and radiation detectors. The company has been marketing the SPR-05 since 1997 and long life is a proven characteristic of Stirling type pulse tube cryocoolers.

Aishin Seiki Co., Ltd. along with CHUBU Electric Power Co., Inc. has been developing a large Sterling pulse tube as a cryocooler for a superconducting magnetic energy storage (SMES) system since 2004. As of 2006, we have completed an evaluation unit, and starting this year we plan on conducting durability tests and verification tests linked with a SMES system.

One notable feature of this cryocooler is it uses two pulse tubes and two regenerators. Increasing size in this manner prevents disturbances in the flow of the working gas (helium) within the pulse tubes and regenerators, thereby enabling a uniform state.

To further improve efficiency at low temperatures, we improved the regenerators to rectify the working gas within them. The improved performance resulting from such rectification was achieved by revising the filling method of the regenerator material into the regenerators.

These improvements lower loss within the regenerators, thereby achieving temperatures of 40 K or under. Improving cryocooler efficiency also makes it possible to reduce power consumption. Furthermore, lowering the reachable temperature results in a dramatic increase in performance at 77 K or under. The following performance is being achieved in the laboratory.

- Power consumption Approx. 6 kW (3ø 200 V)
- Cryocooling output 77 K 300 W
- Reachable temp. Approx. 38 K

Our future plans include continuing to verify the durability performance of large Stirling type pulse tube cryocoolers as well as reduce power consumption and refine various components in an effort to develop cryocoolers that satisfy users.

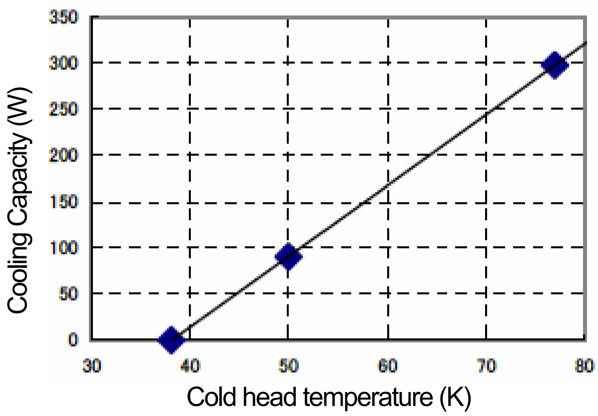

Fig. 1 Diagram of Cooling Capacity

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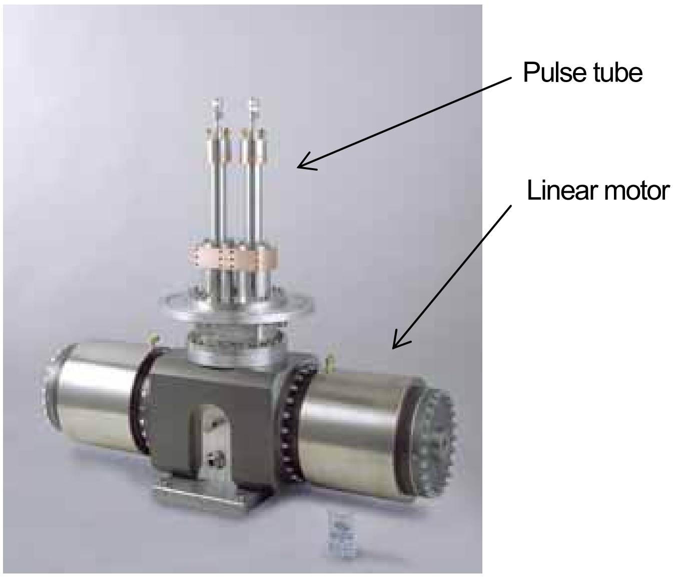

Fig. 2 Stirling type pulse tube cryocooler

(Published in a Japanese version in the June 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Advances in Cooling / Thermal Technology
- Advances in Magnetic Materials Technology for MagneticRefrigeration-

Hideki Nakagome
Graduate School of Engineering
Chiba University

Research on a magnetic cooling method that attempted to apply adiabatic demagnetization for producting ultralow temperatures to an even higher practical temperature level began in the U.S., and it was also carried out in Japan between 1979 and 1987. Fig.1 shows a piston-driven magnetic cryocooler for liquid helium. Carnot magnetic cryocoolers apply a magnetic field to a magnetic material and then release the generated heat via a heat switch on the high-temperaure end (Fig. 2). Then, it lowers the temperature of the magnetic material by demagnetizing it with the switch in the off position. The heat switch on the low-temperature end turns on near the temperature of liquid helium to perform cryocooling. The cryocooler in Figure 1 is operated by making the magnetic material within the piston move alternately in and out of the magnetic field.

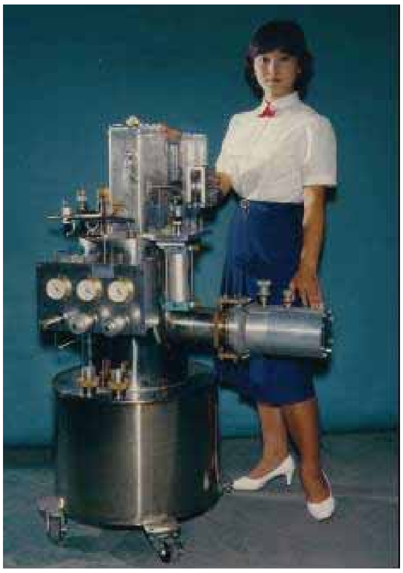

Fig. 1 Piston-driven magnetic cryocooler

Lately, magnetic cryocoolers for the ordinary temperature range and the temperature of liquid hydrogen are being newly developed. This has been made possible by major improvements to the performance of key components, including magnetic materials, superconducting magnets, and permanent magnets, that have been made over the last 20 years.

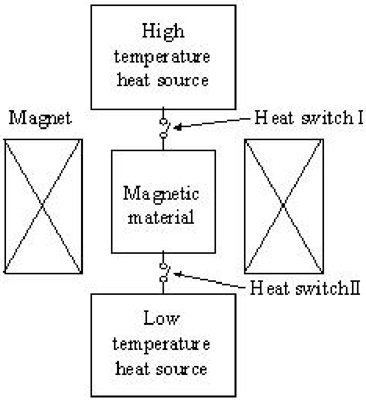

Fig. 2 Conceptual diagram of a Carnot magnetic cryocooler

In the ordinary temperature range, the active magnetic regenerator (AMR) is being introduced in an effort to make coolers and cryocoolers practical. By taking on the role of both the regenerator material and magnetic material, AMR is able to create a large difference in temperature of 20 K or more with an approximately 1 Tesla magnetic field produced by a permanent magnet. Further performance improvements can be expected by employing lanthanum, iron, or silicon-based magnetic materials that have potentially large changes in entropy at 1 Tesla or below.

We are currently developing a system that combines Carnot and AMR for hydrogen liquefaction as well. We have already confirmed an efficiency of 50% Carnot or more for the Carnot portion that liquifies hydrogen and are now aiming toward an expansion of the operating temperature span by AMR in the future.

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Major technological advances in future magnetic cryocooling methods can be expected due to fact that high magnetic fields can now be easily used thanks to superconducting magnets that use conduction cooling. These advance can also be expected by such means as increasing the performance of magnetic materials, including those based on lanthanum, iron, or silicon, and making practical high-magnetic field permanent magnets of the 1-Tesla level.

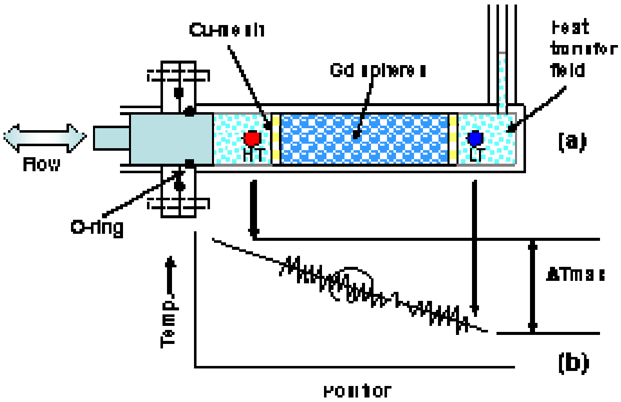

Fig. 3 AMR magnetic cryocooler

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(Published in a Japanese version in the June 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Advances in Cooling / Thermal Technology
- Prospects for Liquid Hydrogen System Technology for Hydrogen Energy -

Shoji Kamiya
Chemical Technology Department ,Technical Institute
Kawasaki Heavy Industries, Ltd.

At the Intergovernmental Panel on Climate Change that was held recently, proposals were made for expanding the introduction of new energies and exhaustively carrying out energy-saving measures to combat the increasing threat of environmental destruction from global warming caused by rising CO_2 levels. Under such circumstances, the development of related technologies and the relaxing of regulations are underway, both in Japan and overseas, in an effort to realize a hydrogen energy society. The full-fledged introduction of hydrogen is not expected until around 2020, and until then, there are a number of hurdles, including lowering the cost of equipment that uses hydrogen (including hydrogen vehicles and stationary fuel cells), building a highly efficient hydrogen energy path that minimizes the amount of CO_2 gas emitted in getting hydrogen from source to user (well-to-tank), and the cost of supplying hydrogen. Fig. 1 shows each energy path from hydrogen source to user. The evaluation of energy paths is affected by a variety of factors, including the form in which hydrogen is used, the amount of hydrogen supplied, transport distances, and regional characteristics and is under debate at present, but the diversity of hydrogen sources is also a feature of hydrogen energy. Furthermore, hydrogen sources are gradually shifting from fossil fuels to renewable energy.

