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Superconductivity Web21

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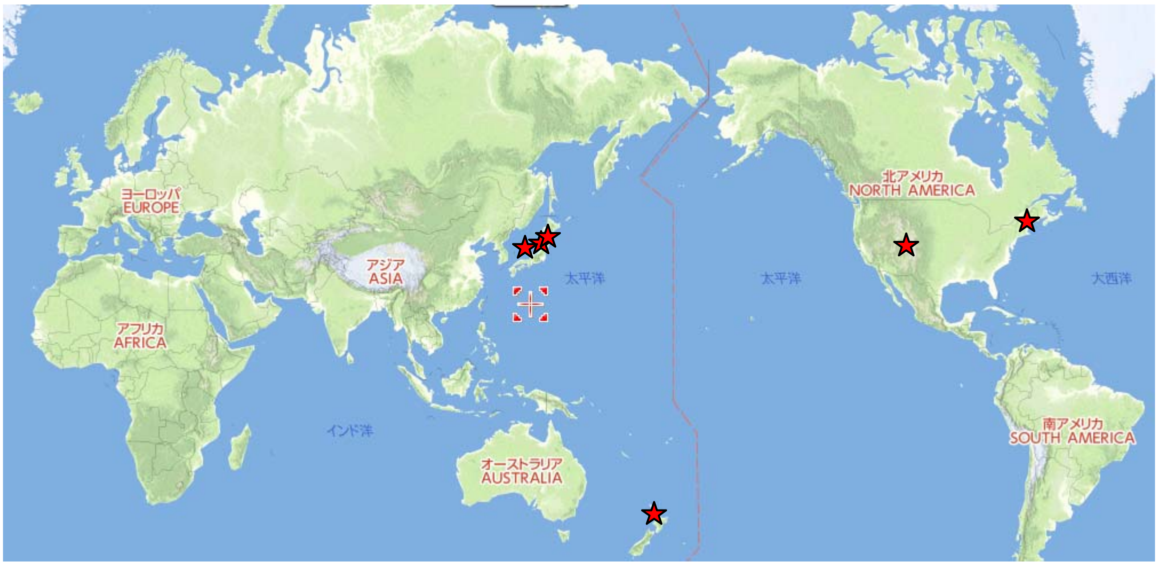
What's New in the World of Superconductivity

초전도 뉴스 –세계의 동향-

超电导新闻 -世界的动向-

chāo diàn dǎo xīnwén - shìjiè de dòngxiàng-

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC



★News sources and related areas in this issue

▸Power Application 전력응용 电力应用 [diànlì yìngyòng]

HTS Transformer with Low Loss Roebel Conductor"

University of Wellington (20 May, 2015)

The Victoria University of Wellington along with industry consortia, have demonstrated experimentally for the first time that HTS power transformers can significantly reduce energy losses compared to conventional transformers, thereby demonstrating their efficiency and reliability, along with the potential of superconducting transformers to deliver real value in transmission grids.

HTS transformers are smaller in size and lighter than conventional transformers, using liquid nitrogen for cooling and insulation instead of transformer oil, thereby eliminating fire and environmental hazards. With funding from the New Zealand Ministry of Business, Innovation and Employment and industry consortia, the researchers teamed up with Callaghan Innovation, which managed the engineering, assembly and testing, Fabrum Solutions for the cryostat engineering, local utility companies Vector and Northpower, Wilson Transformer Company, ETEL Transformers and GCS. Wilson Transformer Company, based in Melbourne, Australia, contributed design and manufacturing expertise to the project and constructed the transformer's steel core.

The HTS transformer is currently undergoing factory testing in Christchurch, where initial trials show that it has successfully handled a current capacity of 1390 A. Also, measurements confirm the energy losses are half those of a conventional transformer. Further tests of the transformer involve mimicking real-world loading profiles for extended periods. Crucial to the transformer's success is the use of low ac-loss Roebel cable on the high-current secondary winding, designed and manufactured in New Zealand by GCS Ltd. Dr Nick Long, a senior principal scientist with the Robinson Research Institute states that, "GCS Ltd has manufactured its own unique HTS Roebel cable." Professor Bob Buckley, Director of the Robinson Research Institute, cites the close working relationship with a number of industry partners that have allowed the team to rapidly overcome technical hurdles.

The researchers are now looking to assemble a team for the next phase of the project, which will develop the first commercial prototype 2G HTS transformer.

Source: "Transforming power transmission worldwide"
(20 May, 2015) Press Release
http://www.victoria.ac.nz/robinson/about/news
Contact: Bob Buckley, bob.buckley@vuw.ac.nz

►Medical Application 의료응용 医疗应用 [yīliáo yìngyòng]

Ultra-High-Field 7-Tesla MRI

National Institute for Physiological Sciences (26 May, 2016)

The National Institute for Physiological Sciences (NIPS), has installed an ultra-high-field 7 T MRI system. The system has a two- to five-fold greater magnetic field strength than standard hospital MRIs, providing greater biological signal sensitivity and more precise images with higher contrast. The MRI system employs a novel type of superconducting magnet - an actively shielded magnet, a first of its kind to be used for human research in Japan. This new type of magnet reduces the emission of magnetic energy, thereby contributing to both safety and measurement accuracy. There are around 50 ultra-high-field 7 T MRI machines are in operation around the world, which includes three in Japan.

The scanner will enable high-precision visual data about the anatomy and function of the brain in a non-invasive manner, expanding the horizon of in vivo human research. It is anticipated that this advanced

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MRI system will enable 100 microns analysis of cerebral microstructure, visualization of important microvessels, and three-dimensional reconstruction of complex neuronal networks.

NIPS has launched the Interactive Research Promotion Committee, which includes representatives from other ultra-high-field MRI research centers in Japan: Iwate Medical University Institute for Biomedical Sciences, Niigata University Brain Research Institute, Kyoto University Human Brain Research Center, Center for Information and Neural Networks of the National Institute of Information and Communications Technology, RIKEN Brain Science Institute, and National Institute for Environmental Studies. NIPS aims to strengthen the technical foundation for ultra-high-field MRI research, nurture interdisciplinary research in MRI, promote international collaborations and accelerate joint activities with national and international colleges and research organizations.

