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超電導 Web21 Superconductivity

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Inaugural Address of Yuh Shiohara, Director General of the Superconductivity Research Laboratory

On February 1 this year, I assumed the post of Director General of the Superconductivity Research Laboratory (SRL).

I am very much aware of the weight of my responsibility as Director General of SRL. Established by the former Director General, Dr. Shoji Tanaka, SRL has accumulated distinguished records of research. I still have much to learn about the fields of superconductor material science. But in addition to my basic knowledge of materials science, and the knowledge of superconductivity that I've gained over the last two decades, I have considerable experience of managing R&D. Based on this foundation, I intend to work closely with the Deputy Director General（Dr. Kei-ichi Tanabe） and our research scientists to pursue R&D for superconducting wires and tapes, as well as electric power devices, electronic devices, and new superconducting materials. Together, we will seek to win universal recognition for SRL as a Center of Excellence (COE) for superconductivity research.

Thanks to the efforts of our research scientists, the Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications (Phase II) project commissioned by the Ministry of Economy, Trade and Industry through the New Energy and Industrial Technology Development Organization (NEDO) ,which was completed last fiscal year, won high acclaim. Similarly, the new project of "Materials and Power applications of Coated Conductors" started last June is making good progress.

SRL will continue to take the lead, bearing clearly in mind the contributions that are required of us in these projects.

Since the second half of last year, the world entered a once-in-a-hundred-years recession. In recovering from this unprecedented slump and in shoring up employment, we recognize the importance of sustainable new technology development aimed towards new industries and job creation, especially in the technology-driven country, Japan.

In the years of change and innovation, great expectations are placed on superconductive materials and its applied technologies in the fields of environment and energy, and we will accelerate the pace of basic R&D towards achieving practical applications. In the spirit of "Yes, we can. Yes we will", we will dedicate ourselves to creating new technologies and industries to benefit society.

We ask for your continued support and guidance going forward.

(Director General of the Superconductivity Research Laboratory/ISTEC, Yuh Shiohara)

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The 17th International Superconductivity Industry Summit (ISIS-17)

Opening address by Yutaka Kiyokawa, Senior Managing Director of ISTEC

The 17th International Superconductivity Industry Summit (ISIS-17) was held at the Tsukuba International Congress Center, Japan, on October 30 (Thu) and 31 (Fri), 2008. More than 40 delegates from Japan, the United States, Europe, New Zealand, Korea and China attended the summit.

Past summits were organized by Japan, the United States and Europe, but at this summit, New Zealand was approved as a new official member and future summits will be organized with the participation of New Zealand. Recently, superconductivity-related development activities have spread beyond Japan, the United States and Europe, and, thus, active development is now underway in New Zealand, Korea, China and other countries. In response to this trend, the summit members have established a new procedure for accepting new official members. Based on the New Zealand's wish to become an official member, the approval was given at the ISIS-17. In New Zealand, development of yttrium-based cables for power applications is underway at present, while R&D to develop suitable transformers using the cable has started. In addition, HTS-110 Ltd., a New Zealand company that sells HTS superconductor magnet products is also active in the field.

This was the 17th summit since the first summit held in the United States in 1992. The theme of the ISIS-17 was "The Expansion of Superconductor Applications." In Japan, the "Fundamental Superconducting Application Technology Project" was completed successfully in March 2008. Subsequently, based on its achievements, the "Materials and Power Applications of Coated Conductors Project" started in FY2008. At the summit, Yuh Shiohara, Acting Director General of the Superconductivity Research Laboratory gave a general report on these projects. From Europe, Gianni Grasso of Columbus Superconductors, from the United States, Steinar J. Dale of Florida State University, and from New Zealand, Donald Pooke of HTS-110 gave reports on their respective country's activities. Minwon Park of Changwon National University and Zhenghe Han of Tsinghua University who were present as observer members from Korea and China reported on their respective country's activities as well. Subsequently, various reports were given from member countries about the main findings, future plans, and the state of progress towards practical applications in the electric and electronics sectors. Participants discussed and exchanged their views so actively and vigorously that the ISIS-17 was very successful.

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In the United States, besides the current cable projects under SPI (Superconductivity Partnership Initiative), new demonstration projects for FCLs and power cables were initiated. In the meantime, the development of yttrium-based wire is making significant advances, and the yttrium-based wire is being used in some of these projects. Some companies in Japan and in Europe are also participating in these projects, thus giving the projects a bit of an international flavor. In Europe and the United States, development of application devices including superconducting motors are progressing steadily and accumulation of related technologies are going on. In Europe, attention is being focused on practical applications of MgB_2 as well. The MgB_2 wire is already commercially available, and development for its magnet applications is underway. Korea has entered the final phase of the DAPAS (Development of the Advanced Power system by Applied Superconductivity technologies) program which started in 2001. Efforts towards commercial applications of high temperature superconductors are accelerated in Korea. China is also steadily moving forward.

As outlined above, activities towards practical applications of high temperature superconductors are spreading beyond Japan, the United States and Europe. At the same time, due to the recent energy price hikes, it is strongly recognized that energy issues are closely related to our national security, while the global warming caused by emissions of CO_2 is becoming a major global political issue as well. Renewable energy and energy saving technologies are indispensable for our sustainable economic development in the future. In this regard, superconductor technology is one of the most promising solutions. The ISIS-17 strongly impressed the fact that superconductivity-related activities are much more widely and deeply expanded to such countries as Korea, China and New Zealand, which goes beyond the conventional framework consisting of Japan, the United States and Europe where the steady progress is being made as well. The summit also strongly demonstrated that expectations toward superconductors for our future sustainable economic growth were increasing all over the world.

It was agreed that the next summit, ISIS-18, would be held in 2009 in Wellington, New Zealand.

At the ISIS-17 venue

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

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

Power

Zenergy Power plc (February 2, 2009)

Zenergy Power plc has received additional funding from the U.S. Department of Energy to extend its existing R&D agreement with Sandia National Laboratories for the development of ground-breaking mass-production techniques for second-generation (2G) low-cost superconducting wires. Zenergy has been developing its own low-cost production techniques for 2G wire since 2003 and subsequently received funding from the DOE in 2006. Since then, Zenergy and Sandia have successfully demonstrated the potential cost advantages of Zenergy's patented 'all-chemical' production technique. As a result of the extension, the total value of the research project is now about US $1.8 million and will last through to 2010. Jens Müller, CEO of Zenergy Power, commented, 'Working with Sandia gives us access to some of the world's most sophisticated research resources and together with the support of the U.S Department of Energy we are rapidly developing potentially the world's most cost effective superconductor materials."
Source:
"Extension of DOE Funded Superconductor Development Project"
Zenergy Power press release (February 2, 2009)
http://www.zenergypower.com/images/press_releases/2009-02-02-sandia.pdf

American Superconductor Corporation (February 3, 2009)

American Superconductor Corporation (AMSC) has reported their financial results for the third quarter of fiscal 2008, ending December 31, 2008. Revenues for the third quarter increased by 27 % to US $41.3 million, compared with $32.6 million for the same period in the previous fiscal year. The gross margin for the third quarter was 23.2 %, compared with 30.9 % for the same period in fiscal 2007. The lower gross margin was mainly attributed to higher than expected costs for certain products, a charge for excess inventory, and unfavorable foreign exchange effects. The company's net loss for the third quarter was $7.8 million, compared with a net loss of $7.3 million for the same period in the previous fiscal year. The company had cash, cash equivalents, marketable securities, and restricted cash totaling $122.6 million as of December 31, 2008. The reported backlog at the end of the third quarter was approximately $602 million, compared with $168 million as of December 31, 2007. Greg Yurek, AMSC's founder and chief executive officer, commented, "Our two core growth drivers – the Chinese wind power market and the U.S. power grid market – remained strong through our third fiscal quarter, a trend we expect to continue for the foreseeable future. Wind continues to be our growth engine; however, more than $27 million of our $46 million in third-quarter bookings were for our D-VAR® Smart Grid solutions. With these new orders, we now have more than $175 million out of the total of $602 million in backlog that we expect to recognize as revenue in fiscal 2009. Our backlog position for both fiscal 2009 and the following two fiscal years and the strength of our core markets position us for strong growth in fiscal 2009 and beyond."
Source:
"AMSC Reports Third Quarter Fiscal 2008 Financial Results"
American Superconductor Corporation press release (February 2, 2009)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1251181&highlight

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Zenergy Power plc (February 9, 2009)

Zenergy Power plc has been commissioned by RWE Power AG to draft a study evaluating the potential increase in electrical output that could be achieved from RWE's existing run-of-river hydro plants if superconductor variable speed generators were to be used. Zenergy will receive data from RWE regarding an existing representative run-of-river hydro plant and will in turn use this data to develop a report on how modernization of the plant using hydro generators based on superconductor components could increase efficiency and overall output, taking into account water flow-rates, turbine efficiencies, and turbine condition. The results of this analysis should be completed by the second half of 2009. RWE will then use the data to compile an economic evaluation of the business case for replacing conventional generators with generators based on superconductor components in run-of-river hydro plants. In total, RWE operates ten run-of-river hydro plants in Germany, which together generate over 800 GWh of electric power annually.

Source:
"RWE Hydro Power Contract"
Zenergy Power press release (February 9, 2009)
http://www.zenergypower.com/images/press_releases/2009-02-09-rwe.pdf

American Superconductor Corporation (February 10, 2009)

American Superconductor Corporation (AMSC) has entered into a Cooperative Research and Development Agreement (CRADA) with the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and the National Wind Technology Center (NWTC) to validate the economics of a 10-MW-class superconductor wind turbine. CRADA agreements enable the Federal government and industrial partners to optimize resources, share technical expertise in a protected environment, and speed the commercialization of technologies. As part of the 12-month agreement, AMSC Windtec™ will analyze the cost of a full 10-MW-class superconductor wind turbine including a direct-drive superconductor generator and all other components. The NWTC will then benchmark and evaluate the wind turbine's economic impact. In parallel with the CRADA agreement, AMSC and the TECO-Westinghouse Motor Company will continue to develop HTS and related technologies for a 10-MW-class direct drive wind generator as part of a project funded by the National Institute of Science and Technology's Advanced Technology Program (ATP).

The industry research firm Emerging Energy Research recently reported that $27 billion was spent on wind turbines in 2007; this figure is expected to double to more than $55 billion annually by 2015.