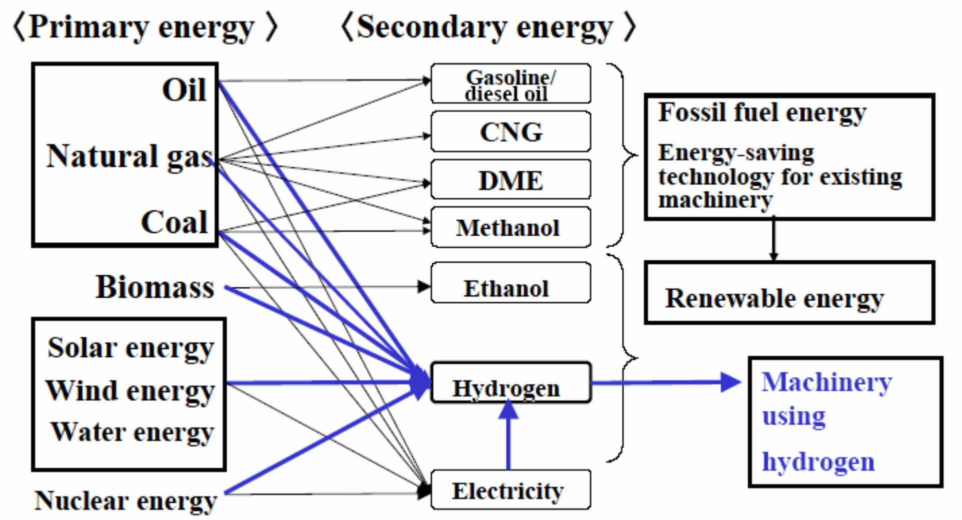

Fig. 1 Hydrogen energy path

Predicting how liquid hydrogen will be introduced into the hydrogen energy path while competing with other hydrogen media is difficult because so many wide-ranging factors come into play. Liquid hydrogen used for special purposes, such as rocket fuel, has approximately 1/800 the volume of hydrogen gas under normal temperature and pressure and a higher weight efficiency (hydrogen weight/system weight) than other hydrogen media, including high-pressure gas and storage alloys. At present, hydrogen vehicle stations with different hydrogen sources and supply forms are being tested both in Japan and overseas. Liquid hydrogen stations are one type, and there is one of these stations operating in Japan and a number overseas. Figure

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2 shows the liquid hydrogen supply flow up to hydrogen vehicles.

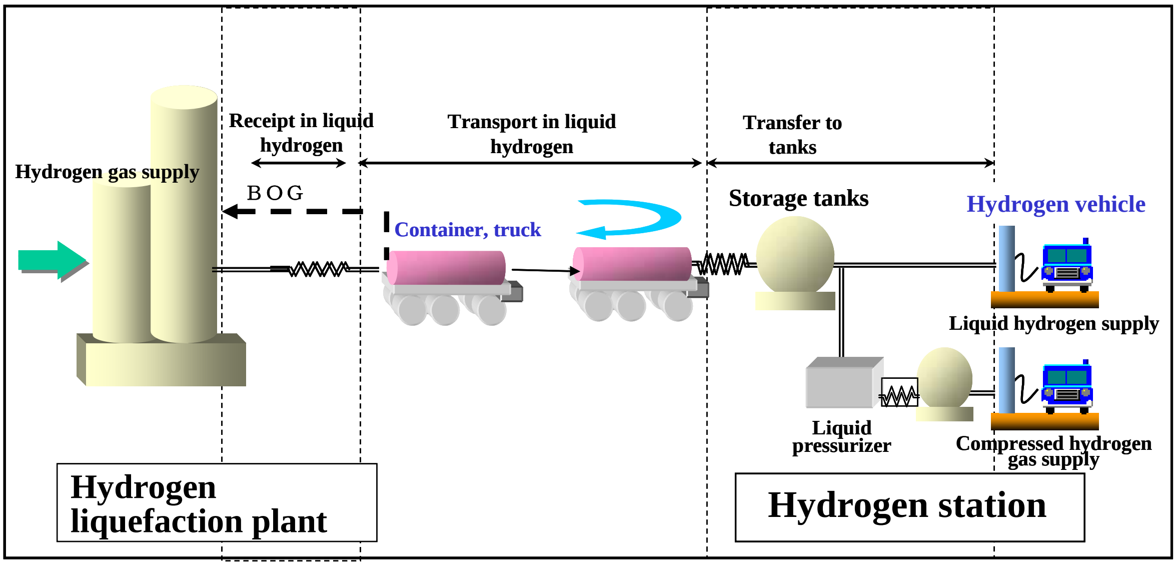

Fig. 2 Liquid hydrogen supply flow up to hydrogen vehicles

In the future, it is forecast that hydrogen use will expand from vehicles that must carry about 5 kg of hydrogen to large transport machines, such as vessels (for example, the 600TUE class that must carry about 1,000 tons of hydrogen) and aircraft (for example, the Airbus 310-class plane that carries 15.6 tons of hydrogen). At this level, there are increased advantages to carrying vast quantities of hydrogen in liquid form. However, problems do exist, such as the approximately 30% loss of energy (higher heating value) as well as evaporation and transport loss. Comprehensive studies that include the user end and performance increases in system components, such as liquefiers, are therefore required to reduce such loss. In addition, lowering the cost of supplying hydrogen to 40 yen/Nm^3 (cost comparable to the calorific power of gasoline) or about 1/3 of its cost today is one condition necessary for making the hydrogen energy market self-sustainable. Analyzing the technological issues in attaining a low-cost hydrogen supply is also essential. The technological progress and commercialization process for liquefied natural gas (LNG), which is a combustible liquefied gas just like liquid hydrogen, will no doubt prove to be a useful reference in the large-scale introduction of the liquid hydrogen system to society at large.

At present, research is underway in Japan and overseas on applying liquid hydrogen as a cryogen for superconducting cables. The technology combining this electric energy transport with the hydrogen energy transport is expected to simultaneously enable energy saving measures and the introduction of new energy, but building a scenario for its feasibility is a crucial first step. Keeping any eye on technological trends, including those in machinery that uses hydrogen and other forms of hydrogen storage, while thinking globally and acting locally is desirable in promoting the development of a liquid hydrogen system.

(Published in a Japanese version in the June 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Advances in Cooling / Thermal Technology
- Development of a Room Temperature Magnetic Refrigeration System -

Naoki Hirano
Superconductivity Group, Electric Power Research Center
Chubu Electric Power Co. Inc.

Hopes are pinned on the development of a refrigeration system that can replace those that use CFCs and their substitutes in a bid to prevent global warming. In addition, electric equipment that uses refrigeration equipment, such as air conditioners and refrigerators are in use for long periods for time, so development work is underway toward reducing the energy they consume. Magnetic refrigeration technology uses the temperature-change phenomenon (magnetocaloric effect) that results when exposing certain types of magnetic materials to a changing magnetic field. It is environmentally friendly, efficient, and saves energy, and development work is underway toward its practical application.

Unlike conventional refrigeration, magnetic refrigeration has the following characteristics:
• It is expected to operate at near theoretical efficiency and thereby save energy.
• It is environmentally friendly because it does not use CFCs and their substitutes.
• It is quiet and has fewer vibrations because there is no compressor.
The refrigeration capacity of such magnetic refrigeration systems can be improved by doing the following:
• Applying a large change in magnetic field.
• Improving heat exchange efficiency.
• Reducing heat leakage.

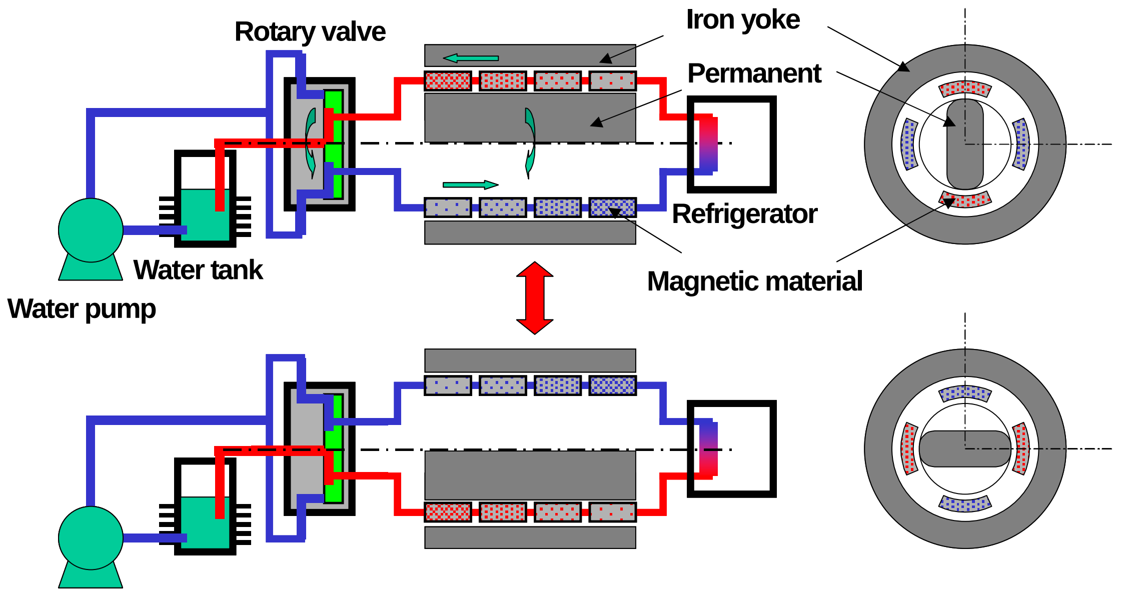
We recently developed a refrigeration system capable of large changes in the magnetic field (1.1 Teslas) by modifying the shape and positioning permanent magnets so that we maximize the utilization of its magnetic field. Specifically, we increased the repulsion of the magnetic field by arranging the magnets in a V shape. This system has a structure that optimizes the structure of the heat exchanger (shortens the tube through which water flows), at minimum triples the flow rate of the heat exchange fluid, and reduces the heat release due to eddy currents occurring in the system's outer tubing (iron yoke) when the permanent magnets spin by optimizing the structure of the magnetic circuit (specifically, sectioning the external tubing and the placing insulators in between) to suppress heat leakage. This enabled us to achieve 540 W of refrigeration power, which is nearly 10 times the 60 W we achieved in 2003.

Comparison of room-temperature magnetic refrigeration systems

	Developed system	Conventional system
Magnetic field source	Neodymium Permanent magnet	Neodymium Permanent magnet
Magnetic field strength	1.1 T	0.77 T
Magnetic materials	Gadolinium	Gadolinium alloy
Heat exchange medium	Water + alcohol	Water + alcohol
Operating cycle	2.4 sec	2.4 sec
Refrigeration capacity	540 W	60 W
Coefficient of performance	1.8	0.1
Dimensions of main unit	H410mm x W400mm x D390mm	H270mm x W270mm x D430mm

Furthermore, in order to curb power consumption and create a highly efficient system, we reduced water pump power by lowering pressure loss and devised a way for the heat exchange medium to flow more efficiently and reduced motor power by reducing magnetic resistance caused by the rotation of the permanent magnets. This enabled us to achieve a coefficient of performance (COP) of 1.8, the highest score for a magnetic refrigeration system in the world.

Structure and operation flow of magnetic refrigeration system



Room Temperature Magnetic Refrigeration System

We plan to advance our work by developing stable manufacturing technology for materials that have a high magnetocaloric effect and designing more compact and highly efficient systems in a bid to put air conditioners, refrigerators, and other appliances that use magnetic refrigeration technology into practical use as soon as possible.

