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Superconductivity Web21

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Contents:

Top of Superconductivity Web21

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

Power

American Superconductor Corporation (February 1, 2007)

American Superconductor Corporation (AMSC) has announced its financial results for the third quarter ending December 31, 2006. Revenues for the third quarter decreased to US $9.5 million, compared with $13.5 million for the same period in the previous fiscal year. The net loss was also $9.5 million, compared with $7.5 million for the same period in the previous fiscal year. These quarterly results were foreseen and were caused in part by funding delays from the U.S. Department of Energy and a technical delay in the 36.5-MW motor being manufactured for the U.S. Navy. AMSC ended the quarter with no debt and $41.6 million in cash, cash equivalents, and short-term investments. The company reaffirmed its previous forecast of revenues between $50 - 52 million and a loss of between $29 - 32 million for fiscal 2007. As of December 31, 2006, AMSC had a total backlog of $43.2 million in orders and contracts. This backlog has since increased to more than $65 million as a result of AMSC's acquisition of Windtec™. Based on new orders that the company expects to close in the fourth quarter, the total consolidated year-end backlog is expected to increase to approximately $70 million as of March 31, 2007, $60 million of which should be recognized as revenue in fiscal 2008.
Source:
"AMSC Reports Third Quarter Fiscal 2007 Financial Results"
American Superconductor Corporation press release (February 1, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=956807&highlight

American Superconductor Corporation (February 6, 2007)

American Superconductor Corporation (AMSC) has received an order for a 20-megaVARs Dynamic VAR (D-VAR) system for the Hallet Wind Farm in Australia. Once completed, the Hallet wind farm will be one of Australia's largest wind farms, with a capacity of 94.5 MW (enough to supply zero-emission electricity to 54,000 Australian homes). The order was placed by Suzlon Energy Australia Pty. Ltd. (SEA). The D-VAR will be delivered to SEA during the second half of calendar 2007, at which time it will be installed in a utility substation connecting the wind farm to the national power grid. The wind farm should be operational in early 2008. Chuck Stankiewicz, Senior Vice President of AMSC Power Systems, commented, "This new order from Suzlon demonstrates our growing international presence and our close working relationship with the industry's leading wind turbine manufacturers. With more than $1 billion in annual revenues and in excess of 7,500 employees, Suzlon has rapidly built a substantial presence in the wind energy market in the Asia-Pacific region. We are pleased to be working on this important project and look forward to growing our business with Suzlon."
Source:
"AMSC Receives D-VAR(R) Order from Suzlon Energy for Australian Wind Farm"
American Superconductor Corporation press release (February 6, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=958988&highlight

American Superconductor Corporation (February 13, 2007)

American Superconductor Corporation (AMSC) announced that Hyundai Heavy Industries Co. Ltd.

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(Hyundai) has achieved world record performance levels for its fault current limiters (FCL), which were developed using AMSC's 344S superconductors. Hyundai, headquartered in South Korea, began development of its FCL in partnership with Yonsei University in late 2004. They have since developed a 13.2-kV/630-A FCL with a capacity of 8.3 MVA using superconducting coils fabricated with wire from AMSC. The device was operated at a voltage of 13.2 kilovolts (kV), which corresponds to a three-phase power equipment voltage class of 22.9kV – a new world record for fault current limiters. The FCL was tested at the Korea Electrotechnology Research Institute (KERI) in December 2006, where it achieved an AC withstand voltage of 143 kV (nearly three times higher than the project's 50-kV goal). Dr. Bok-Yeol Seok, principle researcher of the FCL project at Hyundai Heavy Industries, commented, "We see tremendous opportunities for FCLs in the near term and are pursuing this market aggressively. We will continue our development efforts and now have our sights set on producing 30 to 60-kV FCLs for distribution systems as well as 154-kV FCLs for transmission voltage levels." The FCL program in South Korea is funded by the Ministry of Science and Technology through the Development of Advanced Power Systems by Applied Superconductivity Technologies (DAPAS) program. Hyundai is one of eight companies around the world who are developing FCLs using AMSC's proprietary 344S superconductors.
Source:
"AMSC's 344S Superconductors Utilized by Hyundai Heavy Industries to Successfully Develop Commercial Grade Fault Current Limiter"
American Superconductor Corporation press release (February 13, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=962312&highlight

National Institute of Standards and Technology (February 15, 2007)

Researchers at the National Institute of Standards and Technology (NIST) have reported that a small mechanical strain can cause a large, but reversible, drop in the maximum current that can be carried by high-temperature superconductors. Specifically, a 40% reduction in the critical current of three types of YBCO was observed after the application of a 1% compressive strain. The discovery is the first major reversible strain effect found in practical high-temperature superconductors. This effect will have important consequences to the design of superconducting systems, particularly electric power applications. While accommodations for the effect can be readily made, knowing about it in advance should contribute to the success of many large-scale devices. The research was reported online in *Applied Physics Letters* (January 31, 2007). The researchers are now examining how magnetic fields affect the strain effect.
Source:
"Strain has major effect on high-temp superconductors"
National Institute of Standards and Technology press release (February 15, 2007)
http://www.nist.gov/public_affairs/techbeat/tb2007_0215.htm#htc

SuperPower, Inc. (February 27, 2007)

SuperPower Inc. has received a contract from the U.S. Department of Defense's Office of Naval Research for the second phase of a program to develop an HTS generator based on its second-generation wire. The 18-month contract is worth US $3 million. In partnership with Baldor Electric Company's Reliance Electric Company, General Dynamics' Electric Boat division, Oak Ridge National Laboratory, the Naval Surface Warfare Center Carderock Division, and the Naval Research Laboratory, SuperPower will use the contract to complete a conceptual design for a 10.6-MW HTS generator and conduct a risk assessment for a 36.5-MW class HTS generator.
Source:
"SuperPower Receives $3 Million Office of Naval Research Contract For Further Development of a

High-Temperature Superconducting Generator for Application to the Navy's All Electric Ship Program"
SuperPower, Inc. press release (February 27, 2007)

American Superconductor Corporation (February 28, 2007)

American Superconductor Corporation (AMSC) has received new orders for D-VAR® voltage regulation systems for wind farms in Northern Ireland and Texas. The wind farm in Northern Ireland will be the eighth wind farm in the U.K. to utilize AMSC's D-VAR solution. This number is expected to grow as the U.K. moves towards its goal of generating 10% of its electricity from renewable sources by 2010. Meanwhile, Texas accounted for nearly a third of all newly installed wind power capacity in the U.S. in 2006. These orders bring the installed base and orders for D-VAR and PowerModule ™ solutions to more than 2,900 MW of wind power worldwide – tripling the amount served by AMSC solutions only 12 months ago. The D-VAR solution alone will now be used in 25 wind farms in five countries worldwide.
Source:
"AMSC Continues Sales Growth in Wind Energy Market with Domestic and International D-VAR® Orders"
American Superconductor Corporation press release (February 28, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=968236&highlight

