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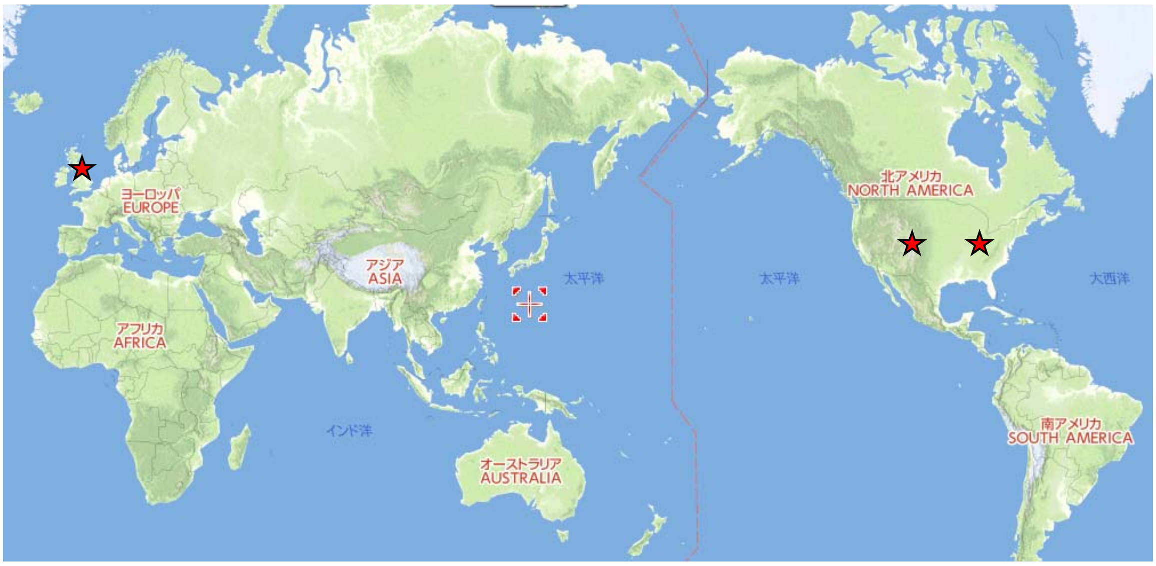
What's New in the World of Superconductivity

초전도 뉴스 –세계의 동향–

超导新闻 –世界的动向-

chāo dǎo xīnwén - shìjiè de dòngxiàng-

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC



★News sources and related areas in this issue

▸Electronics 엘렉트로닉스 电子应用［diànzǐyè yìngyòng]

Superconducting Spintronics for Next-generation Computing

University of Cambridge (January 15, 2014)

Researchers at the University of Cambridge have announced a breakthrough in the field of spintronics—a new technology that could become the basis for a future revolution in computing. The researchers have provided the first evidence suggesting that superconductors could be used as an energy-efficient source for "spin-based" devices, which have already begun to appear in microelectronics circuits. Previously, superconductors and spintronics were thought to be incompatible. The new study, however, has shown that the natural spin of electrons can be manipulated—and detected—within the current flowing from a

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superconductor. To enable both superconductivity and the manipulation of electron spin simultaneously, the researchers added an intervening magnetic layer composed of the rare earth holmium. Within this later, the magnetism rotates and forms a non-collinear interface with magnetic permalloy layers, which are used to manipulate spin. As Cooper pairs pass through this rotating magnetic layer, the pairing is preserved despite the fact that one electron is effectively "flipped" to create parallel-aligned spins. The researchers successfully detected such parallel-spin Cooper pairs, confirming their existence. Dr. Niladri Banerjee of the Materials Science Department commented, "What's never been directly demonstrated until now is that Cooper pairs can serve as transmitters of spin. That's an important step forward since now it is clear that superconductivity can play a key role in spintronics." The study results could pave the way for the use of superconductors in spintronics, making such devices much more energy-efficient. The group's work has been published in *Nature Communications*. As a next step, the group plans to create a prototype memory element based on superconducting spin currents and to search for new material combinations capable of increasing the effectiveness of their method.