Our development work is moving forward as part of the "Development of Non-fluorinated Energy-saving Refrigeration and Air Conditioning Systems " national project that we are pursing under a commission from New Energy and Industrial Technology Development Organization (NEDO). Industry, government, and academia, have joined together to jointly carry out this development work. Our project partners include Tokyo Institute of Technology's Interdisciplinary Graduate School of Science and Engineering, Hokkaido University's Graduate School of Engineering, and Kyushu University's Faculty of Science, Department of Physics.

(Published in a Japanese version in the June 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Forum on Superconductivity Technology Trends 2007

ISTEC held a forum on superconductivity technology trends entitled "Moving Toward an Energy Saving/Resource Saving Society" on Monday, May 28 at the Toshi Center Hotel, Tokyo. Over 200 representatives from the Japanese government, corporations, academia, mass media, and the general public participated in the forum, where research results, challenging issues, and trends in superconductivity development for industrialization were reported and heated discussions took place.

Yuuko Yasunaga, Director, Research and Development Division, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry, and Hideki Fukuda, Director General, New Energy Technology Development Department, New Energy and Industrial Technology Development Organization (NEDO) delivered congratulatory messages. They spoke about how superconductivity was a key technology for solving environmental problems and how there was great potential for its practical application. It was very encouraging to hear that further breakthroughs could be expected towards the practical application of high-temperature superconductivity twenty years after it was first discovered.

In his keynote address entitled "Responding to 21st Century Problems: The Role of Superconductivity Technology," Shoji Tanaka, Director General, Superconductivity Research Laboratory (SRL) pointed out that superconductivity technology could contribute enormously to solving a great many problems, including global warming and changes in the industrial establishment, through not only saving energy and resources, but also through practical applications in new areas, such as medical care and the environment. He also gave an introduction to major research results and the state of practical application and offered his perspective on how research results are steadily being tied together toward a vision of the future from 2010 to 2020.
In a presentation entitled "Characterization Technique for Long Wire in Magnetic Fields," Koichi Nakao, Acting Director, Division of Material Science & Physics, SRL introduced the importance of developing a characterization technique for long wire in magnetic fields and comprehending the distribution of characteristics. He also reported how feedback to wire development is contributing to accelerated development speed.

In a presentation entitled "Advances in Developing Large Bulk Materials and Its Deployment to Various Equipment," Izumi Hirabayashi, Director, Bulk Superconductor Laboratory, SRL reported on the advances being made in developing materials for large functional bulks achieved through experiments conducted in space and their application to various types of equipment.

In a presentation entitled "New Current Carrying Applications for Bulk Processes," Mitsuru Morita, Nippon Steel Corporation reported on technical developments in manufacturing coils in which a bulk superconductor is formed into a spiral using a sandblasting technique. He also gave an introduction on how it could help reduce devices sizes and potentially be applied in a variety of areas due to the high magnetic field of high-temperature superconducting bulks.

In a presentation entitled "Report on Results for Low－Power Superconducting Network Devices Project," Keiichi Tanabe, Director, Division of Electronic Devices, SRL reported on the results of developing low-temperature superconducting SFQ devices that were achieved in the NEDO project, the results on developing high-temperature superconducting SFQ devices, and the direction of future work.

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In a presentation entitled "Developing a Highly Sensitive Magnetic Immunological Testing System Using High-Temperature Superconducting SQUIDs," Akira Tsukamoto, Hitachi, Ltd., gave an introduction on an immunological testing system that uses magnetic markers and high-temperature superconducting SQUID magnetic sensors for the purpose of high-speed, high-sensitivity measurement of trace amounts of biomaterials.

In a presentation entitled "Developing Y-based Wire for Superconducting Equipment: Progress and Outlook," Yuh Shiohara, Deputy Director General, SRL and Director, Division of Superconducting Tapes & Wires reported on the latest progress being made in developing high-performance long wires and low-cost long wires by the Applied Basic Project and the efforts being made in leading research and development on equipment applications.

In a presentation entitled "Development Trends in YBCO Superconducting Transformers/Motors and Cryocoolers in Japan," Masataka Iwakuma, Associate Professor, Kyushu University reported on the progress being made in cryocooler development and the development of elemental technology for practical transformers/motors by utilizing the potential of Y-based wire, namely the size of its critical current in a magnetic field, low AC loss, and low cost. This progress is being made based on the technology for developing transformers/motors using Bi wire thus far.

In a presentation entitled "Is a Sustainable Society Possible? Challenges for High-Temperature Superconducting Wire/System Technology," Kenichi Sato, Sumitomo Electric Industries, Ltd. introduced example applications to various types of equipment using Bi high-temperature superconducting wire and the direction of future work.

In a presentation entitled "Current State and Future of SMES Development," Shigeo Nagaya of Chubu Electric Power Co. Inc. reported on the development details of phase II in the NEDO SMES project and the progress being made and the future of an actual interconnection test for proving both the economic efficiency and performance of SMES system technology based on the results obtained.

Finally, in a wrap-up address entitled "State and Trends in R&D on Superconducting Application Equipment in Various Countries," Osami Tsukamoto, Professor Emeritus, Yokohama National University introduced the state of superconducting equipment development, primarily rotating machinery, that is actively underway in the U.S. and Europe. He also advocated that even though Japan's efforts have come a little late, we should actively seize the opportunity to apply superconductivity to wind power generators.

The forum served to remind us of the significance and importance of further collaboration between industry, academia, and government that must take place for progress to be made in practical applications based on the steadily increasing results being produced by research and development in various superconducting fields.

(Masaharu Saeki, Director, Research & Planning Department, ISTEC)

Shoji Tanaka, Director General, delivering the keynote address

Forum participants

(Published in a Japanese version in the July 2007 issue of Superconductivity Web 21)

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Feature Articles: Forum on Superconductivity Technology Trends 2007 - Responding to 21st Century Problems: The Role of Superconductivity Technology -

Shoji Tanaka
Director General, SRL/ISTEC

Introduction

The world economic situation is undergoing a complete change as we head into the 21st century. Many developing nations, including Brazil, Russia, India, and China, the so-called BRICs with huge populations, are seeking better standards of living all at once and continue on a path of high growth. As a result, energy and mineral resources are growing scarce, leading to explosive price increases, marked environmental pollution, and water shortages. The UN's Pollution Prevention and Control (PPC) has determined that global warming due to CO_2 is caused by humankind, and if appropriate measures are not taken by 2030, it warns that our planet will face dire circumstances in 2050.

Surmounting such massive problems requires that new and revolutionary technology be deployed in a new phase, and superconductivity technology can be expected to play a crucial role therein.

This report covers the latest development work being carried out in the three fields of energy, the environment, and health/safety.

1. Energy

This section is a report on the recent state of next-generation superconducting wire, transport, and superconducting devices.

1-1 Development of Second-Generation Wires

Although the development project ends this year, it has already reached its interim goal of 200 m, 200 A/cm (77 K, 0 T), and it is now moving toward achieving the final goal of 500 m, 300 A/cm (77K, 0 T). In addition, it has been proven that wire using GdBCO exhibits good magnetic-field properties.

1-2 Development of Transport-Related Equipment

Magnets for maglev trains that use Bi-system wire have already been created, and in 2005, operation at a top speed of 550 km/h with no abnormalities has already been proven.

Success is also occurring in manufacturing prototype propulsion motors for ships using Bi-system wire.

1-3 Development of Telecom Equipment for the Internet

The advance of the Internet has been remarkable in recent years, and the total amount of data being transmitted is approximately doubling each year. As a result, the load being placed on the routers and servers installed on countless Internet nodes is rising rapidly, and it is clear that we cannot afford to ignore their energy consumption.

A possible replacement for CMOS devices is Nb single-flux quantum (SFQ) devices, although they operate at a low temperature at present. They deliver high performance, with speeds 100 times faster and energy consumption 1/1000 that of CMOS, and are stable.

It should also be noted that Cisco's CRS-1, the latest and most advanced router on the market, has a throughput of 1 Tbps, but to configure a 100 Tbps router with the same technology would result in a weight of 60 tons and energy consumption of 1.3 MW, both of which are enormous figures. If SFQ devices were used instead, it is estimated that the weight would be reduced to 0.6 t and power consumption to 35 kW. Consequently, it is possible that nodes equipped with SFQ devices may appear in the near future.

2. Development of Environment-Related Equipment

The magnetic separator using superconducting wire that was installed recently at an Osaka paper mill is running smoothly with a performance of 2000 tons/day.

In addition, a magnetic separator that employs bulks has also been developed, and its utilization for offshore oilfields and oil sand fields is currently under study.

3. Development of Health and Sanitation-Related Equipment

Global warming may result in the northern spread of virulent infectious diseases, such as malaria, from the southern hemisphere. Of particular concern is bird flu. Preventing such diseases requires the development of fast and accurate immunodiagnostic equipment.

3-1 Immunodiagnostic Systems Using High-Performance High-Temperature Squid Devices

Immunodiagnostics normally attaches and measures an appropriate antibody on an antigen, but in this method, it attaches a fine magnetic powder to an antibody and then uses a SQUID to measure the faint magnetic field. The diagnostic system developed by Kyushu University and Hitachi can diagnose 12 specimens in 100 seconds.

3-2 A Simple NMR Measurement System Using Superconducting Bulk

It is possible to obtain an extremely uniform magnetic field in the center bore section by opening up a measurement hole in the middle of a large bulk with a diameter and thickness of 6 cm or more. This is being used to manufacture a prototype NMR measurement system that is both small and mobile. If it is successfully completed, it is expected that even small local hospitals will be able to easily detect metabolites from the human body.

Wrap Up

As this article discussed, the problems we face in the 21st century are on a global scale, and they span a diverse range of fields. It is therefore crucial that we fully develop superconducting technology as an industrial technology as soon as possible.

Note: The article contained herein was republished in the exact same form it appeared in the collection of paper from the Forum on Superconductivity Technology Trends 2007.

(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Forum on Superconductivity Technology Trends 2007 - Advances in Basic Superconducting Technology -

This article contains three reports from the Forum on Superconductivity Technology Trends 2007, specifically "Characterization Technique for Long Wire in Magnetic Fields" by Koichi Nakao, Superconductivity Research Laboratory (SRL hereafter), "Advances in Developing Large Bulk Materials and Its Deployment to Various Equipment," by Izumi Hirabayashi, SRL, and “Bulk Processes for New Current Carrying Applications” by Mitsuru Morita, Nippon Steel Corporation.

