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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

▸Power Application 전력응용 电力应用 [diànlì yìngyòng]

Korea Test of High Voltage DC Superconductor Cable

AMSC (29 Oct, 2014)

Korea Electric Power Corporation (KEPCO), LS Cable & System, and AMSC successfully energized a high voltage direct current (HVDC) HTS cable on KEPCO's real smart grid demonstration site in Jeju Island. HVDC HTS cables have high power density capabilities, thus are ideal for transporting large amounts of power underground within a minimal footprint.

The 500-meter, 80 kV DC cable comprises AMSC's Amperium® HTS wire. Daniel P. McGahn, President and CEO, AMSC, stated " "With the energizing of the HVDC cable at Jeju Island, KEPCO and LS Cable have taken another step forward in upgrading Korea's electricity network and fulfilling KEPCO's vision of securing a world-class competitive edge through the development of green and smart technologies." Ja-Eun Koo, President and CEO, LS Cable & System is stated as saying, "The HVDC superconducting cable system offers transmission performance superior to that of alternating current (AC) systems. Interest in this technology has been building up in Asia, the United States and Europe, where new power network implementation is needed". He believes that Korea is the earliest country in the world to implement smart grid, Energy Storage System (ESS), and micro grid. "The energizing of the first DC HTS cable demonstrates KEPCO's commitment to developing world-class, leading edge technologies," said Hwan-Eik Cho, President & CEO, KEPCO.

By utilizing AMSC's Amperium HTS wire, KEPCO is also conducting testing for 1km-class 154 kV AC cable system. In was only back in 2011, when KEPCO, LS Cable & System, and AMSC energized a 22.9 kV AC cable system at the I'cheon substation located near Seoul, operating successfully for two years. KEPCO anticipates that future cable designs will be capable to transporting 10 gigawatts (GW) of power within an 8-meter footprint.

Source: "Korea Energizes High Voltage Direct Current (HVDC) Superconductor Cable"
(29 Oct, 2014) Press Release
http://ir.amsc.com/releases.cfm
Contact: Kerry Farrell, kerry.farrell@amsc.com

World's longest HTS cable in Essen

RWE (27 Oct, 2014)

The world's longest superconducting cable measuring 1 km has exceeded all expectations. It was commissioned on 30 April this year and has now been live for 4,300 hours, delivering around 20 million kilowatt-hours of electricity, around 10,000 Essen households. This was a positive interim report by RWE and its project partners on AmpaCity's first six months. "Operations have so far proceeded smoothly. We have gained valuable knowledge of this technology, which has helped us improve the whole superconductor system further," reported Dr. Joachim Schneider, Technical Director at RWE Deutschland. There have been changes to system monitoring to ensure smoother integration into Essen's grid protection system, as well as adaptations to the cable cooling circuit.

The Parliamentary State Secretary to the Federal Minister of Economics and Energy, Uwe Beckmeyer, stated on his visit to Essen that, "The energy transition calls for bold innovation. We need to design an efficient and secure system to meet tomorrow's energy needs. So we had no hesitation in choosing this excellent project for sponsorship under our energy research programme." It was funding from the German Federal Ministry for Economics and Energy that enabled the flagship project to go ahead. Since then, AmpaCity has been the focus of attention worldwide. Delegations from China, France, Ghana, Japan and the USA have already visited Essen to find out more about the technology on location. The 10,000-volt superconducting cable replaces a conventional 110,000-volt power line, thus making it possible to decrease the numbers of substations and thereby making available valuable inner-city land.

The Ministry contributed EUR 5.9 million of total project costs of EUR 13.5 million, co-investing with RWE and its partners Nexans and the Karlsruhe Institute of Technology (KIT). Nexans designed a superconducting short-circuit current limiter for field trial demonstrations, supported by KIT.

Source: "World's longest superconductor cable yields first new technological knowledge" (27 Oct, 2014) Press Release
URL: http://www.rwe.com/web/cms/en/113648/rwe/press-news/press-release/?pmid=4012082
Contact: Sebastian Ackermann, sebastian.ackermann@rwe.com

▸ Accelerator 加速器 [jiāsùqì] 가속기(加速氣)

Canada's Superconducting Electron Linear Accelerator

TRIUMF (7 Oct, 2014)

TRIUMF's newly constructed superconducting electron linear accelerator (e-linac), generated its first particle beam at an initial energy of 23 MeV. This is a series of recent successes for the Advanced Rare Isotope Laboratory (ARIEL) project, making it one of the most sophisticated rare-isotope facilities in the world and is internationally recognized for its cutting-edge technical and scientific capabilities. ARIEL's e-linac comprises of many sophisticated systems including superconducting radiofrequency (SRF) accelerator cavities that must operate at extreme tolerances in order to deliver the beam effectively.