Source: "Superconducting spintronics pave way for next-generation computing"
University of Cambridge press release (January 15, 2014)
URL:
http://www.cam.ac.uk/research/news/superconducting-spintronics-pave-way-for-next-generation-computing
(This work is licensed under a Creative Commons.)
Contact: Tom Kirk, tdk25@cam.ac.uk

▸Basics 기초 基础[jīchǔ]

Secrets of Superconductivity

Los Alamos National Laboratory (January 3, 2014)

Two separate studies involving researchers from the Los Alamos National Laboratory have produced new findings regarding the relation between superconductivity and magnetism. Superconductivity and magnetism are often considered as rivals, since the electrons in superconductors form freely moving pairs that conduct electrical current with no resistance while magnetic electrons lock themselves into a rigid arrangement that does not move. However, the two above-mentioned studies have shown that the electrons in Cerium-Cobalt-Indium5 ($CeCoIn_5$) are simultaneously both superconducting and magnetic. In an experiment conducted at the Paul Scherrer Institute (PSI), researchers observed an entirely new form of superconductivity in which electrons form pairs with clockwise and counterclockwise spins as well as pairs with spins in the same direction. In the latter situation, the superconductivity only appeared when the electrons were both superconducting and magnetic. Furthermore, the ordered arrangement of the magnetic electrons could be manipulated by modifying the direction of the applied magnetic field. Michel Kenzelmann, the leader of the PSI research team, commented, ""The observed behavior of the material was completely unexpected and is certainly not a purely magnetic effect. This is a clear indication that in the material the new superconducting state occurs together with the spin density wave." These findings suggest the possibility that the quantum state of electrons, which is linked to superconductivity, might be

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directly controllable, an ability that could have important implications for future quantum computers.

In the second study, small amounts of impurities were introduced into CeCoIn5; unexpectedly, these impurities caused the superconducting electrons to form nano-droplets of magnetic order. When the amount of impurities was increased, the droplets grew and eventually overlapped, causing the entire material to become magnetic. The application of pressure to the magnetic material globally reversed the effect of the impurities, causing the material to become superconducting once again. Using a techniques similar to magnetic resonance imaging, however, the researchers found that the nano-droplets of magnetic order actually persisted but were hidden by the superconductivity.

Combined, these studies show that the electrons in $CeCoIn_5$ are more adaptable than previously believed. Joe Thompson, a collaborator in both studies, commented, “Superconductivity continues to give new surprises. As its secrets are revealed, we learn more about the quantum world of electrons and can begin to imagine new ways to use them for future technologies. Superconductivity in Cerium-Colbalt-Indium5, discovered nearly a decade ago at Los Alamos, may be the Rosetta Stone that many of us have been looking for.” Both of the studies were published in the same online issue of *Nature Physics*.

Source: “Secrets of Superconductivity Revealed”
Los Alamos National Laboratory press release (January 3, 2014)
URL: http://www.lanl.gov/newsroom/news-stories/2014/January/superconductivity-and-magnetism.php
Contact: Nancy Ambrosiano of Communications Office, nwa@lanl.gov

Quest for Better Superconducting Materials

Oak Ridge National Laboratory (January 27, 2014)

In a recent study published in *Physical Review Letters*, researchers at the Oak Ridge National Laboratory examined the essential roles of chemical dopants in the creation of high-temperature superconductors. Dopants introduce non-uniformity and disorder to the crystal structure of a material. By understanding how chemical dopants alter the behaviors of pre-doped materials, scientists hope to become able to design superconductors that function at higher temperatures. The lead author of the paper, Krzysztof Gofryk, commented, "Through this work, we have created a framework that allows us to understand the interplay of superconductivity and inhomogeneity. Thus, for the first time, we have a clearer picture of the side effects of dopants." The team leader, Athena Safa-Sefat, added, "Our bulk and atomic-scale measurements on an iron-based superconductor have revealed that strong superconductivity comes from highly doped regions in the crystal where dopants are clustered. If we can design a crystal where such clusters join in an organized manner, we can potentially produce a much higher performance superconductor."

Source: “ORNL study advances quest for better superconducting materials”
Oak Ridge National Laboratory press release (January 27, 2014)
URL:
http://www.ornl.gov/ornl/news/news-releases/2014/ornl-study-advances-quest-for-better-superconducting-materials
Contact: wallira@ornl.gov

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Feature Article: The 26th International Symposium on Superconductivity (ISS2013) -SPL/PL Lectures

Keiichi Tanabe, Yutaka Yamada, Kota Katayama
ISTEC

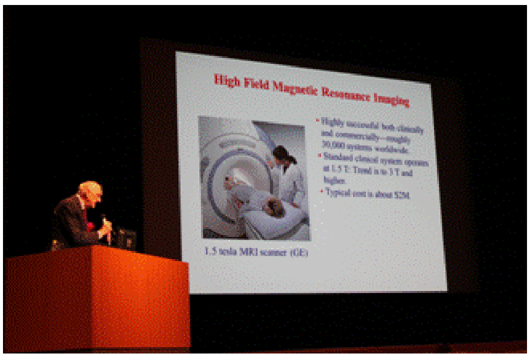
ISS 2013 hosted a special plenary lecture from each category of power equipment applications and MRI. The plenary lectures comprised of Fe-based superconductors, SFQs, Japan's and USA's wire development sectors and an update on the current status of the cable demonstration project in Japan.