It is already possible to manufacture 1 cm-wide tape-like Y wires that are over 200 m long and have a critical current (*I*c hereafter) of over 200A. Superconducting wire must function within magnetic fields, and to complete the manufacturing process, information on the distribution of characteristics by means of testing the entire length is indispensable. Most important is the establishment of technology that continuously measures *I*c in particular over the entire length, even within superconducting characteristics in a magnetic field. Koichi Nakao gave an introduction on the intermediate progress being made on developing such a measurement method. One of the measuring systems currently being developed uses an $Nd_2Fe_{14}B$ permanent magnet (generates a 0.53 T magnetic field) from the U.S.'s Los Alamos National Laboratory. There are cases where it continuously moves a wire while measuring *I*c by means of the four-terminal method, but the magnetic field strength that is considerably lower than the applied magnetic field that is necessary from a practical standpoint is a problem. One of the systems developed by the SRL (Nagoya) can apply a magnetic field of up to 5 T and is equipped with a reel that can continuously move a long wire to be measured. Although valuable data is being obtained with this system, the magnetic field it applied also affects locations other than the measurement site, which can cause problems. In response, Koichi Nakao is currently developing a technique that measures *I*c within magnetic fields using Hall elements or the induction method, and the most promising measurement method therein is the one using the induction method. This method applies a magnetic field perpendicularly to the surface of a tape wire and then performs non-contact measurement using a drive coil and pickup coil. (For more information, refer to K.Nakao et al., Physica C426-431 (2005), 1127.)

The report on "Advances in Developing Large Bulk Materials and Its Deployment to Various Equipment" told how it is already possible to manufacture bulks with 14 cm diameters on Earth, based on the results of manufacturing tests (USERS space experiments) on oxide-based high-temperature superconducting bulks that were conducted in space.

Izumi Hirabayashi provided an introduction to the results of a study on applying this technology to various equipment, including motors, wind power generators, NMR, high-intensity x-ray generators (undulators). The total flux of a bulk body 14 cm in diameter is approximately 4 times that of a bulk body 6 cm in diameter, and when this is applied to motors, torque approximately doubles, indicating that an increase in size has a meaningful effect. Results obtained by NEDO's FS through a study on applying superconductivity to wind power generators were also introduced. The subject of study focused on a 10 MW offshore generator, magnetic field superconductivity, and comparisons with conventional technologies. The potential for applying highly function NMR using bulk magnets was also reported. The concept is extremely interesting, but manufacturing thick bulks ultimately appears difficult.

Mitsuru Morita of Nippon Steel Corporation gave a very interesting report on bulk applications categorized by maglev applications, bulk magnets, and current carrying applications, focusing this time mainly on the last of the three. Nippon Steel Corporation had been studying the forming of bulks into a spiral to create magnets. In their latest effort, they obtained uniformity in magnetic field characteristics by a technique know as composition gradient for bulks 85 mm and 145 mm in diameter, and they were able to manufacture and test split magnets by forming the bulks into spirals. The process using a technique known as sandblasting was used to form a 1 mm-thick bulk into spiral wires 2.1 mm wide and separated by 0.5 mm gaps. The current carrying test was performed under a steady-state current and under high-speed excitation/demagnetization, and it achieved 2.15 T (720A) at a temperature of 52 K and 4.2 T/s (@54 K) under high-speed excitation/demagnetization. There was no degradation even in a heat-cycle test. It would appear that new applications will be discovered. It was a truly magnificent report.

(Osamu Horigami, Director SRL/ISTEC)

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Feature Articles: Forum on Superconductivity Technology Trends 2007 - Results Report for Project on Low Power Consumption Superconducting Network Devices -

Single flux quantum (SFQ) devices that use the flux quantum unique to superconductivity as an information carrier are about two orders of magnitude faster and have a power consumption at least three orders of magnitude lower than semiconductor devices, most notably CMOS. That is why they are expected to be one of the candidates for next-generation logic devices that can overcome the limits of semiconductors. The NEDO project that ended in March this year was conducted under a joint development system consisting of industry, academia, and government, with ISTEC-SRL at the very center. The process and design technologies required to expand circuit sizes were developed for low-temperature superconducting niobium SFQ devices targeting future large-scale information communications equipments, such as network routers and servers, and high-temperature superconducting oxide SFQ devices targeting small-scale portable or distributed equipments, such as ultra-high-speed measuring instruments and analog-to-digital (A/D) converters for base station receivers or transmitters. Prototype small-scale systems were also developed.

With the niobium devices, a rack-size SFQ switch prototype system was developed. In this system, an integrated SFQ chip containing a 4-input, 4-output switch that switches data paths and a scheduler circuit that performs collision avoidance control for data was cooled by a cryocooler. Among four PCs connected to the system, video data transfer and display was successfully demonstrated. A demo was also performed in which a 40 Gbps optical signal, which will become the mainstream optical communication technology of the future, was converted into four-channel 10 Gbps electrical signals, and then after path switching was performed by the switch within the SFQ switch prototype system, the electrical signals were taken out into a room-temperature area and converted back into a 40 Gbps optical signal. These demos show that the SFQ technology can be used by anyone and that it has real-world applications, including optical communications and data transfers. Furthermore, proving that its latent potential exceeds semiconductors was an extremely significant development that was highly rated by system specialists.

With the oxide devices, a desktop high-speed waveform measurement system prototype was developed. This system was equipped with a cooling unit under 4 kg in which a high-temperature superconducting sampler chip was cooled by a Stirling cryocooler. It was shown that the system could potentially deliver wideband performance of over 100 GHz, which exceeds the level of commercial semiconductor-sampling oscilloscopes. A superconductor/semiconductor hybrid A/D converter prototype was also developed. As a superconducting A/D converter, it was proven to have the highest performance in the world and showed prospects of greatly exceeding the performance of semiconductor A/D converters. At present, niobium circuits are being employed in the superconducting circuit section, but operational tests were also performed on oxide main circuit elements with the intent of using oxide circuits instead.

As you can see, great progress has been made in the practical application of the SFQ technology to information communications equipments and measurement equipments thanks to its proven potential and superior performance over semiconductor-based products and systems.

(Keiichi Tanabe, Director, Division of Electronic Devices, SRL/ISTEC)

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Feature Articles: Forum on Superconductivity Technology Trends 2007 - Developing a Highly Sensitive Magnetic Immunological Testing System Using High-Temperature Superconducting SQUIDs -

Akira Tsukamoto, Senior Researcher
Advanced Research Laboratory
Hitachi Ltd.

In the fields of medical diagnostics and pharmaceutical development, there is great demand for detecting the target biomaterial quickly and with high sensitivity. Together with Kyushu University, we are developing a new type of immunological testing system that detects signals with a SQUID using a test reagent (magnetic marker) that was marked with magnetic nanoparticles.[1)] This magnetic detection technique makes a magnetic marker react to an antigen (the material being measured) and then after applying an external magnetic field and magnetizing the magnetic marker in one direction, it uses the SQUID to detect the magnetic signal emitted from the magnetic marker (Fig. 1). Since it is possible to measure faint magnetic signals using a SQUID, it is also possible measure minute amounts of a biomaterial. With the conventional optical method, unbound marker had to be washed off (BF separation) because it also emitted signals, but with the magnetic method, BF separation is unnecessary because the magnetic moment of unbound marker is randomly oriented by Brownian motion so that the signals cancel each other out. Magnetic signals can also pass through biomaterials, enabling the measurement of opaque samples, such as hemolytic samples and stool samples, which are difficult to measure with optical methods. These special features are expected to enable rapid and highly sensitive immunological testing.

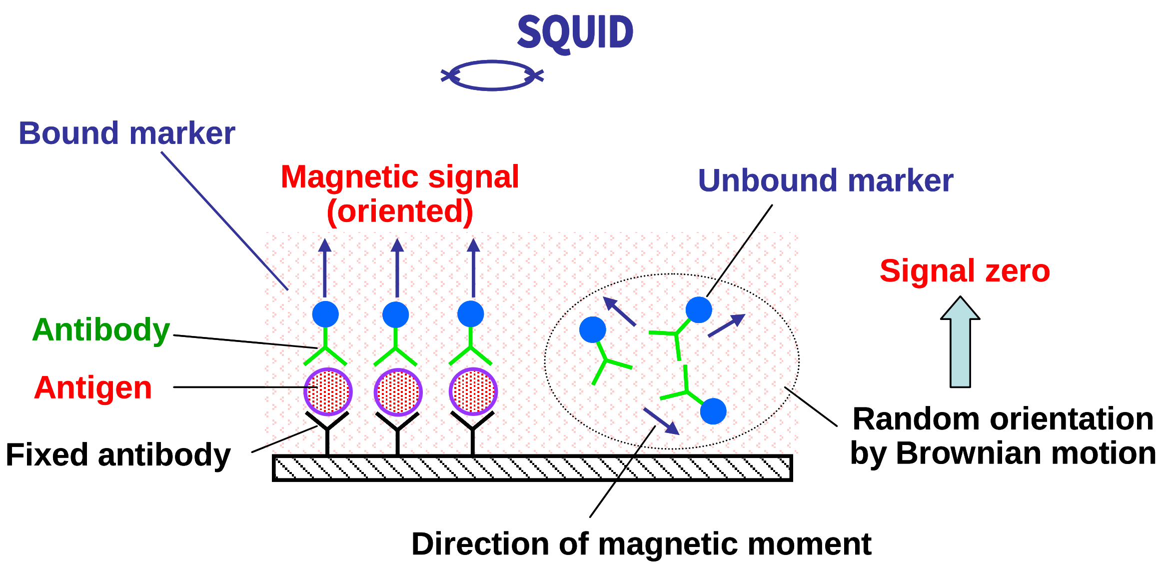

Fig. 1 Magnetic immunological testing

To establish immunological testing technology that uses magnetic signals, we developed a detection system that uses a high-temperature superconducting SQUID,[2)] a magnetic marker, and a nonmagnetic reaction vessel, and then conducted a test where we detected a trace amount of immunoglobulin E (IgE), a protein associated with allergies, under 1 pg. As shown in Fig. 2, it is currently possible to detect up to 2.4 pg (about 10 attomoles) of IgE, and when a wash process is added, up to 0.3 pg of IgE can be detected.[3] This represents a high sensitivity 10 to 100 times that of optical methods. We have also confirmed that it is possible to measure IgE in human serum containing a large amount of impurities.

Further increases in sensitivity and speed along with improvements in reliability as medical equipment and a demonstration of clinical effectiveness are required. Please note that a portion of this research was commissioned by the Ministry of Economy, Trade and Industry's Consortium R&D Project for Regional Revitalization.