Source: "NIPS Introduces An Ultra-High-Field 7-Tesla Magnetic Resonance Imaging (MRI) System" (26 May, 2015) Press Release
http://www.nips.ac.jp/eng/release/2015/05/mri_1.html
Public Relations, pub-adm@nips.ac.jp

Ultra-low-field MRI

Los Alamos National Laboratory (1 Jun, 2015)

Researchers at Los Alamos National Laboratory are developing an ultra-low-field Magnetic Resonance Imaging (MRI) system that could be lightweight and low-power enough to be used on the battlefield and in field hospitals in the Third World. The consensus amongst doctors who routinely work in the Third World have reported that such lightweight MRI systems would be extremely valuable in treating pediatric brain disorders and other serious diseases in children. Mainstream hospital-based MRI devices are large and expensive to operate, requiring considerable infrastructure such as liquid nitrogen and helium.

The team at Los Alamos investigated the use of whether ultra-low magnetic fields produced using SQUIDs would produce images of sufficient quality. The main stumbling block of SQUIDs has been signal interference. The team's first-generation MRI had to be built in a large metal housing in order to shield it from interference.

The Los Alamos team is currently working in an open environment system without the large metal housing. Instead, they are using a series of wire coils that surround the MRI system to compensate for the Earth's magnetic field. Team leader, Espy, stated, "The new system indicates that, with additional development, these systems could be relatively easy and inexpensive to deploy."

Source: "Los Alamos is developing powerful medical tool"
(1 June, 2015) Publications
https://www.lanl.gov/discover/publications/connections/2015-06/science-portable-mri-aid-soldiers.php
Contact: Editor, ute@lanl.gov

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Superconducting Synchrocyclotron Accelerator for Proton Therapy

Mevion Medical Systems (29 Jun, 2015)

Mevion Medical Systems has announced the delivery of the superconducting synchrocyclotron accelerator for its MEVION S250 proton therapy system, which is being installed at University Hospitals (UH) Seidman Cancer Center and UH Rainbow Babies & Children's Hospital in Cleveland. It is expected to begin treating cancer patients in the spring of 2016.This is the sixth accelerator delivery for Mevion, the innovator behind the world's most efficient and cost-effective high-precision proton therapy system.

Proton therapy is an advanced form of radiation therapy targeting cancer cells more directly, thus making it ideal for treating patients with cancer in sensitive locations such as near the heart or brain. Traditional proton therapy systems cost hundreds of millions of dollars to build and are much larger in size. The MEVION S250 offers effective and efficient treatment without the complexity of traditional systems. In addition, the capital costs and the operating costs are significantly less since the system uses less space, less staff and less energy than other proton systems.

Source: "Mevion Medical Systems Delivers Proton Accelerator to Seidman Cancer Center at University Hospitals" (29 Jun, 2015) Latest News
http://www.mevion.com/news/1093-mevion-medical-systems-delivers-proton-accelerator-to-seidman-cancer-center-at-university-hospitals-
Contact: http://www.mevion.com/contact-us

►Basics 기초 基础[jīchǔ]

High T_c , 60 K, of FeSe Film

Tohoku University (2 Jun, 2015)

A research team based at Tohoku University led by Prof. Takashi Takahashi (WPI-AIMR) and Asst. Prof. Kosuke Nakayama (Dept. of Physics), has succeeded in fabricating an atomically thin, iron-based high-temperature superconductor film of FeSe with a superconducting transition temperature (T_c) of up to 60 K (-213 °C). The same team has also established a method to tune the T_c. The research results were published in Nature Materials on June 1, 2015.

Superconductors offer promise in the next-generation advanced electronic devices, because of unique quantum effects that offer energy-saving advantages and ultrahigh-speed processing. The application of superconducting devices has been hampered by the necessity of requiring a large and expensive cooling system due to the low T_c of conventional superconductors. While the T_c of bulk FeSe is only 8 K, an ultra-thin film coating with thickness of between one and twenty monolayers points towards a material with higher-T_c. The FeSe films have been fabricated by molecular-beam-epitaxy (MBE) and the electronic structure investigated using angle-resolved photoemission spectroscopy (ARPES). ARPES enabled the researchers to observe the opening of a superconducting gap at low temperature, which is direct evidence of the emergence of superconductivity in the FeSe films, and estimating the T_c from the gap-closing in a

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monolayer film to be above 60 K, around 8 times higher than bulk T_c of FeSe.

The research team has also discovered novel methods to deposit alkali atoms onto the films and thereby control the electron density, succeeding in converting non-superconducting multilayer FeSe films into high-T_c superconductors with T_c as high as ~50 K. While the T_c achieved in this study is still lower than that of the cuprate high- T_c superconductors, it exceeds the record of other "high- T_c superconductors" such as fullerene (C60) superconductors and MgB_2.

Research to further increase T_c by changing the number of atomic layers, the amount of doped electrons and the substrate type is expected to begin since the T_c of 50-60 K achieved in the present study is high enough to keep the superconducting state by using a closed-cycle-gas-type cooling system without liquid helium.

This work was supported by grants from the Japan Society for the Promotion of Science (JSPS) and Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT).

Source: "High-temperature Superconductivity in Atomically Thin Films"
(2 Jun, 2015) Press Release
https://www.tohoku.ac.jp/en/news/research/news20150602_1.html
Contact: Takashi Takahashi, t.takahashi@arpes.phys.tohoku.ac.jp

High T_c of 49 K in Pressurized FeSe

Okayama University (June, 2015)

Yoshihiro Kubozono and his research team at Okayama University have discovered that materials placed under high pressure can induce significantly greater superconducting transition temperatures (T_c). Kubozono applied high-pressure to ammoniated Cs doped FeSe ($(NH_3)yCs_{0.4}FeSe$)) material and measured the the resistance under pressures of between 0 – 41 GPa.

