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Superconductivity Web21

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ISTEC's 2009 Budget Approved by Board of Directors and Board of Councilors

Katsumi Tajima
Managing Director, ISTEC

On March 16, 2009, the International Superconductivity Technology Center (Hiroshi Araki, president) held its 43rd ordinary Board of Directors' meeting and 33rd Board of Councilors' meeting in the Keidanren Kaikan conference hall, adopting draft proposals such as the "2009 Master Plan and Budget" without modification. In addition, officers were elected at the same time, including directors, with Yuh Shiohara, the Director General of the Superconductivity Research Laboratory, selected as a trustee (part-time), to take office on April 1.

The 43rd Board of Directors and 33rd Board of Councilors

Finally, after the end of the council proceedings, Director General Shiohara gave a speech with the theme "High-Temperature Superconducting Technologies, the Environment, and Energy: The Current Situation and Expected Applications."

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" Fundamental Superconducting Application Technology Project " (Phase II) Post-Project Evaluation Results Disclosed

Katsumi Tajima
Managing Director, ISTEC

On February 18, 2009, the New Energy and Industrial Technology Development Organization (NEDO), an independent administrative organization of the Ministry of Economy, Trade and Industry, held its 20th research evaluation committee meeting, during which post-project evaluation results were discussed and assessed for various projects. One of these projects was the Fundamental Superconducting Application Technology Project (Phase II), which was held from 2003 to 2007 with a total project budget of 17 billion yen. Yuh Shiohara, then Acting Director General (currently Director General) of the Superconductivity Research Laboratory of the International Superconductivity Technology Center, directed the project. The post-project evaluation report of this project was discussed and evaluated as follows below (please refer to the following URL for details):

http://www.nedo.go.jp/iinkai/kenkyuu/hyouka/20h/20/index.html

Evaluation: Although the project's goals were set at an aggressively high level, they were all successfully cleared due to the appropriate strategies that were applied to research management. These superb results, which are of the highest, world-class standard, deserve extremely high praise. At the same time, since the degree of maturity of existing devices is high, even higher goals should be set to replace them, and the development of technology for even greater reductions in cost would also be desirable.

Recommendation: Since wire development is still in the international competition stage, the risk of development remains high for any private corporation working alone, or for any attempts to replace existing devices. Therefore, the continued support of national governments for the promotion of this research and development is preferred, in order to ensure that steady progress is made toward practical applications.

Ratings: Refer to the following table:

	Project Positioning/Necessity	R&D Management	R&D Results	Prospects for Practical Application and Commercialization
Interim (August 2005)	3	2.6	2.9	2
Post-Project (November 2008)	3	2.6	2.9	2

- Excerpted from NEDO's site -

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"Superconducting Power Network Control Technology Project" Post-Project Evaluation Results Disclosed

Katsumi Tajima
Managing Director, ISTEC

On Friday March 27, 2009, the New Energy and Industrial Technology Development Organization (NEDO), an independent administrative organization of the Ministry of Economy, Trade and Industry, held its 21st research evaluation committee meeting, during which post-project evaluation results were discussed and assessed for various projects. One of these projects was the Superconducting Power Network Control Technology Project, which was held from 2004 to 2007, with a total project budget of 6.39 billion yen. Shigeo Nagaya of the Chubu Electric Power Co., Inc. and Hiroshi Nakashima of the Central Japan Railway Company) led the project. The post-project evaluation report of this project was discussed and evaluated as follows (please refer to the following URL for details):

http://www.nedo.go.jp/iinkai/kenkyuu/hyouka/20h/21/index.html

Project:
This project's objectives were the development and verification of power network control technology using a Superconducting Magnetic Energy Storage System (SMES) and superconducting flywheel system technologies, and the stabilization of power networks.

Evaluation:
This collaboration among industry, government, and academia is noteworthy in that it was successful in its approach to SMES, reducing the cost of superconducting coils and high-capacity converters, developing pulse tube cooling systems with a long operating life and current leads with high voltage resistance, and producing other achievements. Also deserving of praise is the prospect of greatly reducing costs underneath those of conventional flywheels, and the demonstration of power input and output in excess of 500 times.

Recommendation:
Recommendations include understanding trends in the development of yttrium-based and other types of superconductor wire, improving coil technology, working to improve reliability and economic competitiveness, and achieving practical application soon through the implementation of even more efficient development.

Ratings:
Refer to the following table:

	Project Positioning/Necessity	R&D Management	R&D Results	Prospects for Practical Application and Commercialization
Post-Project (November 2008) (Entire Project)	2.8	2.3	2.6	1.6

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Note:

This project was judged to be “Excellent” due to its total of 4.0 or higher in total rating points for “R&D Results” and “Prospects for Practical Application,” based on pass/fail and other criteria.

- Excerpted from NEDO’s site -

(Published in a Japanese version in the May 2009 issue of *Superconductivity Web 21*)

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Director General Yuh Shiohara of ISTEC/SRL Discusses "High-Temperature Superconducting Technologies, the Environment, and Energy: The Current Situation and Expected Applications"

Director General Y. Shiohara's Speech

On March 16, 2009, Director General Yuh Shiohara of the International Superconductivity Technology Center's Superconductivity Research Laboratory delivered a speech concerning the theme High-Temperature Superconducting Technologies, the Environment, and Energy: The Current Situation and Expected Applications at the Keidanren Kaikan conference hall.

According to Earth simulators and other sources, global temperatures are projected to increase 10 degrees by 2100 due to the emission of greenhouse gases, including CO_2. According to the 2006 edition of "CO_2 Emissions from Fuel Combustion," the CO_2 emissions caused by Japan's burning of fossil fuels have already exceeded 1.2 billion tons, even when the fuel burned by ships and airplanes is excluded. A plan is being implemented to reduce CO_2 emissions across a wide range of categories, such as electric power, industry, and automobiles, to a level of 0.9 billion tons by around the year 2030.

Although we are carrying out various measures, such as a reexamination of the non-fossil energy ratio, the promotion of high efficiency and low carbon dioxide emissions on the electric power supply side, and the spread of high-efficiency devices and energy-saving devices on the demand side, there are concerns that we may reach a limit as to what can be done through the further development of current technologies, which are already highly advanced. The report indicated that as a result, in order to achieve its target obligations, Japan may be forced to purchase 700 billion yen worth of emission credits.

There are many proposals to improve the non-fossil energy ratio on the electric power supply side, by reevaluating nuclear power generation, solar power generation, wind power generation, the hydrogen society, and so on. In addition, there are many proposals involving the demand side, such as the achievement of zero emissions, extremely high-efficiency energy savings, and others. This state of technological development strongly indicates that superconducting technology can contribute in a major way. In other words, the application of superconducting technology with no power loss is expected to enable a dramatic leap forward in both extremely high-efficiency energy saving technology, as well as environmental technologies such as CO_2 emissions reduction.

Specifically, expectations are running high for the results of the new Development of

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Yttrium-based Superconducting Power Equipment Technologies national project, which has been underway since 2008. For instance, by using high-temperature superconducting cables for transmitting power at the 1,500 MVA capacity level, it will be possible to reduce the current power transmission loss ratio of 5 % by around one thirds (1.7 %), thereby enabling the achievement of extremely high-efficiency power transmission. Also, by using superconductivity in an 8 MW class wind power generation system, not only will it be possible to reduce wind turbine nacelles to a volume of under 1/20th, a weight of less than 1/3rd, and a cost of less than 1/2, the synergistic effects of using superconducting transformers, superconducting fault current-limiting devices, SMES, and other related electric power devices will greatly contribute to energy savings as well. Furthermore, the CO_2 emission reduction effects of Japan's introduction of superconductivity in the year 2050 are expected to amount to 0.23 billion tons, including the categories of electric power and energy, industry and transportation, and information and communication.

Finally, the development of these superconducting power generation devices and the high-temperature superconducting wire technologies to be applied to them will also follow the environmental energy technology measures formulated by the Council for Science and Technology Policy in October 2008. The benefits of Japan coming together to implement these technologies cannot be overestimated.

(Editorial board)

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

Akihiko Tsutai, Director
International Affairs Division
ISTEC

Award

U.S. Office of Naval Research (May 20, 2009)

George Stimak, a program officer at the Office of Naval Research (ONR), has been acknowledged as the "Top Navy Scientist and Engineer of the Year" for his leadership in the breakthrough research that yielded the world's first high-temperature superconducting ship degaussing system. This award is presented annually to Navy civilian and military personnel for exceptional scientific and engineering achievement. Stimak remarked, "This is a great honor for me, but it was truly a team effort. Support from NAVSEA, Carderock, industry and especially the crew of USS Higgins, where we installed the HTS coils, were vital to the successful development of this technology, and everyone's partnership was outstanding." Degaussing technology eliminates a ship's magnetic signature, making the ship "invisible" to undersea mines.