Magnet

Northwestern University (February 11, 2007)

Researchers at Northwestern University have identified Bi-2212 as a material that might be suitable for fabricating a 30-Tesla magnet. Such a magnet would be the most powerful superconducting magnet in the world. Presently available low-temperature superconducting magnets for medical and research MRI applications are capable of attaining a maximum magnetic field of about 21 T. The Northwestern researchers demonstrated that Bi-2212, when cooled to below 12 K, could be used to achieve the stable state necessary for a 30-T magnet. The group's research was published online in the journal *Nature Physics* (February 11).
Source:
"Physicists set 'speed limit' for future superconducting magnet"
Northwestern University press release (February 11, 2007)
http://www.northwestern.edu/newscenter/stories/2007/02/halperin.html

Electronics

D-Wave Systems, Inc. (February 13, 2007)

D-Wave Systems, Inc., a privately held Canadian firm, has publicly demonstrated the world's first commercially viable quantum computer. Quantum computing is expected to be applicable to areas where problems or requirements exceed the capability of digital computing, such as "NP-complete" problems where the sheer volume of complex data and variables prevent digital computers from achieving results in a reasonable amount of time. Furthermore, quantum technology will enable precise answers to problems that can only be answered at present in general terms, thereby broadening the scope of computer applications. Nevertheless, D-Wave emphasized that the new device is intended to complement conventional computers,

not replace them. The quantum computer utilizes a new type of analog processor based on quantum mechanics, rather than conventional physics. D-wave intends to use "scalable" processor architectures that are based on available processes and technologies. For more information, please visit www.dwavesys.com.
Source:
"World's First Commercial Quantum Computer Demonstrated"
D-Wave Systems, Inc. press release (February 13, 2007)
http://www.dwavesys.com/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=4&cntnt01origid=15&cntnt01returnid=21

Communication

ISCO International Inc. (February 22, 2007)

ISCO International Inc. has announced their financial results for the fourth quarter and fiscal year 2006. Revenues for the fourth quarter and full year grew significantly to US $3.8 million and $15 million, respectively, compared with $2.5 million and $10 million, respectively, for the same periods in the previous fiscal year. Net loss for the fourth quarter and full year were $1.3 million and $4.4 million, respectively, compared with $1.1 million and $3 million, respectively, for the same periods in the previous fiscal year. The year-end backlog was less than $0.5 million. John Thode, Chief Executive Officer of ISCO, commented, "We were able to achieve these results [a breakeven cash flow during the second half of the year] while making substantial investments in areas that we believe will drive futures revenue opportunities for the company, most notably our fully digital interference mitigation produce, which is due to be completed during this year. We view this as a company-changing event, as we believe it will enable us to penetrate more markets, more deeply, than we can contemplate with today's platforms."
Source:
"ISCO International Reports Financial Results for the Fourth Quarter and Full Year 2006"
ISCO International Inc. press release (February 22, 2007)
http://www.b2i.us/profiles/investor/ResLibrary.asp?ResLibraryID=18956&f=1&BzID=826&Category=135&Nav=1&LangID=1&s=0

Basic

Carnegie Institution of Washington (February 26, 2007)

Researchers at the Carnegie Institution's Geophysical Laboratory, in collaboration with the Chinese University of Hong Kong, have discovered that pressure and the substitution of different oxygen isotopes have similar effects on the electronic properties of high-temperature superconductors. The group's results suggest that phonons within the lattice structures of these materials are essential to the phenomenon of superconductivity. Xiao-Jia Chen, lead author of the study explains, "In this study, we found that by substituting oxygen-16 with its heavier sibling oxygen-18, the transition temperature changes; such a substitution is known as the isotope effect. The different masses of the isotopes cause a change in lattice vibrations and hence the binding force that enables pairs of electrons to travel through the material without resistance. Even more exciting is our discovery that manipulating the compression of the crystalline lattice of

the high-Tc material has a similar effect on the superconducting transition temperature. Our study revealed that pressure and the isotope effect have equivalent roles on the transition temperature in cuprate superconductors." The group also determined that phonons could account for both the magnitude of the isotope effect as a function of the doping level and the variations seen among different types of cuprate superconductors as well as how modifications of the electronic structures among various optimally doped materials influence the superconducting properties. Collectively, the results represent a unified picture for the oxygen isotope effect in cuprates at ambient condition and under high pressure. The group's research was published in the online edition of the *Proceedings of the National Academy of Sciences* (February 26 - March 2). The Office of Basic Energy Science and the National Nuclear Security Administration of the US Department of Energy and the Hong Kong Research Grants Council supported this study.
Source:
"New insights into high-temperature superconductors"
Carnegie Institution of Washington press release (February 26, 2007)
http://www.carnegieinstitution.org/news_releases/news_2007_0226.html

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

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Top of Superconductivity Web21

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Feature Articles: Superconducting Microwave and Terahertz Technology - New Evolution of Superconducting Electronics: From Microwave to Terahertz Photonics -

Masayoshi Tonouchi, Professor
Laser Energy Science Research Laboratory
Osaka University

The application of high frequencies is an important issue to superconducting electronics. To date, the application of SIS junction to radio astronomy has been made and in the United States, a high-temperature superconducting microwave filter and other devices have been commercialized, while China, meanwhile, is targeting the use of high-temperature superconducting microwave filters during the Beijing Olympic Games. In Japan, the use of the latter in base stations of terrestrial digital broadcasting is being studied. By making these filters high power, they can also be used as power transmission antennas. Recently, there has been a prominent evolution in the terahertz field, in which superconducting electronics are expected to play a major role. Aside from high frequency applications, superconducting electronics are expected to have roles in X-ray sensors, superconducting quantum bits and various other fields. The author is proposing the creation of “superconducting photonics engineering” merging “superconducting electronics” and “optoelectronics.”