The successful completion of the project is the result of a remarkable collaboration between TRIUMF, Canadian industry, and 13 Canadian universities led by the University of Victoria, who contributed on building, installing, and commissioning the e-linac. The Government of British Columbia funded the project through the BC Knowledge Development Fund (BCKDF), jointly with the Government of Canada through the Canadian Foundation for Innovation (CFI), and the National Research Council Canada through TRIUMF and in-kind contributions. "This is a tremendous accomplishment for these scientists, their teams, and for British Columbia," said Minister of Technology, Innovation and Citizens' Services Andrew Wilkinson. He trusts that British Columbia is set to become a global leader in the field of superconductors and rare-isotope research.

The next phase of the ARIEL project will further expand the collaboration to 19 Canadian universities and five provincial governments. New partnerships will be formed with industries, which will offer greater opportunities for the training of the next generation of scientists and engineers. The plans for ARIEL over the next five years include advancing scientific and technical capabilities that will culminate in even greater societal and economic benefits for Canada, making TRIUMF an international hub for cutting-edge rare-isotope research. In fact, the Variable Energy Cyclotron Centre (VECC) in Kolkata, India and TRIUMF has signed a joint partnership to develop accelerator and isotope production technologies for each facility.

Source: "Canada's Superconducting Electron Linear Accelerator Produces First Beam"
(7 Oct, 2014) TRIUMF News Release
URL: http://www.triumf.ca/sites/default/files/NR_2014-10-07-ARIEL_BEAM-vFINAL_0.pdf

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Contact: Melissa Baluk mbaluk@triumf.ca

▸Industrial Application 산업응용 工业应用 [gōngyè yìngyòng]

18 Tesla Bulk Magnet

University of Cambridge (22 Oct, 2014)

Cambridge University's bulk superconductivity group, led by Professor David Cardwell, who earlier this month was appointed head of the university's department of engineering, says that the large magnetic fields that have been employed in Maglev train technology could hold the key to improving treatment of serious illnesses and in cancer treatment.

Professor Cardwell stated, "We try to make bulk superconductors generate large magnetic fields." It was only earlier this year that the group generated the highest magnetic field ever recorded in a superconductor of 18 tesla. The Cambridge team broke the record using a disc-shaped gadolinium barium copper oxide superconductor, cooled above the boiling point of liquid nitrogen.

The most high profile use of this technology is in Maglev applications, for example Shanghai Maglev and the SCMaglev in Japan. Maglev trains remain expensive to build, with the Shanghai Maglev costing $1.2bn, and estimated costs of SCMaglev are around $100m per km of track. Such high costs prevent the use of Maglev trains becoming more widespread according to Professor Cardwell, who states that, "it would be hugely expensive and take a long time to build a Maglev railway network, but we'll see superconductors being used more widely, particularly in healthcare." Applications envisaged include smaller MRI scanners that could be installed at local doctors' surgeries rather than being available only at hospitals.

Professor Cardwell added, "There's also the possibility of using them in cancer treatment. If you can insert something magnetic into the body, it could be used to direct treatment to the part of the body which is affected by the cancer, rather than treating the whole body as we do at the moment. This could potentially reduce the side effects for patients. We could see this sort of technology come into use in the next few years."

Source: "Cambridge University's bulk superconductivity group says levitating train tech could be used in cancer treatment" (22 Oct, 2014) Cambridge News
URL:http://www.cambridge-news.co.uk/Cambridge-University-s-bulk-superconductivity/story-23341897-detail/story.html
Contact: reception@eng.cam.ac.uk

▸Management and Finance 경영정보 经营信息[jīngyíng xìnxī]

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KIT and BASF Open a New Lab.