Metal-intercalated FeSe's fabricated using liquid ammonia technique exhibited very high T_c of 30 - 45 K. The T_c increased rapidly with changes of FeSe plane spacing (d), suggesting that increases in two-dimensionality increases T_c. Previously, the recognized limit of T_c was 45 K, but a study by Sun et al. measured a T_c of 48 K in pressure-induced high-T_c superconducting phase for two metal doped FeSe materials ($Tl_{0.6}Rb_{0.4}Fe_{1.67}Se_2$ and $K_{0.8}Fe_{1.7}Se_2$). However, such characteristics are rarely reported because of the difficulty of conducting experiments to validate this.

The T_c of $(NH_3)yCs_{0.4}FeSe$ (31K at ambient pressure) decreased gradually with increases in pressure, but no superconductivity was measured down to 4.2 K at 11 – 13 GPa. Above 13 GPa, the superconductivity rematerialized and a U-shape pressure-dependence of T_c was found between 15 - 41 GPa. The maximum T_c reached 49 K at 21 GPa.

Source: "High-Tc superconductivity found under high pressure"
(Jun, 2015) Research Highlights Okayama Univ. e-Bulltin

http://www.okayama-u.ac.jp/user/kouhou/ebulletin/research_highlights/vol11/highlights_003.html

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Feature Article: Reporting on the 2015 Forum on Superconductivity Technology Trends
-Current Status of Superconductivity Development in Korea

Minwon Park, Professor
Changwon National University, Korea

In 2001, Korea saw the unveiling of power equipment exploiting high temperature superconducting wires, e.g. the DAPAS program. More than 10 billion yen has so far been invested in R&D funding over the past ten years, with more than 15 billion yen coming from industries over the same period. The research has continually focused on themes related to high temperature superconducting power cables, superconducting transformers, fault current limiters and superconducting rotors. Around 1/3 of the funding has been invested in the development of the next-generation high temperature superconducting wires. Here, high temperature superconducting power cables have been demonstrated in 23 kV AC and 80 kV DC grids even though their future prospects may change over the next ten years. Additional trials in 154 kV AC grids are planned for later this year. High temperature superconducting transformers have issues with AC losses and offer no clear efficiency advantages. Consequently, it has proved difficult to find corporations to fund R&D activities, which has hampered their practical realization. The R&D focus involving high temperature superconducting fault current limiters has solely been for demonstration studies in 154 kV grids. Their installation in an actual grid is anticipated sometime in 2016. Whilst research in high temperature superconducting rotors is still ongoing, the author expects quite a few issues that remain to be resolved before they can be realized for practical applications.

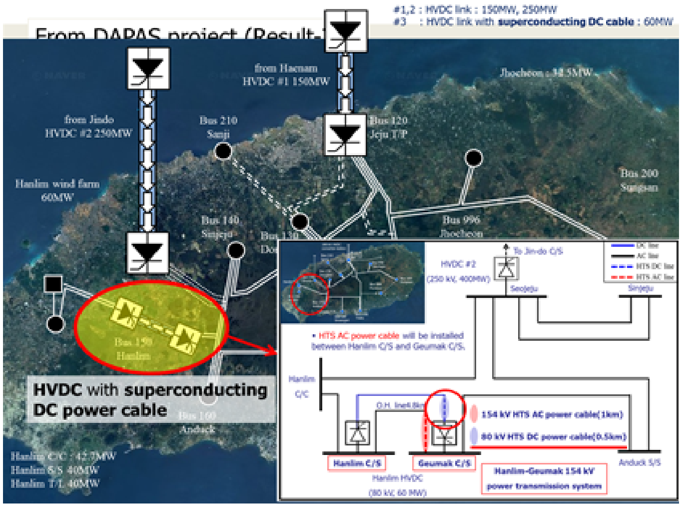

Fig.1 DC-Superconducting cable in Jeju Island

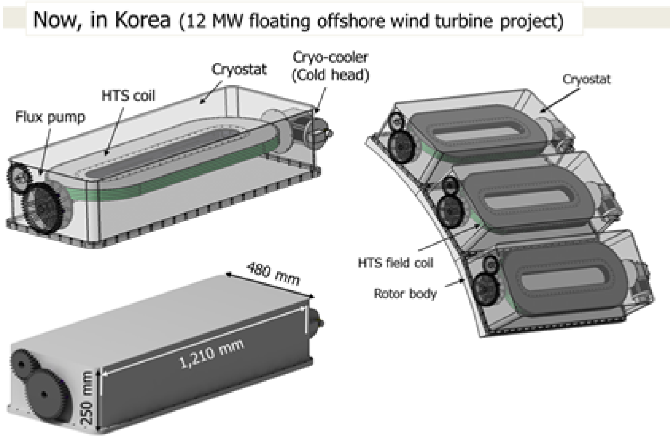

Fig.2 Superconducting generator for 12 MW wind turbine

SUNAM and the Korea Electro-technology Research Institute have led R&D studies on high temperature superconducting wires. Their track records and achievements until now have been exceptional, and been responsible for the supply of the cheapest next-generation high temperature superconducting wires worldwide. The DAPAS program has been instrumental in their achievements, thereby highlighting the importance of national R&D investment for the industrialization of technology. 2011 saw the end of the DAPAS program with commercialized research outcomes being high temperature superconducting power cables and superconducting wires, whilst other research studies remained midway through development. It is always challenging to expect that all research themes will produce practical and commercial success, however, the author is delighted since 1/3 of the research outcomes have become closer towards industrialization.

Ongoing programs in 2015 include, developments of high temperature superconducting cables connected to 154 kV AC grids, 1500 A-class DC reactors, 12 MW-class high temperature superconducting wind power generators and high temperature DC-induction heaters. New R&D studies for the next-generation high temperature superconducting wires and MgB_2 wires have been launched. The developments are funded by organizations that mainly include KEPCO, which has a strong focus on superconductivity and is pursuing a project program aiming for their industrialization. (Figure 1 and 2)

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Feature Article: Reporting on the 2015 Forum on Superconductivity Technology Trends -Current Status of Superconducting Power Equipment in Japan and their R&D Prospects

Hiroyuki Ohsaki, Professor
Graduate School of Frontier Sciences
The University of Tokyo

The current development of superconducting power equipment technology has been mainly initiated by NEDO projects, and dedicated towards the development of power turbine generators, SMES, flywheel energy storage systems, power cables, fault current limiters and transformers. A demonstration project (2007-2013) involving a high temperature superconducting cable with 66 kV 200 MVA-class characteristics (about 240 m-long), was installed at the Asahi sub-station of Tokyo Electric Power Company, completing a one-year trial of actual power grid connection. Three-year demonstration plans that began in 2014 are now progressing and focused on studies to verify safety/reliability of the next generation transmission systems. The development of 275 kV high voltage cables utilizing Y-based coated conductors have been undertaken and long-term current load tests performed. Demonstration trials involving superconducting fault current limiters have been actively pursued overseas, which is in stark contrast to developments in Japan.