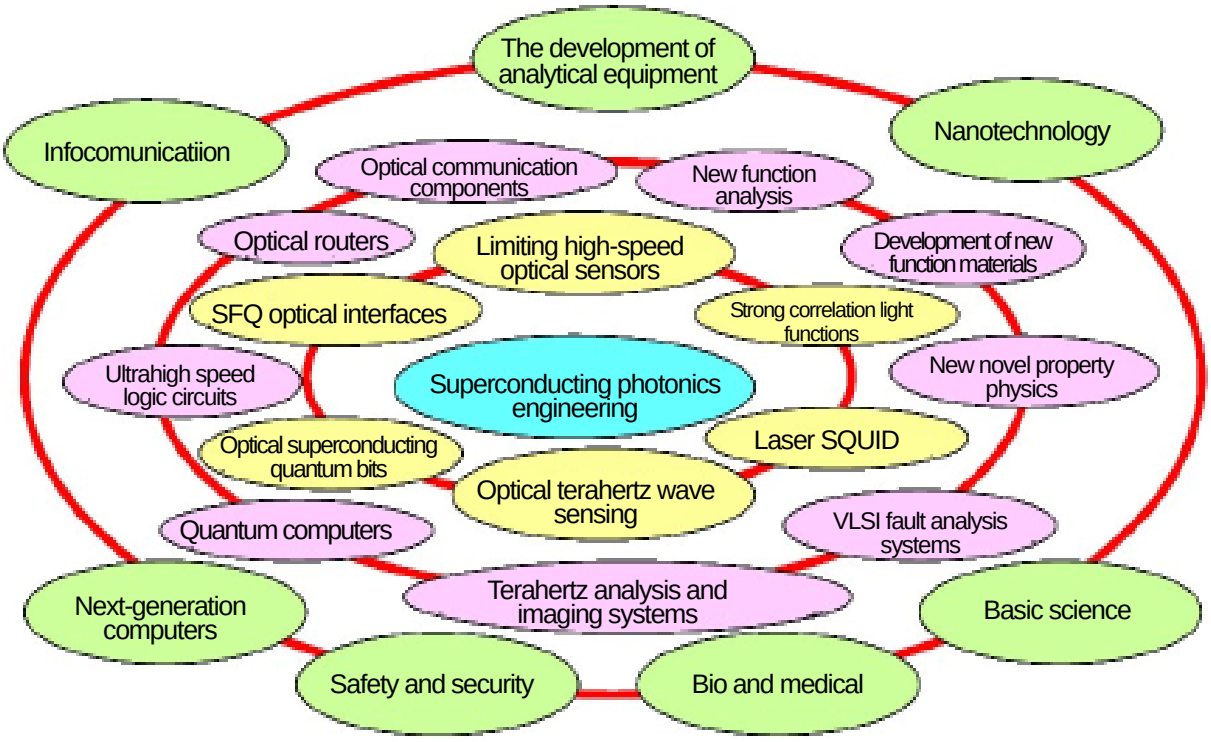

Fig. “Superconducting photonics engineering” - New superconductivity research field

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As illustrated in the diagram, superconducting photonics engineering covers a wide scope, from X-rays to microwaves, as well as application targets such as optical communication components, optical routers, super high-speed logic circuits, quantum computers, new function analysis, imaging equipment and VLSI fault analysis systems. Superconducting photonics engineering can make a contribution to a variety of fields, including establishing a safe and secure society, next-generation infocommunications, and bio medical and basic science.

Here, optical sensors are the key device, including X-ray sensors which demonstrate outstanding performance and beginning to come into use. Sensors in the infrared region can also be used in input interfaces between optical communication signals and super high-speed logic circuits and the development of super high speed and low power consumption interfaces for use in SFQ circuits is regarded as vital for next-generation computers. The rapid evolution of the terahertz field will see various applications emerge for terahertz photon sensors, while devices using SIS and HEB will become indispensable for radio astronomy and earth environment measurement. Focal plane array sensors will spawn ultrahigh sensitivity terahertz cameras, paving the way for the development of high value added systems, such as security systems. The terahertz single photon counter will be a key device in quantum information communication.

Applications such as Laser SQUID that actively use lights can be unfolded and superconducting quantum bit devices are also attracting attention as key next generation devices, for which new applications will be found by combining them with lights. It is hoped that a variety of activities will be undertaken to comprehensively target the creation of new fields.

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Masayoshi Tonouchi, Research Data 80, 146th Committee Meeting, Japan Society for the Promotion of Science, p. 2, 2006.
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(Published in a Japanese version in the February 2007 issue of *Superconductivity Web 21*)

Top of Superconductivity Web21

Spring, 2007 Date of Issue: April 16, 2007
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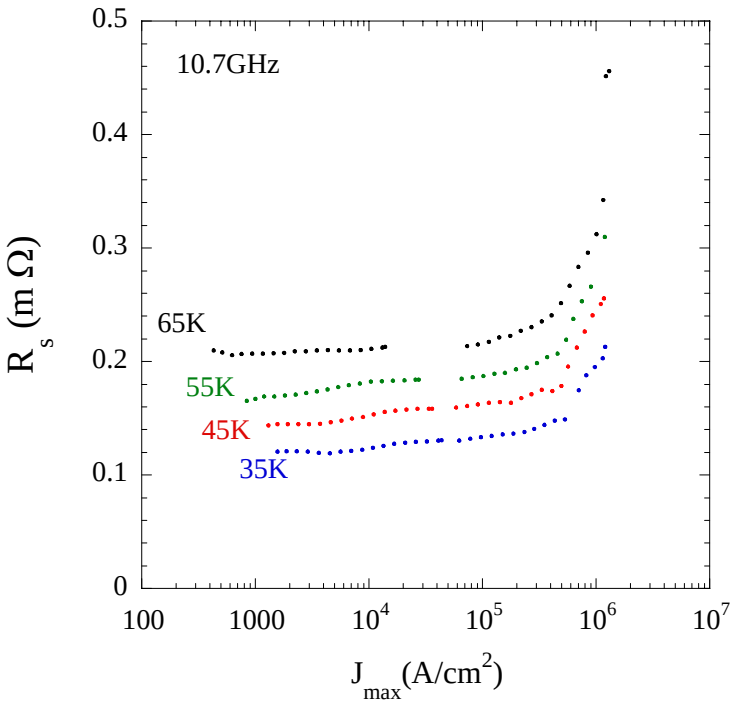
Feature Articles: Superconducting Microwave and Terahertz Technology - Technical Challenges for Application of Oxide Superconducting Films to High-powered Devices -

Haruhiko Obara
Energy Technology Research Institute
National Institute of Advanced Industrial Science and Technology

Passive devices in the microwave band that use oxide superconducting films, such as receiving band-pass filters, have been successfully introduced to the market for use in cellular phone base stations. They have also frequently been cited as successful examples of electronics applications for oxide superconductors, having accomplished commercialization at an early stage. [1)] Only a few companies in the United States, including Superconductor Technologies Inc. (STI), have succeeded in producing them and their market size remains modest compared with early expectations. In Japan in particular, superconducting filter systems are not widely used in the base stations of cellular phones, due to the system that differs from that of the United States and to the low cost demand for base stations.

The commercialization of high powered microwave devices, such as signal transmitting filters, is expected to trigger the penetration of superconducting passive devices. One prominent feature of superconductors themselves is their ability to achieve a high current density as high magnetic field magnets and as wires for power transmission cables. The diagram plots the relationship between a shielding current flowing on the film surface of a YBa_2Cu_3Oy and the surface resistance to 10GHz-band microwaves, measured while varying the microwave power. The surface resistance varies at a slightly lower current density, but it remains almost constant to a current density that equivalent to the critical current density, which suggests the potential for superconducting films to power major microwave applications.



Measurement example of maximum current density J_{max} of shielding current flowing on the film surface and surface resistance R_s. The film is a YBCO film, manufactured by THEVA and about 500nm thick.