Special plenary lecture 1, Dr. B.P. Strauss, US Department of Energy (DOE) "R&D FOR THE NEXT GENERATION OF SUPERCONDUTING MAGNETS"

Dr. B.P. Strauss (DOE)

Looking back at wire and coiling technology developments since the discovery of superconductivity, Dr. Strauss from the DOE, through his long tenure at the National Laboratories and the DOE, highlighted potential HTS issues that could arise in the future. He commented that although 95% of superconducting wires have been employed for magnet applications, the development of principal technologies ceased during the 80s and that no significant progress has occurred since then. For example, concerns associated with ultra-thin filamentary wires, twisting wire filaments and stabilization issues were raised. The USA recently published a report on high-field superconducting magnet applications (assumed to be a ¥100billion worldwide market, inclusive of accelerator applications). He went on to emphasize that in order for HTS to penetrate further in the market incorporating the above-mentioned areas, it was necessary for cable and wire engineering standards including "length, homogeneity, strength, stability, loss, insulating strength" to satisfy certain criteria required by users. It was his opinion that the establishment of these factors would be desired to realize regular viable sales.

Special plenary lecture 2, Dr. J. Clarke, University of California "ULTRALOW FIELD MAGNETIC RESONANCE IMAGING"



Prof. J. Clarke (University of California)

MRI is employed for clinical use, currently reaching 30 thousand-units worldwide in a market valued at around ¥200million. Mainstream systems have evolved from 1.5T to 3T. With the higher magnetic fields offering greater MRI sensitivities, ultra-low field MRIs (ULFMRI)

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employ a gradiometer utilizing a superconducting SQUID enabling 100 μT applications.

Dr. Clarke, a pioneer of SQUID, lectured on the current status and future prospects of these innovative ultra-low-field MRI technologies. Ultra-low-field MRIs employs a gradiometer that utilizes SQUID sensor allowing nuclear magnetic resonance imaging to be done at low magnetic fields equivalent to terrestrial magnetism. This realizes compact systems, however, spatial resolutions are currently inferior compared to high-field MRI systems. Despite this, advantageous attributes remain including the ability to distinguish between cancerous cells by determining differences in the longitudinal magnetic relaxation time (T_1) of the cells. The lecture introduced imaging data from different elements of the brain performed by measuring differences in T_1. Future prospects to improve image-processing times, which are currently significant issues, were also presented. Also, Dr. Clarke commented that systems costs could be significantly reduced since high-field superconducting coils would not be utilized.

Plenary lecture 1, Professor Kitaoka, Osaka University
"RECENT TOPICS ON HIGH-T_C SUPERCONDUCTIVITY IN CUPRATES AND PNICTIDES"

Prof. Kitaoka (Osaka University)

Professor Kitaoka from Osaka University, reported on the microscopic electron states of copper-based or Fe-based high temperature superconductors. He clarified that for copper-oxide superconductors, the hole (electron) density and superconductivity-antiferromagnetism (AFM) phase diagram could be explained using a t-J model, emphasizing spin fluctuations as a promising candidate for the origin of the attractive interaction of the Cooper pairs. For Fe-based superconductors the shape of the Fermi surface holds the key. The change in shape of the Fermi surface strengthens spin fluctuations, which produce the superconducting phase. It was also reported that the increase of T_c from 28 K to 50 K in the La1111-system occurred due to changing nesting conditions that led to Fermi surface reconstructions.

Plenary lecture 2, Dr. Izumi, ISTEC-SRL
"ACHIEVEMENTS IN M-PACC PROJECT AND FUTURE PROSPECTS ON R&D OF COATED CONDUCTORS"

Dr. Izumi (ISTEC-SRL)

Dr. Izumi from ISTEC-SRL, lectured on the research outcomes and future prospects of wire development undertaken as part of the NEDO project entitled "Technology Development of Yttrium-based Superconducting Power Equipment", which concluded March last year. The past five years has seen an improvement in the I_c characteristics and lengths of wires. In particular, improvements of in-field characteristics, including long wires and demonstrations involving

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multifilament wires along with further reductions in losses are anticipated to realize an array of further applications. Also introduced was a 5-yr project launched last year entitled “Development of HTS Coiling Technology”. The aims of the project are to develop wire and coiling methodologies for MRIs and Heavy-Ion Medical Accelerators. A particular target of the project is the likelihood of realizing the fabrication of a 200-m long wire at 600 A (65 K, 3 T), 1000 A (35 K, 10 T). It is anticipated that future outcomes of this project will contribute to Japan’s and the wider international communities where demand for high-tech medical-use equipment are increasing in the future.