Amongst the ALCA program led by JST, R&D studies of liquid hydrogen cooled superconducting equipment and its related technology is advancing. Additionally, the development of superconducting wind power generators greater than 10 MW-class for offshore wind farms has focused on solving issues that include their low speed characteristics, high torques and their large footprints. These studies are dedicated towards high power output, direct drive synchronous machines. FS has progressed by NEDO projects undertaken in 2013 and 2014.

From the summer of 2013, superconducting maglev trains operating with commercial carriages resumed test runs at the 42.8 km-long Yamanashi test track, which has undergone revision upgrades and has also been extended. A speed of 603 km/h was recorded on 21st April 2015, beating the previous world speed record for a train. Commercial operations of the Chuo Shinkansen superconducting maglev line between Tokyo and Nagoya are planned for 2027. Ongoing R&D led by the JST S-innovation program relates to superconducting DC-cable applications for the DC feeder system, its aims being the suppression of feeder voltage drops, improvement of regenerative ratios, reduction of sub-station capacities etc. Experimental test runs at the Railway Technical Research Institute have taken place.

With regards to ship propulsion motors, in 2013, Kawasaki Heavy Industries developed a 3 MW-class superconducting ship propulsion motor aimed at a mid-size ship. A research group in Kyoto University and Sumitomo Electric is currently undertaking the development for a superconducting motor for electric vehicles.

Recently, the focus has been on heavy-ion cancer therapies, which have built up a considerable track

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record. The development of a rotating gantry has been undertaken to reduce the time to ascertain the radiation focus and thus improve the treatment plan. NbTi superconducting magnets were able to realize a compact/lightweight, rotating gantry. A project for high temperature superconducting fundamental technology, led by the Ministry of Economy, Trade and Industry launched in 2013. Its objectives are to develop the potential of high temperature superconducting coil technology and for this technology to be applicable for clinic-use MRI and heavy-ion medical accelerator systems. From 2015, this project will be led by the Japan Agency for Medical Research and Development (AMED), and plans are to complete this within one year.

We cannot say whether Japan has reached a stage where high temperature superconducting technology is being practically realized in equipment applications. Foreseeing the economic benefits is necessary in order to validate the superior fundamental performance characteristics attained by high temperature superconducting equipment, in addition to demonstrating its reliability and benefits of system upkeep. To this effect, it is therefore important to establish a fundamental technology for the stable supply of low-cost high-performance wires, coiling technology, cable technology, rotor technology etc.

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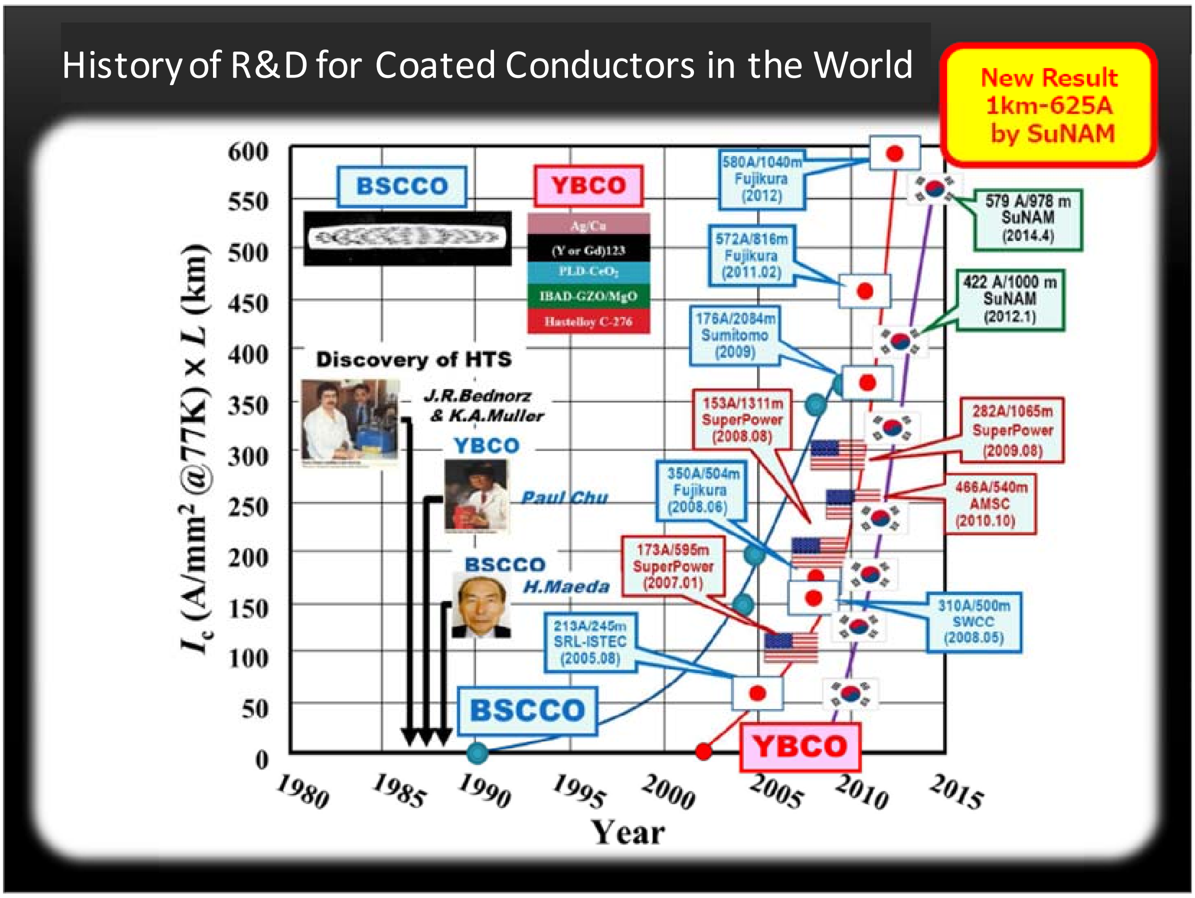
Feature Article: Reporting on the 2015 Forum on Superconductivity Technology Trends
-The Current Status and Prospects of RE-based Superconducting Wire Development in Japan