Transmitting filters as products will offer advantages, such as reductions in the leakage of outside-band electromagnetic waves without considerably increased costs, as well as the reduction of transmit amplifier output, so research into the application of high-powered microwave devices is actively underway in Europe, the United States and Japan. In Japan, the Ministry of Internal Affairs and Communications has taken up superconducting filter technology in its research and development for

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the expansion of radio wave resources and is sponsoring a project aimed at the commercialization of transmitting filters. [2)]

The development of a film, device and system that excel in resistance to power is needed to produce transmitting filters. However, the device and system development face many research challenges, including a device design that differs from that for receiving devices [3)], and removal of the heat entry from transmission lines. There is a tendency to consider producing films that have the excellent power resistance characteristic of superconductors relatively easy, thanks to the advances achieved in film manufacturing technology. However, microwave devices require a film that is sufficiently thick (normally about 500nm or thicker) compared with the magnetic field penetration depth of superconductors. Films of a relatively large thickness, as mentioned above, and featuring superconductivity characteristics and surface smoothness, must be manufactured stably, since rough surfaces of superconducting films, cracks and other defects in particular prominently degrade the microwave characteristics. A low-cost dielectric substrate is also necessary for inexpensive superconducting devices and numerous research challenges must be addressed, such as the fabrication of quality superconducting films onto a sapphire substrate.

Regrettably, Japan has lagged behind the United States in terms of the commercialization of receiving filters, although it remains fully capable of competing with the latter on a technical level. Supported by the state through the sponsoring of a national project, the potential for Japan to seize the initiative in creating a new market for superconducting passive devices for high-powered microwave application are high.

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1) E.g. feature articles in “Superconductivity Web 21,” February 2006.
2) For a project overview, visit http://www.soumu.go.jp/s-news/2005/pdf/051027_1_1.pdf.
3) K. Yamanaka, A. Akasegawa, M. Kai, *et al*., Physica C - Superconductivity and Its Applications 445, 998 (2006).

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

Top of Superconductivity Web21

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Feature Articles: Superconducting Microwave and Terahertz Technology - Development of Millimeter- and Submillimeter-Wave Mixers -

Takashi Noguchi, Associate Professor
Advanced Technology Center
National Astronomical Observatory of Japan

1. Introduction

Superconductor-insulator-superconductor tunnel junction (SIS junction) devices are widely used as heterodyne mixer devices in high-sensitivity receivers for the observation of extremely feeble cosmic radiations at the millimeter- and submillimeter-wave bands. Since mid 80s, the National Astronomical Observatory of Japan has been conducting to develop Nb-based SIS junctions and low-noise millimeter- and submillimeter-wave receivers using those SIS junctions. This paper describes the current status of R&D of the SIS mixers, which is the key component of the high-sensitivity receivers used in the observation of cosmic radiations.

2. Current Status of Low-Noise Receivers Using SIS Mixers

Due to the existence of the energy gap in Nb (2Δ~3 meV), a current rapidly increases at the gap voltage Vg (= $2\Delta/e$; e is the charge of an electron) in the current-voltage characteristics of a Nb/AlOx/Nb SIS junction. Using this strong non-linearity at the gap voltage, the SIS mixer can detect electromagnetic waves with high efficiency. If a leakage current of the SIS junction is very small in the sub-gap region, and the rise in current at the gap voltage is very sharp, a noise temperature near the quantum limit, $h\nu/k_B$, can be achieved in the SIS mixer, where h, k_B and ν represent Planck's constant, Boltzmann constant and a signal frequency, respectively.

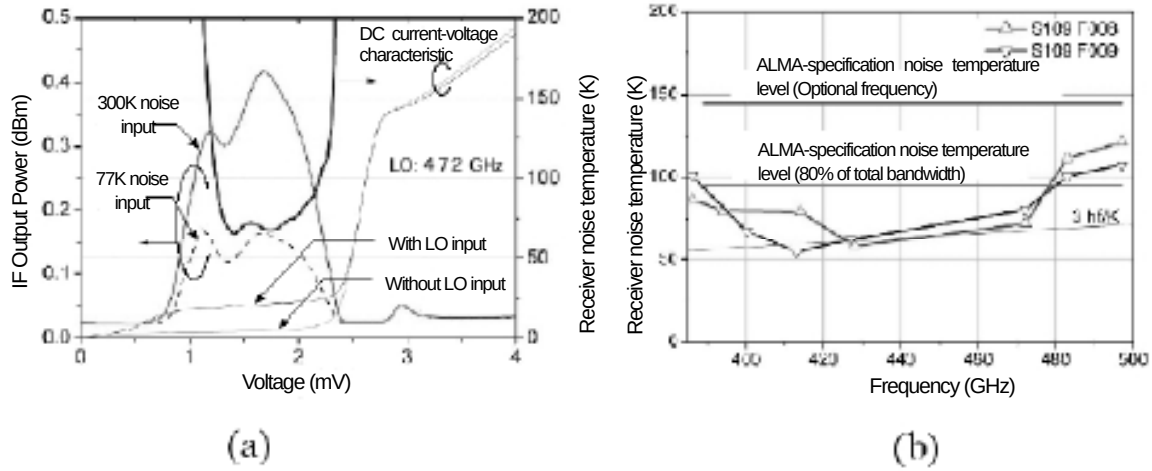

Fig. 1 Performance of a 500-GHz band receiver that uses an SIS mixer.
(a) DC I-V characteristics of a SIS mixer with and without local oscillator (LO) and its IF response as a function of frequency. (b) Frequency dependence of the receiver noise temperature of SIS mixers. The two straight lines represent the noise temperature required for the SIS mixers to be used in the Atacama Large Millimeter/Submillimeter Array.

Figure 1(a) shows the DC I-V characteristics of a 500-GHz band SIS mixer and its IF output as a

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function of voltage when radiations from standard noise sources at room temperature and 77K are applied. Minimum signal-to-noise ratio of the SIS mixer is obtained at the voltage of the IF peak just below the gap voltage and the input equivalent noise temperature in this case is called a receiver noise temperature T_{RX}. Figure 1 (b) plots the frequency dependence of the noise temperature of a typical 500GHz-band receiver. It is demonstrated that a minimum receiver noise temperature T_{RX} of 60K (at 430GHz), which is only about three times the quantum-limited noise temperature of $h\nu/k_B$, can be achieved.

The noise temperatures of the SIS receivers at the millimeter and submillimeter wavelengths reported previously are plotted in Fig. 2. It is shown that receivers with very low noise have been built from 100 GHz to 1000 GHz. It is clearly demonstrated that the noise temperature of radio receivers using Nb-based SIS mixers are about 3 times the quantum limit ($3h\nu/k_B$) at frequencies below 700 GHz, but that the noise temperature of the receiver rapidly increases at frequencies above 700GHz. This can be attributed to an increase in losses of the Nb film used for the wirings and tuning (resonance) circuit, due to the absorption of electromagnetic waves with a frequency above the Nb gap frequency (about 700 GHz). At the Advanced Technology Center of the National Astronomical Observatory of Japan has been currently starting to develop SIS mixers employing a Nb-based SIS junction in combination with a NbTiN thin film with low absorption loss near 1THz, aiming to build a low-noise SIS mixer at around 1 THz.