Plenary lecture 3, Dr. D.S. Holmes, Booz Allen Hamilton
“SFQ COMPUTING IN THE USA”

Dr. D.S. Holmes (Booz Allen Hamilton)

Dr. Holmes of Booz Allen Hamilton, introduced the current developmental status of SFQ (Single Flux Quantum) computing technology in USA. Power volumes consumed at a new large-scale data center are rapidly increasing. Computing technologies with process capabilities exceeding exa-scales (exa=10^{18}) cannot be realized without significantly reducing power consumptions. SFQs are potential candidates able to address and solve this issue. A new circuit that radically reduces the power consumed at the conventional SFQ gate has been developed and progressed in the USA. A 3-year IARPA project was recently launched with SFQ computing memory development as a top priority.

Plenary lecture 4, Professor Nakamura, The University of Tokyo
“PROGRESS ON SUPERCONDUCTING QUANTUM CIRCUITS”

Prof. Nakamura (The University of Tokyo)

Professor Nakamura from The University of Tokyo, lectured on the progress made in superconducting quantum circuit technology aimed for quantum computing. Specifically, the design improvement of a superconducting quantum bit and controlling the electromagnetic mode by coupling to a resonator was highlighted. Materials engineering has remarkably prolonged the coherence time, the greatest technological issue, from initial 1 ns to 100 µsec, producing low error rate gate operations.

Plenary lecture 5, Professor V. Selvamanickam, University of Houston
“STATUS OF COATED CONDUCTOR AND HTS DEVICE PROJECTS IN USA”

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Professor V. Selvamanickam from the University of Houston reported recent research findings of Y-based coated conductors developed in the USA. Wire development was originally spearheaded by AMSC and SuperPower, but now STI has joined in. Applications of interest presented at the symposium included Y-based high-field coiling developed by the National High Magnetic Field Laboratory in Florida, HTS 4-pole magnet developed by BNL and Conductor-on-Round-Core (CORC) cables produced by Advanced Conductor Tech. LLC. CORC cables have already demonstrated 6000 A at 4.2 K, 19 T, which seem promising for nuclear fusion applications.

Prof. V.Selvamanickam
(University of Houston)

Plenary lecture 6, Dr. Honjo, Tokyo Electric Power Company
"HIGH TEMPERATURE SUPERCONDUCTING CABLE DEMONSTRATION PROJECT IN JAPAN"

Dr. Honjo (Tokyo Electric Power Company)

Dr. Honjo from Tokyo Electric Power Company reported on Bi-based superconducting cables that are currently being demonstrated at the Yokohama Asahi Substation. These trials are first of a kind in Japan with the cable connected to the actual grid, and there have been no operational issues associated with cooling or current transmission reported. The track record so far demonstrated the remarkable reliability for future superconductors operating in power utility applications. It was clear from the arguments set out by Honjo that current cables in Japan have already passed 20-40 years since their installation, and a period for their replacement was imminent. If a superconducting cable can be installed in existing cable ducts without the need for new locations and additional land, this will be a great opportunity for the significant effectiveness afforded by superconductivity to be realized.

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Feature Article: The 26th International Symposium on Superconductivity (ISS2013) -Physics and Chemistry (incl. Vortex Physics)

Atsutaka Maeda, Professor
Department of Basic Sciences,
Graduate School of Arts and Sciences, The University of Tokyo

Snapshot of the session

The ISS program committee in charge of the physics and chemistry sections has organized a dedicated session on specific themes for the past couple of years, with invited lecturers selected to address the themes. Their aims at the ISS are to facilitate fruitful discussions on the progress of superconductivity research on physics and chemistry conducted over the past year within a relatively short 1.5 - 2 days. Below is a brief summary of the Physics and Chemistry session at the ISS2013.