Source:
"Accolades for superior program leadership on groundbreaking superconducting degaussing technology"
Office of Naval Research press release (May 20, 2009)
http://www.onr.navy.mil/media/article.asp?ID=187

Power

Zenergy Power plc (May 1, 2009)

Zenergy Power plc has released a report on the company's preliminary results for the year ending December 31, 2008. Highlights of the report include descriptions of a commercial upgrade to an existing order for a superconducting hydro-generator for E.On AG, the installation of the world's first superconductor induction heater in a commercial facility (exceeding all expectations and enabling dramatic energy savings while simultaneously increasing productivity), the establishment of a joint development program for superconducting wires with Honeywell, the successful testing of superconducting electromagnetic coils for renewable energy, and the successful testing and delivery of a Smart Grid device. These activities have generated tremendous momentum for Zenergy heading into 2009. In addition to the successful installation of a smart grid device in a U.S. electricity grid, the company has now received a commercial contract from Con Edison (New York) for the development of a second smart grid device. The company has also received a commercial contract for a superconductor hydropower evaluation from RWE AG and has successfully completed an institutional fundraising of £9.5 million to support its commercial expansion in the United States so that it may take advantage of government spending for stimulus packages aimed at the clean energy sectors. These stimulus packages are expected to have clear implications for the commercial prospects of superconducting fault current limiters and induction heaters.

With regard to the shifting worldwide economic climate, Michael Fitzgerald, Chairman of Zenergy Power, stated, "These [shifts in the world's economies] have placed the renewable energy industry in the

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centered and formidable position that it finds itself today. 2008 can be defined as the year in which a paradigm shift occurred in the perception of the renewable and clean energy industries, which in turn led to a fundamental increase in the importance now being conferred upon them to provide the means of sustainable economic and social development. This move from the periphery to mainstream consciousness and commercial industry is today manifesting itself in the type of capital investment, public policy commitment and regulatory change that will lay the foundations from which our target industries can flourish."

Focusing on the validation of their superconducting technologies, Dr. Jens Mueller, Chief Executive Officer of Zenergy Power, stated, "Overall, 2008 can be considered to be the year in which our technology left our research and development facilities and entered into the real commercial world." He continued, "...this was achieved through both commercial sales and rigorous third party testing and validation. In both instances, the outcome underlines the same significant fact; that our technology has proven itself capable of living up to, and beyond, our expectations in both laboratory and real-world conditions. The importance of this 'real-world' operation cannot be overstated and already we have been able to progress a number of commercial discussions as a direct result of the technical achievements of 2008."

Source:
"Preliminary Results for the Year Ended 31 December 2008"
Zenergy Power Preliminary Results Report (May 1, 2009)
http://www.zenergypower.com/images/press_releases/2009/2009-05-01-final-results.pdf

American Superconductor Corporation (May 13, 2009)

American Superconductor Corporation (AMSC) has received an order valued at more than US $10 million from ACCIONA Energy, a division of ACCIONA SA (Spain), for its new Dynamic VAR Ride Through (D-VAR RT) solution. The D-VAR RT product enables individual wind turbines to continue operating smoothly by "riding through" voltage disturbances that might otherwise interrupt their operation. AMSC's D-VAR RT product will enable such turbines to meet Spain's strict grid interconnection requirements for both existing and new wind turbines. The order follows extensive field-testing and operation by an AMSC-ACCIONA Energy team at a wind farm situated in one of Spain's most difficult climates. As a result of these field tests, the solution recently received an official certification of compliance with the grid interconnection requirements. AMSC is expected to deliver the D-VAR RT solutions over the next few months. Timothy Poor, AMSC's Senior Vice President of Global Sales and Business Development, commented, "With more than 6,000 megawatts of wind power installed and more than 15,000 additional megawatts in development, ACCIONA Energy is a global clean energy powerhouse and is an ideal first adopter for our new D-VAR RT solution. We see great potential for this product in Spain and other countries that adopt similar standards in the years ahead as wind power continues to play a more prominent role in the world's electricity supply."

According to the Global Wind Energy Council, Spain was the world's third largest wind power market as of the end of 2008, with an installed base of more than 16,000 MW.

Source:
"AMSC Signs Contract with ACCIONA Energy for New Wind Turbine Low Voltage Ride Through Solution"
American Superconductor Corporation press release (May 13, 2009)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1287795&highlight

American Superconductor Corporation (May 14, 2009)

American Superconductor Corporation (AMSC) has reported its financial results for its fourth quarter and full year ending March 31, 2009. Revenues for the fourth quarter were $61.2 million, a 60 % increase from the $38.4 million in revenues reported for the same period in the previous fiscal year. The gross margin for the fourth quarter of fiscal 2008 was 32.6 %, compared with 33.2 % for the same period in the previous fiscal year. Also in the fourth quarter, AMSC generated its first quarterly profit in company history, with a reported net income of $1.3 million compared with a net loss of $1.8 million for the same period in the previous fiscal year. The company generated a non-GAAP net income of $4.1 million, compared with $2.7 million for the same period in the previous fiscal year.

For the full year, revenues totaled $182.8 million, an increase of 63 % from $112.4 million for full-year fiscal 2007. The gross margin for the full year was 28.4 %, compared with 28.5 % for full-year fiscal 2007. AMSC's net loss for full-year fiscal 2008 was $16.6 million, compared with $25.4 million for full-year fiscal 2007.On a non-GAAP basis, the reported net loss was $3.1 million for full-year fiscal 2008, compared with $6.8 million for full-year fiscal 2007. As of March 31, 2009, the company had $117.2 million in cash, cash equivalents, marketable securities and restricted cash; this compares with $119.4 million as of March 31, 2008. The reported backlog as of March 31, 2009, was approximately $558 million, compared with $199 million as of March 31, 2008. This increase was mainly due to a $450 million, three-year contract for wind turbine core electrical systems that was received from Sinovel Wind Company in June 2008.

Greg Yurek, AMSC's founder and chief executive officer, commented, "AMSC posted its strongest financial performance to date in the fourth quarter of fiscal 2008. We generated record revenues and achieved our first profitable quarter. During fiscal 2008, we expanded our global workforce by 36 % as we increased our revenue by 63 % while also developing and introducing several new wind power and power grid solutions. We self-financed these activities, which resulted in a small net use of cash for the fiscal year. We are now sharply focused on delivering profitable growth and net cash flow positive results for full-year fiscal 2009 as we continue to make the investments that will enhance our long-term growth prospects."

AMSC expects its revenues to increase to within a range of $225 million to $235 million for fiscal year 2009, with a gross margin target of 30 – 32 %.

Source:
"AMSC Reports Fourth Quarter and Full Year Fiscal 2008 Financial Results"
American Superconductor Corporation press release (May 14, 2009)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1288260&highlight

American Superconductor Corporation (May 27, 2009)

American Superconductor Corporation (AMSC) has announced that its wholly owned subsidiary, AMSC Windtec^{TM}, has licensed its proprietary 2-MW doubly-fed induction wind turbine design to Inox Wind Limited, part of India's Inox Group of Companies. The license will provide Inox with the right to manufacture and sell wind turbines globally. Inox plans to begin producing a 2-MW wind turbine in 2010. AMSC will also help Inox to localize its supply of key wind turbine components, establish a manufacturing line, and build and test its first prototype. In return, AMSC will receive an upfront license fee as well as royalty payments in addition to providing the electrical systems. Inox presently owns and operates several wind farms in India and has a diverse line of business with nearly US $600 million in annual sales.

Greg Yurek, founder and CEO of AMSC, commented, "We view India as a tremendous growth opportunity for all AMSC products. Similar to our strategy in China, we have entered India through the wind energy market, which not only provides us with a growing stream of revenue, but also provides a concrete rationale to establish our in-country base of operations and contacts. From this base, we expect to address not only the wind market, but also the huge power grid market opportunity."

Source:

"AMSC Expands Business in India with License to Inox Wind Limited"
American Superconductor Corporation press release (May 27, 2009)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1292657&highlight

Medical

Brookhaven National Laboratory (May 12, 2009)

A researcher at the U.S. Department of Energy (DOE)'s Brookhaven National Laboratory has developed a simpler, less-expensive gantry design for making high-precision particle cancer therapy accessible to more patients. Brookhaven Science Associates, the company that manages the laboratory for the DOE, has applied for a U.S. non-provisional patent for the design, which is now available for licensing and commercial development. The new design uses smaller, fixed-field superconducting magnets to both steer and focus the particle beams, greatly reducing the cost, weight, and size of the particle-delivery system as well as simplifying its operation. Even with the equipment required to cool the superconducting magnets, the particle delivery system is still more compact and economical than existing designs. Thus, the new design could make particle cancer-therapy facilities more economical to build and operate, making particle therapy more accessible to cancer patients throughout the world.
Source:
"Compact cancer-therapy particle-delivery system patented"
Brookhaven National Laboratory press release (May 12, 2009)
http://www.bnl.gov/bnlweb/pubaf/pr/PR_display.asp?prID=947

Quantum Computer

University of California – Santa Barbara (May 28, 2009)