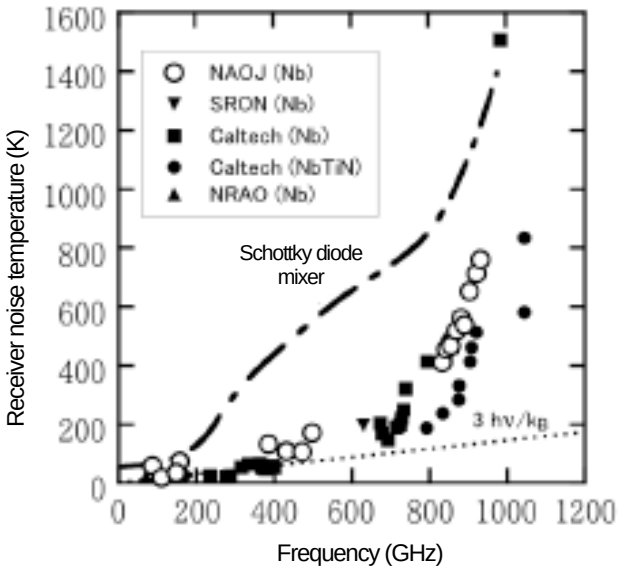

Fig.2 Noise temperatures of radio receivers at millimeter- and submillimeter-wave frequencies using the SIS mixer reported to date. Abbreviations in the upper left panel represent the research organizations. NAOJ: National Astronomical Observatory of Japan, SRON: Space Research Organization of the Netherlands, Caltech: California Institute of Technology (USA), NRAO: National Radio Astronomy Observatory (USA).

3. Conclusion

It has been past just 20 years since a 40-GHz band receiver using an SIS mixer was installed and used in the 45-m radio telescope at the Nobeyama Observatory of the National Astronomical Observatory of Japan in 1987. During the past two decades, a lot of great effort has been put into the research of SIS mixers not only to improve their noise performance but also to extend their application frequency. Now it is possible to build high-performance SIS mixers and receivers with noise performance approaching a quantum limit at frequencies as high as 1 THz. At present, we are developing a 150-GHz and 450-GHz band SIS receivers to be installed and used in the Atacama Large Millimeter/Submillimeter Array (ALMA), the world's largest interferometer telescope at millimeter and submillimter wavelengths being built in the Atacama desert at an altitude of about 5000 m in northern Chile as illustrated in Fig. 3. The first SIS receivers are scheduled to be shipped to Chile at the end of this year or early next year.

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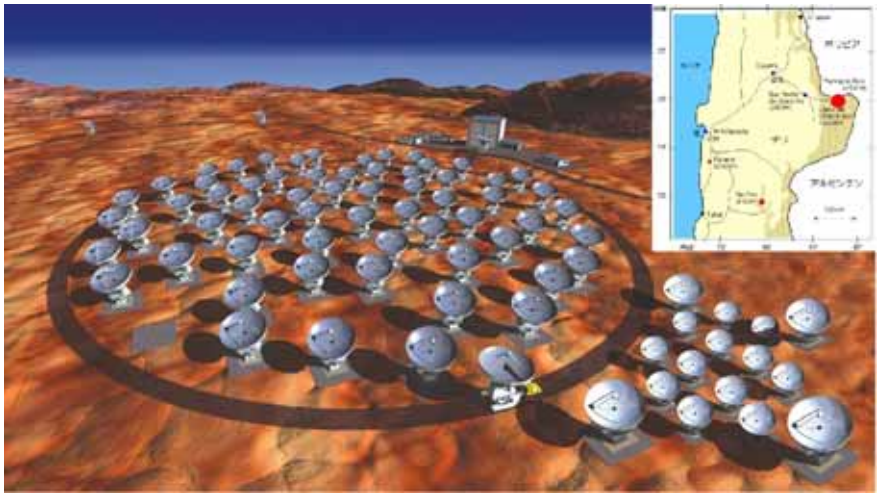

Fig. 3 An artist's image of the Atacama Large Millimeter/Submillimeter Array (ALMA), which will be completed in construction by the end of 2011.

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

Top of Superconductivity Web21

Spring, 2007 Date of Issue: April 16, 2007
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Feature Articles: Superconducting Microwave and Terahertz Technology - Remote Sensing Technology by Millimeter- and Submillimeter-wave Band Mixer -

Yoshihisa Irimajiri
Environmental Information and Sensing Network Group
Applied Electromagnetic Research Center, Research Department 3
National Institute of Information and Communications Technology (NICT)

The millimeter- and submillimeter-wave band superconducting receiver system is one of the powerful tools to observe stratospheric trace gases related to ozone depletion and global warming (HO_x, NO_x, ClO_x, BrO_x). Radio spectra radiated by molecules are received by the heterodyne system and the altitude distribution of these molecules is measured in high sensitivity and high altitude resolution via a technique to observe the limbs of the atmosphere called the "limb sounding method."

Our Group developed a balloon-borne superconducting submillimeter-wave limb-emission sounder (BSMILES) and conducted ballooning tests at the Sanriku Balloon Center of the Institute of Space and Astronautical Science (ISAS) of Japan Aerospace Exploration Agency (JAXA) in 2003, 2004 and 2006 respectively. BSMILES consists of an antenna-calibration system, optics system, receiver system, intermediate frequency system, spectroscopic system, data acquisition and control system, attitude detection system, power source and balloon engineering system (command and telemetry system and other systems). Fig. 1 shows a block diagram of the system. The gondola measures about 1.35m x 1.35m x 1.26m and weighs about 600kg in total, consuming about 150W of electricity. The submillimeter-wave band contains many radio wave spectra radiated by atmospheric molecules, with strong radiation intensities, which are advantageous to observation. Moreover, observation unaffected by the absorption of water vapor in the troposphere will be possible by lifting the system into the stratosphere via a balloon.

The antenna system consists of a plane mirror for beam scanning, an offset parabolic antenna 300mm in diameter and a secondary mirror. Calibration data is obtained by changing to a hot load and cold sky (elevation angle 50°) for each scan via a switching mirror for calibration. The receiver contains a submillimeter-wave (650GHz) band superconducting receiver, cooled to 4K by liquid helium, and a superconductor-insulator-superconductor (SIS) mixer. The SIS device is a Nb/AlO_x/Nb of the PCTJ type.[1)] The best value of the DSB system noise temperature (measured in front of the antenna) of the SIS mixer is about 300K in the 630GHz band. After being converted into an intermediate frequency (5 to 7GHz) by the mixer, the signal is amplified by a high electron mobility transistor (HEMT) amplifier (cooled to 15K) and ambient-temperature amplifier and its spectrum is obtained by an acousto-optic