Source:
"AMSC and U.S. Department of Energy Agree to Collaborate on 10 Megawatt-Class Superconductor Wind Turbines"
American Superconductor Corporation press release (February 10, 2009)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1254866&highlight

Nexans (February 26, 2009)

Nexans has supplied a superconducting fault current limiter (SFCL) to Applied Superconductor Limited (ASL) for a pilot installation in a medium voltage (11 kV) substation in Lancashire, UK. The SFCL will be used to optimize the performance and safety of the local power network. As well, the pilot installation will serve as a practical demonstration of the benefits provided by SFCLs, which are expected to play an increasing role in meshed networks, the connection of renewable energy sources, and future Smart Grids. Dr. Joachim Bock, Managing Director of Nexans SuperConductors, commented, "The threshold of superconducting fault current limiter commercialization is being crossed with this project. Further limiters for medium voltage applications and with varying specifications are in production. Adapting them to specific customer needs, such as to protect power plant auxiliary networks, can easily be achieved, thanks to the

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modular nature of the device. With this product we have progressed up the value chain from material via component to system, to provide our customers with the optimum solution." Nexans SuperConductors designed and assembled the SFCL, including the cryostat; the current limiter has already successfully undergone high-voltage tests as well as a full series of short-circuit tests.
Source:
"Nexans supplies innovative Superconducting Fault Current Limiter to Applied Superconductor Ltd. for pilot UK installation"
Nexans press release (February 26, 2009)
http://www.nexans.com/eservice/Corporate-en/navigatepub_142482_-20191_297_2579/Nexans_supplies_innovative_Superconducting_Fault_C.html

Sensor

Delft University of Technology (February 2, 2009)

Researchers at the Delft University of Technology (The Netherlands) have used superconducting tunnel junctions to drastically improve the functioning of a radiation sensor that will serve as a major component of the Atacama Large Millimeter Array (ALMA) of supertelescopes that are being constructed in Chile. The ALMA consists of 66 advanced telescopes placed at an altitude of 5,000 m; the array is anticipated to represent a major step forward in the field of astronomy when it becomes operational in 2012. Using aluminum nitride in place of aluminum oxide, the researchers were able to construct nanostructures with vastly superior homogeneity and sensitivity. This research will also be applicable to the Herschel Space Telescope, which is due to be launched in April and will be used as a successor to the Hubble telescope. The Delft University of Technology has developed many of the tunnel junctions that are crucial for the Hershel Telescope's measuring equipment.
Source:
"Nanotechnology makes supertelescopes much more sensitive"
Delft University of Technology press release (February 2, 2009)
http://www.tnw.tudelft.nl/live/pagina.jsp?id=08a577a7-209b-43f6-b85b-6d74fb4a629c&lang=en

Accelerator

CERN (February 6, 2009)

A recent workshop has provided CERN management with a set of recommendations for the restart schedule of the Large Hadron Collider (LHC). If accepted, these recommendations should ensure that the LHC begins producing physics data in late 2009, with ongoing operation throughout the winter and continuing until autumn 2010. This schedule would ensure the collection of a sufficient amount of data to produce the first new physics results.

One of the topics discussed at the workshop was the underlying cause of the incident that led to the temporary shutdown of the LHC. Since this incident, considerable progress in the detection of small anomalies has been made, and a new early warning system will be installed and fully tested prior to the restart of the LHC. Examinations have also revealed two additional suspicious connections, one of which

has been investigated and will be corrected. Steve Myers, CERN's Director for Accelerators, commented, "CERN's priority for 2009 is to get collision data for the experiments, but with caution as the guiding principle. The recommendations made to the CERN management are cautious, while achieving the goal of running this year."
Source:
"CERN to set goals for first LHC physics"
CERN press release (February 6, 2009)
http://press.web.cern.ch/press/PressReleases/Releases2009/PR01.09E.html

CERN (February 9, 2009)

CERN management has confirmed the recently proposed restart schedule for the Large Hadron Collider (LHC). According to the new schedule, the first beams will be produced at the end of September 2009, with collisions initiated in late October. With the exception of a short technical stop in December, the LHC is then scheduled to run through to autumn 2010, thereby ensuring the accumulation of a sufficient amount of data to enable the first new physics analyses, with the subsequent release of results in 2010. The new schedule would also permit the possible collision of lead ions in 2010. Rolf Heuer, CERN Director General, commented, "The schedule we have now is without a doubt the best for the LHC and for the physicists waiting for data. It is cautious, ensuring that all the necessary work is done on the LHC before we start up, yet it allows physics research to begin this year."

The new schedule is delayed by six weeks, compared with earlier forecasts that predicted the LHC would be "cold at the beginning of July." The delay was partly caused by the implementation of an enhanced protection system and early-warning features.
Source:
"CERN management confirms new LHC restart schedule"
CERN press release (February 9, 2009)
http://press.web.cern.ch/press/PressReleases/Releases2009/PR02.09E.html

Basic

Queen Mary, University of London (February 22, 2009)

Researchers at Queen Mary, University of London and the University of Fribourg (Switzerland) have reported evidence indicating that magnetism is involved in the mechanism responsible for high-temperature superconductivity. The researchers observed that oxypnictides, a new class of high-temperature superconductors, are similar to copper-oxide high-temperature superconductors in that in both materials, superconductivity emerges from a magnetic state. Dr Alan Drew from Queen Mary's Department of Physics, commented "Last year, a new class of high-temperature superconductor was discovered that has a completely different make-up to the ones previously known - containing layers of Arsenic and Iron instead of layers of Copper and Oxygen. Our hope is that by studying them both together, we may be able to resolve the underlying physics behind both types of superconductor and design new superconducting materials, which may eventually lead to even higher temperature superconductors." The group's research was reported in *Nature Materials*.
Source:
"Secrets behind high temperature superconductors revealed"
Queen Mary, University of London press release (February 22, 2009)

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http://www.qmul.ac.uk/news/newsrelease.php?news_id=1196
(Akihiko Tsutai, Director, International Affairs Division, ISTEC)

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Feature Articles: ISS2008 Topics

- The 21st International Symposium on Superconductivity (ISS2008) –

The opening ceremony

The International Superconductivity Technology Center (ISTEC) held the International Symposium on Superconductivity (ISS2008) at the Tsukuba International Congress Center, Japan, over three days from October 27 (Mon) to 29 (Wed), 2008. ISS is held every year with the purpose of promoting development of superconductor industry technologies by presenting the findings of domestic and overseas research and technology development concerning superconductivity and through international exchange. It also aims to promote greater public understanding of superconductivity. ISS was held for the 21st time this year. At this year's symposium, 684 participants took part including 157 delegates from 18 participating countries, making it a very well attended event. Seventy-five invited speakers gave a total of 498 talks, with 130 oral presentations and 368 poster presentations. The articles behind the presentations will be published in a special edition of the journal Elsevier Physica C. An exhibition of superconductor-related materials, products and technologies was held at the same time by nine companies and associations.

On the first day, Dr. S. Tanaka, Honorary Director General of SRL/ISTEC gave the opening address, followed by a congratulatory speech from the guest of honor T. Nikai, Minister of Economy, Trade and Industry (delivered by O. Tsukamoto, Director-General of the Kanto Bureau of Economy, Trade and Industry). Two special plenary lectures and six plenary lectures were delivered with introductions from K. Takita (University of Tsukuba) and Paul M. Grant (Stanford University), the chairpersons of ISS2008 Program Committee. For the special plenary lectures, Y. Shiohara (ISTEC/SRL) spoke on the topic of "Japanese efforts on coated conductor processing and its power applications; - New 5 year project for materials and power applications of coated conductors (M-PACC) -, while J. W. Spargo (Northrop Grumman Space Technology) gave a talk on "Superconducting technologies for very high-end computing". For the plenary lectures, Y. Onuki (Osaka University) spoke on "Superconductivity in heavy fermion systems", D.F. Lee (Oak Ridge National Laboratory) spoke on "Progress in the development of 2G wires and tapes in the USA", K. Matsumoto (Kyushu Institute of Technology) spoke on "Challenge of nanotechnology applications to votex pinning in high-T_c superconductors", J. Maguire (American Superconductor Corporation) spoke on "Status of high temperature superconductor cable and fault current limiter projects at American Superconductor", K. Tanaka (SII Nano Technology, Inc.) spoke on "Transition-edge sensor systems for materials analysis using electron microscope ¥", and H. Ikuta (Nagoya University) spoke on "Processing and magnetization techniques of bulk superconductors to fulfill

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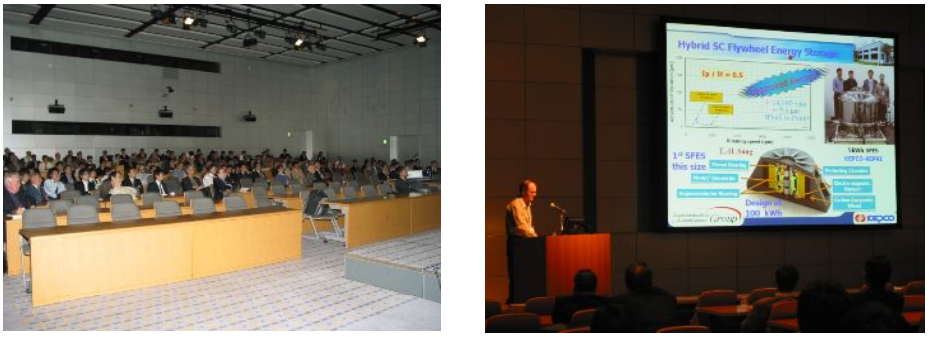
requirements from practical applications". A banquet was held in the evening, providing the participants with an opportunity for lively exchanges.

On the second and third days, there were oral presentations on five fields, physics and chemistry/vortex physics, bulks and characterization, wires/ tapes and characterization, films/junctions and electronic devices, and large scale system applications. Two poster sessions were also held with intensive reporting and discussion.



Oral session

In the physics and chemistry field, two topical sessions were planned entitled "Relation between Pseudo-Gap and Superconducting Gap in High-T_c Cuprates" and "New High-T_c Superconductors, Oxypnictides", with discussion of the latest topics such as new superconductor materials and superconductivity mechanisms. In the bulk superconductor field, there were reports and discussion on the latest topics and findings, including research into manufacturing processes for large-sized devices and improving critical current, as well as evaluation technologies for practical applications. In the wire and tape field, there were reports and lively discussion concerning the findings in leading edge technology development concerning yttrium-based high-temperature superconductor wire and tape in Japan, America and Europe, techniques for evaluating characteristics such as current density and AC loss in tape wire, and applications in the power component field. In films/junctions and electronic devices field, there were reports on the topic of the SQUID yttrium-based high-temperature superconductor and filter development, as well as on findings in the development of highly integrated devices such as AD converters, routers and SFQ processors using Nb-based low-temperature superconductors and ultra high-speed low-power consumption servers.

In the large system applications field, there were reports on developments and progress including industrial applications such as superconducting magnets and motors, generators and transformers, and magnetic levitation bearings, as well as verification testing of power system applications including cables, SMES, and current-limiting devices

In closing on the third day, there were roundups of the respective presentations by S. Tajima (Osaka University) for the physics, chemistry and vortex physics field, I.-G. Chen (National Cheng Kung Univ.) for the bulk superconductor field, D. F. Lee (Oak Ridge National Laboratory) for the wires and tapes field, N. Yoshikawa (Yokohama National University) and H. Myoren (Saitama University) for the films/junctions and electronic device fields, and P. N. Barnes (Air Force Research Laboratory) for the large system applications field. Finally there was a closing speech from Y. Kiyokawa, ISTEC Senior Managing Director and Chairperson of the ISS2008 Steering Committee, inviting everybody to ISS2009, scheduled to be held in

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Tsukuba for three days from November 2 (Mon) to 4 (Wed). This brought to a close this highly successful event.


Poster session

(Masaharu Saeki, Director, Public Relations Division, ISTEC)

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Feature Articles : ISS2008 Topics - Physics and Chemistry -

Setsuko Tajima, Professor
Graduate School of Science
Osaka University

In this field, there were more than 130 presentations, and here we will summarize the lectures from two topical sessions (TS).