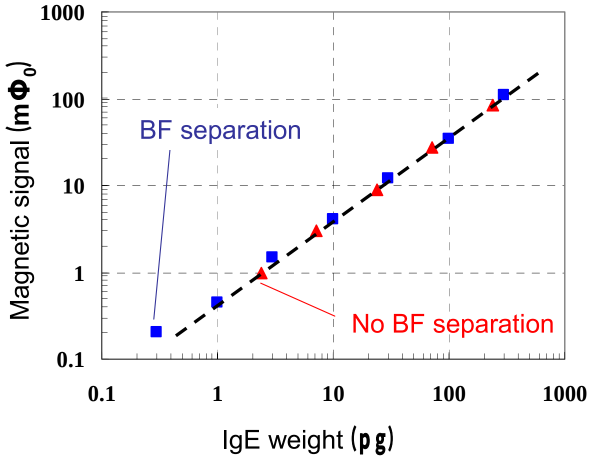

Fig. 2 Result of IgE measurement (IgE weight dependency of magnetic signal)

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(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007
Superconductivity Web21
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Feature Articles: Forum on Superconductivity Technology Trends 2007 - Development Trends in YBCO Superconducting Transformers/Motors and Cryocoolers in Japan -

Masataka Iwakuma, Associate Professor
Research Institute of Superconductor Science and Systems
Kyushu University

This article briefly introduces the goals that have been set and the current state of development for the elemental technology for transformers, motors, and cryocoolers under Research and Development of Superconductivity Applied Basic Technology (Phase II).

1) Transformers

The development goal for transformers is 66/6.9 kV-20 MVA for a power distribution unit, and the elemental technology for implementing this is currently being developed. The manufacture of an actual unit is planned for the next phase. The main development items are: (1) low AC loss technology; (2) high current capacity technology; and (3) withstand voltage technology.

Despite the fact that conventional superconducting wire is multicore and that the quantitative expressions for AC loss and the guidelines for reducing AC current loss are clear, no concrete techniques have been proposed thus far for lowering AC loss on YBCO tape wires. The Applied Basic Project advocates a new technique for lowering AC loss on thin-film tape wires and is currently testing it, based on the recognition that the lowering of AC loss is a key technology for electrical equipment. First, a laser beam several microns wide is continuously emitted in the length-wise direction of the wire and the YBCO superconducting layer and the silver protective layer on it are divided into filaments of equal width. Since the intermediate CeO_2 and GdZrO layers below the YBCO layer are insulators, each filament is electrically isolated and insulated, even if the filaments are stuck on a hastelloy substrate. With this alone, normally, electrical current will not flow uniformly due to the self-magnetic field, and the filaments will be shorted with each other at the electrode, and as a result shielding current is induced in a coil shape, and reduced AC loss cannot be achieved. However, the Applied Basic Project aims to enable the balancing of inductance between filaments by means of a special winding method for thin-film tape that was scribe-processed with a laser, thereby achieving uniform current flow and low AC loss. The project has already manufactured a 16-layer coil using a 34 m long wire in which a 10 mm wide wire was processed into a three-filament structure. Compared to coils of similar dimensions that were manufactured using wire that was not processed into filaments, it reduces AC loss during AC operation to 1/3 and the current of each filament under energization up to a critical current of 100 A has been confirmed to be uniform. Furthermore, the project is also using a 74 m long wire in which a 5 mm wide wire was processed into a five-filament structure to test whether AC loss can be reduced to 1/5 with the same coil shape compared with unprocessed wire. This sort of technology for lowering AC loss can be applied to not only transformers, but also to all electrical equipment that include SMES.

Regarding increased current capacity, the manufacture and testing of a 1 kA conductor prototype is being planned. The conductor structure is transposed parallel conductors, and the creation of conductors in a winding process using several tape wires is planned along with transposition of the conductors.

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As for increased voltage, a turn-to-turn model coil and phase-to-phase model coil were manufactured and withstand voltage tests are now being performed on them to find a compact insulated structure that can withstand the provisions stipulated in JEC2000 (a lightning impulse voltage of 350 kV and an AC overvoltage of 140 kV).

2) Motors

The aim of superconducting motors is to create smaller, lighter, and more efficient motors than normal conduction motors, which are currently comprised of iron and copper and have limited power density due to the 1.7 T saturated magnetic flux of iron, by making the most out of the special features of superconducting wire, specifically its high magnetic field, low loss, and light weight.

The Applied Basic Project already created a 360 rpm-15 kW motor prototype last year, although it used a method with a superconducting field stator coil and normal conducting rotating armature. It has been combined with a propeller with a 50 cm diameter and propulsion tests are now taking place in a test tank at Nagasaki Shipyard & Machinery Works, Mitsubishi Heavy Industries, Ltd. So far, the technology is being shown to perform as it was designed. As a follow-up to this, the design of a 7.5 kW motor that uses a method with a superconducting revolving-field and normal conduction fixed armature has been completed and is now entering the manufacturing stage.

3) Cryocoolers

When superconducting cables, transformers, SMES, and other equipment that uses YBCO superconducting wire were first developed and introduced, they had to be accompanied along side by a small, light-weight, highly efficient, low maintenance-cost cryocooling system. The required cooling capacity ranged from several kW to 10 kW at 64 to 77 K for cables and transformers to around 1 kW at 20 K for SMES. Securing such cooling capacity requires several of the currently available Stirling and GM type cryocoolers to be operated in parallel, and achieving a compact, lightweight, and highly efficient cooling system is thought to be difficult. Furthermore, the period between maintenance work has not reached the required level. In response, the Applied Basic Project has started developing a cryocooler that can deliver the required cooling capacity with a single system (several units are actually used) and that has a 30,000 hour period between maintenance work. It delivers long-term reliability with helium cryocoolers and employs a turbine expansion system (a reverse Brayton cycle) that has a proven manufacturing record. Development is now moving forward in an effort to reduce the turbine size. The development target by the end of this year is a 2k W at 80 K cryocooler, and a turbine test is being planned for this July. This system uses a commercially available reciprocating compressor, but the project is also aiming to eventually develop a turbine compressor as well.

(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007

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Feature Articles: Forum on Superconductivity Technology Trends 2007 - Challenges for High-Temperature Superconducting Wire /System Technology -

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R&D Unit
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High-temperature superconducting (HTS) wire can carry a current 210 times that of copper with zero resistance if it is cooled with inexpensive and readily available liquid nitrogen. This saves energy while delivering revolutionary performance. If it is applied to power cables, it will lead to low power-transmission loss, reduced construction costs, and enhanced systems, as well as a global and even universal power network with long-distance DC cables. It is a key technology for establishing a highly efficient global network by its application to MAGLEV and ship motors and contributing to the creation of the super high field magnets required for high-resolution NMR of 1 GHz or higher and to major advances in life sciences research.

The key here is materials technology that can extract and realize the innate performance of HTS wire and system technology that can make full use of it. We would like to contribute to building a sustainable society by making these two halves of the puzzle come together.

Take Bi-2223 superconducting wire for example. The challenges faced with this material are controlling crystals several nm in size over a kilometer, implementing (10^{12} gaps) a nanometer (10^{-9} m) structure in a kilometer (10^{3} m) long. This is the result of a technological development that raises the density of the Bi superconducting section (a ceramic) to 100%. At present, a critical current of 210 A has been achieved with a 4 mm wide wire and the total length has advanced to 1,800 m.

The challenges facing systems technology are as follows: (1) Issues in the three dimensional /thermomechanical behavior (0.3% contraction); (2) The fact that copper has a variety of constraints due to the heat it generates, while HTS has zero resistance and is steady state of cooled condition (temperature is constant and liquid nitrogen is abundantly used); (3) Application to transport technology (size and weight must be reduced); (4) Technological saturation with copper/aluminum: Application to long wire (electric cables); (5) Implementation of high magnetic fields (making the impossible possible).

HTS motors and magnets are expected to be vital technology for highly efficient means of transport in the future, and they are considered mandatory for all future candidate technology that deals with environmental issues.

As for cables, the 350 m-long three-core integrated cable in Albany had already exhibited stable operation for 9 months (7,000 hours), and in the future, a DC cable will be spotlighted alongside AC applications. In particular, the combination of renewable energy, such as solar cells, and HTS DC cables will be a highly efficient low-voltage/high-current electric transport technology that makes the impossible possible.

The creation of a high magnetic field magnet with an 8.1 T/200 mm bore is expected to contribute creating a sustainable society in the form of environmentally-friendly technologies, including magnetic separation.

(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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Feature Articles: Forum on Superconductivity Technology Trends 2007 - State and Trends in R&D on Superconducting Rotating Machinery -

Osami Tsukamoto
Professor Emeritus, Yokohama National University
Visiting Professor, Sophia University

The application of superconductivity enables a high magnetic flux density with low loss without the use of an iron core. This makes possible drastic reductions in size/weight and higher efficiency in superconducting rotating machinery compared with conventional models. In particular, the higher the torque, the greater the weight/size-reduction effect, and applications can be expected in low-rpm high torque motors for ship propulsion and wind power generators. The lack of an iron core enables light weight and small centrifugal force rotors for high rotating-speed machines, and direct-drive generators for gas turbine power plants can also be realized. Furthermore, a machine with an air core and large air gap can be realized and the spatial harmonic components in the magnetic field distribution in the gap become lower. This results in low operating noise, and in the case of power generators, low harmonics in the output voltage, and in the case of motors, low torque ripples and high torque-controllability. Focusing on these merits, research and development is underway in the U.S. and Europe (primarily Germany) on superconducting rotating machinery for ships, power generation, and industrial uses.

Rating	8 MVAR (prototype) 12 MVAR (production)
Voltage	13.8 kV line to line
Ambient Temp.	-30° to +40℃
Losses	1.2% rating at 8 MVA Including 30 kW 480 V auxiliary power

Fig.1 Synchronous condenser using an HTS synchronous rotating machine (AMSC)

The U.S. company AMSC is actively involved in the development of rotating superconductor machinery and has already developed a 36.5 MW 120 rpm motor for ship propulsion using Bi-silver-sheathed wire. It also manufactures synchronous condensers using 12 MVA synchronous rotating machines (Fig. 1), and they have been introduced onto power systems to stabilize system voltage. The German company Siemens has developed a 4 MW 3600 rpm generator for ships using Bi-silver-sheathed wire and is now testing their performance (Fig. 2). The U.K. electrical equipment manufacturer Converteam, the German wire company Trithor, and other companies have kicked off the joint development of a 1.7 MW 214 rpm hydroelectric generator. The generator has a superconducting rotator with an iron core, and a copper armature coil with an iron core, and in terms of weight and size, it is nearly the same as conventional models, but it is aiming at a large 92% to 98.5% increase in efficiency over conventional models. Plans call for the generator to be put into test operation in 2009 at a small hydroelectric generation plant in Germany.