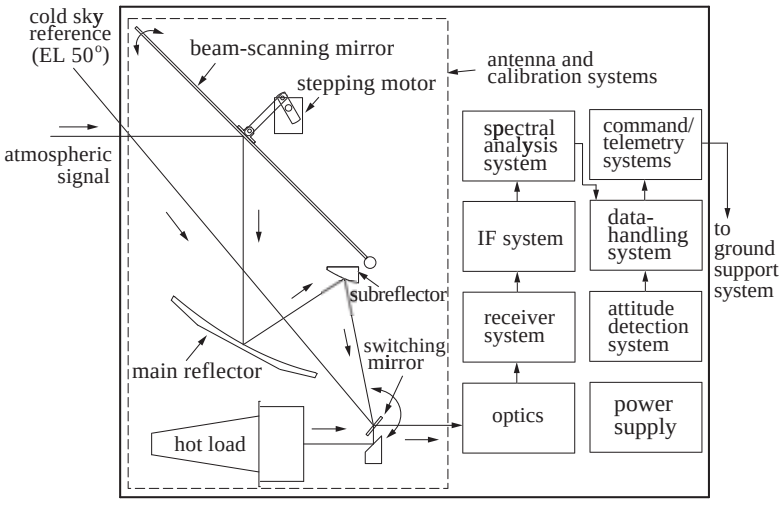

Fig. 1 Block diagram of BSMILES

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spectrometer (bandwidth 1GHz, resolution about 1MHz). The data obtained is recorded in a PC card of the personal computer installed in the balloon and then recovered at sea. A tri-axial fiber-optical gyroscope, tri-axial accelerometer, and dual-axis geomagnetism sensor to detect the gondola attitude are installed. The equipment is contained in a pressurized container sealed with nitrogen gas for waterproofing and noise shielding and powered by a lithium battery designed to provide power for 30 hours.

Fig. 2 shows spectra of O_3, O_3 isotope, $H^{35}Cl$, $H^{37}Cl$, HO_2 and others obtained during observation in 2004. This data was obtained by scanning in an altitude direction. The integral time of one spectrum is about one minute. The observation succeeded in the short-time observation of trace molecules that radiate an extremely weak radio wave called HO_2. The system noise level (r.m.s.) was about 70mK.

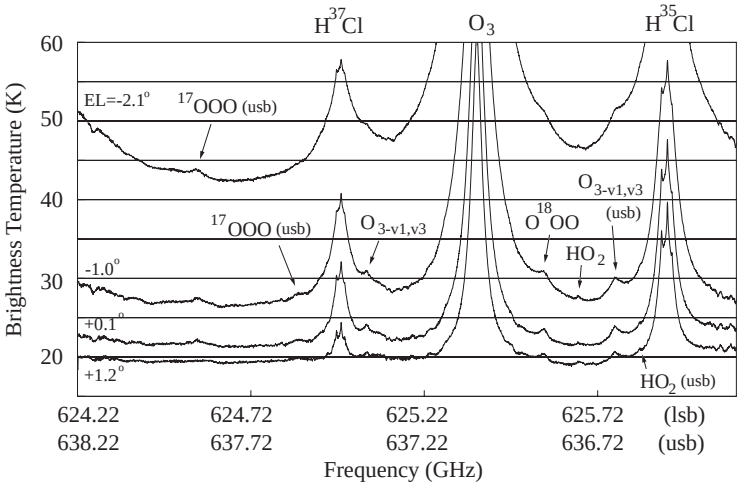

Fig. 2 Radiation radio wave spectra of O_3, $H^{35}Cl$, HO_2 and others

The superconducting submillimeter-wave band receiver installed on a balloon can simultaneously observe ozone and trace molecules related to the ozone depletion and represent one of the powerful tools of atmospheric observation. A superconducting high-sensitivity receiver installed on the balloon enables the observation of trace molecules, which was previously impossible, in a short time, thereby solving the photochemical reaction process and greatly contributing to future forecasts of the ozone layer. By installing a hot electron bolometer (HEB) mixer, a significant contribution to the development of a THz-band heterodyne receiver, atmosphere observation (OH radicals and others) and astronomic observation can be made, in the future as well.

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Top of Superconductivity Web21

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Feature Articles: Superconducting Microwave and Terahertz Technology - Direct Detection and Imaging of Terahertz Waves by Superconducting Tunnel Junction Detector Array -

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Considerable hope is placed on a variety of spectral analysis and imaging applications in the terahertz (THz) band. Most THz imaging is performed by single-pixel detectors and there is considerable demand for the development of high-performance array detectors to see through materials with the good special resolution. The authors are developing two types of high-performance THz wave direct detectors using superconducting tunnel junction (STJ) devices consisting of a 5-layer film of Nb/Al/AlOx/Al/Nb.

The first detector is a band-type detector array that uses photon-assisted tunneling process (Fig.1) . One element consists of an Nb plane antenna and Nb micro strip line brideged by twelve STJ devices, and operates below 0.7 THz in frequency which corresponds to 2Δ of Nb (about 3 meV in energy). This detector electrically constitutes a high frequency LCR circuit at its central frequency of 0.65 THz, with more than 10% bandwidth, 10^{-16} W/√Hz in noise equivalent power (NEP) and more than 4 x 10^6 in dynamic range, succeeding in THz imaging for the first time for STJ direct detectors. [1] (Fig. 2) The frequency characteristics of a 5-pixel linear array has been confirmed to coincide each other[2], and the test observations by a 3x3 array with the ASTE telescope in Chile have commenced. [3]

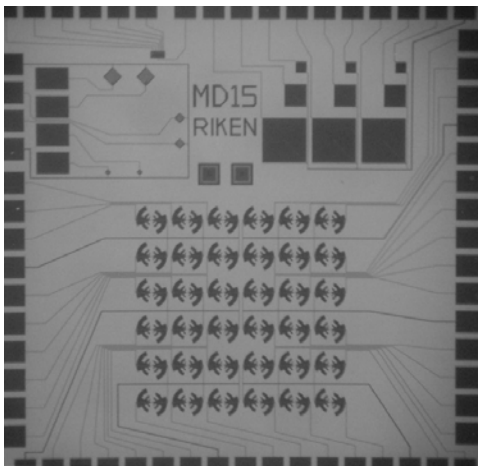

Fig.1 6 x 6 pixel on a sapphire substrate

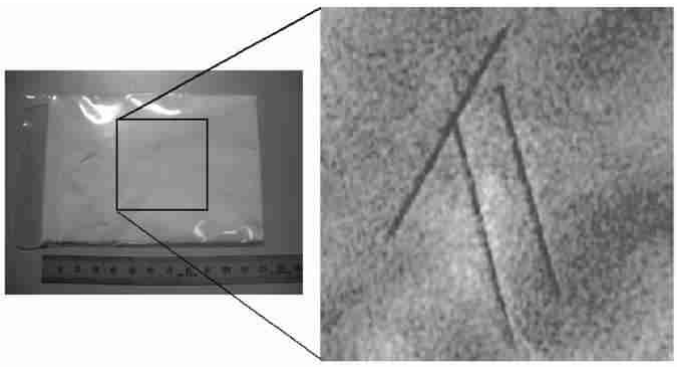
Fig.2 Example of THz image (Needle in powder milk)