Researchers at the University of California – Santa Barbara have demonstrated a breakthrough in the quantum control of photons that may have important implications for quantum computing and thus for banking, drug design, and other applications. The group used a superconducting electronic circuit known as a Josephson phase qubit to create highly unusual quantum states using microwave-frequency photons. In their experiments, photons were stored in a microwave cavity that acted as a "light trap". The researchers found that they could create states in which the light trap simultaneously contained different numbers of photons stored within. Measuring the quantum state by counting how many photons were stored forced the trap to "decide" how many there were; but prior to counting, the light trap existed in a quantum superposition, with numerous outcomes possible. While such superposition states are a fundamental concept in quantum mechanics, the group's results represent the first time that these states have been controllably created using light. The group's research has been published in *Nature*. The research itself was funded by the U.S. government's Intelligence Advanced Research Projects Activity (IARPA).
Source:
"UCSB researchers describe breakthrough in the quantum control of light"
University of California – Santa Barbara press release (May 28, 2009)
http://www.ia.ucsb.edu/pa/display.aspx?pkey=2026

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Communication

Superconductor Technologies Inc. (May 6, 2009)

Superconductor Technologies Inc. (STI) has reported their financial results for their first quarter ending March 28, 2009. Total net revenues for the first quarter were U.S. $1.7 million, compared with $3.5 million for the same period in the previous fiscal year. Net commercial product revenues were $1.1 million, compared with $2.0 million for the same period in the previous fiscal year. Government and other contract revenue totaled $546,000, compared with $1.5 million for the same period in the previous fiscal year. Compared with the fourth quarter of the previous fiscal year, all of the first quarter figures for the present fiscal year were either comparable or higher. Jeff Quiram, STI's president and chief executive officer, commented, "We are encouraged to see the market starting to stabilize after the uncertainty at the end of 2008. In the first quarter our commercial business improved in both revenue and sales backlog. In addition, our government business levels are expected to increase for the remainder of 2009 due to a $4.1 million contract award with the U.S. Air Force for the next phase of the Semiconductor-Tuned High Temperature Superconducting Filters for Ultra-Sensitive Radio Frequency Receivers (SURF) program." Also during the first quarter, the company completed a CDMA field trial in China that resulted in significantly improved coverage and performance. The company's SuperLink solution is now expected to be deployed in a Chinese communications network. STI will also be participating in a Long-Term Evolution (LTE) network field trial with a tier-one U.S. wireless operator for the new 700-MHz spectrum in North America. Furthermore, the company is pursuing two other strategic initiatives, one of which involves the production of HTS tapes for next-generation electric grid applications.

The net loss for the first quarter was $3.5 million, compared with $2.3 million for the same period in the previous fiscal year. As of March 28, 2009, STI had $5.1 million in cash and cash equivalents and a commercial product backlog of $434,000, compared with a commercial backlog of $192,000 at the end of the year-ago quarter.

Source:
"Superconductor Technologies Inc. Reports First Quarter 2009 Results"
Superconductor Technologies Inc. press release (May 6, 2009)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1284920&highlight

Basic

Washington University in St. Louis (May 15, 2009)

Researchers at Washington University in St. Louis (WUSL) have discovered that europium becomes superconducting at 1.8 K and 80 GPa, making it the 53rd known elemental superconductor and the 23rd at high pressure. James S. Schilling, a professor of physics at WUSL, explained, "...when europium atoms condense to form a solid, only two electrons per atom are released and europium remains magnetic. Applying sufficient pressure squeezes a third electron out and europium metal becomes trivalent. Trivalent europium is nonmagnetic, thus opening the possibility for it to become superconducting under the right conditions." The discovery provides new data that should be useful for refining theoretical models of high-temperature superconductivity. The research was published in the May 15, 2009, issue of *Physical Review Letters*. The research itself is supported by a four-year, $500,000 grant from the National Science Foundation, Division of Materials Research.

Source:

"Europium discovery"
Washington University in St. Louis press release (May 15, 2009)
http://news-info.wustl.edu/news/page/normal/14190.html

University of Illinois at Urbana-Champaign (May 27, 2009)

Researchers at the University of Illinois at Urbana-Champaign have demonstrated that the entire collection of superconducting electrons in an ultrathin superconducting wire can "tunnel" as a pack from a state with a higher electrical current to one with a markedly lower current, providing new macroscopic evidence of the phenomenon of quantum tunneling. The quantum tunneling phenomenon can be observed as a result of a "phase slip", during which the energy locked in the motion of electrons is dissipated as heat as they "slip" from a higher electrical current state to a lower one. This heat causes the nanowires to switch from a superconducting state to a resistive one, which in turn enables the quantum tunneling phenomenon to be observed. While the tunneling of single electrons is well established, little evidence of the group tunneling of a large ensemble of superconducting electrons confined in a thin wire has existed until now. Knowledge obtained from research into quantum tunneling could have applications in the field of quantum computing. The group's research was recently published online in *Nature Physics*. The research itself was funded by the U.S. Department of Energy.

Source: "Evidence of macroscopic quantum tunneling detected in nanowires"
University of Illinois at Urbana-Champaign press release (May 27, 2009)
http://news.illinois.edu/news/09/0527tunneling.html

Forschungszentrum Dresden, Rossendorf (May 28, 2009)

Scientists at the Forschungszentrum Dresden-Rossendorf (FZD) research center in Germany have successfully produced superconducting germanium for the first time. In addition, they have unraveled a few of the mysteries associated with superconducting semiconductors. To produce a superconducting semiconductor, germanium samples were doped with about six gallium atoms per 100 germanium atoms (an extremely high ratio). Superconductivity was subsequently demonstrated in a 60-nanometer thick sample of a germanium layer doped in this manner. As the doping process (using ion implantation) damages the germanium lattice, the lattice must be repaired after doping. For this purpose, a flash-lamp annealing facility has been established at FZD. In this facility, the destroyed crystal lattices are repaired by rapidly heating the sample surface, while maintaining the distribution of the dopant atoms. The resulting material is very promising, as it exhibits a surprisingly high critical magnetic field with respect to the temperature where the substance becomes superconducting (at about 0.5 K). FZD researchers expect to further increase the critical temperature by changing various parameters during ion implantation or annealing. At present, germanium is being rediscovered as a semiconducting material for micro- and nanoelectronics and is thought to be a promising material enabling both faster processes and further miniaturization beyond what is achievable using silicon. Superconducting germanium could thus help to realize novel computer circuits. The group's findings were published in a recent issue of *Physical Review Letters*.

Source:
"Superconducting chips to become reality"
Forschungszentrum Dresden, Rossendorf, press release (May 28, 2009)
http://www.fzd.de/db/Cms?pOid=28713&pNid=473

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Feature Articles: Advances in Superconducting Industrial Equipment Technology
- Prospects in Superconducting Industrial Equipment Technology -

Shigehiro Nishijima, Professor
Division of Sustainable Energy and Environmental Engineering,
Graduate School of Engineering, Osaka University

Examples of superconducting equipment that have been put into practical and widespread use include nuclear magnetic resonance, magnetic resonance imaging, and crystal growth equipment. If nuclear magnetic resonance equipment is categorized as analytical, and magnetic resonance imaging equipment is categorized as diagnostic, then crystal growth equipment is the only superconducting equipment that is used for industrial applications. For superconducting equipment to spread, it goes without saying that the development of industrial superconducting equipment will be required. The development of various types of equipment is proceeding vigorously at present. For instance, superconducting power transmission devices, transformers, current-limiters, motors, SMES devices, flywheels, and other such equipment are under development. All of this equipment is related to electric power. The details of this R&D are being widely reported.

Applications for superconductivity go beyond the power industry, and can conceivably include the effective use of strong magnetic fields as well. At present, however, the only industrial application of magnetic force control that has been put into practice is in wastewater treatment equipment, which is used in the manufacture of paper and the washing of drums. In addition, environmental processing equipment using functional iron powder is also undergoing on-site verification in some locations. It could be said that superconducting magnetic separation are already being put into practical use in wastewater processing equipment, although the scale of operation is still small. Further efforts to expand the range of applications are being made. Also, the focus of R&D is shifting toward the reduction of operating costs, and the trade-offs between this equipment and traditional equipment are increasingly being considered. For this reason as well, it can be said that the existence of this kind of technology is starting to be recognized in industrial equipment. The demonstration of conditions for superiority in terms of cost over traditional equipment is an issue to be resolved in the future.

R&D is being pursued vigorously in magnetic force control equipment in fields other than wastewater processing equipment. This type of R&D is characterized by the fact that to a certain extent, it is clear that there are end users who want to use the results. Therefore, it is assumed that the question as to whether or not to introduce this kind of equipment will be decided within a short period of time. Specific applications under consideration include the separation of ferromagnetic particles from powder and viscous fluids, both of which are envisioned for use in the manufacturing process for industrial products, food, and pharmaceuticals. Ferromagnetic particles can slip into these processes, and so there is a need to separate such particles from the products. These particles are generated during the abrasion of products within the manufacturing process pipeline, or are abrasive powder from sliding parts, or fragments from working parts. Although most of this material is comprised of stainless steel, due to the heavy processing applied, a martensitic transformation occurs that exhibits ferromagnetism. In the past, permanent magnets would be used to magnetically separate this material, but since there are limits to the performance afforded by this type of system (due to factors such as the strength of the magnetic force or the size of the working space),

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the possibility of using superconducting magnetic separation is under consideration.