In the TS "The relationship between pseudogap and superconducting gap in cuprate superconductors", participants intensively discussed the genesis of the pseudogap that arises from temperatures far higher than the superconducting transition temperature (T_c). There are two opposite views of the pseudo gap—that it is a precursor phenomenon of superconductivity, and that it is an ordered state in competition with superconductivity. Based on angle-resolved photoemission spectroscopy (ARPES) measurement, Kaminski (Iowa University) and Tanaka (Osaka University) reported that the superconducting gap and pseudo gap are not simply a matter of differences in energy, but also entirely different *k*-dependence, temperature dependence, and doping dependence. Y. Kosaka (RIKEN) reported that in observations with a scanning tunneling microscope, the superconducting gap could not be observed in half of the Brillouin zone, and as a result, the outside was in a non-coherent state corresponding to the charge-ordered state. On the other hand, although tests of the Nernst effect represent the most effective argument for the pseudo gap as a precursor to superconductivity, Behnia (ESPCI) reported that even in NbSi thin film BCS superconductors, the Nernst signal is observed from temperatures 30 times the superconducting transition temperature, contending that cuprates alone are not special. Drew (Maryland University) reported that measurement of the infrared Hall effect indicates that extremely small Fermi pockets were formed in underdoped areas. As theories for the causes of this pseudogap formation and change in the Fermi surface, Jarrell (Cincinnati University) proposed strong electron correlation, while Kontani (Nagoya University) proposed spin fluctuation.

In the other TS, "Fe-oxypnictide, a new high temperature superconductor", there were lectures on the new superconductor discovered in February this year from the Hosono Group at Tokyo Institute of Technology that discovered it, followed by the Chinese research groups that rapidly thereafter succeeded in raising the transition temperature, and researchers in theoretical calculation. The current highest temperature is 55 K reported for SmFeAs (O, F) (Ren: Chinese Academy of Science), but superconductivity has been discovered in a total of four types of layered iron compound. Points of particular interest include; When Fe in CaFeAsF is replaced with 10 % Co, superconductivity occurs (Hirano: Tokyo Institute of Technology); The temperature is sensitive to the bond length and angle of Fe/As (Lee: AIST); Anisotropy is not very high at about two to five (Wen: Chinese Academy of Science); It appears to be an *s*-wave superconductor (Kondo: Iowa University).

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Feature Articles : ISS2008 Topics
- Bulks and Characterization -

In the BL session for bulk superconductor reports there were 25 reports on fabrication methods for REBCO bulk superconductors, characteristic improvement and evaluation, 10 presentations on applications, nine presentations on improving the characteristics of MgB_2 polycrystals, and five presentations on fabrication methods and evaluation of single crystalline Bi-based superconductor In the SA session, there were about eight presentations on applied development using bulk superconductors. Below we report on several interesting presentations.

First, H. Ikuta (Nagoya University) reported on a method of improving the characteristics of J_c-B by replacing the planar site Cu with Zn, the chain site Cu with Co, and the Ca of the RE site either singly or jointly, as well as on pulse field magnetization. K. Iida (IFW, Germany) gave an interesting report on recycling bulk superconductors. When a GdBCO bulk superconductor was well pulverized and then melt-processed once again, a largely equivalent bulk superconductor was fabricated. As a technology for suppressing defects and improving strength, Fujimoto et al. (RTRI) reported that fabrication in oxygen improves the mechanical strength of densified bulk GdBCO superconductors. X. Chaud et al. (CNRS, France) reported that it is possible to fabricate bulk superconductors with no cracks in a very short time by applying heat treatment in high-temperature, high-pressure oxygen. S. Horii (University of Tokyo) showed that biaxial orientation can be obtained by using the differences in the magnetic susceptibility of the axial direction of each crystal in a layered oxide and the configuration of the crystals, and applying static and rotating magnetic fields in combination. This represents an interesting new development in magneto-science. In terms of applications, interesting results continue to emerge using the characteristics of bulk superconductors such as non-contact stable levitation and small, powerful magnets. Applications for levitation including flywheels, actuators, mixers and spin coaters were reported. Here, K. Nagashima et al. (RTRI) reported that they were able to obtain extremely high force for lift of 9000 N using a superconducting magnet designed to have a high field gradient, and a bulk GdBCO superconductor with a diameter of 60 mm. This is expected to be used for flywheels for railway applications. T.H. Song et al. (KEPRI, Korea) are developing flywheels for electric-load leveling. They have already completed testing up to 10 kWh, and they have begun building a 100 kWh-class flywheel. Here, bulk superconductors are used as radial magnetic bearings to control lateral vibration. Other applications using the characteristics of bulk superconductors were reported such as a magnetic drug delivery system (MDDS) and magnetic separators using their high magnetic gradients, as well as R&D for compact NMR using their internal homogeneous magnetic field.

(Naomichi Sakai, Advanced Materials & Physics Division SRL/ISTEC)

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Feature Articles: ISS2008 Topics
- Wire and Tape Materials and Characteristic Evaluation Field -

For the ISS2008 session on wire, there were 29 oral presentations and 100 poster presentations, of which one covered LTS, 12 covered MgB_2, 12 covered bismuth-based wires, and 97 covered Y-system coated conductors. For MgB_2 wire, there were several reports about doping materials, concerning both In-situ and Ex-situ methods from National Institution for Materials Science (NIMS) and others, and methods using nanocrystal powder from Leibniz Institute for Solid State and Materials Research Dresden. Sumitomo Electric Industries gave a presentation on progress in the DI-BSCCO method for bismuth-based wire, and there were presentations on bending strength (Kyoto University), barrier materials (Toyohashi University of Technology) and other topics. Below, we summarize the main contents on the coated conductors which were the most common topic of the presentations.

In the Special Plenary session, Yuh Shiohara of ISTEC gave a review of the Fundamental Technology Superconductivity Applications Project that finished at the end of March this year, and introduced the content of the new project starting this fiscal year. The main aim of the fundamental application project was the process development of coated conductors. In this project, Fujikura successfully fabricated an IBAD (GZO)–PLD (GdBCO) tape with *Ic* value of 350 A/cm-width over 500 m (WT-2 Kutami). ISTEC has achieved high-performance 50-m-class wire with end-to-end *Ic* performance in excess of 500 A/cm-width (WT-9 Yamada). In a process for introducing pinning centers in order to improve characteristics in the magnetic field, tapes incorporating BZO nanorods achieved I_c (min.) of 30.5 A/cm-width at 77 K and 3 T, and 61 m tape using this material was successfully fabricated (WT-9 Yamada). As an approach to achieving low cost with this combination, development IBAD-MgO layer is progressed, and a 500 A/cm-width over 40 m long has been already obtained. In addition, as a development of technology for forming superconducting layers by the PLD method lowering the cost, development of in-plume PLD techniques has been developed. On the other hand with a combination of an IBAD substrate and TFA-MOD superconducting layer, ISTEC found that the Ba-deficient starting composition is effective for high-J_c technology, achieving an extremely high *Ic* performance of 735 A/cm-width (WT-15 Izumi). As an implementation of this technology, Showa developed a batch-type heat-treatment system for TFA-MOD process and successfully fabricated 500 m long tape with confirmed performance of at least 310 A/cm-width (WT-05 Aoki). Furthermore, ISTEC developed the process introducing pinning centers in TFA-MOD film. In this development, uniformly distributed BZO nanodots in YGdBCO or YSmBCO films were achieved and and confirmed isotropic I_c characteristics in relation to an applied magnetic field obtaining I_c (min.) of 35 A/cm-width at 77 K and 3 T (WT-15 Izumi & WT-16 Kato).

As a consequence of these findings, the new project starting this fiscal year aims to select SMES, electric power cables, and transformers from among the power applications and to verify their applicability in a small scale. As well as developing these three types of equipment, the development of coated conductors is still continued to realize the specifications for characteristics, cost and so on required for commercialization stages.

In other activities in Japan, Prof. Matsumoto of Kyushu Institute of Technology reviewed artificial pinning control technologies in the plenary lecture, comparing the pinning forces in the various types of pinning. BZO nanorod pins which have been used successfully by many organizations with PLD films have pinning force of 17 GN/m^3, demonstrating a high pinning effect. As a recent topic, Prof. Matsumoto introduced the phenomenon where the BZO nanorods bend in thick films, which has a significant effect on their magnetic

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field characteristics, particularly their field angle dependence. The bending behavior of $BaSnO_3$, rods in thick films, which is a similar pin material, is different, showing high linearity in the same film thickness. As a new topic on a different theme, Dr. Kutami of Fujikura talked about fabricating a 6 μm-thick GdBCO film using high-power PLD deposition technology, achieving the high I_c value of 1,040 A/cm-width.

In a Plenary Lecture (PL-2) on trends overseas, Dr. Lee gave a roundup of the state of development in the US. Concerning the development of coated conductors, SuperPower Inc. is taking the lead and has already s fabricated IBAD (MgO)-MOCVD (REBCO) tape over 1 km long (1.3 km. × 153 A/cm), obtaining high I_c of 302 A/cm-width at 630 m. (WT-1 Xie). Another development entity, AMSC is developing a wide tape processes by forming superconducting layers with the TFA-MOD method on textured metal substrates with the aim of starting up mass-production facilities. The company has also achieved long length wire with *Ic* performance of 250 A/cm-width over 200 m (WT-6 Fleshler). As venture companies, both are strongly focused on commercializing coated conductors, and are working quickly to achieve mass production. Both AMSC and SuperPower explained that their pilot lines can produce tapes at rate of 100 m/h. In addition, concerning thick film products, at LANL performance of 1,500 A/cm-width at 75.5 K has been confirmed in 9 μm-thick PLD-YBCO film, and even in a magnetic field, performance of 400 A/cm-width at 75.5 K, 1 T was obtained. Concerning artificial pinning centers, ORNL achieved a PLD-YBCO film of 4 μm containing BZO, and even at 65 K, 3 T, high I_c value of was obtained. In addition, SuperPower succeeded in improving the characteristics of B//c orientation by doping YGdBCO tapes with Zr, achieving high performance of 250 A/cm-width at 65 K, 3 T with a film of 3.3 μm thick.

(Teruo Izumi, Directors of Superconducting, Tapes & Wires Division SRL/ISTEC)

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Feature Articles: ISS2008 Topics - Films, Junctions and Electronic Devices

On the first day, J. W. Spargo of Northrop Grumman gave a special keynote speech on the Single Flux Quantum (SFQ) processor project recently begun in USA. This was descended from the Hybrid Technology Multi Threaded (HTMT) project in the 1990s and the Superconducting Technology Assessment (STA) report prepared in 2005, and it is aimed towards very High End Computing (HEC). When this project gets fully up and running, it will be financed to the tune of $437 million over five years. It is an ambitious project with the goal of establishing technologies for mass fabrication of SFQ processors with clock frequency of 50 GHz or more and 100,000 gates/cm^2. A small advanced research project started recently, but it is expected to be expanded in future.