The second sensor uses high frequency phonons generated on the detector's single crystal substrate which operates as an absorber of THz waves. When THz photons are absorbed, high-frequency phonons are generated in the substrate and reach the STJ device. When the phonons' energy is above 2Δ, then they break Cooper pairs and produce extra quasiparticles in the Nb superconductor electrode. Kurakado *et al*., developed a technique to utilize the substrate phonons for detecting X-rays and high-energy particles. However, this is the first verification for detecting low energy photons in the THz band. A flat spectral response in at least 1 to 2THz has been confirmed, featuring the use of a frequency-tunable THz source. The detectors are expected to play a major role as broadband ones suitable for the use of specific absorption spectra of many materials in the THz region. [4]

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Top of Superconductivity Web21

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Patent Information

Introduction of Published Unexamined Patents in the 3rd Quarter of Fiscal 2006

The following are ISTEC's patents published from October through December, 2006. For more information, access the homepange of the Patent Office of Japan and visit the Industrial Property Digital Library (IPDL).

1) Publication No. 2006-268928 "Superconducting Sense Circuit Driven by DC Power"

This invention relates to a sense circuit driven by a DC power supply in superconducting random access memories (RAMs). In a earlier DC driven sense circuit, it was proposed that the memory data is decided to be "1", if a sense signal falls within a predetermined period from the front edge of the sense signal, and to be "0" if the sense signal does not fall. This conventional example requires a complex timing sequence and the operation margin of the bias current is small, thus inappropriate for expansions of the memory capacity. The sense circuit of the present patent is characterized by connecting a novel sense-line information detection block (SIDB) to the RS flip-flop circuit (RS-FF) of SFQ circuit configuration, in where the SIDB is implemented by connecting a sense-line cascading plural read-gates, a bias-resistor connected to DC power supply terminal, a load-resistor and an inductor. This circuit configuration enables these read-gates to change to the voltage state when a cell of read data "1" is selected, transmitting single flux quantum (SFQ) pulses to the RS-FF as signal data of memory data "1." When a cell of memory data "0" is selected, the read-gate does not change to the voltage state and no SFQ pulse is generated. This invention achieves generating an SFQ pulse output with a large bias current margin without a complex timing sequence even in the case of DC power supply.

2) Publication No. 2006-269347 "Manufacturing Method and Manufacturing Equipment for Tape-shape Oxide Superconducting Wire"

This invention relates to a heat treatment furnace in which a superconducting long wire is manufactured by arranging a tape-shape wire coated with a superconductor precursor between a pair of reels and by reacting the superconductor precursor with a reactive gas while feeding it through a reaction tube. This invention is characterized by vertically feeding the reactive gas on the tape surface to react with the superconductor precursor, following which the gas is exhausted through gas outlet holes arranged in direction of both sides of the tape. The appropriate number of the gas inlet holes and gas outlet holes are respectively selected in accordance with the width of the tape, and reaction areas, consisting of gas inlet and outlet holes, can also be arranged along the tape direction of travel. The conventional systems facilitate the horizontal gas flow onto the surface of a tape by providing gas inlet holes in positions horizontal to the tape surfaces, but this generates a difference in the reaction speed of the precursor at the ends of both sides of tape as the tape width increases, and finally the uniform superconductive characteristics in the width direction cannot be obtained. This invention solves above mentioned problem and can be used for wide tape-shape wire, which makes the wire manufacturing speed increase.

3) Publication No. 2006-270282 "DC Power Driven Superconducting Loop Driver Circuit and Driving Method"

This invention relates to a driver circuit for cell-selection signals of superconducting random access memories (RAMs), in which single flux quantum (SFQ) devices are adopted. Normally, memory cell array are two-dimensional matrix array and specified memory cell is selected by supplying selection signals to a row and a column of the matrix. Selection signals are implemented by amplifying level logic

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signals (square wave signals), for supplying simultaneously to all memory cells belonging to the selected row or column. This invention is characterized by the use of a driver-gate consisting of an amplifier-gate (AMP) that generates SFQ pulse train in response to the input of a SFQ pulse, a buffer-gate that prevents the SFQ pulse train from propagating to the input direction and a magnetically coupled superconducting quantum interference device gate (SQUID) that is temporarily switched to a voltage state for a period of the SFQ pulse train, and characterized also by the use of a reset gate of equivalent configuration to that of the driver-gate. After an input of a SFQ pulse, this driver circuit can generate a desired level signal to a superconducting strip line with plural memory cells as a load, and can be powered by a DC power supply.

4) Publication No. 2006-278384 "Superconducting Random Access Memory and Manufacturing Method Thereof"

This invention relates to the structure of memory cell in superconducting random access memory and the manufacturing method thereof. The structure of memory cell based on this invention is of a multilayer structure including superconducting ground plane layers (GP layers) and characterized by stacking a superconducting loop with Nb-based Josephson junctions and a resistance layer on the uppermost superconducting GP layer. The other resistance layer, inductance layer and a superconductive passive transmission line layer that is suitable to high-rate signal transmission are individually inserted between the superconducting GP layers under the uppermost GP layer. This invention does not need the ground plane layer on the inductance layer constituting the superconducting loop and can reduce the size of memory cell. Plural GP layers also effectively shield magnetic fields generated from the DC power line. Because this invention permits to use a high temperature process, such as plasma CVD, for process before forming Josephson junctions, it becomes practical to use a high permittivity material for insulation layers.

5) Publication No. 2006-310259 "RE123-based Oxide Superconductor and Manufacturing Method Thereof"

This invention relates to RE123-based superconducting wires manufactured by a new method. This RE123 oxide superconductor is characterized by being constructed with a $REBa_2Cu_3O_{7-\delta}$ oxide superconductive layer and a supporting member that support the superconductive layer which is formed from a mixed raw material including at least RE_2BaO_4 and Ba-Cu-O raw material powders. In this invention, the heating of mixed raw materials in a low oxygen atmosphere will initially change the Ba-Cu-O material into a liquid phase (liquid phase component). By further increasing the temperature, the liquid phase component reacts with the RE_2BaO_4 raw material (solid phase component with a high melting point temperature) and the RE123 phase with crystalline orientation is grown in the new solid - liquid reaction. This growing temperature of RE123 phase is significantly lower than that for the RE123 phase generation by the conventional melt-solidification using the RE123 raw material.

(Katsuo Nakazato, Director, Research and Development Promotion Division, SRL/ISTEC)

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Top of Superconductivity Web21

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Standardization Activities

Topics in December 2006

- 3rd Superconductivity Standardization Panel Discussion -

With support provided by the New Energy and Industrial Technological Development Organization, the International Superconductivity Technology Center (ISTEC) sponsored the third panel discussion on superconductivity standardization at the Nagoya International Conference Hall on October 31, 2006. A total of 32 representatives from five countries (Korea, EU, USA, China and Japan) participated in the panel discussion. The discussions focused on technological development and future prospects related to superconducting power equipment and apparatus and were successfully adjourned.