Teruo Izumi, Deputy Director General
SRL/ISTEC



RE-based superconducting wires are anticipated in the deployment of an array of potential applications that includes power applications, because of their superior superconductivity and mechanical characteristics. However, difficulties in the manufacturing process to replicate these superior characteristics have delayed their deployment in contrast to Bi-based superconducting wires. A national collaborative project involving ISTEC, universities and wire manufacturers, have led a full-scale development project involving RE-based wires, which has seen recent commercial success and has resulted in further development of equipment employing such wires. The author provides a brief historical account, the latest progress and future prospects of RE-based superconducting wire development.

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All three superconducting crystal axis need to be aligned in order to realize the superior characteristics afforded by RE-based superconducting wires. An IBAD-substrate developed by Fujikura exhibits high orientation because of the orientation of the buffer layer, which even today, forms the mainstream of worldwide RE-based superconducting wires. Later, ISTEC discovered the self-organization of CeO_2, which improves orientation and has significantly contributed towards the advancement involving the substrate. Additionally, several methods including PLD, MOD and MOCVD are presently employed for the fabrication of superconducting layers, exploiting the advantageous characteristics of each of these methods.

For long-wire manufacturing, national projects in both Japan and USA have led the world since 2000. I_c x L values has progressed remarkably over the past 10 years. This has spurred SuNAM in Korea who have caught up with the leaders and is currently included as one of the major wire manufacturers together with Japan and USA. Whilst single-length 1000 m wires have already been realized, wires with I_c characteristics exceeding 500 A/cm@77 K, s.f. are currently being manufactured.

Apart from I_c x L characteristics, equipment specifications to meet functional improvements such as enhanced in-field I_c properties and to reduce AC losses are now necessary. Such developments have been actively undertaken by projects conducted over the past several years, namely the development of yttrium-based superconducting power equipment technology and ongoing studies of high temperature superconducting fundamental coil technology. $BaHfO_3$ artificial pinning centers in PLD superconducting films have proved effective in demonstrating the superior in-field characteristics of (example: 569A/cm width@65 K, 3 T B//c) for EuBCO+BHO films. Regarding the reduction of AC losses, the progress of scribing technology has seen the world's first success in a 10-filament scribing process of 100 m (5 mmw) long-wire. Reduced AC-losses in a coiled shape have been also confirmed.

These research outcomes have recently advanced equipment development that includes MRIs, heavy-ion medical accelerators and rotors, in addition to power applications such as transmission cables and transformers. Generally categorizing future issues from the viewpoint of wire development include; 1) reliability enhancement (relating to lower cost by improvements in yield and replication); 2) performance enhancement (high performance attained by in-field characteristics and scribing technology in order to ensure the competitiveness of equipment); and 3) fundamental issues (improvement in configuration and characteristic anisotropy, fundamental issues related to Y-based superconducting wires such as superconductor/superconductor joints). In particular, parallel research is necessary to prioritize items 1) and 2). The author expects a rapid expansion of potential applications by addressing the issues of item 3) without delay.

This report partially comprises the research outcomes of projects that have been commissioned by the Ministry of Economy, Trade and Industry, New Energy and Industrial Technology Development Organization, and Japan Agency for Medical Research and Development.

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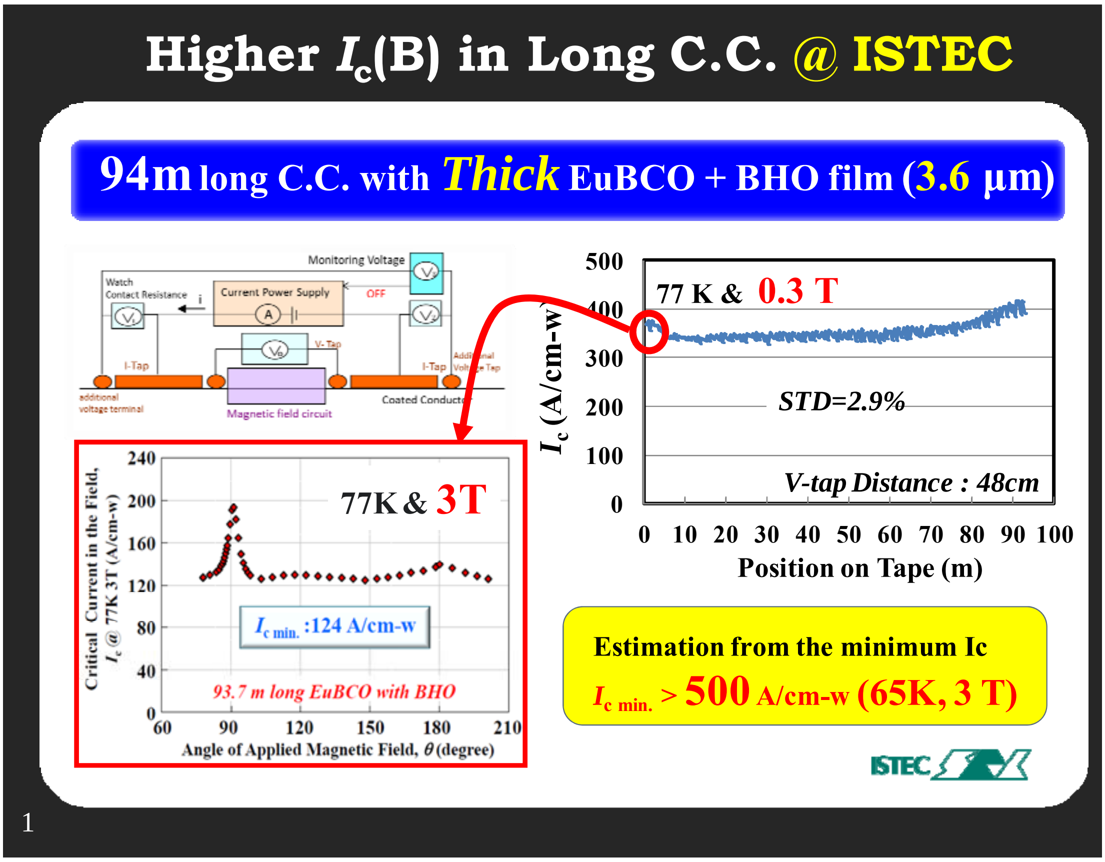