In a keynote speech, K. Tanaka of SII Nano Technology reported on Transition Edge Sensors (TES) for materials analysis. TES are sensors that use the sharpness of superconductive transition, and with energy resolution of 15 eV or less at electron beam of 1.5 KeV, they offer overwhelming performance in compared with other sensors such as semiconductor detectors. They developed a TES system with a cryocooler that can be used in conjunction with an electron microscope (TEM or SEM), and verified its performance with various samples. SII Nano Technology is scheduled to make this system available for sale next fiscal year.

NICT reported on experiments in quantum communication over 100 km using NbN Superconducting Single-Photon Detectors (SSPD), obtaining a communication speed of 12 kb/s. This system used six-channel SSPDs, and stable operation was confirmed for more than 10 hours. As applications of Superconducting Quantum Interference Device (SQUID), the report from Research Center Juelich and Toyohashi University of Technology on lower field NMR and on Hitachi's unshielded SQUID magnetocardiograph were very interesting, because they were directly linked to real applications . SRL reported on results of nondestructive tests for high-temperature superconducting wire using high-temperature SQUID. Wire was inspected for detecting defects at a speed of 30 m/h using a five-channel SQUID. Fujitsu and Yamagata University reported on power filters for transmissions. The target is 100-W class, and a 10-W class filter was demonstrated. Tsinghua University reported on the spread of superconducting filters for mobile-phone base stations in China. Eight superconducting CDMA base stations are operating, and more than 200,000 people are conversing via superconducting filters.

M. Dorojevets of Stony Brook University (SBU) introduced the architecture of processors planned in USA, From November this year SBU and HYPRES will jointly conduct a 15-month project, and their announced intention to develop an 8-bit, 15,000-junction SFQ circuit operating at 20 GHz or more. From Japan, which is taking the lead in this area, an SFQ Processor Project (Nagoya University, Yokohama National University, Kyushu University and SRL) reported operations of several circuits, such as floating-point adder and multiplier, whose clock frequencies were in excess of 20 GHz using over 10,000 junctions. In addition, cell libraries are being developed for a new niobium 10-layer process, and circuit including 1,000 junctions was operated at twice faster speeds compared with convetional SFQ circuits. SRL reported successful operation of a 10,000-junction shift register circuit to assess the reliability of the new process. SRL also reported increasing critical currents across Josephson junctions caused by hydrogen diffusion were prevented by introducing a molybdenum layer, and operation of SFQ circuits with 40 Gb/s optical input.

(Mutsuo Hidaka, Director, Low Temperature Superconducting Device Division SRL/ISTEC)

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Feature Articles: ISS2008 Topics - Large System Applications

The Large Systems Applications session consisted of 15 oral sessions and 64 poster lectures. Below we report on several presentations including the keynote speech on the first day.

AMSC reported on the state of progress in the LIPA (Long Island Power Authority) cable project using bismuth-based wire. Operation started from April this year, and the cable continues to perform as expected. The second stage of this project involves replacing part of the line with yttrium-based wire. Additionally, as part of the DOHS project HYDRA, yttrium-based cable with a current limiting function was demonstrated. Tests of a 115 kV current-limiting device at a Southern California Edison substation were also reported.

The Korea Electric Power Research Institute (KEPRI) reported on superconducting flywheels for power storage. After completing development and evaluation of a 5 kWh-class flywheel using liquid nitrogen cooling, the findings were used for development of a 100 kWh-class flywheel. KEPRI reported that system design is complete, the superconductor bearings have been fabricated, and trials are underway.

The High Energy Accelerator Research Organization reported on the cryomagnets used in the European Organization for Nuclear Research (CERN) large accelerator. The large accelerator known as Large Hadron Collider (LHC) is an accelerator for identifying the unknown particles of high energy physics. The magnets of the accelerator are made up of Nb-Ti superconducting magnets, which are installed in the 27-km circular tunnel of the accelerator. There was also a report on the ATLAS particle detector. In terms of shape, dimensions and weight, it is the world's biggest superconducting magnet and it was constructed over eight years from 1998.

Furukawa Electric reported on development of high temperature superconducting cable. The company has achieved a low-cost, 1-m conductor with low current loss of 0.048 W/m at 1 kA. Furthermore, a 20-m conductor including connectors passed a 2-second overcurrent test at 31.5 kA, meeting the R&D targets.

Sumitomo Electric Industries reported on a high temperature superconducting cable demonstration project planned by Tokyo Electric Power Company. Aiming to develop a 200 to 300 m 66 kV 200 MVA-class cable, the company installed a 3-core high temperature superconducting cable in TEPCO's Asahi Substation for verification on a 5-year plan from 2007. The report covered the shape of the cable, evaluation of the impact of lightning surges and so on.

Taiyo Nippon Sanso Corporation reported on the development of a turbine neon cryocooler that uses only a few kilowatts, for motors, transformers and cables. The expanding parts have no mechanical friction, and the cooler achieves maximum revolutions of 96,000 rpm at 70 K. The company reported that further development to improve refrigeration efficiency and to reduce the weight and size of the cooler is required for future commercialization.

Kyushu University reported on the development of a superconducting transformer in its yttrium-based superconducting power component development project. They reported that, based on verification of conduction in a multilayer parallel conductor with low current loss through filamentation of the wires, it is possible to achieve a superconducting transformer. The researchers intend to build and test a 2 MVA-class transformer towards achieving a 20 MVA class transformer in future.

(Takashi Ito, Acting General Manager, Electric Power Equipment Division SRL/ISTEC)

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Feature Articles: Superconducting Microwave Device Technology
- The Prospects for Superconducting Microwave Device Technologies -

Shigetoshi Ohshima, Professor
Graduate School of Science and Engineering
Yamagata University

In 2005, a Review Board for the strategic map for superconductor technology was organized by researchers and engineers from universities and companies. The Board conducted an investigation into strategies for commercializing superconductor technologies, proposing a strategic map and implementation scenario in March 2006. In the field of information and communications, superconducting devices including computer and network equipment (principally SFQ routers and switches and SFQ computers and servers) and wireless access system equipment (principally AD converters for wireless, receive filters, transmit filters, and satellite communications equipment) were suggested as important issues for consideration. Three years have passed since then. How do developments now stand? Here we will look at the prospects for recent superconducting microwave device technologies, and compare the original roadmap with the current situation. In particular, I would like to discuss the superconducting microwave device technologies related to wireless access systems, which have a deep relevance to my research.

The roadmap proposed in March 2006 envisioned that the following technologies would be established and widespread in 2009, three years hence.

A. Superconducting filter technologies for receiving:
Available for about two million yen per system.

B. Superconducting filter technologies for transmitting:
Filters up to 30 W-class

What is the current state of these two technologies now?

A. Superconducting filter technologies for receiving

The cost of superconducting filters can be roughly divided into the price of small refrigerator systems (including vacuum chambers etc.), the price of superconducting filters, and the price of electronic devices (control systems, amplifiers etc.) Recently, small refrigerator technologies have made significant advances, and Fuji Electric Systems Co., Ltd. sells a 77 K · 1 W pulse tube cryocooler for less than 1.5 million yen. The price of superconducting filters is largely determined by the price of thin films. Unfortunately, the only company that can yet provide reliable superconducting thin film is THEVA of Germany. Although several Japanese companies are considering working towards commercial sales, demand is hard to forecast and progress is at a standstill. Electronic devices can be fabricated at largely the same price as current room temperature filters, so this is not a problem. The low-temperature Low-Noise Amplifiers (LNA) specific to superconducting filters has also been achieved without difficulty. Therefore, the forecast cost of two million yen from three years ago is still far off, but we are steadily drawing nearer to the target price.

B. Superconducting filter technologies for transmitting (superconducting filters for high-power systems)

Another field of application of superconducting filters is filters for transmitting. Existing transmit filters have limited out-of-band rejection properties and poor skirt characteristics. Accordingly, it is difficult to use frequencies effectively, and coupling loop interference from other signals in the station cannot be

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suppressed. Therefore, amplifiers for transmitting must be designed to be above specification, which invites cost overruns. If filters for transmitting can be made with superconductors, out-of-band rejection properties can be raised to 60 dB and above, and skirt properties can be increased, it will be possible to reduce the cost of current transmission systems. Superconducting filters for transmitting are still at the research and development stage. Here I will present some of the examples reported over the last few years.

Japan: The organizations that are actively examining superconducting filters for high-power systems are Fujitsu, Toshiba, and Yamagata University. Fujitsu is researching dual mode filters using disk-shaped resonators, and has succeeded in developing a filter that can withstand several dozen watts. Toshiba is proposing composite filters combining superconducting thin films and dielectrics, and the company has succeeded in developing a filter that can withstand several hundred watts. Yamagata University is proposing bulk filters and planar filters using split microstrip lines, reporting filters that can withstand several watts.

What sort of research is being carried out overseas into superconducting filters? The main research institutions engaged in superconducting filter R&D are now limited to Birmingham University in the UK (Prof. Lancaster), Tsinghua University in China (Prof. Cao), the University of Science and Technology of China (Prof. He), Dayeh University in Taiwan (Prof. Wang), and the group at STI Inc. in the US. Cryoelectra of Germany and RFtron in Korea are active in the field, but are generally not publishing papers and so on. Of the research institutions above, it is Prof. Cao's group that is publishing most papers. In the last few years, high-power filters, super narrow bandpass filters, tunable filters and the like have been announced in succession.

Superconducting microwave devices, particularly high-power bandpass filters, group delay lines, multiplexers for satellite communications and so on offer extremely high performance, and hold out strong potential for practical applications. However, compared with other typical communications devices, they have been stigmatized as expensive, unreliable, and high-maintenance, so that they face an uphill struggle. It is important to eliminate this stigma, and this issue affects all superconducting equipment. It is critical to reverse the image of superconducting equipment. We must also work in the spirit of "*Yes, we can*".

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Feature Article: Superconducting Microwave Device Technology - Superconducting devices and front-end for transceiver -

Kazunori Yamanaka, Kazuaki Kurihara
Mobile Systems Unit,
Fujitsu Limited

Research and development of high-T_c oxide superconductor (hereafter, HTS) filters used for radio receivers in the Ultra High Frequency (UHF) to low microwave band has made more rapid advances than HTS filters that handle larger microwave power. Wireless applications of microwave power HTS filters include, among other components, wireless base stations and transponders for frequency selection in radio frequency (RF) transmitters[1)] (Fig. 1). Although there are many conditions including frequency band, frequency bandwidth, and power requirements according to the application, within the same wireless system, in many cases the transmit filter uses higher power, in the range of several dozen to several hundred decibels (dB), than the receive filter. By using a filter with high Q characteristics and high frequency-selectivity, it is possible to reduce unwanted components (out-of-band and/or spurious signals) in electromagnetic wave radiation from the transmitter output. This should be effective in reducing interferences between many kinds of wireless systems. For example, it should be possible to set up high-sensitivity receivers of a different wireless system that uses adjacent frequencies. Therefore, HTS transmit filters appear to be a promising candidate for raising the performance of transmitter systems. Below we look at some methods of improving the power characteristics of HTS filters and technologies for incorporating them in devices, including R&D undertaken by the authors already mentioned here[1)].