Fall, 2007 Date of Issue: October 15, 2007
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Data	
Output:	4 MVA
Voltage:	6,6 kV
Speed:	3600 rpm
Frame size:	500 mm
Efficiency:	98,7 %
HTS wire:	6 km

Fig. 2 4 MVA generator for ships (Siemens)

Interest in applying superconducting technology to wind power generation is rising in Europe. There are scale merits in wind power generation, and development work on increasing capacity is aggressively underway in Europe. At present, a 5 MW conventional generator is being developed, and future plans call for even greater increases in capacity. However, increasing capacity leads to larger windmill diameters, which in turn creates more noise, necessitating a reduction in rotation speed. The end result is generators that are even higher in torque and lower in rotational speed. With conventional technology, capacities greater than 5 MV are difficult to achieve, but the introduction of high-temperature superconducting (HTS) is expected to break through the capacity limit. Aiming for a manufacturing launch in 2011, Converteam is now developing an 8 MW 12 rpm direct-drive HTS generator. It has already completed the design phase and resolved the various issues associated with the move to superconducting technology. The introduction of superconducting technology halves the size and weight of an optimally designed generator using a permanent magnet, and it also makes it possible to reduce power generation costs 10% to 20% over conventional generators.

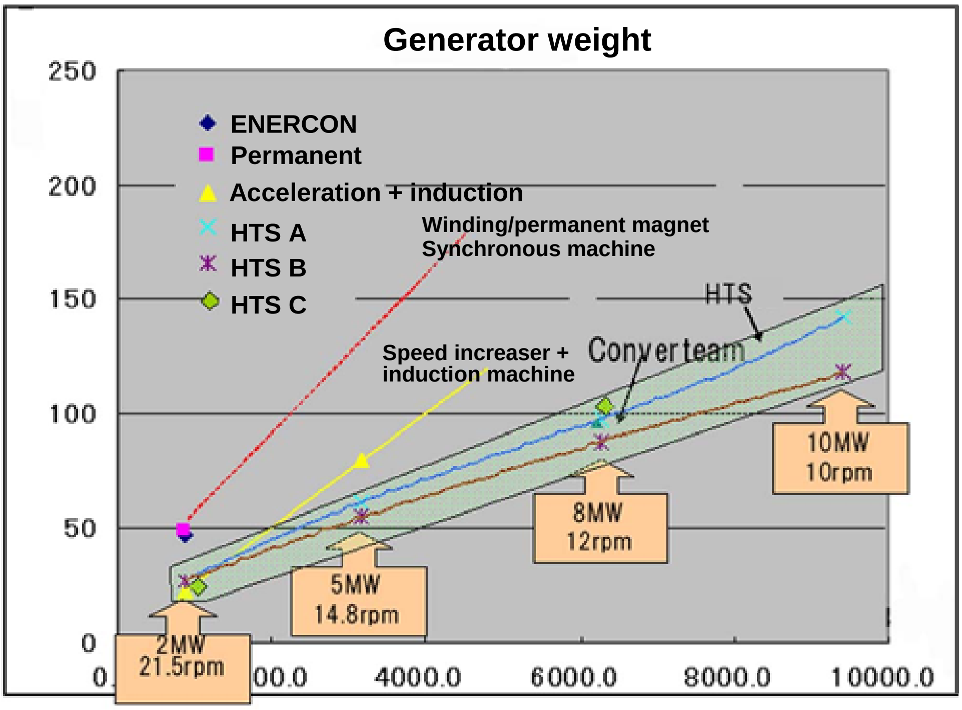

Fig. 3 Weight comparison of superconducting wind power generators
(Conventional models: Includes weight of speed increaser; Superconducting models: HTS A, B are spiral bulk winding models and HTS C is a wire winding model)

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The introduction of superconducting technology to wind power generation is also taking place in Japan, where a feasibility study committee has been formed by NEDO to study the advantages of such technology. Their results show that it has the potential to greatly reduce the weight of power generators, as shown in Fig. 3. Japan leads the world in superconducting technology, and it is also expected to play a leading role in applying it to wind power generators as well.

(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007

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Feature Articles: Superconducting Medical Device Technology
- Advances in Magnetocardiograph Technology and Its Expanded Uses -

Keiji Tsukada, Professor
Graduate School of Natural Science and Technology
Okayama University

Magnetocardiograph is a device using SQUID sensor array, which functions as an ultra high-sensitivity magnetic sensor, to measure the magnetic field produced by the heart. They can supply time- sequence images of electrophysiological phenomena in the heart. In the bimonthly article series "History of Our Development of superconducting Magnetocardiograph," I introduced the history up to the practical application of a magnetocardiograph as a clinical instrument before anyone else in the world. In 2007 at the National Cardiovascular Center, a leading institution in the field of cardiovascular disease, a magnetocardiograph was used for the first time as a clinical diagnostic device. In addition, clinical research is continuing at Tsukuba University and Iwate Medical University. Clinical applications of magnetocardiographs have included the diagnosis of arrhythmia for many years, both in Japan and overseas, but recent interest is to establish early diagnosis of ischemic heart disease, which has the highest mortality of all heart diseases.

In addition, since electrocardiography is difficult to apply to fetus, research in fetal magnetocardiogram is gradually activated because of good signal quality obtained by magnetic measurement. Clinical applications for magnetocardiography are steadily being established, and magnetocardiographic research using primates, a new trend in the field, was born for the first time in the world at the Tsukuba Primate Research Center, National Institute of Biomedical Innovation. Analyzing magnetocardiograms using heart disease models of non-human primates that are very similar to humans will not only clarify the pathologic mechanisms of heart disease, it will also accelerate the standardization of magnetocardiogram diagnosis method.

The spread of magnetocardiographs requires not only development of clinical diagnostic technology, but also the development of low-priced equipment. A 51ch high-temperature superconducting (HTS) SQUID magnetocardiograph that is compact and easy to maintain has already been reported for application of adult heath exams. The major problem of HTS SQUIDs is low sensitivity compared with low-temperature SQUIDs (<10 fT/√Hz). However the HTS SQUID we developed can improve sensitivity to around 50 fT/√Hz, and its applicability to magnetocardiographic measurement of the adult heart has already been proven. Improvement of the sensitivity of HTS SQUIDs is underway at numerous research labs. At Jűlich, for example, they have increased sensitivity up to 20 fT/√Hz, and it has been reported that they achieved a fetal magnetocardiogram by performing noise cancellation using several SQUIDs inside a magnetic shield. This shows that practical applications of HTS SQUIDs are in a near future. However, reducing the cost of such technology currently requires improvements in magnetic shielding technology, which is another major problem.

(Published in a Japanese version in the August 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007
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Feature Articles: Superconducting Medical Device Technology
- Magnetic Drug Delivery System (MDDS) -

Akira Sasaki, Director
Deputy General Manager of Marketing Division
Hitachi Medical Corporation

Drug Delivery System (“DDS”), which is said to be the ultimate therapy technique, has been in the spotlight in recent years. The Japan Society of Drug Delivery System defines DDS as "A system that delivers drugs to affect only on the region requiring such drugs when needed"; specifically, delivering particles containing drugs to the therapy target region such as tumors and releasing the drugs, when needed, to have them directly affect only on the target tissues continuously.

Drugs with prominent medication effect but with rather intense adverse effect can be also expected as ideal choice for therapy when reduction of dosage is achieved and high therapy effect on the targeted tumor is confirmed.

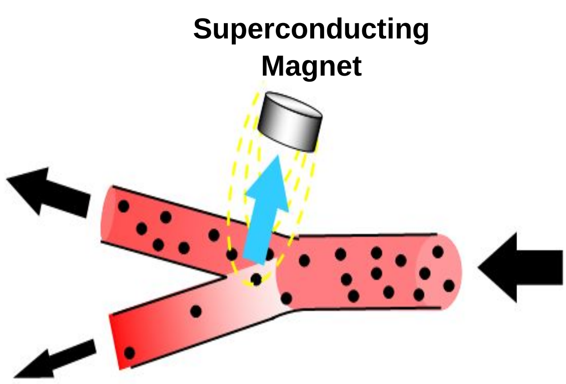
As development of stable nanosize carrier particles (drug carrier: in the form of capsules) and tissue-selective antibodies advances in recent years, R&D on DDS has been revitalized.[1),2),3)]

The methods for improving tumor targeting directionality include: (1) improving the carrier particles themselves, such as controlling of particle size or addition of antibodies; (2) guiding of particles to the target and retention thereof with external energy such as a magnetic field; and (3) activating/enhancing medication effects by such means as ultrasonic irradiation.

This article refers to “Targeting by means of magnetic force induction (Magnetic DDS: MDDS).

Essentially, ideal targeting therapy is to obtain valid DDS effect with only medication effect. In reality, however, there exists a difficulty in the development of drugs that can balance two conflicting effects; stability in the blood and the capability of sustained release over time. A resolution under consideration against this issue is to use external energy to enhance medication effect. There are certain methods (using laser beam, ultrasonic wave, etc.), and DDS using magnetic force (MDDS) is one of those.