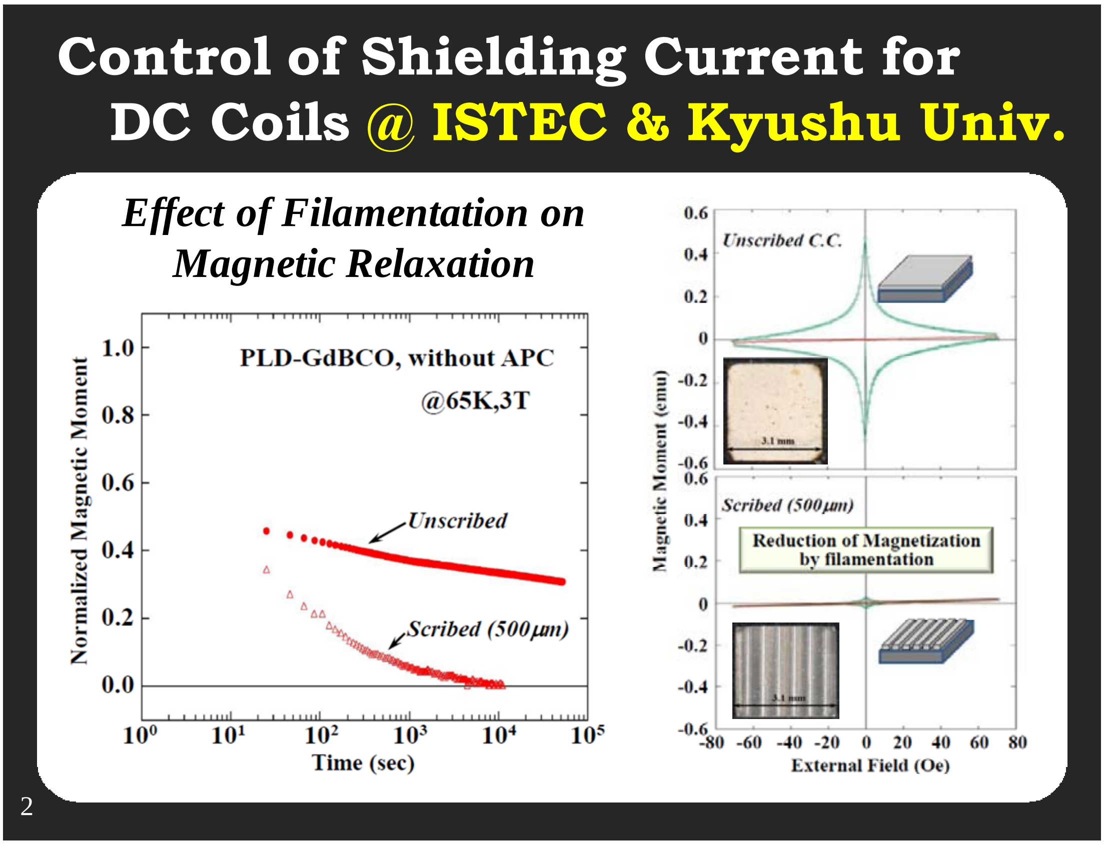

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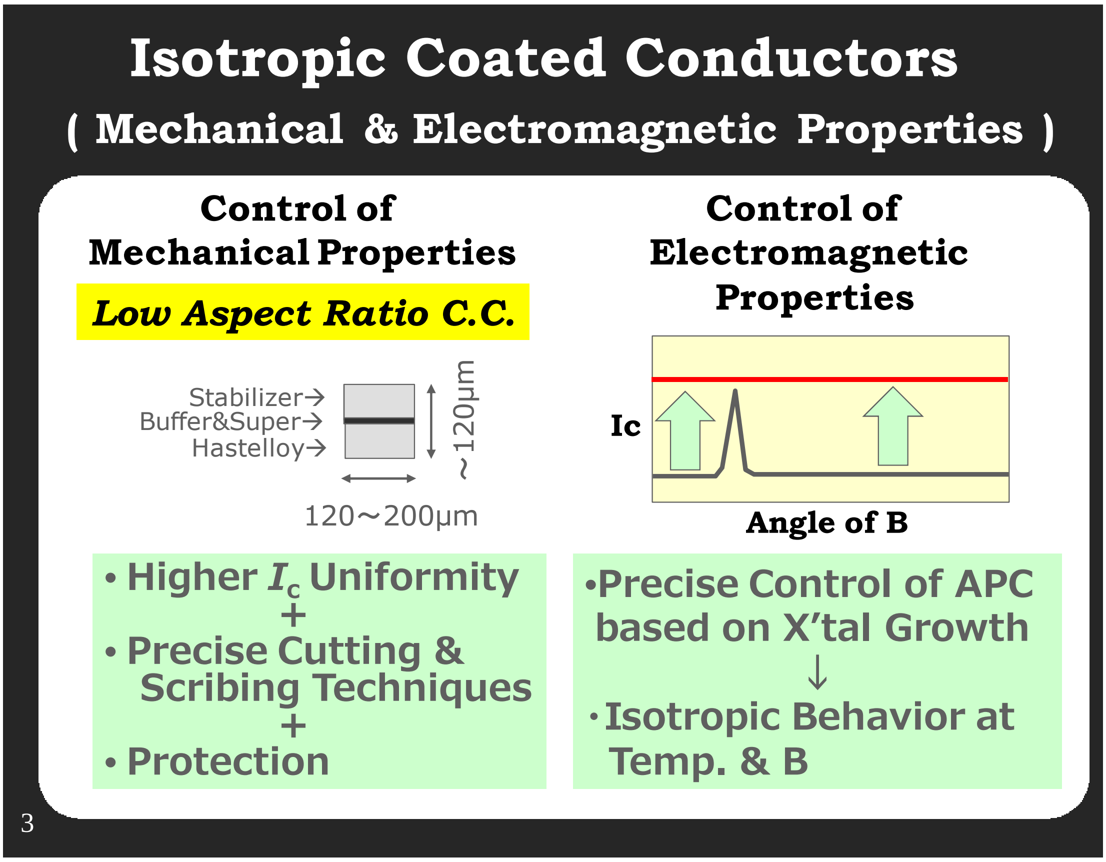