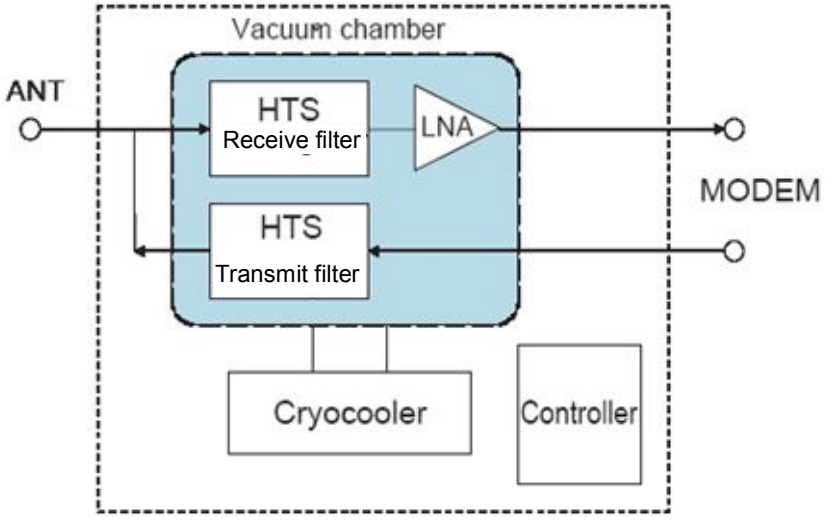

Fig.1 Block diagram of HTS send-receive front end

As shown in Fig. 2, compared to the resonators often used for receiving which have relatively narrow line-shaped patterns, resonators with disk-shaped patterns (hereafter, disk patches) for improving the handling of higher power and the multistage filters with the disk patches also can be considered effective. However, when they have a multistage structure, the dimensions of the filter are relatively larger, so that

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electromagnetic coupling between the resonators is difficult to control. By developing prototypes of HTS disk-patch dual-mode resonators that had unique circuit-patterns and filter characteristics with attenuation poles out of the wanted frequency band[1], the conditions for obtaining third-order intermodulation distortion (IMD3) characteristics of -70 dBc or less at 10 W[2, 3] in the 5 GHz band were clarified. In addition, we developed methods of improving power characteristics, etc. by placing a dielectric plate on the disk pattern[4, 5]. It is identified that the issues of coupling between the dual-mode disk-patch resonant circuits, and sought improved coupling methods[6]. Furthermore, prototype HTS filters with further multistage of dual-mode disk-patch resonators were made, and those operations[7] were Confirmed.

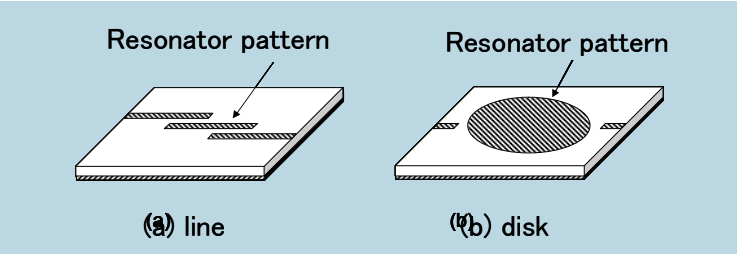

Fig.2 Typical resonance pattern (schema when using a microstrip half-wavelength resonator)

Using these technologies, Prototypes of front-end equipped with both HTS transmit and receive filters, for 5-GHz band wireless station were designed and constructed. The operations were tested successfully[8, 9]. The prototype front-end is built for outdoor use and with a volume of less than 15 L (excluding connectors and other projecting parts). It can be carried by a single person. Pulse tube cryocoolers for installation in the cooling unit of the similar front-ends has been developed with the aim of achieving higher reliability and improving COP[10]. Examinations passing broadband test modulation signals from an RF amplifier through the HTS transmit filters were carried out. As the result of assessing the power spectrum, the spectral characteristics with a good ability to suppress unwanted components[11] were obtained.

Lastly, some part of the technologies mentioned in this report was supported by “Research and development of fundamental technologies for advanced radio frequency spectrum sharing in mobile communication systems” from the Ministry of Internal Affairs and Communications (MIC) of Japan. The authors would like to express our gratitude to the MIC support and the parties concerned.

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Feature Articles: Superconducting Microwave Device Technology - Advances in Superconducting Filter Technologies for Weather Radar -

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In recent years, the use of devices that use radio waves including digital televisions, mobile phones, and wireless LAN is expanding, and expectations are rising for the future of high-speed communications. In order to meet these expectations, it is becoming increasingly important to use the limited frequency resources available effectively, and to ensure an appropriate environment for radio utilization. In particular, use of 5 GHz band wireless LAN has increased explosively, and effective utilization of frequencies is becoming a matter of urgency. At Toshiba, we anticipated the expansion of the 5 GHz band wireless LAN frequency band and carried out R&D towards a 5 GHz band weather radar system operating in a narrower band. In our last report, we reported on a narrow band superconducting filter for receiving that separates out signals transmitted at four times the normal density[1),2)]. Here we report on a narrow-band filter for transmission that reduces spurious in adjacent signals.

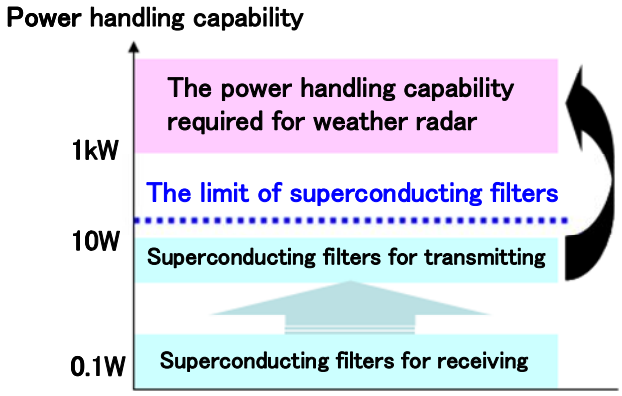

Fig. 1 The power handling capability required for weather

Fig. 1 shows a comparison of the power handling capabilities required of transmission filters for weather radar, and the power handling capabilities of superconducting filters. In general, the power used in receive filters is quite small so that power handling has not been much of a problem. However, the signal power used in transmit filters is bigger, and so the critical current density characteristics of superconductors becomes a significant issue. Although there are reports of superconducting filters for transmission of several dozen watts with a resonator structure to reduce current crowding, they are affected by many problems including power handling capability, narrow band characteristics and distortion. In order to achieve the three-digit or higher power handling capability required of weather radar, we developed a cavity resonator with excellent power handling capabilities and a hybrid filter using a superconducting resonator with excellent narrow-band low-loss characteristics[3)]. Fig. 2 shows the operating concept while Fig. 3 shows the operating principle of the filter. The hybrid filter has a structure that bypasses large amounts of power. Instead, by passing only the spurious of low-powered components through the superconducting resonator we succeeded in achieving both sharp characteristics and high power handling capabilities. Fig. 4 shows an

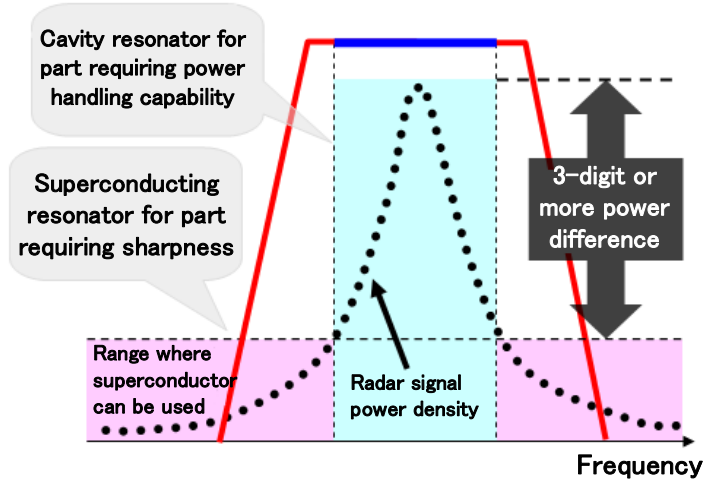

Fig. 2 Hybrid filter concept

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external view of the developed filter unit. It is a 19-inch rack-mounted 15 U sized unit. It achieves filter characteristics of 1.5 dB or lower insertion loss with narrow fractional bandwidth of 0.075 %. In addition, when the filter was connected to the weather radar for testing, operation at 3.5 kW was demonstrated. Unwanted radio emissions can be suppressed by 1/10 or more, and the filter achieves a signal waveform with low intermodulation distortion characteristics of -60 dBc or less. This filter should enable up to four times greater bandwidth utilization efficiency.

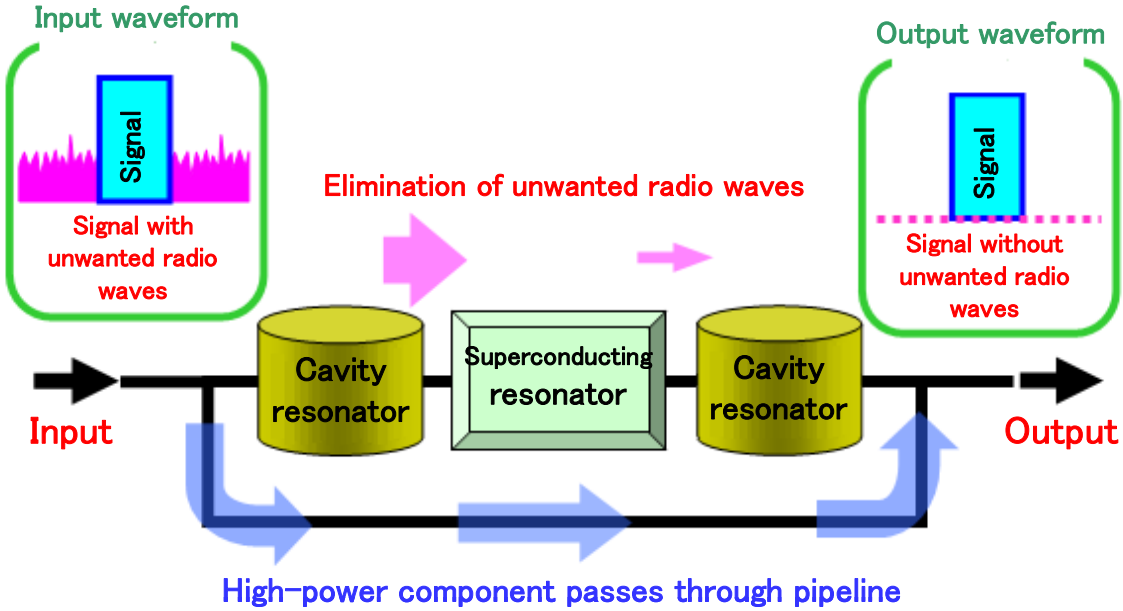

Fig. 3 Hybrid filter operating principle

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Fig. 4 Hybrid filter unit

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Feature Articles: Superconducting Microwave Device Technology - Advances in THz wave oscillator technologies using high temperature superconductors with intrinsic Josephson junctions -

Kazuo Kadowaki , Professor
Materials Science, Graduate School of Pure and Applied Sciences,
University of Tsukuba

About 18 months have passed since the experimental confirmation at the end of June 2007 that strong THz electromagnetic waves are emitted in Continuous Wave (CW) oscillation from the intrinsic Josephson junctions of high temperature superconductors[1), 2)]. Since then, many experimental results have appeared, with subsequent theoretical discussion[3)-9)]. We cannot explore all of them here, but we will discuss the experimental facts and the current understanding.