Furthermore, the use of superconductivity in resource recycling is also undergoing serious consideration. One possibility, for instance, is the reuse of the slurry discharged during semiconductor processing. This was already considered in the past, but since the societal demand for reuse was weak, the main goal at the time was the reduction of industrial waste. Currently, however, the possibility of a resource crunch is on the horizon, and so there is a movement towards the aggressive use of recycling. This method is aimed at the separation of iron powder from slurry during processing, which is a task for which magnetic processing is well-suited. Although attempts are being made to add chemicals in order to dissolve the iron powder, since this may generate new waste products, efforts in this area are not currently successful. In addition to the reclamation of semiconductor processing slurry, investigations have also begun in many other fields in which the use of magnetic force makes recycling easy. It will, however, be important to differentiate between this and permanent or electric magnets, as it is expected that trade-offs between superconducting and traditional magnets will be considered.

I have touched upon the current state and future possibilities for industrial applications of magnetic force with superconducting magnet. Although I expect this field to expand its base in the future, as with previous types of equipment, it will be necessary to argue the advantages and disadvantages of this new type of equipment in the same arena as other equipment. For superconducting technology to survive this argument, I expect the discussion of life cycle costs to become important as well. These discussions have already begun, with an eye toward industrial applications.

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Feature Articles: Advances in Superconducting Industrial Equipment Technology

- Prospects in Portable Superconducting Bulk Magnet System Technology -

Norihide Saho, Senior Researcher
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Portable superconducting bulk magnet systems, with their compact size and light weight, and their ability to be transported easily with a passenger vehicle while maintaining a state of superconductivity after field magnetization, feature the generation of powerful local magnetic forces. Increasingly high demand is expected for these systems in areas such as the rapid magnetic separation of magnetic materials, magnetic drug delivery systems (MDDS) to deliver nano-sized magnetic drugs to the sites of disease inside blood vessels, and R&D applications of intense magnetic fields.

The magnet in the prototyped superconducting bulk magnet system weighs 9.5 kg and, as shown in the overview image in Fig. 1, is portable enough to be easily carried by one person. The magnet itself is 79 mm (the diameter of the vacuum case's tip section) by 640 mm (the length of the vacuum case's tip section). The magnet part uses a gadolinium-based high-temperature bulk superconductor (external diameter 45 mm, thickness 15 mm, 6 layers) and a compressor integrated with a direct-cooling compact helium refrigerator configuration. The bulk superconductor's field magnetization was performed using a field cooling method. The cooling temperature achieved by the cyrocooler of the bulk superconductor is 38.1 K, with a cool-down time of 6½ hours. The power consumption of the cyrocooler is 195 W (in the case of water cooling using tap water), and the power consumption of the magnet system including the water cooling chiller unit is 457 W (cooling water circulating system). Whichever system is used, the prototype can be run on a low amount of energy.

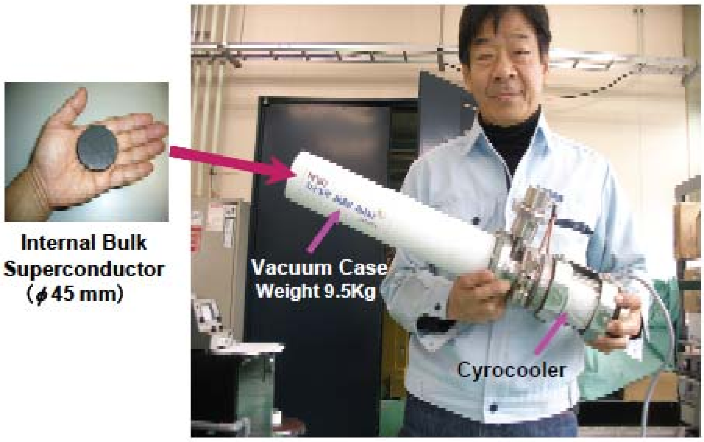

Fig. 1 Superconducting Bulk Magnet Prototype

The result of the field magnetization test run with an applied field intensity of 6 T showed a maximum flux density of 5.07 T in the vertical direction (the direction of the Z axis) on the vacuum case's surface, and a magnetic flux density gradient (magnetic gradient) of 750 T/m. Also, the magnetic gradient of a location 50 mm away from the vacuum case's surface was 9.5 T/m. The critical currents of the conditions for this field magnetization were obtained from the test results using the Bean model, and these values were used to plot the distribution chart of a three-dimensional magnetic force coefficient fm (magnetic flux density x magnetic gradient), as shown in Fig. 2. As this figure indicates, an fm region of 1,000 T^2/m or higher was generated on the surface of the bulk superconductor (with X＝0 mm and Z＝8 mm).

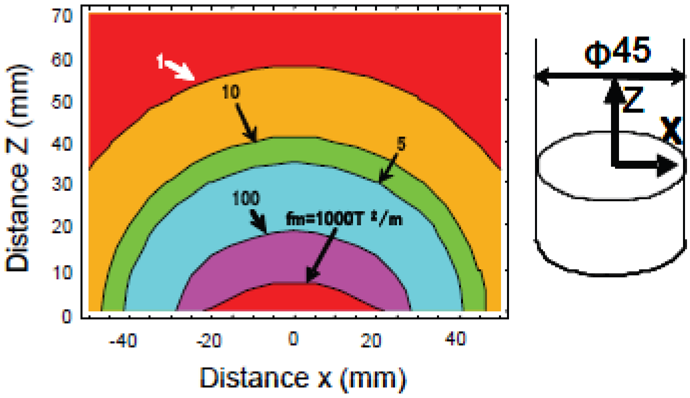

Fig. 2 Distribution Chart of the Magnetic Force Coefficient fm for the Superconducting Bulk Body's Surface

Fig. 3 is a photograph that shows the Moses Effect in tap water in which the regional magnetic force is made visible by using the diamagnetism of water.

In addition, the ability to transport this magnetic system with a continuous cooling operation 1,500 km without problems by using the 100 V power supply inside a transport vehicle was verified.

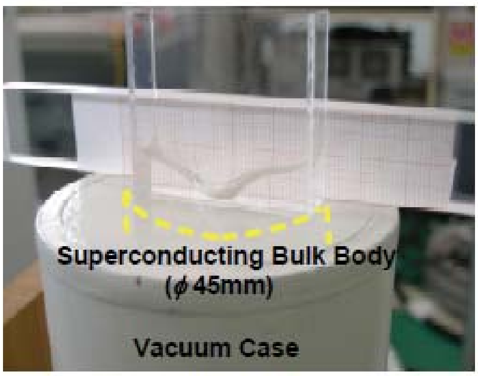

Fig.3 Moses Effect of Tap Water on the Magnet Surface

It is expected that within the near future, portable superconducting bulk magnet systems will be put into practical use in a widespread system whereby it will be possible to use a superconducting bulk magnet with a strong magnetic field that is delivered from the manufacturer without any need for the user to own expensive superconducting magnets for field magnetization.

The development of this system's technology was made possible with the aid of the New Energy and Industrial Technology Organization's (NEDO) sponsorship in 2006.

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Feature Articles: Advances in Superconducting Industrial Equipment Technology
- Prospects in Magnetic Filtration Technology Using HTS Bulk Magnets for Drum Washing Wastewater -

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The stacking of used drums outdoors has been causing environmental degradation problems due to the leakage of residual waste and other materials, leading to the spread of a new trend in which used drums are cleaned and reused.

It takes 70 liters of water to wash one drum, however, and since there are currently 13,500,000 drums in domestic drum washing plants alone, the washing of drums requires approximately one million tons of water each year. If it becomes possible to appropriately process and reuse this washing wastewater, not only will this contribute to environmental conservation, it will offer economic benefits as well thanks to a reduction in the use of industrial water.

Therefore, a magnetic filtration system is being developed in which after magnetic seeding equipment is used to convert the contaminants in the washing wastewater into ferromagnetic flocs (magnetic seeding is performed by adding ferromagnetic particles to paramagnetic and diamagnetic material), and these flocs are then moved to the proximity of HTS bulk magnets, where magnetic force purifies them with a high level of efficiency.

Although the wastewater treatment equipment of recent years includes a filtration system known as the High Gradient Magnetic Separation (HGMS) system, which uses a magnetic field to rapidly process large amounts of fine particle materials to be separated, the hardware of this system is based on an entirely different fundamental concept. The fundamental concept of the HGMS is to form a high magnetic gradient by inserting a ferromagnetic material filter (ferromagnetic wire) into a coil bore. This type of system requires, among other measures, the installation of a device to wash the filter inside the bore, so that its processing performance does not degrade. This system, on the other hand, is configured to have an HTS (high-temperature superconductor) bulk magnet at the bottom of a gutter-shaped flow channel. For this reason, the system is easy to handle, and the ferromagnetic flocs captured inside the flow channel can be washed with a simple mechanism that moves the magnetic field generator away from the capturing part, for instance.

The reasons HTS bulk magnets are used as magnetic field generators are that after a bulk magnet is magnetized, it can be handled in the same way as a permanent magnet, it generates a cone-shaped magnetic field with the strongest magnetic force generated from the center of the magnet, it can generate a strong magnetic field, and just a single magnet can form a high magnetic gradient. This is why the system is fully capable of rapidly processing large amounts of fine particle materials.