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Feature Article: Reporting on the 2015 Forum on Superconductivity Technology Trends
-Current Status of Superconductor-based Equipment Development Undertaken by Toshiba

Kenji Tasaki, Group Leader
Superconductor/Accelerator Technology Development Group,
Electrical Instrumentation System Division,
Power and Industrial Systems R&D Center,
Toshiba Corporation

Amid the improving characteristics of high temperature superconducting wires, Toshiba has advanced the development of conduction-cooled high temperature superconducting equipment from its initial developmental stage. An inherent disadvantage of current conduction-cooling systems is their difficulty with operating the refrigerator continuously after power cuts and other incidents cause it to stop. There are however many advantages, which include system compactness, their ease of installation in developing countries and in remote areas where liquid coolants would be otherwise difficult to supply, as well as simple cooling operations (cooling commences by only switching on the compressor). The author proposes that the most important technological development themes to realize conduction cooling systems involve fabrication technology that does not lead to degradation in the superconductivity characteristics of high temperature superconducting coils, and also quantitative studies of thermal runaway analysis to predict coil-current loading limits. Toshiba has focused their efforts towards the development of high temperature superconducting equipment, with an emphasis placed on developing such technological issues. Since precise thermal flows have to be secured within the coil in order to realize conduction cooling, it is necessary to employ an epoxy-impregnated structure that fills the gaps between the turns. To address this, the author and his team have dedicated their investigations towards the development of epoxy-impregnated high temperature superconducting coils. There have been no issues with bismuth-based coils. However, yttrium-based coils have had significant degradation in critical currents and n-values. This problem has been addressed in Japan and overseas, and led to buoyant research studies in research institutions. By introducing a method to reduce the delamination stresses in yttrium-based wires i.e. inserting a mold release between the turns, the author and his research team were able to fabricate coils with reduced degradation properties. Additionally, quantitative results from thermal runaway analysis have been precisely predicted over the wide ranges of temperatures, corroborating both experimental and analysis data. The design technology necessary for conduction-cooled high temperature superconducting equipment has therefore been established for both bismuth and yttrium-based coils. Based upon the technological outcomes, the development of high temperature superconducting magnets for a ring accelerator designed for heavy-ion radiotherapy has been carried out under the JST national project, whilst the development of a high temperature superconducting magnet for a rotating gantry utilized for heavy-ion radiotherapy and high-temperature superconducting magnet for high-field MRI have been carried out under the AMED national project. For these three projects, the fabrication of prototype magnet is planned for completion during 2015, along with an evaluation of its performance attributes.

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Feature Article: Reporting on the 2015 Forum on Superconductivity Technology Trends -Mitsubishi Electric – Challenges in Manufacturing Superconductor-based Products

Shunji Yamamoto, Executive Advisor
Mitsubishi Electric Corporation

1. Introduction

For a manufacturer, reliability is always of paramount importance for all types of manufactured products that are brought to market. From an R&D perspective, the particular focus of investigation is always towards functionality and performance characteristics. From a practical viewpoint, products that meet their designed functionality/characteristics, and in addition are inherently reliable are as important as the wheels on an automobile.

Mitsubishi Electric has 10 business units, where many products from different categories exist, apart from power equipment and superconducting equipment categories, which will be addressed mainly by this article. The existing array of products comprises space satellites, elevator/escalators, automobile electrical components, factory automation equipment, high power semiconductors, water filtration units and consumer electronics such as air conditioning and telecommunication equipment etc. A common denominator shared by these numerous products is their inherent reliability.

2. Power equipment and superconducting equipment

Superconducting equipment is advancing in the power equipment arena in particular, i.e. transformers, rotors, breakers, nuclear plants and transmission systems etc. Such equipment requires high levels of reliability, which has been investigated by the design manufacturing division. This is the reason why the power equipment manufacturing division is advancing the development of superconducting equipment, including mutual investigations involving electromagnetic field analysis and magnetic applications.

3. Technology group/engineers to support the manufacturing

A number of technologies to realize the functionality/performance attributes of superconducting equipment include wire winding, structure, insulation, vacuum, electromagnetic analysis, thermal analysis, stress analysis etc. Cryostat technology can serve in the background of realizing performance and functionality.

At the start of superconducting magnet development, there was no technology adequate to store helium, which has a small molecular weight, and this led to slow leaks. Nowadays, this type of incident does not occur. This demonstrates that product reliability has definitely been realized in the natural course of daily life during the development dedicated over many years.

As manufacturers, our responsibility is dedicated in promoting fundamental technological skills to ensure greater reliability and also nurture in-house welding engineers to align welding beads, for example for vacuum resistance welding.

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4. Practical realization and mass production of superconducting magnets

Dependent on product category types, markets exist where large volumes of superconducting magnets could be employed i.e. MRI and NMR applications. Currently, there are around 40,000 MRI clinical units worldwide and the majority employs superconducting magnets as part of their functional operations. Superconductors utilize direct current simply and with greater reliability. The higher magnetic fields permit clearer clinical images. The attributes of superconductors can further expand the performance characteristics of imaging diagnosis.

5. Addressing exceptional superconductor issues

Generally, one of the reasons why superconducting equipment is not easy to use is because of superconducting fracture events i.e. an occurrence of quench.