There can be no doubt that the foundation of this oscillation phenomenon is the AC Josephson effect[10)]. The AC Josephson effect itself is one of the basic quantum mechanical properties relating to the transition between the two energy states of electric charges (or aggregates of charges). It can be expressed as $2eV = 2e(V_2-V_1) = \Delta E_{2,1} = E_2-E_1 = h\nu$ (V_1 *and* V_2 are the electro static potentials of two superconductor electrons, $\Delta E_{2,1}$ is the potential (energy) difference between superconductors, h is the Planck's constant, and ν is the frequency of the electromagnetic wave). There is no difference from the emission of light by atoms[1]. The AC Josephson effect of a single Josephson junction is well understood, and it is now well known that it is used as a voltage standard[2].

A high temperature superconductor is a system comprising serial stacks of these single Josephson junctions, of which a typical example is $Bi_2Sr_2CaCu_2O_{8+\delta}$ (abbreviated as Bi2212). High-temperature superconductivity depends on the CuO_2 plane in the crystal, and since that separation is about 1.5 nm, it is understood that Bi2212 is densely stacked with Josephson junctions at the atomic layer level. If this single crystal Bi2212 is patterned into mesa structures and a direct current is passed through several 100 to several 1,000 layers, strong

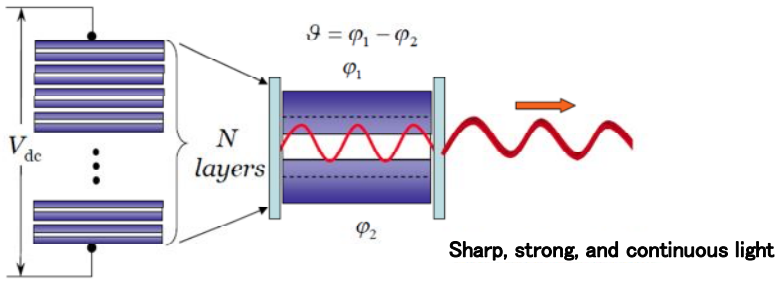

Fig. 1 All the intrinsic Josephson junctions in the Bi2212 enter a synchronized oscillating state, behaving as a single giant Josephson junction. The mesa itself works as a resonator, oscillating as a laser.

[1] One difference is that while atoms transition between the quantum states of a single electron, with Josephson junctions the transition is between quantum levels of multielectron systems. In this case, there are overwhelmingly more numerous degrees of freedom, so that a wide variety of phenomena are possible including continuous energy transitions, individual excitations, and collective excitations.

[2] If the voltage between Josephson junctions is V, the AC Josephson effect is $h\nu = 2$ eV, and the frequency of the alternating current ν is proportional to the voltage. The proportionality coefficient $K_J = 2e/h$ is the ratio of the elementary charge and Planck's constant 0.483597891± 0.000000012 (THz/mV), and is known as the Josephson constant. This is also $K_J = 1/\phi_0$ (ϕ_0 is quantized flux).

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electromagnetic waves in the THz frequency (the frequency is $\nu = 2eV/h$) are obtained as continuous wave oscillation. If single crystals are ideal crystals, the intrinsic junctions are all equivalent so that they are synchronized with quantum coherence and can be expected to operate as a big single Josephson junction. A diagram of the operating principle of this oscillation is shown in Fig. 1.

This oscillation does not occur continuously at any voltage. Another important condition is required for oscillation. This is that the wavelength of the electromagnetic waves λ is limited by the width of the mesas w. With rectangular mesas, this width w corresponds to the short side, as represented by the relational expression $\nu = c_0/n\lambda = c_0/2nw$. Here, c_0 is the speed of light in a vacuum, and n is the refractive index of Bi2212, which is $n = 4.0 \sim 4.1$. This shows that half the wavelength of the oscillating electromagnetic waves is exactly equivalent to the width of the rectangular mesa, which makes it clear that the mesa itself plays the role of a resonant cavity (resonator). Oscillation does not occur unless the AC Josephson effect and the resonance conditions are fulfilled simultaneously[3].

A very interesting point is the temperature dependence of the intensity of the oscillation. In many instances, oscillation is strong in the mid-range temperature region of 20 to 50 K, but at lower or higher temperatures, the oscillation vanishes. Some only oscillate in a narrow temperature range of around 10 K, but the temperature range for oscillation differs significantly with the conditions used for fabricating the mesas (see Fig. 2). This is probably because heat is generated due to the significant resistance when a voltage is applied and the temperature of the mesa easily exceeds T_c. How this heat is eliminated greatly affects the state of oscillation. It is extremely difficult to obtain detailed information such as the heat distribution within the mesas due to heat generation[11]. The temperature inside the mesas differs significantly from that of mesa substrates provided with thermometers, sometimes rising to temperatures in excess of T_c, and they can be inferred to be in a strong nonequilibrium state. In many cases, when the current is reduced from the temperature higher than T_c, it falls below T_c there, it immediately enters the oscillating state if the other conditions are met. In this region, most particles are thought to be quasiparticles, but these experimental facts point unmistakably to the conclusion that if there were no quasiparticles, the superconductor would not oscillate. This comes as major surprise. Figure 2 shows a typical *I-V* curve and the temperature dependence of oscillating intensity. The intensity itself is proportional to the square of

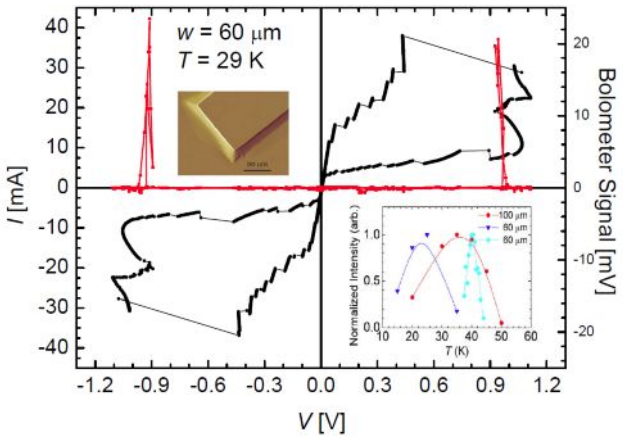

Fig. 2 Oscillation output power of a typical rectangular mesa (red line) and the *I-V* curve (black line). The bottom right of the figure shows the temperature dependence of the output power of three types of mesa (widths of 60, 80, and 100 μm). The output of the detector shows one peak on each of the positive and negative sides of the voltage, which indicates oscillation. On the high voltage side, the junctions are in a state of resistance and the temperature is higher than T_c. The temperature is the temperature of the mesa substrate. The top left of the figure is an AFM photograph of a processed mesa. It is 60 μm wide and 1.2 μm thick. The shape of the mesa is not rectangular but broadens toward the end.

[3] This is a necessary condition, not a sufficient condition. This is because even if the mesas are prepared in the same way, they do not always oscillate. Processing and cooling conditions are thought to be contributing factors in this, but at present, the issue is not well understood.

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the number of intrinsic junctions in the mesa N[1]. In addition, the *I-V* curve itself shows an extremely complex behavior, but we cannot go into that in detail here.

Normally, the electromagnetic energy inside a superconductor exites phonons, and due to loss from the resistance of conducting electrons, it is consumed as heat and decays. Since superconductors have a superconducting gap, there are no quasiparticles in the gap. It is therefore likely that electromagnetic excitation (if it is possible) does not result in decay other than excitation of phonons, so a very stable excited state can be maintained[4]. The existence of this electromagnetic excitation has already been demonstrated in tests with Josephson plasma resonance conducted in the microwave region[12]. It is thought that this excited state is continuously supplied with energy from the AC Josephson effect, with amplification through self-resonance in the mesa structure, and finally, an inverted distribution is formed resulting in oscillation. This is the same as a laser, so it is named a Josephson laser or STAR emitter[5,9]. The observed spectrum width was very narrow, below the limit of spectroscopes currently being used, and the fact that it is about 8 GHz or less also supports this.

It is possible to determine experimentally the electromagnetic-wave excitation mode inside the mesas by measuring the intensity distribution of the electromagnetic waves from a distance. Currently, this experiment is underway and analysis is being undertaken. At present, the oscillation source is experimentally understood to be the largely uniform AC Josephson current inside the mesas, therefore, the mode is the symmetric mode shown in Fig. 3, and harmonic modes are excited.

To begin with, the AC Josephson effect is a typical nonlinear phenomenon. In many serially connected intrinsic Josephson junctions and individual AC Josephson effects work as the oscillation source in a completely synchronized collective excitation mode like a laser, causing quite strong oscillation even in a nonequilibrium state in the vicinity of T_c. These and other points are still not very clearly understood. Recently, theoretical calculation is being undertaken, but it does not necessarily reproduce the experimental results[3)-6)]. There are various possible reasons for this but basically, a methodology for handling this kind of nonlinear phenomenon has not been fully established, and it does not include the effects of finite temperature, particularly nonequilibrium effects. A mathematical approach from the point of

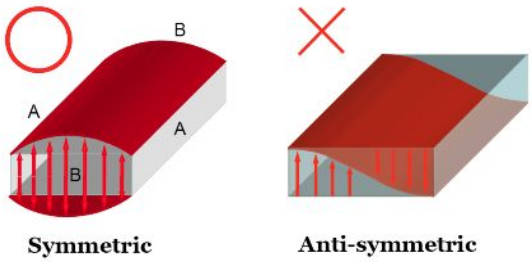

Fig. 3 Electromagnetic wave mode inside a rectangular mesa observed in testing. The arrows show the electric field (Josephson current). The length of the mesa is not considered. Assuming a symmetrical electric field, the following test results can be explained consistently; The intensity of the oscillation is stronger from the long sides (A) than from the short sides (B); it was about 30 – 60 % of the maximum intensity stop of the mesa. ; the intensity is greatest in a direction angled about 30 degrees perpendicular to side A from directly above; in the direction parallel with the substrate plane, intensity diminishes monotonically to zero due to the superconductor substrate; and the electromagnetic waves have a strong linear-polarization light in the direction of the thickness of the mesa. If it is assumed that the electric field is an asymmetric mode, the ~~top~~ mesa intensity top should be maximum and the intensity should diminish monotonically to zero due to the superconductor substrate[9] in the direction parallel with the substrate plane.

[4] Since there are actually quasiparticles at finite temperature, it is likely that the excited electromagnetic waves (plasma mode) decay. This is acceptable with s-wave superconductors, but high temperature superconductors are thought to be d-wave superconductors, and Bi2212 is not an exception. Rather, it is known to have a strong quasiparticle effect in the vicinity of absolute zero. That this THz wave oscillation phenomenon is observed with strong intensity even at T_c where quasiparticles are dominant merits considerable surprise.

[5] STAR is an acronym for Stimulated Terahertz Amplified Radiation.

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view of nonlinear oscillation is a very intriguing new avenue[13]. In closing, I would like to point out that for a complete understanding, there are still many important issues that remain to be clarified.