It is expected that magnetic filtration systems with an even higher level of performance can be easily implemented by placing a ferromagnetic material filter inside the system, thereby generating an even higher magnetic gradient.

This system will offer features not available in previous systems, such as compactness, low cost, easy operation, and expandability. In addition, this system can be modified somewhat in order to work as more than just wastewater treatment equipment by turning it into a precise magnetic separator for removing contaminants and other materials, in order to support a variety of different material separation needs. Since the existing distribution channels for the equipment can be used, it should be possible to spread this system using HTS bulk magnets in a short period of time.

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Feature Articles: Advances in Superconducting Industrial Equipment Technology
- Prospects in Sludge Treatment Technology Using Magnetic Force -

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Water purification technology and sludge treatment technology are two sides of the same coin. For instance, in Japan, 14 billion m^3 of sewage is purified each year, generating 400 million m^3 of sludge annually. The most prevalent water treatment process used on organic wastewater is the activated sludge process, which generates small amounts of sludge. However small the amount, when these organic compounds are biodegraded approximately half of the organic material is converted into microbes and becomes sludge. The flocculation method, on the other hand, involves the addition of flocculation agent in amounts many times greater than the amount of contaminant, and generates large amounts of sludge. Sludge treatment technologies are advancing in different directions according to two different strategies, namely: **1) the cut of sludge;** and **2) the effective utilization of sludge.**

1) Sludge reducing technology using magnetic force includes the magnetic activated sludge (MAS) process under research and development by myself and others. The microbial floc used for activated sludge is magnetically seeded with magnetite that enables the magnetic separation of the microbial floc. By returning the magnetically separated microbes to the reaction tank, it becomes possible in principle to store the sludge inside the reaction tank until its magnetic separation concentration reaches the critical concentration. By treating the organic material with a high concentration of microbes, it is possible to put the individual microbes into a state of undernourishment, thereby promoting death and decomposition of the microbes, which inhibits proliferation. By continuing the water treatment with a microbe concentration in which the microbe death/decomposition rate is the same as the microbe proliferation rate, it is possible to continuously treat water without any sludge being generated by microbe proliferation. The 50 person scale sewage treatment pilot plant has already achieved operation with zero excess sludge over a period of several years, offering a level near practical use of low-concentration organic wastewater.[1] One of the benefits of zero excess sludge operation is that it is possible to reduce the running cost of magnetic powder like magnetite, which is added for use in magnetic separation. If sludge is removed, it is possible either to recover magnetic powder and reuse it, or add new magnetic powder. If neither of these actions is taken, the concentration of magnetic powder will become insufficient, and magnetic separation will fail.

Fig. 1 Magnetic Activated Sludge Process Pilot Plant — The sewage of 50 people can be treated without generating excess sludge.

Other approaches to the reduction of sludge that have been proposed include the ozone treatment process, the microbe dissolution process, the use of special microbes, and so on. Although some of these

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processes have been put into practical use, no technology has been developed as of yet that satisfies all required conditions, including cost, stability, and sludge reduction. The approach using magnetic force in an activated sludge process simultaneously solves both the problem of instability of solid-liquid separation, and the sludge reduction problem, which problems are the big issues in the activated sludge process. This system can be applied anywhere in the world to easily purify organic wastewater with a sustainable water treatment process.

2) Technology to effectively utilize sludge by using magnetic force can magnetically concentrate sludge, thereby improving the efficiency of dehydration.[2)] The sludge generally produced by wastewater treatment is a liquid that contains approximately 99 % water. By using a method of magnetically seeding sludge with a substance such as magnetite, rapid separation can be achieved as shown by many different reported examples, such as the magnetic separation of activated sludge, blue-green algae separation, paper manufacturing wastewater treatment, and so on. These methods take advantage of the benefits of magnetic separation by using magnetic force to efficiently and easily concentrate sludge. Our research shows that even if it is not possible to dehydrate to the level achieved through mechanical compression with a filter press, it is still possible to obtain dehydrated sludge between 90 % and 96 % of water contents simply by using magnetic force, without using high-pressure compression or other such methods. By combining this method with simple press hydration, it is possible to dehydrate at a level several percentage points higher. It is possible to create sludge with a water content of 90 % or less with one rotation of the magnetic separation drum. This level of savings in both energy and time may only be achievable through magnetic separation. In the sludge treatment process, thickening and dehydration processes require a lot of time, cost, and chemical agents, and so the benefits of magnetic separation are considerable. One issue to consider is the necessity of adding magnetic powder, but if the running costs of doing so are offset by the aforementioned advantages, then it may be possible to put magnetic separation technologies into practical use in the concentration and dehydration of sludge.

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1) "Cleaning Up Wastewater Magnetically", ACS, Chemical Engineering News, Dec. 21, 2005.
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Feature Articles: Advances in Superconducting Wire Technology - Prospects in Superconducting Material Technology -

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In recent years, a fierce competition has been brewing in the development of yttrium-based superconducting wire or coated conductor, especially in Japan and the US, resulting in wires with a top record self-field I_c of 200-400 A/cm-width at a temperature of 77 K, and lengths between 500 m and 1 km. In Japan, the achievements of NEDO's leading project in yttrium-based wire development have led to the start of the "Technological Development of Yttrium-based Superconducting Power Equipment" project in June 2008, with the goal of demonstrating prototypes of power devices such as SMES, cables, transformers. This project involves the development and demonstration of device prototypes made by using yttrium-based wire at the current technological level. For the practical application and introduction stages of devices anticipated for around 2020, a high critical current density (J_c) in the magnetic field, a high level of uniformity in both length and width directions, further reductions in cost, and other higher-performance features are demanded of the yttrium-based wire. The project also includes the parallel development of this kind of high-performance wire.

Copper oxide superconducting materials, which are represented by yttrium-based and bismuth-based versions, are characterized more than anything by a T_c of 90 K or higher, which is sufficiently higher than the liquid nitrogen temperature. Because of the layered structure, however, these materials generally have a high level of anisotropy, and this has the effect, for instance, of the irreversibility field (B_{irr}), that is the maximum magnetic field under which a certain level of critical current can be maintained, being much lower than the upper critical magnetic field (B_{c2}). In addition, when the T_c is high, the superconducting coherence length shortens as a result, and this combines with the high level of anisotropy to make it hard for the flux pinning to work. However, yttrium-based materials have the lowest level of anisotropy of all copper oxide materials (anisotropic parameter Γ = 5-7), and the self-field J_c of films and wires in tape shape with many spiral dislocations and lattice defects are 30-80 MA/cm^2 at low temperatures or 3-8 MA/cm^2 at 77 K. These values reach 20-30 % of the depairing current density, which is the ideal theoretical limit. This ratio is roughly comparable to the percentages achieved with niobium-titanium based wires that are already being put to practical use. Also, in recent years, the incorporation of trace impurities such as $BaZrO_3$ during film formation has enabled the development of wires with distributed pinning centers, such as nanorods and nanodots, and a considerably improved J_c in the magnetic field of around 1-5 T (for instance, 0.7-1 MA/cm^2 at 77 K, B(//c) = 1 T). In the future, the understanding of the flux pinning mechanisms and J_c improvements at lower temperatures and in higher magnetic fields, both of which will be necessary for applications to such as SMES, motors, and high-field magnets, will be major issues in materials. It will also be important to understand and inhibit the heterogeneity arising from complicated structures and compositions.

When, however, we turn our eyes to materials other than those based on copper oxide, the iron-based superconducting materials newly discovered by the Tokyo Institute of Technology group in February 2008 have been attracting a lot of attention recently. At the current stage, now that roughly one year has gone by, the material similar to LaFeAs (O,F) (T_c = 26 K) discovered by the group has the highest T_c of approximately 55 K among these ion-based materials, when samarium or neodymium is substituted for La. These materials are configured in a stack structure in which layers comprised of tetrahedral Fe-As networks

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that bear the superconductivity alternate with tetrahedral RE-(O,F) layers. It has become apparent that the anisotropy of such a system is at roughly the same level as that of yttrium-based copper oxide. Also, in (Ba,K) Fe_2As_2 in which Fe-As layers are alternated with (Ba, K) layers, although its T_c of 38 K is lower, the anisotropy is about the same or lower than that of MgB_2 (Γ= 1.5 -2). It is also apparent that the upper critical magnetic fields of these materials are at the same level or higher than those of yttrium-based materials. At present, however, there are many problems involved in applying these materials to wires. In addition to the fact that the T_c does not exceed the temperature of liquid nitrogen, it is difficult to synthesize single phase polycrystalline materials, a high J_c cannot be achieved, the toxic substance arsenic is present in a considerably high ratio, and there are other issues. On the other hand, this type of material allows for combinations with more elements than copper oxide-based materials do, and we will not be able to stop focusing on it for the time being due to the possibility that material with a higher T_c might be created.