Presided by Prof. Kozo Osamura of the Research Institute for Applied Sciences, the following eight panelists supplied related information to the panel discussions.

1) Kozo Osamura, Research Institute for Applied Sciences
Current status of superconductivity standardization activities
2) Osamu Horigami, ISTEC/SRL
Market trends of superconducting power equipment and apparatus
3) Yasuzo Tanaka, Director, Standardization Department, ISTEC
Standards denotation matters for commercialized superconducting wires
4) Norikiyo Koizumi, JAEA
Current status of tests on wires for ITER
5) S. S. Oh, KERI
Current status of tests on wires for superconducting power equipment and apparatus in Korea
6) P. X. Zhang, Northwest Non-Ferrous Metal Research Institute
Current status of tests on wires for superconducting power equipment and apparatus in China
7) A. P. Malozemoff, AMSC
Development and test methods for next-generation high temperature superconducting wires
8) H.-W. Neumueller, Siemens AG
Current status of tests on wires for superconducting rotating machines at Siemens AG

Based on the information supplied by the panelists, the following discussions took place:

1) Current status of superconductivity standardization activities

It was agreed that superconductivity standardization activities had been continuously undertaken since 1989, with a focus on IEC/TC90 and with Japan acting as the secretariat, that one terminology standard and 13 testing standards, or a total of 14 standards, had already been established as international standards, and that at present, the enhancement of testing standards, maintenance of existing standards, deployment to product standards and formation of an international consensus through panel discussions were all being carried out.

2) Marketability of superconducting power equipment and apparatus

Low temperature superconductors and SMES and other equipment and apparatus employing low temperature superconductors were already on sale on the market. However, full-scale market entry would follow the market debut of superconducting power equipment and apparatus using high temperature superconductors.

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A comment was made that the market entry of power cables, rotating machines and others would come earlier than market forecasts, which stated that the full scale market introduction of superconducting power equipment and apparatus using high temperature superconductors would come after 2010.

3) Layers of standardization

Layers of superconductivity standardization were explained using SMES systems as an example. As layers move up from materials to wires, conductors, devices and equipment and systems, specification requirements became special and discrete so that selection as standardization objects would become more difficult as the layers move up.

It was agreed that it would be useful to continuously study superconducting wires that were commonly used in a wide range of superconducting power equipment and apparatus as a layer for standardization.

4) Standardization related to the ITER Project

The ITER Project would soon procure a large amount of superconducting wires internationally and purchasing specifications, including a method for tests of characteristics, were being studied. Organizations capable of conducting characterization tests of cable-in-conduit conductors (CICCs) were limited globally and local standards had to be used.

On the other hand, Nb_3Sn superconducting strands that used CICCs were commonly used and a test method based on IEC 61788-2Ed.2 was basically scheduled for use. However, a one-mandrel method using a titanium alloy tube could be used in critical current tests in a distortionless state. The development of a test method on the periodic bending strain effect over the lengthwise direction of superconducting strands themselves, anticipating CICCs, was agreed as an urgent requirement.

5) Test method of high temperature superconducting wires

Bi wires, Y wires, tape wires, round wires, twisted wires, reinforcement wires and various other wire varieties were being developed as high temperature superconducting wires. Applied research and development into superconducting cables, transformers, motors, fault current limiters and other apparatus was conducted simultaneously.

It was therefore agreed that test methods for high temperature superconducting wires depend significantly on the constructions of wires and conductors, manufacturing process and application fields, making them diverse and varied. It was also agreed that standardization was indispensable in future for high temperature superconducting wires to be accepted as industrial materials, but that, for the moment, reference test methods should be written and shared among the parties concerned. It was also pointed out that they should be handled as quality management matters as they would become industrial products.

The following summary was made as a result of the third panel discussions on technological development and the future prospects of superconducting power equipment and apparatus.

1) The understanding on the current status of superconductivity standardization and on the usefulness and necessity for international standardization was deepened through the interchange of technical information on superconducting power equipment and apparatus.

2) It was agreed that the technological development of low and high temperature superconducting wires should steadily be undertaken to meet diverse needs. Under these circumstances, it was agreed as sound to select parts and materials that were closer to the market and those that were commonly used in many superconducting power equipment and apparatus as standardization objects to promote standardization for the moment.

3) Even though the results of the third panel discussions could not be fully discussed yet, the discussions were useful in deepening understanding of the necessity to promote international standardization and in gaining more knowledge of superconductivity standardization as was the case with the previous two panel

discussions. It was agreed that meetings of this nature would become more important in the future also.

A scene during panel discussions

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

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Top of Superconductivity Web21

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Standardization Activities

Topics in February 2007

- IEC/TC90 (Superconductivity) establishes new WG12 (Current Leads) -

IEC/TC90 (Superconductivity) conducted international voting between September and December 2006 on new work item proposals (NWIPs). Consequently, the establishment of a new working group (WG12) was approved. It was decided to start standardization on the characterization test methods of current leads used in superconducting equipment and apparatus, while the voting also approved the appointment of Prof. Toshiyuki Mito, National Institute for Fusion Science, National Institutes of Natural Sciences, as a convener.

IEC/TC90/WG12 is tasked to internationally standardize terminology, test methods and other items related to current leads for the supply of power to superconducting magnets, superconducting magnetic energy storage (SMES) systems, superconducting power cables, superconducting transformers, superconducting fault current limiters, superconducting rotating machines and other superconducting equipment and apparatus.

Current leads as objects of standardization are made of a normal conductor, such as copper, and/or a superconductor such as an oxide superconductor.

Unlike standardization of test methods for single basic characteristics in conventional standardization, the collective standardization of characterization test methods is anticipated as characterization test methods for current leads, such as the mechanical characteristics (stress and strain effect tests) products should possess, thermal characteristics (thermal load test), electrical characteristics (rated energizing test, contact resistance test, voltage drop test, withstand voltage test), hydraulic characteristics (rated gas pressure drop test, sealing test), safety factor characteristics (gas flow rate test, quenching test) and other characteristics.

WG12 will be organized by experts recommended by five countries, the United States, Italy, Germany, Poland and Japan, and will work under the convener, Prof. Toshiyuki Mito. As experts, Mr. Masayuki Konno (Japan), Dr. Huub Weijers (USA), Dr. Ballarino Amalia (Italy), Dr. Reinhard Heller (Germany) and Dr. Jacek Sosonowski (Poland) have already been recommended.

The work agenda and target schedules for WG12 are generally as follows:

1) Organize WG12 organization	Spring 2007
2) Prepare working draft (WD)	Summer 2007
3) Propose working draft (WD)	Autumn 2007
4) Propose committee draft (CD)	January 2008
5) Propose voting committee draft (CDV)	-2009
6) Propose final draft international standard (FDIS)	-2010
7) Issue international standard (IS)	December 2010

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

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Top of Superconductivity Web21