This research was carried out with experiments by Hidetoshi Minami (lecturer), Takashi Yamamoto (researcher), Kazuhiro Yamaki, Hayato Yamaguchi, and Manabu Tsujimoto (graduate students). I am also grateful to Masashi Tachiki (Professor Emeritus), Dr. Xiao Hu, S. Lin, Shota Fukuya (graduate student), Dr. Wai K. Kwok, Dr. Ulrich Welp, and Dr. Alexei Koshelev (Argonne National Laboratory) for their many valuable insights as joint researchers.

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Feature Articles: Superconducting Microwave Device Technology - Advances in Non-destructive Testing with Terahertz Wave -

Takeshi Yasui
Graduate School of Engineering and Science
Osaka University, Japan

1. Real-time two-dimensional terahertz (THz) tomography

In fields of nondestructive testing and evaluation, it is important to visualize internal structures of an object as a cross-sectional image. Although X-rays and ultrasonic waves have been utilized for this purpose in industrial and biomedical applications, ionizing effect harmful to human health in the former and contact measurement in the latter limit certain applications. Terahertz (THz; freq. = 0.1 ~ 10 THz, wavelength = 30 ~3,000 μm) tomography has recently attracted attention as a possible substitute for these conventional methods because it can serve as a non-ionizing and non-contact probe. THz tomography is realized by the time-of-flight measurement of THz pulse echoes when a THz electromagnetic pulse is incident upon a sample in a reflection geometry. We have applied this technique to non-contact, remote measurement of coating thickness[1)-3)] and human skin[4)]. However, since usual THz tomography is based on a point-to-point measurement, it is necessary to perform 2D mechanical scanning of the time delay and sample position to construct a 2D tomographic image of the sample. The resultant high time consumption of this method has limited its application to stationary objects. If THz tomography can be extended to moving objects, the fields that THz tomography can be applied to will be greatly increased. For this, real-time image acquisition is essential.

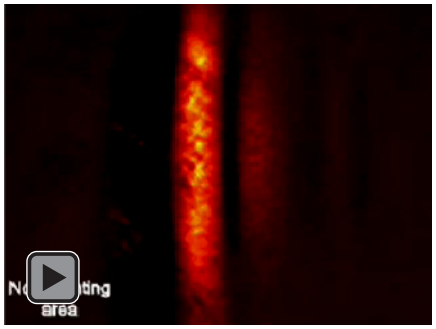

Fig. 1 Real-time THz tomography of moving coating film

Rapid image acquisition can be achieved if instead of a mechanical stage we use an alternative technique for measuring the time delay and sample position. One effective method to realize a stage-free configuration is a combination of a single-shot measurement of the temporal waveform and its one-dimensional (1D) transverse imaging, enabling real-time 2D spatiotemporal imaging. We achieved real-time 2D THz tomography by combing this imaging technique with THz tomogtaphy setup[5)]. To confirm the performance of the proposed method, we have demonstrated real-time 2D THz tomography of a moving object. The sample used in the experiment was a coating film, in which the coating (thickness = 175 μm) is layered on half the area of an Al substrate. Because the THz beam is line-focused on the sample, the sample was continuously moved along the direction of the focus line by a translation stage (moving speed = 5 mm/s). Figure 1 shows the resulting two-dimensional cross-sectional image at a frame rate of 10 frame/sec. The horizontal axis indicates the depth information whereas the vertical axis corresponds to a line image following the THz focused line. Depending on the movement of the sample, one can see that the two-dimensional cross-sectional image changes with the following sequence: Non-coated area > boundary > coated area > boundary > no sample. In the uncoated

Fig. 2 Monitoring of drying process in wet coating film

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area, one THz echo signal from the surface of the flat Al substrate appears. In the coated area, two THz echo lines from the coating surface and the coating-substrate interface are clearly separated. Since the time separation between the two echoes corresponds to optical thickness of the coating film, uniformity of the coating thickness was determined to be 162 ± 21 μm using the group refractive index of the coating (2.14) and the time delay. We next applied the proposed system for monitoring of drying process in the wet coating film. For this examination, a quick-drying coating was made on an Al substrate just before the start of the measurement. A THz tomographic movie of the drying process in the wet coating film was measured over 20 minutes just after coating. Figure 2 shows THz tomographic movie of drying process, which is fast-forwarding movie for 20 min. One can confirm the temporal evolution of the 2D cross-section in the wet coating film with respect to drying progress. The left echo comes from the coating surface and hence relates to change of the geometric thickness of the coating film. On the other hand, the time separation between two echo signals are corresponding to the optical thickness of the coating film. The geometrical and optical shrinkage of the coating film through the wet-to-dry transformation is clearly visualized. Such drying progress is completed at 10 min because the sample is the quick-drying coating. In this way, real-time THz tomography can be used to monitor the thickness and dryness in the wet coating film.

2. THz color scanner

We often use color scanners in our daily work, which is a spectroscopic imaging system using a visible light. However, since the visible light is strongly scattered in opaque objects, probing depth is limited in the vicinity of the surface, resulting in limited use, such as reading of documents. If the color scanner is extended to THz region, in which many non-metal materials are transparent, it is possible to obtain information about the inside of opaque objects. Furthermore, since color, or spectral, THz images can be acquired, it is possible to identify the test object by characterization of chemical components using THz spectral fingerprint absorption. One could understand “where” and “what” is the test object on the basis of its THz color pictures, providing wide application of the THz color scanner. Although such THz color scanner can be realized by a THz time-domain spectroscopy (THz-TDS) imaging system, overall measurement time of the conventional THz-TDS imaging based on point scanning is quite long in the same manner as the THz tomography. Such long time measurement limits its application into a steady object. Therefore, we applied the real-time 2D spatiotemporal THz imaging, used in the real-time THz tomography, for the THz-TDS imaging. Since the proposed system equipped with a line-focused THz beam can generate vertical line images of a moving sample consecutively in the order depending on the movement at all THz frequencies, it can be applied for moving object. Figure 3 shows THz spectral images of a sliced tooth specimen (1 mm. thick) obtained with this system. One can see the characteristic THz image at each frequency. Since tooth has crystal structure of hydroxyapatite, interaction between such crystal structure and THz wave results in unique THz color images. Such spectral and/or local dependence of THz absorption may give information on structural change of tooth crystal caused by aging or caries. In addition to biological objects, since this system can be

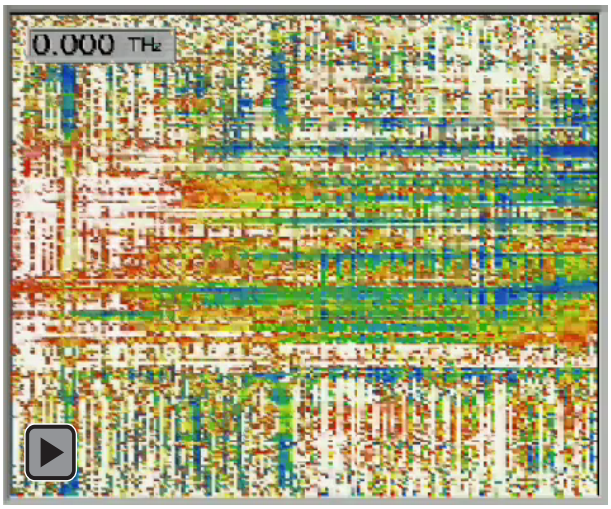

Fig. 3 THz spectral images of a sliced tooth

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applied to nondestructive testing of various industrial products including semiconductor ICs (Fig. 4) and pharmaceutical products, it is expected to find a variety of industrial applications.

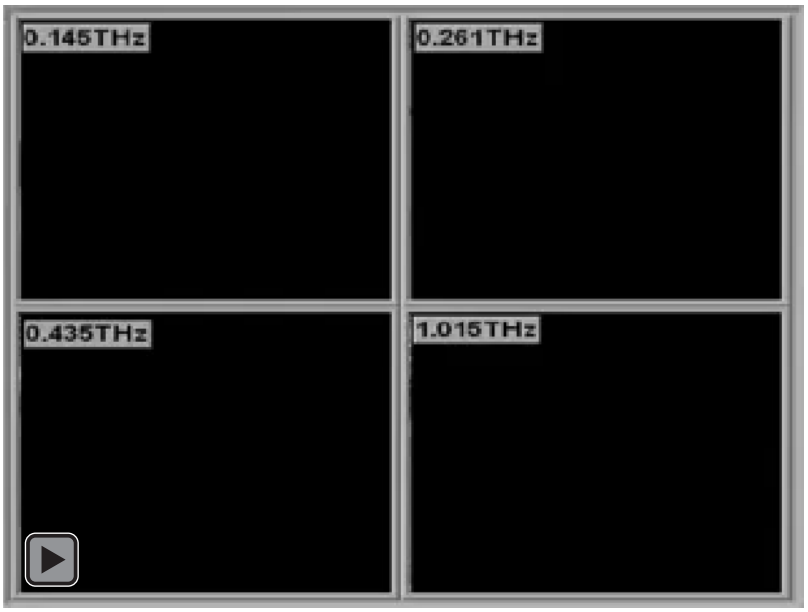

Fig. 4 THz spectral images of semiconductor IC

This work was supported by Grants-in-Aid for Scientific Research Nos. 18686008 and 18650121 from the Ministry of Education, Culture, Sports, Science, and Technology of Japan, the Sumitomo Foundation, and a Sasakawa Scientific Research Grant. More detailed information on the principles and results of both methods is given at the URL below.
http://sml.me.es.osaka-u.ac.jp/araki_lab/research/thz/

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Feature Articles: Superconducting Microwave Device Technology - Development of a Wideband Terahertz Wave Receiver and Its Applications in Gas Spectroscopy -

Satoshi Kohjiro
Nanoelectronics Research Institute
National Institute of Advanced Industrial Science and Technology

In the terahertz band, there are a considerable number of gas absorption spectra for carbon monoxide, hydrogen chloride, hydrogen cyanide, sulfur dioxide and other gases that are harmful to human health. Existing gas analysis methods include mass spectronomy and chromatography of collected samples, and remote absorption spectroscopy using mid-infrared lasers. However, when deciding countermeasures in disaster areas and around volcanoes based on observation of the gases present, it is difficult for people to approach the site to collect samples, and situations are envisioned where the site is obscured by smoke and flames, which infrared light cannot readily permeate. Terahertz waves can be applied to remote detection and since their wavelength is longer than that of infrared light, they are resistant to scattering by smoke and particles. In addition, compared to the infrared region, in the terahertz band, frequency spacing between absorption lines of different gases is narrow, so it should be possible to achieve a single general purpose spectroscope that can be applied to component analysis of many different gases. However, the terahertz band is referred to as an undeveloped frequency range, and there were no general purpose spectroscopes with both the power and frequency required for spectrum analysis with high precision, high sensitivity, over a wide band. The shortest route to achieving a measuring device that fulfills these requirements is thought to be use of heterodyne receiving technology that faithfully converts terahertz band input signals to microwave band electrical signals which can be used with already established high precision spectrum analysis techniques.