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Feature Articles: Advances in Superconducting Wire & Tape Technology - Current Status of R&D for REBCO Coated Conductors -

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Ever since high-temperature superconducting materials were discovered, lots of applications, including applications at the temperature of liquid nitrogen, have been expected. Of these, electrical power applications have been central, and the deployment of these materials has been expected for use in a variety of devices, such as energy transmission equipment (cables, transformers, and current limiters), generators, energy storage equipment, and so on, all of which require wire and tape material. A BSCCO tapes has been advancing in development of tape materials comparing with REBCO coated conductors. However, REBCO coated conductors are expected because of the following advantages:

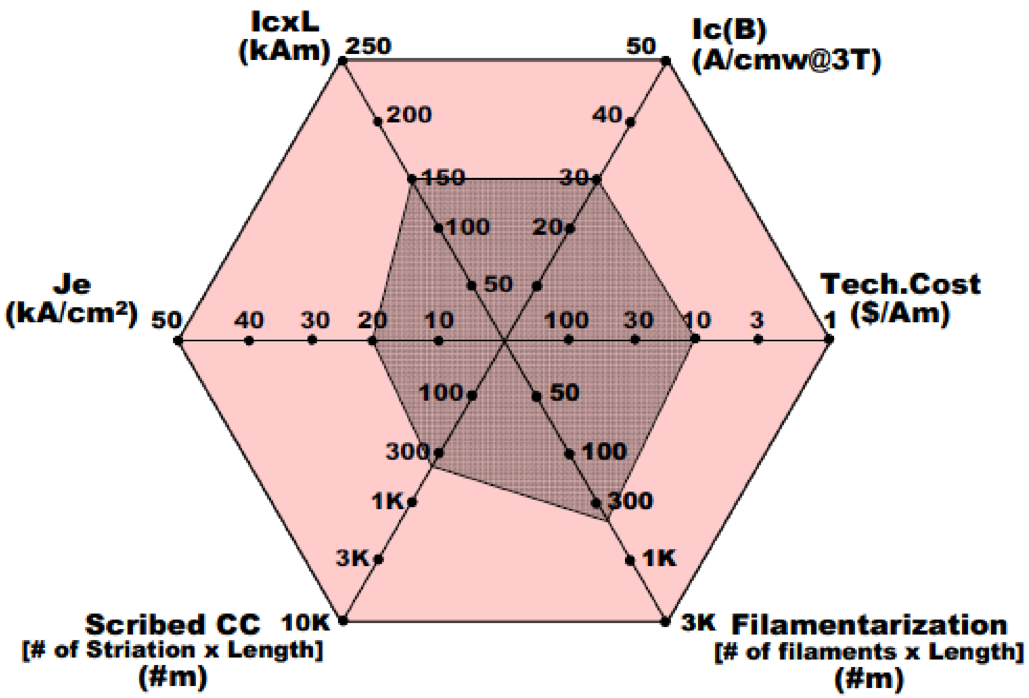
1) low cost
2) moderate to strong magnetic field characteristics
3) high mechanical strength
4) low current loss

The development of the long tape processing has been delayed due to its difficulty, especially for obtaining biaxial grain orientation in the superconducting layer. Major advances in this technology were recognized in the national project, "Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications", which had been supported by NEDO. ISTEC played a central role in this project, in which many power companies, wire manufacturers, heavy electric machinery manufacturers, and universities also participated. The knowledge of each institution was brought together and the length of REBCO coated conductors was dramatically improved, as well as other characteristics.

In order to achieve high-performance characteristics in REBCO coated conductors, it is necessary to bi-axially align grain orientation. Fujikura Ltd. and ISTEC used IBAD (ion-beam assisted deposition) technique, which were firstly developed by Fujikura, for an alignment of buffer layer. Additionally, they also developed CeO_2 layers that promote this orientation further. In addition, a PLD (pulsed laser deposition) technique was used on this substrate in order to fabricate superconducting layer. This has enabled us to continue to consistently lead the world in competition with the US up to this point. As of the time of the completion of the project of Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications at the end of 2007, $GdBa_2Cu_3O_y$ coated conductors on IBAD-$Gd_2Zr_2O_7$ buffered substrate was successfully created, with a length of 504 m and a critical current (*Ic*) of 350 A/cm-width. This tape achieved the global record of $I_c \cdot L$ product at the time of 176 kAm. On the other hand, SWCC Showa Cable Systems Co., Ltd. and ISTEC are also pursing a process development of the TFA-MOD technique (metal organic deposition using trifluoroacetates) for superconducting layer, in order to achieve low-cost tapes. This method involves a process that can be expected to be low-cost in principle, and the inclusion of fluorine enables low-temperature reaction for formation of superconducting phase. The start of development was late, however, and so this method is behind the PLD tapes described above. Regardless, in this project, development has proceeded rapidly, including breakthroughs in reaction mechanisms, the development of high-J_c film manufacturing technology, the development of precision-control gas flow firing furnaces using simulations, and so on. Recently, long tape with high performance have been realized in using the IBAD type substrate with properties including a length of 500 m and a width of 310 A/cm, at I_c・L values that are roughly the same as those of PLD tapes. Furthermore, in order to achieve the even lower costs that are a mandatory requirement for applications, a process was developed that can achieve lower than 3 yen/Am as the technology cost. This work demonstrated that in principle, the aforementioned cost can be achieved, for instance, in tape high-speed IBAD using MgO materials.

As described above, the development of REBCO coated conductors have been advancing rapidly in recent years, reaching the level where device development can begin. To this end, as part of the project of Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications that began in 2006, elemental technology development was started for devices using REBCO coated conductors, including cables, transformers, motors, current-limiting devices, and so on. The achievements of these works have demonstrated the characteristics of REBCO coated conductors, including the low current loss and the current-limiting effect. Based on these achievements, the new national project, “Materials & Power Applications of Coated Conductors”, was begun in 2008, centered on the development of devices using REBCO coated conductors. This project is designed to use these previously attained achievements to provide tape manufacturers with the tapes they need to development equipments, and is consequently developing SMES, cables, transformers, and other electric power application devices.

On the other hand, although it is definitely possible to start developing devices as described above from the perspective of the technological level of tapes, when one considers practical applications, there are still many issues that require further development, such as characteristic improvement including Ic in the magnetic field, mass production, high production speed, low cost, high material yield, and so on. The demanded specifications in these areas far exceed the levels currently achieved. The figure summarizes the wire development level at the end of the previous project, along with the wire specifications expected to be demanded around 2020, for the introduction and spread of electrical superconducting devices. The required tape specifications are at a level that is far in excess of each item at the time of completion of the entire project, and so, unless each of these items is converted to technology that can be used for stable mass production, the amounts of tape produced will not be large enough to support what is required for introduction and growth. Therefore, major advances in technology will be necessary. Along with the device development described above, tape development will continuously be indispensable if superconducting devices are to be put into practical use, and tape manufacturing technology development is also being carried out as one pillar of the Materials & Power Applications of Coated Conductors. This technological development is not being done from the perspective of the traditional material development side, but rather from the demand side. In other words, targets are set for the specifications that must be achieved for the devices, and ISTEC is playing a central role in moving this development forward. In the future, achievements from this development and the additional development that will stem from it, will be deployed as mass-production-ready technology, and the development of technology that can handle the introduction and spread of future superconducting devices is anticipated.



Note: In this figure, the "Segments" value is standardized for 10 mm width wires.

Figure: Major Specifications Needed for the Introduction and Spread of Tapes and Technological Levels Achieved for Tapes by the Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications Project (shaded region)

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Feature Articles: Advances in Superconductor Wire Technology
- The Current State of Yttrium-Based Superconductor Wire Technology Using the IBAD-PLD Method -

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IBAD-PLD method superconducting wires are fabricated by forming a superconducting layer using an excimer laser to apply laser evaporation to the intermediate layer, which has its crystalline orientation set in an advanced manner with the IBAD method. The Fundamental Superconducting Application Technology Project, which ended in 2007, achieved its final goal of a wire with a 300 A critical current and a 500 m length, as well as its manufacturing speed and cost goals. To use this wire in practical applications, however, improvements are demanded in both performance and cost. In terms of performance, although a 600 A class critical current was achieved with a short length, efforts are underway to raise this performance further.

One example of these efforts is the successful fabrication of wire with a critical current of 1,000 A/cm. In the past, in order to improve critical current, development focused on improvements in the critical current density and an increase in film thickness. In the case of this 1,000 A/cm wire, the critical current was mainly improved through an increase in film thickness. In the process of thickening the superconducting layer, when approximately 3 μm is exceeded, the crystalline state of the resulting film's superconductive layer gradually degrades, the crystals in the proximity of the intermediate layer begin to decompose, and other problems cause the critical current to increase more slowly or decrease in relation to the film thickness. In order to resolve this issue, the heating method used during film formation was changed from the previous method of heating from the underside of the substrate to a hot-wall heating method that heats the entire deposition space. In spite of the fact that the superconducting layer of the superconducting wire is given a film thickness in excess of 5 μm, the critical current increases along with the film thickness, resulting in wires greater in width than 1,000 A/cm. This improved critical current also contributes to a lower cost per ampere-meter, and can lead to the achievement of highly magnetic superconducting devices at the 70 K level and a more compact size.