It is thus necessary to take measures to prevent quenching and thereby promote their practical realization. Technologically, the development of wire winding technology that prevents quenching is required. Alternatively, quenching could be viewed as not a malfunction and an alternative processes maybe required to ascertain performance, in a similar fashion to quench training.

Mitsubishi Electric continuously aims to improve reliability and challenges the technological skills necessary to address an array of fields including superconductivity.

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Feature Article: Reporting on the 2015 Forum on Superconductivity Technology Trends -High Temperature Superconducting Technology Development at Furukawa Electric

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1.1 The development of superconducting cables

A 275 kV high temperature superconducting cable (HTS cable) can achieve high-capacity transmissions, which are equivalent to compressed gas-insulated transmission lines and overhead transmission lines at 1.5 GW, corresponding to a power plant unit. Furukawa Electric has developed 275 kV 3 kA HTS cables, concluding long-term current trials for 30m-long cables in Shenyang City, China. For the practical realization of 275 kV superconducting cables and as part of demonstration studies of safety and reliability, Tokyo Electric, Sumitomo Electric, Fujikura, and Mayekawa MFG have currently investigated the behavior of ground-fault and short circuit incidents as well as security measures necessary to prevent such incidents. In addition to AC superconducting cable development, the development of DC superconducting cables has been also undertaken taking into account the potential industrial applications that include trains and data centers.

Fig.1. 275 kV HTS cable

1.2 The development of superconducting magnetic bearings for the next-generation flywheels

The development of magnetic bearings employing repulsion forces due the Meissner effect has been achieved by combining bulk superconductors and superconducting coils. Such magnetic bearings have been successfully employed to levitate a 4-ton CFRP rotor. Demonstration trials involving a 300 kW flywheel assembled using these magnetic bearings is underway and engages collaborations between Railway Technical Research Institute, KUBOTEK, MIRAPRO and Yamanashi Prefecture Government.

1.3 The development of a superconducting magnet for 10 MW-class wind power generator

Future wind power generators are predicted to have larger power outputs, and for offshore wind turbines in particular, 10 MW-class large-scale wind power generators are anticipated. The combination of a superconductor and an iron core can realize a direct drive power generator that is compact and easy to maintain, and therefore suitable for offshore wind turbines. Fundamental studies investigating the design of a superconducting generator have been undertaken by collaborative undertakings involving AIST and

Mayekawa MFG. A single-pole racetrack coil has been fabricated and successfully tested at cryocooling current trials.

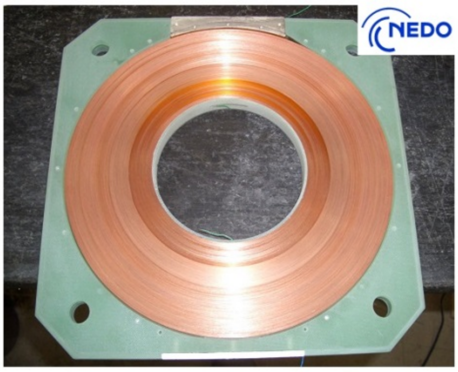

Fig.2. Superconducting coil for flywheel

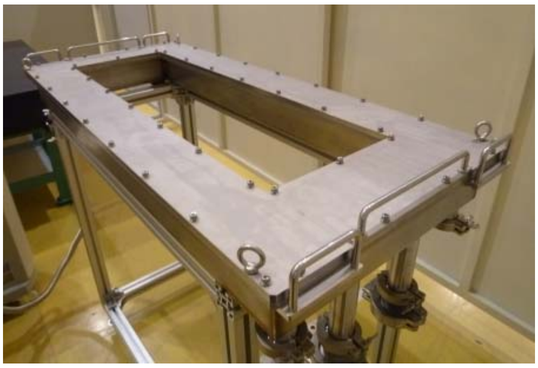

Fig.3. Race-track coil for 10 MW wind power generator

2. Furukawa's development of superconducting wires

REBCO coated conductors employed in such high-temperature superconducting equipment are manufactured by SuperPower, a subsidiary of Furukawa Electric. REBCO coated conductor characteristics include:

1. high in-field characteristics
2. product quality, homogeneity
3. high mechanical characteristics (tensile, delamination)

The introduction of artificial pinning in particular has remarkably enhanced the critical current at low temperatures and at high magnetic fields, and therefore has proved suitable as wires for magnet applications. At present, artificial pining using ZrO_2 doping up to 15 % has been successful in realizing enhanced magnetic characteristics and stable performance. Also, the utilization of a Hastelloy substrate and thermal process optimization has produced REBCO coated conductors with strong tensile and delamination properties.

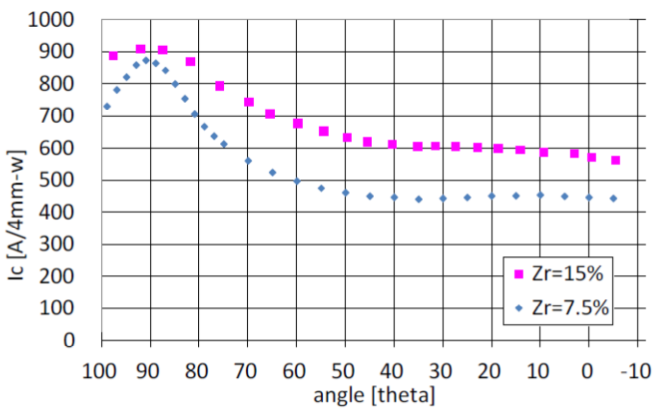

Fig.4. Cross-section of a pin within a superconductor and a graph showing I_c improvement

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This research has been partially undertaken under the following projects:

275 kV superconducting cable: NEDO commissioned project "Development of yttrium-based superconducting power equipment technology"
(2008-2012)
Security/reliability verification: NEDO promotion project "Demonstration studies for security/reliability of next-generation transmission system"
(2014-2016)
Next-generation flywheel: NEDO promotion project "Development of reliable/low-cost large-scale power storage system technology"
(2011-2015)
Superconducting magnet utilized for 10 MW-class ultra wind power generator: NEDO commissioned project "Research studies for 10 MW-class ultra wind turbine"
(2013-2014)

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