This year's themes focused on: 1) new superconducting materials; 2) the current status of theoretical research; 3) iron-chalcogenide superconductors, and 4) spectroscopic experiments (STM in particular). Apart from these themes, on the first day of the symposium, a plenary lecture delivered by Kitaoka (Osaka University), reported the overall relationship of antiferromagnetic fluctuations, Fermi surface nesting and structural parameters, focusing particularly on the critical temperature T_c of copper oxide/Fe-based superconductors. Regarding theme 1) new materials, Japan's research activities in this area were prominent as all five invited lecturers were from Japan despite this being an international symposium. The contents of the lectures included: (Ca,La)Fe_2As_2 (T_c =45 K) by Kudo (Okayama University); $BaTi_2Bi_2O$ (T_c=4.6 K) by Yajima (The Institute for Solid State Physics, The University of Tokyo); BiS_2-based superconductor (T_c=10.6 K) by Mizuguchi (Tokyo Metropolitan University); $HgBa_2Ca_2Cu_3O_8$ (T_c^{zero}=153 K) by Takeshita (AIST); Alkali metal intercalated iron-chalcogenide superconductors (T_c=45 K) by Hatakeda (Tohoku University; selected from contributed papers), and

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the world's first hole-doped superconductor with the so-called T'-structure copper-oxide superconductor by Takamatsu (Tohoku University). Regarding theme 2) theoretical research, several theories based on different standpoints were presented, which, however all failed to form any consensus – Casula (CNRS); Capone (CNR-IOM); Ku (Brookhaven). Concerning theme 3), Iron-chalcogenide superconductors, have recently attracted considerable attention as potentially very high T_c materials, since higher T_c's have been consecutively reported in the 122-structure, intercalated system, mono-layer film, etc. In fact, Xue (National Tsing Hua University), introduced their research on mono-layer films during the last ISS. Also in ISS2013, the enhancement of T_c by the above-mentioned intercalation research and the introduction of local strains induced in high quality epitaxial thin films – Nabeshima (The University of Tokyo; selected from contributed papers), attracted the attention of the audience. In the spectroscopy session, 4), high–quality data were presented by Nishida (Tokyo Institute of Technology→Toyota Physical and Chemical Research Institute) and Suderow (Autonomous University of Madrid), which accentuated the high quality STM research undertaken worldwide. In particular, both groups have succeeded in observing vortex motion. Other lecturers included, Eskildsen (University of Notre Dame) on small-angle neutron scattering experiments; Roditchev (INSP) and Kato (Osaka Prefecture University), both presenting their theoretical research on the vortex phase diagram and the vortex state of nano-sized superconductors.

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Feature Article: The 26th International Symposium on Superconductivity (ISS2013) -Wires, Tapes and Characterization

Teruo Izumi, Director
Masateru Yoshizumi, Associate Director
Division of Superconducting Tapes, Wires, and Power Application
ISTEC-SRL

The session comprised of 29 presentations and around 40 posters. This article summarizes several selected presentations along with a synopsis of a related plenary lecture presentation.

The plenary lecture was held on the first day of the symposium, where Professor Selvamanickam from the University of Houston highlighted Y-based wire development and related power device research ongoing in the USA. Y-based wire development has realized the fabrication of 100m-long wires at 1m/450A at STI, and is now being prepared to produce 1km-long wires. The University of Houston has focused on enhancing the in-field characteristics of MOCVD wires. The latest reported data confirms high in-field characteristics (2172A/12mm@30K,3T) with 25% Zr additions. The resulting characteristics are 6.4-times greater than those targeted by the ARPA-E project, which were aimed at enhancing the characteristics by 4-times. In particular, the observation confirmed that the ab-surface was doped when the doping volume increased above a certain value. For power device development, 15.7 T was confirmed using a 16 T demo HTS magnet. Additionally, SMES (ARPA-E), smart grid (equipped with SFCL), cable for SMES, helium gas-cooled cable and 1.5 T MRI utilizing BSCCO wires were also introduced.

At the wire session, held on the second day of the symposium, Dr. Miyatake (JASTEC) was the first speaker of the day. NMR development was described, highlighting the essential factors required to realize PC mode, which is a trade-off between superconducting connections and the degree of magnetization. It was reported that these factors significantly benefited other essential field characteristics such as, field strength, and n-value.

Professor Obradors introduced the research activities undertaken in Europe. Europe holds their highest I_c x L value of 200m-250A, achieved by BRUKER, a record that has already been achieved by Japan and USA more than five years ago. Although a variety of film deposition methods onto substrates have currently been investigated, a firm decision has to be made sooner or later. It is the author's perception that the only new research studies reported from Europe pertained to low loss results for 120-filament short wires.