Improved manufacturing speeds are also necessary from the perspectives of longer lengths and lower costs. In particular, although the intermediate IBAD layer offered good performance, manufacturing speed was a shortcoming. In the first stage of the IBAD method's development, a compact IBAD device could only be used to fabricate an intermediate layer of about 0.1 m per hour. Since then, the Fundamental Superconducting Application Technology Project has been working to develop a high-speed deposition technology in excess of 5 m/h. In order to achieve even faster speeds, there are plans to replace the Gd-Zr-O intermediate layer material that has been used in the past with MgO. Although in the case of a Gd-Zr-O intermediate layer, around 1 μm is required for the intermediate IBAD layer's thickness with a thin base layer of Al-O or Y-O, when an MgO intermediate layer is used, a length of only several dozens of nm is required, and this enables an increased speed. It has been confirmed that the uniformly high orientation of the MgO intermediate layer and Ce-O layer combination results in the same superconductive characteristics as were achieved when the previous type of intermediate layer was used. This IBAD intermediate layer can now be fabricated at a speed of 500 m/h, and this greatly contributes to longer lengths and lower costs.

We will continue focusing on the development of yttrium-based superconducting wire in order to help spread yttrium-based superconducting equipment by raising performance and lowering costs even further.

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Feature Article: Advances in Superconductor Wire Technology - Advances in YBCO Tape Scale-up Lengthening Technology Using the MOD Method -

Yuji Aoki, Project Leader
R&D Center Superconductivity Project
SWCC Showa Cable Systems Co., Ltd.

Metal-organic deposition (MOD) process is a method that coat a solution dissolving the metal-organic salts to the surface of a substrate in order to fabricate a precursor film (preheated film), and then applies a further heat treatment to fabricate a crystallized thin film. In the fabrication of $REBa_2Cu_3O_y$ superconducting wire, The MOD process using a trifluoroacetate is called the TFA-MOD method. In this method, a heat-treatment was carried out in the humid oxygen atmosphere for the formation of a superconducting phase. The HF gas generated by this reaction process inhibits the growth of the superconducting film, and so reducing the HF concentration of the thin superconducting film's growth interface, or in other words, quickly discharging the reaction gas outside the furnace, is key to this process. Every researchers are focusing its ingenuity on this problem.

Scale-up of the long wire fabrication are being led by three institutions — American Superconductor (AMSC) in the US, and Superconductivity Research Laboratory (SRL) and SWCC Showa Cable Systems Co., Ltd. (SWCC-CS) in Japan. Whereas AMSC and SRL use a reel-to-reel system in a continuous heat treatment process at normal pressures, Showa Cable uses a batch type heat treatment process in a reduced-pressure atmosphere. Although in principle, the reel-to-reel system heat treatment process has an unlimited wire fabrication length, because the wire movement speed is determined by the electrical furnace's length and growth speed, this system is not suited to high-speed manufacturing. The batch type heat treatment process, on the other hand, wraps the preheated film on a drum and heat treats it all at once, and so the possible manufactured wire length is limited by the size of the equipment. Since the heat treatment is applied in a sealed chamber, it is easy to control the atmosphere. Therefore, once the burning conditions are determined, a high level of reproducibility is demonstrated. The greatest length recorded with the reel-to-reel heat treatment system is the 200 m long x 250 A/cm-width wire announced by AMSC in the fall of 2008. Showa Cable used the batch type heat treatment system to achieve a wire measuring 200 m long x 250 A/cm wide in February 2007, followed by the development of a large electric furnace that can handle wire measuring 500 m in length. Although it was difficult to optimize the gas introduction and HF gas discharge mechanisms required

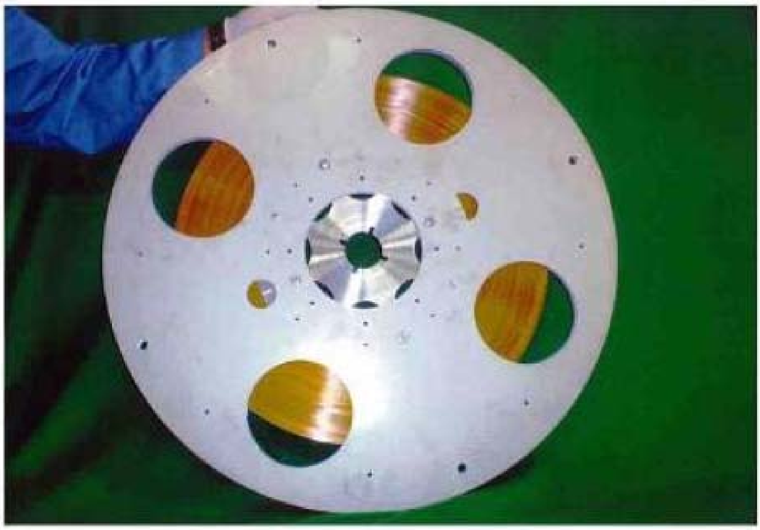

Fig. 1 500 m Wire Fabricated with the Batch Heat Treatment System

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due to the increased size of the furnace body, Showa Cable successfully fabricated a wire 500 m long x 310 A/cm wide in November 2008. In addition to SuperPower's MOCVD method and Fujikura's IBAD-PLD method, the MOD method's ability to fabricate wire measuring 500 m long x 300 A/cm-width has been demonstrated. Figure 1 shows the external view of the 500 m wire, and Figure 2 indicates the lengthwise distribution of the wire's I_c as measured in 1 m intervals.

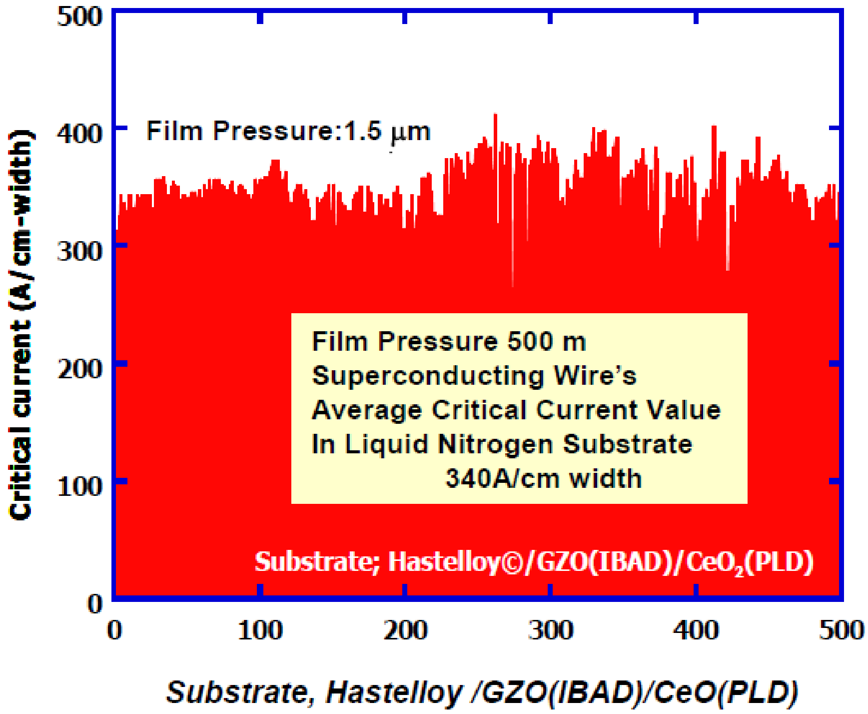

Fig. 2 500 m Wire I_c Distribution in the Lengthwise Direction

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Feature Articles: Advances in Superconductor Wire Technology - Advances in Tape Coated Conductor Technology Using Textured Substrates -

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A Tape coated conductor on a textured metal substrate has a structure such that a diffusion barrier layer and a textured layer are formed as an intermediate layer on a textured metal or a textured metal-surfaced tape substrate. A superconducting layer is formed on top of this structure. Although Ni-5 at %W (referred to as "Ni-W" below) is commonly used as the textured metal, losses in AC applications for cables and other parts have become an issue due to its magnetic properties. To avoid this, a clad type substrate with low magnetism is being developed.

Sumitomo Electric Industries, Ltd. has developed superconducting tape coated conductors using the clad type substrate that has a textured metal layer on its surface. [1)-2)] While the Ni-W substrate has magnetization loss of 1,300 J/m^3, the clad type has that of 52 J/m^3, resultantly the magnetization loss was reduced to $1/25^{th}$. Mechanical strength which is another issue, was also evaluated for both substrates. The I_c started to be degraded at the tensile strength of 200 MPa for the Ni-W substrate, while at 500 MPa for the clad type substrate. The clad type substrate showed high suitability for practical use.

Improvements of smoothness and texture of the surface were considered to widen the use of the clad type substrate for a coated conductor. Despite the in-plane texture of the Ni-W substrate with the $\delta\phi$ of 6.2°, that of the clad type substrate was 4.1° with the same Ra of 30 nm. An RF sputtering method was used to form three intermediate layers, namely a CeO_2 seed layer (up to 0.1 μm), a yttria-stabilized zirconia diffusion barrier layer (0.2 to 0.3 μm) and a CeO_2 cap textured layer (0.05 to 0.08 μm). The PLD method was used to grow a GdBCO superconducting thin film. The maximum I_c was 380 A/cm with a superconducting film thickness of 2 μm on the clad type substrate which is comparable to one on the Ni-W substrate.