The performance of heterodyne receivers depends on two elemental devices, the frequency converter (mixer) and the local oscillator which supplies the frequencies that constitute the reference for conversion. With the most widely used compound semiconductor mixers and local oscillators that multiply the frequency of microwave oscillation to obtain terahertz waves, at the center frequency the normalized frequency band (hereafter, fractional bandwidth) is limited to 40 % and 30 % respectively. For this reason, to cover a wide frequency band, a number of mixers and oscillators are required, which makes receiver systems complex, very large, and expensive. Furthermore, receiver noise temperature is several hundred times of the quantum noise limit, while detection of a weak terahertz signal takes a long time.

Superconducting tunnel junction mixers have so far been developed for radio astronomy and observation of the earth's atmosphere, and although they demonstrate extremely low noise characteristics approaching the quantum noise limit, their fractional bandwidth has been limited to 40 % or less. However, we have succeeded in increasing the bandwidth and raising fractional bandwidth to 60% or more[1]. In addition, Nippon Telegraph and Telephone Corporation (NTT) has developed a photonic local oscillator that emits difference-frequency terahertz waves from two near-infrared semiconductor lasers with different wavelengths using high-speed photodiodes. A fractional bandwidth of over 100 % has been demonstrated. Working jointly with NTT, we first developed a heterodyne receiver that covers the 200 to 500 GHz band (fractional bandwidth: 86 %) with a single mixer and local oscillator, and at a fractional bandwidth of 74 %, the receiver noise temperature demonstrates low noise characteristics 20 times below the limit of quantum noise[2]. Furthermore, this receiver is suitable for spectroscopy of the weak terahertz waves of about 100 fW

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emitted by nitrous oxide (N_2O), which has an absorption spectrum very similar to carbon monoxide, a highly lethal gas that often occurs at disaster sites.

By developing optical systems for remote spectroscopy and technologies for mounting compact mechanical cryocoolers on mixers, we aim to achieve the applications indicated in the title.

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Topics in December

- Shin Kosaka et al. Receive 2008 Awards for Industrial Standardization from the Ministry of Economy, Trade and Industry -

Commemorative photo of recipients of the 2008 Awards for Industrial Standardization (Back row, right: Mr. Shin Kosaka)

On October 20, 2008 (Monday), an award ceremony for the 2008 Awards for Industrial Standardization by the Ministry of Economy, Trade and Industry, METI, was held in the Phoenix Hall of the Toranomon Pastoral Hotel. This year, one person received the Prime Minister's Award, 20 people and three organizations received the METI's Award, and 32 people received the Director General of the Industrial Science and Technology Policy and Environment Bureau's Award (26 people received the Award for Contribution, while 6 received the Award for Encouragement). Shin Kosaka (the researchers of the Energy Technology Research Institute, National Institute of Advanced Industrial Science and Technology) was presented with the METI's Award for superconductor-related research. At the same time, 22 people were notified of IEC (International Electrotechnical Commission) 1906 Awards.

Since 1953, the METI's Award has been presented to persons and businesses that have made conspicuous contributions to industrial standardization, and in recent years, it has been awarded as part of the industrial standardization award ceremony held during October, the industrial standardization promotion month.

Shin Kosaka, recipient of the METI's Award, has worked since 1997 as the convener of IEC/TC90/WG8 (Superconductivity/Test methods for electronic characteristics of superconductors). In addition to compiling comments from other countries concerning Japanese proposals, as Japanese chairman of WG8, he made an enormous contribution to strengthening international standards activities in Japan and overseas by playing a central role in drafting and maintenance of international standards. He also made an enormous contribution to standardization activities in the superconductor field working as the JISWG8 chairman to incorporate JIS (Japanese Industrial Standards) in the international standards.

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

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Standardization Activities

Topics in December

- 6th Superconducting Power Equipment Panel Discussions in Tsukuba Cosponsored by NEDO and ISTEC -

The New Energy and Industrial Technology Development Organization (NEDO) and ISTEC cosponsored the 6th Superconducting Power Equipment Panel Discussions on October 27, 2008 in Conference Room 202 at the Tsukuba International Congress Center "EPOCHAL TSUKUBA" as part of the program commissioned by NEDO "Development of Yttrium-Based Superconducting Power Equipment Technologies – Standardization of Applied Technologies for Superconducting Power Equipment Technologies." The discussions took place with 44 participants and ended successfully.

At the 6th Superconducting Power Equipment Panel Discussions

The meeting was chaired by Teruo Matsushita (Chairman of the Superconducting Power Equipment Technologies Research Committee, Kyushu Institute of Technology).

◇ Firstly, Chairman Matsushita reported on "Standardization in IEC/TC90 for Superconductivity" to deepen understanding of international standardization relating to superconductors.
◇ Kozo Osamura (Research Institute for Applied Sciences) reviewed the state of the panel on superconductors and standardization activities at IEC/TC90.
◇ David Larbalestier (Florida State University, USA) spoke on the subject of "HTS wire development and measurement methods in ASC".
◇ Koichi Nakao (SRL/ISTEC) reported on "Measurement methods of Y-system coated conductors".
◇ Hiroyuki Osaki (Tokyo University) spoke on the subject of "HTS power cable technology and measurement methods".
◇ Ken-ichi Sato (Sumitomo Electric Industries) reported on "How to international-standardize SC power cable".
◇ Paul N. Barnes (Air Force Laboratory, USA) spoke on the subject of "SC machines related measurement methods".
◇ After these reports and topics, the following discussion took place.

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1. Concerning international standardization of superconducting wire
   - For international standardization, wire is also currently under development, so it is necessary to identify what is intended for standardization.
   - For wires that are in development, it is necessary to assess how far microscopic test experiments, testing methods for the uniformity of characteristics and so on can be simplified in industrial testing for superconducting wire for actual applications which is assumed to be uniform.
   - It is necessary to review the definition of the critical current I_c and engineering critical current density (overall) J_c of long-length superconducting wires for actual applications for IEC60050-815 maintenance.
   - The process guarantee implemented for LTS as part of the guarantee of characteristics for superconducting wire for actual applications is very rigorous.
2. Concerning superconducting power cable
   - There is no liaison between the International Council on Large Electric Systems, CIGRE and IEC, and so careful consideration is required for international standardization.
   - Because there are many constituent elements in superconducting power systems including superconducting wire, superconducting cable, interconnects, cooling systems, termination connectors and so on, it is vital that standardization is based on close cooperation and discussion with the system designers in order to meet all the requirements.
   - Since cooling systems are essential for the superconducting power cable system, consideration must be paid to documentation of reliability testing and safety matters.
3. Concerning superconducting equipment
   - Although there are many individual parameters for superconducting equipment, it is necessary to make a clear distinction between the parameters common to all superconducting equipment and those specific to particular devices.
   - With regard to the overall engineering critical current density J_c and insulation, it is necessary to clarify that the definitions are different at the product stages of superconducting wire and device.
   - In devices where HTS wire is used, consistency between the quench detection method and test methods are necessary.
4. Concerning international standardization of superconducting power equipments
   - The motivation to introduce superconducting power equipments depends significantly on life cycle costs. Therefore, it is vital to pay some consideration to standardization of individual devices.
   - For international standardization of superconducting power equipments, close cooperation between researchers, device engineers and users is required.
   - It is appropriate to take the decision to start the international standardization of superconducting wire and superconducting power cables based on the timing of international standardization concerning superconducting power equipments.

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Standardization Activities

Topics in December

- 2nd Superconducting Electronics Panel Discussions in Tsukuba Cosponsored by NEDO and ISTEC -

The New Energy and Industrial Technology Development Organization (NEDO) and ISTEC cosponsored the 2nd Superconducting Electronics Panel Discussions on October 28, 2008 in Conference Room 202 at the Tsukuba International Congress Center "EPOCHAL TSUKUBA" as part of the program commissioned by NEDO for "Research into Standardization of Superconducting Electronics Elemental Technologies". The discussions took place with 27 participants and ended successfully.

The meeting was chaired by Masataka Okubo (National Institute of Advanced Industrial Science and Technology, AIST).

◇ Masataka Okubo began the meeting by explaining the purpose of the panel discussion and introducing the following six panelists and their technical backgrounds.
◇ Kei-ichi Tanaka (SII NanoTechnology) presented information concerning "Standardization concerned with evaluating the energy resolution due to the transition-edge sensors (TES) system for material analysis".
◇ Daiji Fukuda (AIST) presented information concerning "Optical photon detection techniques with superconducting detectors and some topics of standardization", and examples from IEC/TC86 (optical fiber systems).
◇ Boris Karasik (California Institute of Technology) presented information concerning "Sensitive superconducting THz detectors: calibration issues and need for procedures and standards".
◇ Shigehito Miki (National Institute of Information and Communications Technology) presented information concerning "Standardization & Application in SNSPD system". He presented the example of successful quantum cryptographic communication over 97 km, the longest distance in the world.
◇ Nobuyuki Yoshikawa (Yokohama National University) presented information concerning "SFQ time-to-digital converters".
◇ Quentin Herr (Northrop Grumman Space Technology) presented information concerning "Output & Packaging Standardization." He presented topics concerning standardization of ADC output and packaging.

After these presentations on the current situation and standardization of these technologies, reports and topics, the following discussion took place.

1. Concerning the potential for international standardization of superconducting electronics
   – Detector calibration, noise measurement methods and so on may be suitable for standardization.
   – Instead of standardizing individual superconducting elements, one proposal is to integrate it with standardization of the superconducting application field of optical communications.
   – Rather than pursuing standardization of packaging aggressively, a de facto standard will probably emerge instead.

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2. Concerning mutual recognition of areas that can be standardized and areas where standardization is not desirable

- For standardization systems related to superconductors for quantum cryptography and optical devices, general requirements and testing methods are envisioned for elemental devices, while optical device basic characteristic tests and local and environmental tests are envisioned for systems. For the standardization system for time-to-digital converters which use SFQ, at the basic stage, basic parameter test methods for *Ic*, *Jc*, βc, and bias current, voltage and resistance and circuit parameter test methods for JTL, DFF, PTL, *LIc* and so on are envisioned. At the design stage, CAD tools, Cell libraries, timing definitions, design systems IP and so on are envisioned, while at the system stage, chip carrier, chip size/pad design, probe, magnetic shielding, filter, voltage amplifier, test sequence, error rate test and so on are envisaged.
- With superconducting electronics systems where development is underway, standards are already basically agreed between the parties involved. However, providing this information to other parties is difficult in some cases. In addition, at the system design, production and operation stages, a lot of system-specific technology and know-how are involved, and this may not be amenable to standardization.
- Therefore, in areas where standardization is possible, if the scope of the standardization system is focused appropriately, it will be possible to carry out standardization with the aim of improving the efficiency of basic research, sharing elemental device parameters and improving efficiency at the R&D stage.
- For this reason too, research into elemental device parameters is important.

3. Concerning sharing of standardization item information

- General requirements and rules of superconducting electronics systems
- Definitions of elemental devices that make up systems and characteristic testing methods, etc.

4. Future developments

- It is necessary to choose whether to take an analog or digital system route for future standardization procedures.
- Conduct research into the parameters of elemental devices that make up systems.
- Carry out development of standards for important system principles, equipment and device testing methods.
- As a means of fostering consensus on international standardization it will be effective to continue holding this kind of panel.

At the 2nd Superconducting Electronics Panel Discussions

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