Dr. Oh (KERI) explained the developmental status in Korea. The following two projects have been launched aimed at future materials development;

2013-2017	DC-Reactor, wire development	1kA/cm	$5M
2013-2018	Materials development within KERI	APC SmBCO	$5M

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It was reported that Dr. Moon at SuNAM led the former project. Recent research topics presented by Korea University included the results of forming superconducting connections. Further to this, the person in charge made a further presentation on the final day of the symposium. Having etched the silver layer of the wires made by SuperPower, a micro-hole was punched and layered face-to-face. This went through a short-time heating process under low pressure. After processing, a 211 + Ba-Cu-O phase melt was present. A long period of heating in oxygen followed and produced superconducting connections without any deterioration in its initial characteristics of 85 A. A final transient processing was deemed necessary for incongruent-system materials when fabricating connections utilizing a melt. However, their results did not disclose the microstructure and how this issue was resolved. The disclosure of microstructure of the material is now expected, including the E-J characteristics measured at low electric field regions.

Dr. Iijima from Fujikura reported their recent developments related to wire fabrication. Noteworthy was their successful fabrication of a 1km long wire exhibiting relatively homogeneous characteristics. Tapestar evaluations recorded approximately 20% homogeneity.

Recent years have seen an improvement of the in-field characteristics necessary for the realization of applications for practical use. The table summarizes the in-field data characteristics reported at the symposium, realized by major manufacturers and research institutions at the forefront of wire fabrication based in Japan and USA. In addition to favorable characteristics achieved with short-length wires, data on longer-length wires was only reported by Japan. This shows Japan's superior technological prowess.

Table Comparison of measured in-field characteristics of Y-based coated conductors fabricated by major wire manufactures and research institutions in both Japan and USA

		ISTEC		U. Houston SuperPower	amsc	Fujikura
		EuBCO+BHO by PLD	YGdBCO+GZO by MOD	GdBCO+BZO by MOCVD	Y(Dy)BCO? by TFA-MOD	GdBCO by PLD
Short-length wire	20K 3T(B//c)					~2404 A/cm
Short-length wire	30K 3T(B//c)			1153 A/cm (1384 A/12mm) 2413 A/cm* (2895 A/12mm)	~720 A/cm	
Short-length wire	30K 3T(Min.)	~2730 A/cm		~833 A/cm (~1000 A/12mm) ~1743 A/cm*	~720 A/cm	
Short-length wire	77K 3T(Min.)	141 A/cm	70 A/cm			95 A/cm
Long-length wire	77K 3T(Min.)	>100 A/cm (94m)	50 A/cm (124m)			~40A/cm (1km)

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An overall impression of the session proved Japan's high level of technology developed under the M-PACC project.

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Feature Article: The 26th International Symposium on Superconductivity (ISS2013) -Films and Junctions/Electronic Devices

Mutsuo Hidaka, Chief Senior Researcher
Nanoelectronics Research Institute
National Institute of Advanced Industrial Science and Technology

The number of presentations at the Films, Junctions and Electronics Devices (FD) session was 59, including both oral presentations and posters. Amongst these, 22 presentations were on films/junctions, 15 on SQUIDs, 12 on digital, 6 on detectors, 1 on quantum bits and 3 related to microwaves.

The Films and Junctions session was mainly focused on the fabrication methodology of Fe-based thin films. Professor Naito from Tokyo University of Agriculture and Technology, highlighted two routes for F-doping into SmFeAs(O,F) thin films. The first route involves a two-step process by first, depositing an SmF_3 thin film on SmFeAsO, followed by F diffusion into an SmFeAsO thin film, producing a T_c^{end} = 56.4 K. The other is a single-step route involving the supply of F from FeF_2 during deposition, producing T_c^{end} = 54.0 K. Professor Holzapfel from IFW, Dresden, reported their successful deposition of high quality Fe-based Ba-112 and 11 heterostructure thin films.

The session related to SQUIDs was presented with an array of associated applications. Professor Clark from UC Berkeley reported the developmental trends of ultra low-field MRIs utilizing SQUID detectors and driven at 130 μT, which is at an equivalent level to terrestrial magnetism. The setup allows each component to be resolved, for example, MRI-imaging of a human brain clearly resolved the cerebrospinal fluid and blood separately. Professor Enpuku from Kyushu University introduced a SQUID project undertaken under JST's S-Innovation program. One characteristic of this project was the SQUID, a common module developed in joint collaborations and with each research institution employing the module for their own application purposes. Professor Tanaka from Toyohashi University of Technology has developed a device to detect foreign-metal bodies within lithium-ion batteries by utilizing high temperature superconducting SQUID. He presented the potential detection of a foreign-metal body having 35 μm diameter, much smaller than current technological limits of 100 μm diameter.