Furthermore, in order to confirm the low current loss of the clad type substrate, a prototype conductor was fabricated. First, the coated conductor was slit into 4 mm from 1 cm. Then it was coated with the copper by an electrolytic plating as a stabilization layer with the thickness of 20 μm. Two 4-layer conductors using 56-4 mm wide coated conductors were fabricated. The coated conductors using the Ni-W substrate and the clad type substrate were applied separately for each conductor. Their AC losses at 1 kA were evaluated and they were 2 W/m or higher for the coated conductor with the Ni-W substrate and 0.17 W/m with the clad type substrate. This indicates that the low magnetism of the clad type substrate is effective for low AC loss.

Tape coated conductor made on a textured clad type substrate has various advantages, such as the low cost of the material, fewer intermediate layers than for other methods, and so on. The clad type substrate will be available for a wide variety of different applications.

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Reference:
1) Y. Shingai *et al*., 2MX09, 2008 Applied Superconductivity Conference, Chicago, Illinois USA, August 17 - 22, 2008.
2) T. Nagaishi *et al*., WT-7-INV, 21st International symposium on Superconductivity, Tsukuba, Japan, October 27-29, 2008 (to be published in the ISS 2008 proceedings as a special volume of Physica C).

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Feature Articles: Advances in Superconductor Wire Technology - Current State of Nb_3Sn Wire Technology for International Thermo Nuclear Experimental Reactor (ITER) Toroidal Field Coils -

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In March 2008, both Hitachi Cable, Ltd. and Japan Superconductor Technology, Inc. (JASTEC) received one order each for Nb_3Sn wire for TF coils from the Japan Atomic Energy Agency (JAEA), the ITER Organization's domestic agency. Both companies fabricate their wire using the bronze method. The amounts ordered at this time were approximately 50 t out of a total of 420 t TF coil wires (Japan being in charge of 25 % of this amount), with fabrication to last approximately two years, ending in February 2010.

A cross-section of this TF coil Nb_3Sn wire is shown in Figure 1, and its major specifications are provided in Table 1. These specifications have been demonstrated to be feasible from performance of several wire prototypes developed by JAEA and all supply candidates, including both companies. A critical current I_c greater than 120 % of the specification was achieved by using the bronze with high Sn content almost identical to the solid solubility limit, and by developing technology to process this into the wire. Since the hysteresis loss P_h follows a trend in proportion to the critical current density J_c, it is difficult to realize Nb_3Sn with higher J_c and lower P_h. The filament materials, arrangement, and other factors of the wire were developed as to satisfy the specifications.

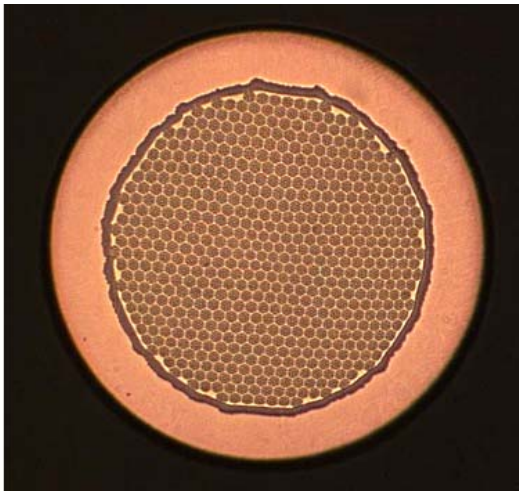

Fig. 1 Cross-Section of Nb_3Sn Wire for TF Coils
(Made by Hitachi Cable)

The TF conductors are comprised of 900 Nb_3Sn wires and 522 copper wires, assembled to make a Cable-in-Conduit (CIC) conductor. JAEA used the wire prototype to manufacture a CIC conductor prototype, which was used to verify that the conductor performance meets the TF coil operating conditions (an effective field of 11.3 T, a temperature of 5.7 K, and axial deformation of -0.77 %). In the wire orders, both companies have been required to produce wires with the same performance as the prototype securely. For this reason, the I_c specification has been revised from the value shown in Table 1 according to the initial fabrication results. Up to now, both companies have produced several tons of wire, with average I_c values that exceed specifications by more than 20 %, and with favorable quality. In March, the first lot of the wire was shipped from JASTEC to Hitaka Works, Hitachi Cable, Ltd., which is in charge of cabling the wire. Deliveries are scheduled from both companies after this date.

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Table 1. Major Specifications for the TF Coil Wire (Bronze Method)

	Specifications	Notes
External Diameter	0.82 mm	
Copper Ratio	1.0	
Chromium Coating Thickness	2.0 μm	
Critical Current	>190 A	@12 T,4.2 K,ε-0.25 %
Hysteresis Loss (per wire)	<500 mJ/cm^3	@±3 Tcycle,4.2 K

This project will provide a significant boost to the establishment of Nb_3Sn wire engineering technology. In the past, the steady market for Nb_3Sn wire was limited to NMR magnets, and around 20 t of these were produced worldwide on an annual basis. Any company joining to ITER Nb_3Sn wire production, however, will mass-produce the wire in excess of 10 to 20 t annually over a period of several years, and this experience should get many findings concerning raw materials, the influence of process on performance, production technology, quality control, and so on.

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Patent Information

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Planning & Management Division
SRL/ISTEC

Published Unexamined Patents in the 2nd through 4th Quarter of Fiscal 2008

The following are ISTEC patents published from July 2008 through March 2009. For more information, visit the Japan Patent Office Web site and the Industrial Property Digital Library (IPDL) or other patent databases.

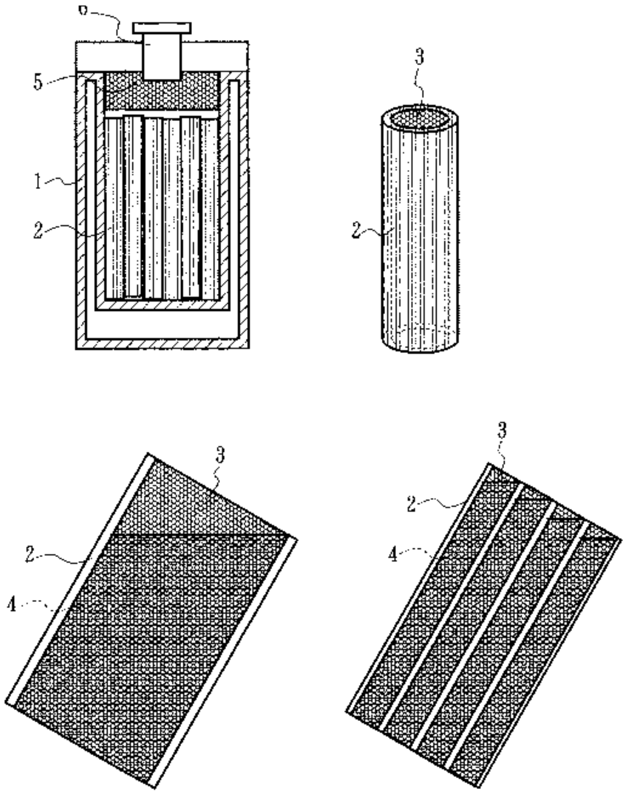
1) Unexamined Patent Application 2009-47335 - Cooler Using Liquid Nitrogen:

This patent, which is for a cooler using liquid nitrogen, is aimed at achieving a liquid nitrogen cooler that is both low-cost and portable.

In recent years, a Superconducting Quantum Interference Device (SQUID) has been used for conducting non-destructive tests on superconducting wire, nuclear power plants, other plants, airplanes, elevators, playground equipment, and other applications. The options for cooling these SQUID devices and other such high-temperature superconducting devices have included a method using liquid nitrogen stored in a vacuum insulating container, and a method using a cryocooler.

There have been increasing demands for convenient microelectronics that can be easily inspected whenever necessary for electronic devices such as those shown above, in particular for microelectronics such as non-destructive evaluation systems using a SQUID gradiometer.

Schematic Diagram Showing Invention's Principle Configuration



1. Insulating Container
2. Hollow Tube-Shaped Container
3. Fiber Assembly
4. Liquid Nitrogen
5. Thermal Insulation
6. Pressure-Opened Valve

In the case of cooling with liquid nitrogen stored in a vacuum insulating container, however, since the liquid splashes around during transport and measurement, there is the danger of liquid spillage and bumping. The cryocoolers are expensive, difficult to run on batteries, cause noise with their vibrations, and have other problems that make them difficult to use in convenient-sized measurement device

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applications.

This invention is an inexpensive, light, and cordless cooler that uses liquid nitrogen (4).It is characterized at the very least by an insulating container (1) and a structure for absorbing and retaining liquid nitrogen (4) inside an insulating container (1) by using multiple hollow tube-shaped containers (2) with fiber assemblies (3) with interconnected cells that are inserted internally. The absorption and retention of liquid nitrogen (4) inside the interconnected cells of the fiber assembly (3) ensure that liquid nitrogen (4) does not splash around during transport or measurement, and inhibit bumping. In addition, the inclusion of multiple hollow tube-shaped containers (2) improves heat transference and controls spillage of liquid nitrogen (4) effectively if the container is tilted.

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