MDDS is a method wherein nanosize magnetic carrier particles with drugs adhered thereto are guided to certain lesion with strong external magnetic force. Research on this method has began in the 1970's. At that time, however, it was not possible to avail of sufficient magnetic force and to develop nanoparticle drugs having stability in the blood, As a result, MDDS has not yet been brought into practical use.[4),5)]



Guidance of drugs at vessel branches

Development of MDDS is also advancing in Japan. Using a 5 T superconducting bulk magnet that can generate a high field gradient even at a distance of 50 mm, Muragaki, et al. are attempting to build a system (apparatus) that can guide 100 nm magnetic particles.[6)] With this system, magnetized drugs are brought into vessels by intravenous injection and circulated to reach the vessel for

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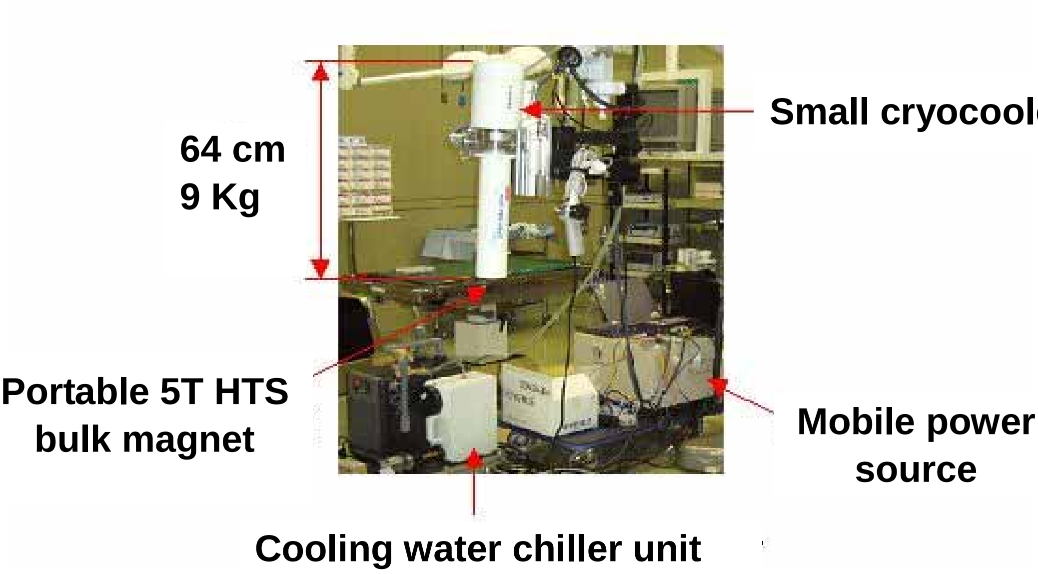
the tumor region. At the branches of blood vessels on the way, guidance of the drugs to intended direction is done by the superconducting magnet from outside the body as described in the above diagram. By repeating such guidance with each in vivo circulation, this system aims at delivering drugs to the target lesion. The report says the efficiency in guidance of magnetic particles at vessel branches has been remarkably improved thanks to use of this system.

If guidance of particles containing magnetic material by generating a powerful and concentrated magnetic field is enabled, then it becomes possible to confirm the accumulation of carrier particles under monitoring by MR imaging systems, by which MDDS will prove to be prominent method for guiding, accumulating and locating the drugs. Furthermore, by irradiating focused ultrasound to such accumulated drugs to crush the carrier capsules, sustained release of drugs at the targeted region is facilitated. This will enable highly efficient and therapy with much less adverse effect to the human body.

Finally, we are expecting this new concept of MDDS become a practical tool in future.



MDDS apparatus developed under NEDO support

This research was carried out with the support of a commission by the New Energy and Industrial Technology Development Organization (NEDO) in fiscal 2006.

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(Published in a Japanese version in the August 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007

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Feature Articles: Superconducting Medical Device Technology - Three European and U.S.-affiliated Companies' Efforts to Increase MRI Magnetic Field Intensity in the Japanese Market -

Magnetic resonance imaging is commonly known by its acronym MRI. The main portion of the superconducting MRI market in Japan is represented by 1.5 Tesla MRI, but the full-fledged introduction of 3 Tesla MRI began in 2005 by three European and U.S.-affiliated manufacturers, specifically GE Yokogawa Medical Systems Ltd., Philips Medical Systems Japan, and Siemens-Asahi Medical Technologies Ltd. Some 80 3 Tesla MRI systems have already been introduced in the Japanese market by those three manufacturers alone, and they are being backed by hospitals where clinical work takes place and brain research institutes. This figure is not even 20% of the superconducting MRI market in Japan, but over the next several years, the annual introduction of some 50 systems is expected.

SIGNA EXCITE 3.0T
GE Yokogawa Medical Systems Ltd.

However, as Hidetomo Takase, Product Manager of the BU MR Marketing Div. at Philips Medical Systems Japan points out, the 3 Tesla MRI systems being introduced are positioned as one piece of equipment that functionally complements computed tomography (CT scan), 1.5 Tesla MRI, ultrasonic diagnostic equipment, x-ray machines, nuclear medicine diagnostic equipment, and positron-emission tomography (PET). This means that 3 Tesla MRI is not about to supplant current 1.5 Tesla MRI.

If the annual market for superconducting MRI is seen as limited to 300 systems a year, the three European and U.S.-affiliated manufacturers and one Japanese manufacturer each have had a one-fourth share of the 1.5 MRI market over the long term. The factors that are assumed to be trying to undermine this sort of stable market balance are the Japanese system of medical treatment fees, the approval system of the Pharmaceutical Affairs Law that is accompanied by clinical trials, and the divergent mindsets of the manufacturers regarding the needs of the MRI market. Specifically, It is believed that the introduction of 3 Tesla MRI was delayed in Japanese manufacturers as a result of the system of medical treatment fees that

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gives the same medical treatment fee points to 1.5 Tesla and 3 Tesla MRI and the comparison of the complexity of pharmaceutical approval over the long term to the clinical effect of 3 Tesla MRI and its cost, which is 1.5 to 2 times higher. Meanwhile, European and U.S.-affiliated manufacturers take the future prospective of prioritizing the needs of clinical sites and medical research labs over the economic efficiency of medical treatment fee points and so on, and that is why they have cleared the paramedical approval procedures on the assumption on clinical trials that takes three to five years.

GE Yokogawa Medical Systems, which has the most sales both in Japan and overseas, first gained approval under the Pharmaceutical Affairs Law for 3 Tesla MRI limited to the head region in 2003. This was followed in 2005 by all three European and U.S.-affiliated manufacturers gaining approval for 3 Tesla MRI for the entire body. Thus began the competition between the three European and U.S.-affiliated manufacturers to market 3 Tesla MRI in Japan. These three manufacturers were able to secure a new market in Japan by harnessing their technical capabilities accumulated thus far and gaining the support of medical sites by adding new diagnostic and analysis technology such as IT in an effort to quickly respond to the darkness within the body and the diagnostic time barrier, which are key to the needs of clinical sites and medical research institutes.

While conventional MRI technology cannot adequately provide diagnoses for the so-called darkness within the body, namely abdominal tissue, such as the small intestine in obese patients, and the deep tissue of the brain, such as the hippocampus, 3 Tesla MRI offers high-definition image quality as a result of a doubled S/N ratio and has improved accurate tomographic diagnosis technology for target sites by using angled magnetic fields and RF transmission/reception technology. Meanwhile, measurement wavelengths have lowered along with the increasing of MRI magnetic field intensity which had been feared, and the trend of the depth that can be diagnosed becoming shallow has also been overcome by 3 Tesla MRI, and the darkness within the body has been eliminated by MRI.

With conventional MRI there was also the issue of the so-called diagnostic time barrier, which was said to be longer than with other competing medical diagnostic imaging systems. This issue was also marvelously overcome by 3 Tesla MRI. In particular, it is now possible to shorten the overall diagnosis time from 30 minutes to 5 minutes by synchronizing with moving targets such as the intestines and blood flow, reducing image capture time, and dramatically improving image calculation speed. According to Haruhiro Akeda, Marketing Manager, GE Yokogawa Medical Systems, it has shortened diagnostic time required to determine whether a stroke is being caused by cerebral infarction or cerebral hemorrhage, making emergency room treatment possible with time to spare, even with the three-hour time limit for the administration of medication at The University of Tokushima. These are future technologies that can be linked with the field of biological function sciences, including the study of the brain and functional MRI (fMRI), which are essentially superior Japanese technologies.

Furthermore, the companies are giving full play to each of their special features, including the comprehensive consideration of operability and patients in 3 Tesla MRI clinical sites. Philips Medical Systems Japan is offering 3 Tesla MRI with a large aperture bosh angle for easing the patients' sensation of being closed in and enabling a compact design nearly the size of conventional 1.5 Tesla MRI to secure workability at clinical sites. In addition, Takashi Moroi, Product Manager at Siemens-Asahi Medical Technologies says there is a need for differentiation by offering MRI that even takes into account lowering the specific absorption rate (SAR) and the reducing the average noise value to the IEC standard of 99 dB or less, not only for patients, but for people who work with MRI systems as well.

Fall, 2007 Date of Issue: October 15, 2007

Superconductivity

Superconductivity Web21

Published by International Superconductivity Technology Center
5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan Tel: +81-3-3431-4002, Fax: +81-3-3431-4044

MAGNETOM Trio, A Tim System
Source: Siemens Asahi Meditech Co., Ltd.

Regarding further increases in MRI magnetic fields, at minimum, GE Yokogawa Medical Systems is analyzing the demand for advancing to the level of full-body 7 Tesla MRI. A 7 Tesla MRI system has already been installed at Niigata University, where it is being put to use in clinical research. In addition, the demand for high-magnetic field MRI is high in the fields of biofunction sciences and Alzheimer's disease study, and expectations for results in such fields are rising. However, new issues that arise must be solved one at a time, including the enormous equipment cost, limited installation environment, expanded area of magnetic field leakage, wooziness patients experience from magnetic fields, and the SAR problem of patients and maintenance technicians.

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

(Published in a Japanese version in the August 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007

Superconductivity Web21

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Feature Articles: Superconducting Medical Device Technology
- NMR Utilization and Recent Technological Developments at RIKEN -

Hideaki Maeda, Team Leader
Genomic Sciences Center, RIKEN Yokohama Institute
Guest Associate Processor, Supramolecular Biology
International Graduate School of Arts and Sciences, Yokohama City University

The RIKEN Yokohama Institute has the largest Nuclear Magnetic Resonance (NMR) facility in the world, and it was used as an NMR 3D structural determination pipeline in the National Project on Protein Structural and Functional Analyses (by the Ministry of Education, Culture, Sports, Science and Technology). It has already succeeded in analyzing the 3D structure of proteins from over 900 higher eukaryotes. In fiscal 2005, it determined 375 structures applicable to 70% of the entries in the Protein Data Bank (the largest protein database in the world) for human and mouse proteins. The National Project on Protein Structural and Functional Analyses concluded in March this year, while a new project entitled the Target Protein Research Project Program, was launched by the said ministry. This project will select proteins important to academic research and industrial development and carry out research along with technology development based on the foundation laid by the National Project on Protein Structural and Functional Analyses. RIKEN is utilizing the NMR facility in this research program. Furthermore, it is preparing to allow access to the NMR facility outside the organization starting this year. The facility will be used in government projects and be made available in a wide range of fields, including biotechnology, materials, and organic chemistry.