The session dedicated to digital applications amassed topics on low energy and multiplexing outputs from detection devices. Dr. S.Holmes, who leads the superconducting supercomputer project launched at the beginning 2014 in USA, commented that there was a deadlock in reducing power consumption in CMOS technology designed for 1 Exa-scale supercomputers, which exhibit 100-times the computation capabilities of a K computer. It was established that only superconducting technology was able to realize lower power consumptions and therefore the potential to break the deadlock. Dr. Yamashita, NICT, reported on experiments undertaken to multiplex the output from superconducting single photon detectors (SSPD) by utilizing SFQ circuits to bring out to room temperature with a line. The SFQ readout circuit integrates a 4-element SSPD array, producing the fundamental operation of a single output line. Further development of this method showed potential to significantly reduce the number of output lines from a multi-pixel detector.

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Professor Yoshikawa from Yokohama National University presented a new type superconducting digital circuit called an Adiabatic Quantum-Flux Parametron (A-QFP). A switching energy of 10 ZJ (1×10^{-20} J) was confirmed by their experiments. This value is the world's smallest logical element, three digits smaller compared to that of a conventional single flux quantum (SFQ) circuit.

The trend is now towards multi-pixel detectors. Dr. Ukibe, AIST, introduced a materials analysis and mass spectrometer systems that employed a 100-pixel superconducting tunnel junction (STJ). The material analysis system successfully detected light element of N in SiC and effectively observed mass-separation utilizing a signal with the same mass-to-charge ratio. Additionally, a significant reduction in measurement time utilizing a 100-pixel STJ was confirmed. Professor Yamamoto from Nihon University reported on the experimental study of Surface Plasmon Polaritons (SPPs) utilizing 50/50 beamsplitter. The Transition Edge Sensor (TES) developed at AIST is the only device able to precisely count the number of SPP necessary and has therefore been employed for this experiment.

Professor Nakamura from the University of Tokyo introduced recent progress in superconducting quantum computers. One of the major issues with superconducting quantum bits is that the coherent times are too short quantum calculations. Over the past ten years, investigations to disrupt the quantum states have been performed, producing a 6-digit improvement in coherent time from an initial several-10 ps to several-10 μs. The idea now in progress is to hybridize other types of quantum bits such as superconducting quantum bits and spin by utilizing microwave and photonic interfaces.

At the microwave session, Dr. Du from CSIRO introduced microwave and terahertz applications employing high temperature superconducting step-edge Josephson junctions. For microwave applications, a digital down-converter operating at 8~10 GHz incorporates an integrated Josephson mixer onto one chip. The operation at a wide temperature range from 20~80 K was confirmed. Regarding terahertz applications, a terahertz imaging device operating at 600-GHz has demonstrated the clear observation of hidden materials, which were not visible under light.

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Feature Article: The 26th International Symposium on Superconductivity (ISS2013) -Large-Scale System Applications

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The session devoted to large-scale system applications had 31 presentations and 108 posters. Reports were mainly based on YBCO coils with investigations pertaining to power applications such as cables and fault current limiters. With regards to cables, Furukawa Electric reported their results of current trials of a cable in China whilst Fujikura reported their first findings of their cable demonstration test; (SA-1: STATUS OF 275 kV REBCO HTS CABLE DEVELOPMENT IN THE NEDO PROJECT, S. Mukoyama, Furukawa Electric, SA-3:DEVELOPMENT OF 66kV-5kA CLASS HTS POWER CABLE WITH IBAD/PLD REBCO TAPES, M. Daibo, Fujikura).

The symposium also addressed an exceptional issue from Okazaki, ISTEC, who was proposing wind-heat power as potential a renewable energy source obtained by using superconducting heat generators. This proposal does not generate power from conventional wind energy itself, but instead, the concept involves the heat induced by revolutions of the wind turbine is stored, and subsequently the stored heat is used to generate electricity using a steam turbine. Superconducting magnets generate induced current from the rotary motion due to wind, producing the direct conversion of rotational energy to thermal energy and subsequently storing the thermal energy. Power from wind can only be generated when it is windy, and therefore the power generated is sporadic. The installation of more wind turbines requires greater control of the power output generated. In such cases, utilizing the stored energy for thermal power generation would allow greater control of the power output. According to calculations made by Okazaki, this method looks promising for the future allowing cheaper energy costs than compared to conventional battery-powered applications. （SA-7:SUPERCONDUCTING HEAT GENERATOR FOR WIND HEAT POWER, T. Okazaki, ISTEC）.

This year's symposium had many presentations related to high temperature superconducting MRI and NMR applications. Mine and his group at GE Global Research, reported their research results of an MRI system employing MgB_2 wires. A 10-inch bore coil at 3 T was fabricated and its initial n-value was small between 3-4 and deemed impractical. This was modified to improve I_c homogeneity, which resulted in an improvement of the n-value to around 20-26. The wire has a cross section of 0.7x3.1 mm, and has a 0.2mm-thick copper stabilizer layer. The 30cm-diamter coil applicable to MRI systems was fabricated. Some 2 T (transmission current 300A) was generated at 14 K, therefore successfully causing excitation without a large voltage. Although these demonstration trials were not performed in permanent-current mode, the only measured resistance of the coil voltage was (0.03 μΩ) generated due to the solder connection. Investigations into superconducting connections were undertaken in parallel and a 10^{-11} ohm resistance was recently recorded (the details was not published) (SA-10: DEVELOPMENT OF a 3 T-10-inch BORE MgB_2 MAGNET AT GE, S. Mine, GE Global Research).

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Yanagisawa from RIKEN introduced future prospects regarding high temperature superconducting NMR originating from their recent research studies. Current NMR systems have been fabricated having a maximum 1GHz (23.5 T) by utilizing metal-based superconducting wires such as NbTi and Nb_3Sn. High temperature superconducting REBCO, Bi2212, and Bi2223 wires demonstrated high critical current densities even at high magnetic field of 20-40 T and at low temperatures of 4.2 K, potentially leading to NMR systems with even greater magnetic fields between 2-3GHz. Additionally, it is possible at such magnetic fields that NMR system can be significantly reduced in size facilitating future ease of use. The group at RIKEN actually fabricated and investigated a 500MH NMR (11.74 T) composed of low temperature superconducting wires and REBCO wires. NMR systems conventionally require accuracies of 10^{-9}/5mm (wire-width) for spatial homogeneity and 10^{-10}/h precisions for temporal stabilization. (SA-11: TOWARDS NEXT-GENERATION COMPACT HIGH FIELD NMR; THE WORLD'S FIRST LTS/REBCO NMR MAGNET OPERATED AT 400 MHZ (9.4 T), Y. Yanagisawa, RIKEN) Many issues still remain for investigation in order to realize applications for practical use. There are therefore high expectations for Japan's first project led by METI into investigation of high temperature superconducting medical equipment applications.

Urayama from Kyoto University reported their current results from a 3 T MRI system (utilizing Bi-based coil) development. Soldering connections and a high-precision power source were employed in place of superconducting connections. Realizing homogenous magnetic fields and stability at high levels of precision in MRI systems have led to the acquisition of an actual human brain image. An important issue reported during the presentation was coil burnout. A refrigerator cryocooled system experienced magnet burnout during the third demagnetization process. It was when the cryo was opened that the burnout between the coil turn terminals was confirmed. The reason behind the burnouts is currently under investigation and the results from these investigations are eagerly awaited since the majority of high temperature superconducting applications utilize cryocoolers. The findings are thus important with regards to future HTS applications. (SA-12: A CRYOGEN-FREE 3 T MRI SYSTEM FOR HUMAN BRAIN RESEARCH USING Bi-2223 HIGH-TEMPERATURE SUPERCONDUCTING TAPES, S. Urayama, Kyoto University)

There were a number of presentations from Korea reflecting their motivation in this area. For example, Changwon University presented their investigations on wind power generator applications and reactors. (SA-14: SUPERCONDUCTING POWER APPLICATION PROJECTS IN KOREA ESPECIALLY CONSIDERING THE RENEWABLE POWER ENERGY SOURCE, M. Park, Changwon University), as well as recent studies on non-insulated HTS coils. （SA-21: MECHANICAL AND ELECTRIC CHARACTERISTICS OF VACUUM IMPREGNATED NO-INSULATION HTS COIL, S. Kim Changwon University)

The presentations pertaining to the wire session were promising with regards to being applicable to both MRI and NMR applications (connection resistance 10^{-17}ohm, transmission current 26 A). The author considered that combined with the results related to coiling, significant progress would be highly anticipated for industrial application of YBCO coils over the next couple of years.

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