As for technology development, work started in October of last year on a beyond 1 GHz NMR that uses high temperature superconductivity (HTS) as a cutting-edge technology/equipment development project of the Japan Science and Technology Agency (JST). The core body behind the project is the National Institute for Materials Science (NIMS). NIMS and Kobe Steel, Ltd. are in charge of the HTS coil, while RIKEN and JEOL Ltd. are in charge of the NMR instrumentation technology. The project is attempting to strengthen the existing NMR magnet to generate a magnetic field exceeding 1 GHz. Since HTS coils have extremely low resistance and superconducting connections between conductors are almost impossible, a permanent current at the level required by NMR is impossible. Consequently, we envision the operation of HTS coils in current driven mode. To prevent current fluctuations from the power source from causing modulation on the NMR signal, a method is being developed for stabilizing the sample magnetic field while power is being fed. Another technology being developed is a 4 K NMR probe. Cooling the RF antenna of an NMR probe reduces thermal noise and improves signal sensitivity. A 20 K system is already on the market. RIKEN has succeeded in developing a system that can cool down to 4 K by switching the small cryocooler from a conventional Gifford-McMahon (GM) cryocooler to a GM-JT cryocooler. Sensitivity is improved by a factor of 6 over room temperature. Future plans call for utilizing it in NMR measurement of proteins.

(Published in a Japanese version in the August 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007

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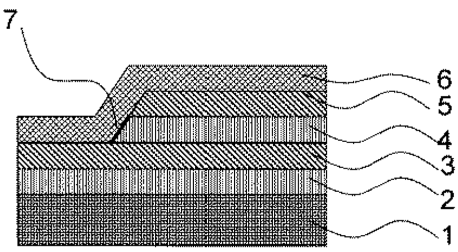
Patent Information

Introduction of Published Unexamined Patents in the 1st Quarter of Fiscal 2007

The following are ISTEC's patents published from April through June 2007. For more information, visit the Japan Patent Office's Web site and the Industrial Property Digital Library (IPDL) or other patent databases.

1) **Publication No. 2007-109717: " Superconducting Element and Its Fabrication Process"**

This invention relates to the fabrication of ramp edge Josephson junctions 7 of oxide superconducting element. Josephson junctions are formed on the foundation layer 1, such as the superconducting ground plane layer 2 and the insulation layer 3, but the surface roughness of this foundation layer greatly impacts the uniformity of junction characteristics. An average surface roughness of 2 nm or less is desirable, but no manufacturing techniques with good reproducibility have been reported. Starting with the oxide substrate layer 1, it successively forms each layer, namely the first superconducting layer 2, the first insulator layer 3, the second superconducting layer 4, and then the second insulator layer 5. Junctions are formed at slope of an obtuse angle to the second superconducting layer 4 and the second insulator layer 5 and to the first insulator layer 3. Furthermore, after forming an extremely thin insulator layer on the slope of the second superconducting layer 4, the third superconducting layer 6 is laid down. When doing this, an average roughness of 2 nm or less can be achieved for the first superconducting layer 2 and the second superconducting layer 4 with good reproducibility of the insulation and superconducting layer by employing cerium oxide formed by pulsed-laser deposition. Using cerium oxide insulator, which has superior oxygen permeability, also largely shortens the oxygen annealing process, which is one factor that induces surface roughness.

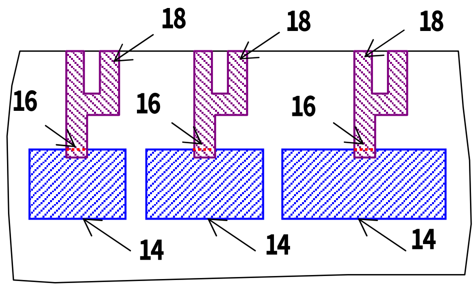


2) **Publication No. 2007-115592: " RE-Ba-Cu-based Oxide Superconductive Long Tape with Excellent Critical Current Density and Manufacturing Method of Thereof"**

This invention relates to RE-Ba-Cu oxide superconducting film formed by pulsed-laser deposition over a buffer layer on a metal substrate and its manufacturing method. The superconducting film in this invention has a ratio of RE:Ba:Cu=1:(2-x):3 (note that $0.01 \leq x \leq 0.2$) and is characterized by a Ba composition that is lower than the stoichiometric composition. The manufacturing technique is characterized by the use of RE-Ba-Cu oxide with a Ba composition that is lower than the stoichiometric composition as a target material. The superconducting film manufactured by this invention exhibits superior superconducting characteristics, specifically, a critical temperature (T_c) of 93 K and a critical current density (J_c) of 2.2×10^6 A/cm^2.

3) **Publication No. 2007-115930: "Superconducting Junction Element and Superconducting Junction Circuit"**

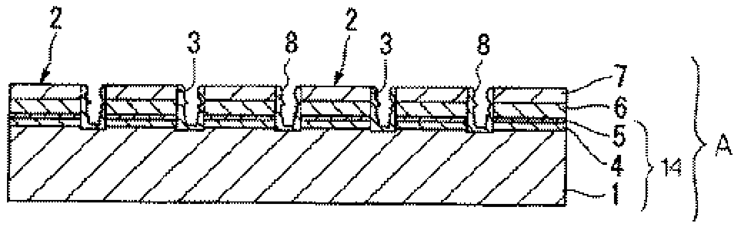
This invention discovered that the critical current of junction 16 at the superconducting junction element consisting of the lower electrode 14 and the upper electrode 18 as well as the barrier layer in between them



depends not only on junction dimensions, but also on the dimensions of the lower electrode of the junctions. This invention provides a superconducting circuit characterized by the setting of critical current of the junction based on the areas of the lower electrode of the superconducting junction. This invention makes it easy to design superconducting circuits and ensure stable operation.

4) Publication No. 2007-141688: "Low AC Loss Oxide Superconductors and Their Manufacturing Method"

This invention relates to the forming of wires on a multilayer superconductor that has oxide superconducting layer 6 through oxide insulation layers 4 and 5 on a metal substrate 1. This invention is characterized by the division of oxide superconducting layer 6 into multiple filament conductors 2 by wire groove 3 formed by laser scribing or similar means in the length direction of the aforementioned superconductor and by the formation of high-resistance oxide layer 8 inside wire groove 3. This invention effectively utilizes the multilayer structure of the superconductor, and it is able to raise the insulation properties between the individual filaments and produce an oxide superconductor with low AC loss.



5) Publication No. 2007-165153: "Manufacturing Method for Thick Film Tape RE (123) Superconductors"

The manufacturing method for thick film tape RE 123 superconductors by this invention, which uses metal organic deposition using trifluoroacetates (TFA -MOD), coats a basic solution consisting of a metal organic acid that includes fluorine of a metal element comprising a $RE_{1+x}Ba_{2-x}Cu_3O_y$ superconductor and organic solvents onto a substrate with a 2-axis orientation. It then performs intermediate heat treatment less than generation temperature of a $RE_{1+x}Ba_{2-x}Cu_3O_y$ superconductor between the preliminary baking heat treatment and superconductor formation heat treatment and performs preliminary baking heat treatment at or above a decomposition temperature of the metal organic acid and the sublimation temperature of the organic solvent in the mixture solution, and at a temperature lower than the temperature of the intermediate heat treatment. The conventional TFA -MOD method stopped at superconducting film of about 1 µm due to the appearance of pores and cracks, but this invention enables the manufacture of tape RE (123) superconductors that have YBCO superconducting film exceeding a thickness of about 2 µm.

(Ichiro Nagano, Associate Director, Research and Development Promotion Division, SRL/ISTEC)

(Published in a Japanese version in the August 2007 issue of *Superconductivity Web 21*)

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Summer, 2007 Date of Issue: Julyl 17, 2007

超電導 Web21
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Published by International Superconductivity Technology Center
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Standardization Activities

Topics in June 2007

- IEC Issues One Revised IS Related to Superconductivity -

The International Electrotechnical Commission (IEC) is conducting maintenance on 14 existing superconducting-relates standards, and on April 24, 2007, the commission revised and released the following standard. This revision/release will result in the revision of six existing superconducting-related IEC standards.

◇ IEC 61788-4-Ed. 2.0: 2007-4 Superconductivity - Part 4: Residual resistance ratio measurement - Residual resistance ratio of Nb-Ti composite superconductors*

* Maintenance result date on 2011

Substantial maintenance on this standard commenced at the 9th International Electrotechnical Commission/Technical Committee 90 (Superconductivity) (IEC/TC90) held in 2004 at the Argonne National Laboratory in the U.S., and its CDV approval was deliberated at the 10th IEC/TC90 held in 2006 in Kyoto, Japan. They reconfirmed the following technical content and editing errors and the shift to the final draft of international standard (FDIS) state was approved.

In particularly, the first introduction of uncertainty toward the IEC/TC90-related standards was resolved at the 2006 Kyoto conference, and this matter which was at the deliberation stage was selected as the first standard to be revised. Consequently, uncertainty was applied to all IEC/TC90-related IEC standards after this one.

The main revisions are as follows.
◇All instances of "accuracy" specified for quantities within the text of standards were revised to "uncertainty."
◇New annexes were added to further the understanding related to "uncertainty."
◇Temperature-voltage relationship in Fig. 1 was changed to temperature-resistance relationship.

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

(Published in a Japanese version in the June 2007 issue of *Superconductivity Web 21*)

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Fall, 2007 Date of Issue: October 15, 2007

Superconductivity Web21

Published by International Superconductivity Technology Center
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Standardization Activities

Topics in July 2007

- IEC-APC Presents the Chairperson Award to Kikuo Ito-

The International Electrotechnical Commission (IEC) Activities Promotion Committee of Japan (APC) presented Dr. Kikuo Ito of the National Institute for Material Science (NIMS) and 21 others with IEC-APC chairperson awards at the 17th IEC Activity Promotion Committee held on Thursday, May 24, 2007.
This year, one person received the special chairperson award, 11 received the chairperson award, and 10 received letters of appreciation.

The IEC-APC chairperson awards are presented each year to individuals or groups making a prominent contribution in the IEC segment, such as the development of IEC standards proposed by Japan. The awards are presented by the IEC-APC, inaugurated in 1991, for Japanese contributions to the IEC and for the reflection of industry views.

The IEC-APC chairperson award was awarded to Dr. Kikuo Ito of the NIMS for his work as a IEC/TC90 (Superconductivity) Domestic Technical Committee member and as a Superconducting Technology Study Member, his proposal of a strategy for the international standardization of domestic superconducting technology, and his valuable contributions in coordination between the Versailles Project on Advanced Materials and Standards (VAMAS) and the TC90.

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

Commemorative photograph of IEC-APC chairman award recipients (Dr. Kikuo Ito on left of back row)

(Published in a Japanese version in the July 2007 issue of *Superconductivity Web 21*)

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