BASF(23 Oct, 2014)

The Karlsruhe Institute of Technology (KIT) and Deutsche Nanoschicht GmbH (a BASF subsidiary) have signed relevant cooperation agreements to develop bespoke high-temperature superconductors for energy applications such as current limiters and transformers for public power grids, power cables for urban supply networks and coils for generators and electric motors. The joint venture between the two partners will see the opening of a new laboratory that will be based at the Institute for Technical Physics of KIT in early 2015, to optimize and tailor superconducting thin film conductors for individual applications. For example, superconductor characteristics will need to be adapted for applications that would be applicable to AC, high current density and strong magnetic field environments.

"KIT has extensive knowledge about the synthesis and use of superconductors. Cooperation with KIT therefore ideally complements our activities in building up our growth field E-Power Management," says Dr. Stefan Blank, Managing Director, BASF New Business GmbH. Dr. Michael Bäcker, Managing Director of Deutsche Nanoschicht GmbH adds that, "Our unique coating technology will make it possible to manufacture superconductors with the price-performance ratio required for them to be more applicable throughout the energy sector". Prof. Dr. Bernhard Holzapfel of the Institute of Technical Physics at KIT will supervise the new laboratory.

Source: "Tailored superconductors for energy technology"
(29 Oct, 2014) Joint News Release
URL: http://www.basf.com/group/pressrelease/P-14-379
Contact: Vanessa Holzhauser BASF, Vanessa.holzhaeuser@basf.com

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Feature Article: SQUID Application
- Development of HTS Gradiometer Using 2-SQUID Rotation Mechanism

Akira Tsukamoto, Senior Research Scientist
Materials/Physics & Electronic Devices Division
SRL/ISTEC

Metallic ore deposits are magnetized by the Earth's magnetic field. This influences the terrestrial magnetic field measured at the ground surface. An underground exploration technique that investigates changes in the Earth's field is commonly referred to as magnetic prospecting. Since the Earth's field varies between several tens of nT (magnetic quiet day) to several hundreds of nT (geomagnetic storm) in a day, measuring the Earth's field should not be about determine nominal values, but instead ascertain the magnetic changes between the two sites. To this aim, a prototype HTS gradiometer comprising of two rotating SQUIDs was fabricated, allowing absolute values of magnetic gradient to be measured.

Due to a principle of feedback operation of SQUID, the measurement does not determine absolute magnetic field values, but instead measures only relative changes from a certain offset value. Since the offset value differs according to an individual SQUID, a simple calculation of the difference cannot be used to produce an absolute value of the magnetic gradient. To address the discrepancies with a SQUID measuring absolute values, we have investigated a method employing two SQUIDs that measures the magnetic signals at remote sites alternately, thus eliminating global changes in the measured magnetic fields, as shown in Figure 1.

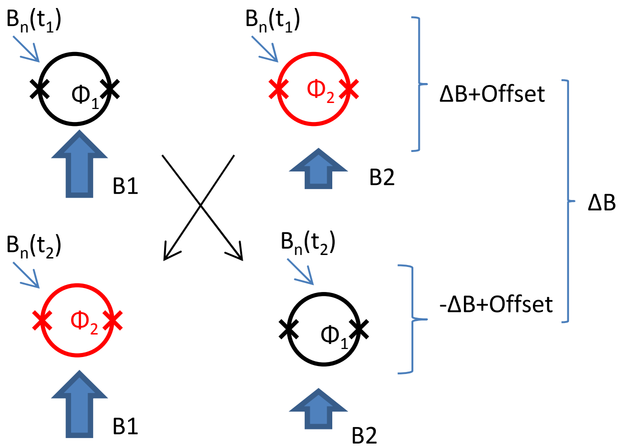

Fig. 1 Diagram showing the measurement principle

Mobile measurements made at two sites using the same SQUID can cancel the measured offset values, thereby allowing an absolute value of the difference of two signals to be measured. Also, conducting simultaneous measurements of the difference between two SQUID output signals allow global variations in the magnetic field to be eliminated.

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Figure 2 provides an overview of the prototype system. The technique involves two SQUIDs that are continuously rotating concentrically allowing their positions to be altered. Two HTS-SQUID magnetometers (detection coil diameter 13.5x13.5 mm), facing towards the vertical direction (rotation axis direction) are each cooled by their respective dewars. Each dewar has a self-revolving mechanism, transporting the dewar on the rotating stage whilst the in-plane direction remains unchanged. An ultrasonic motor is used for rotation since it offers reduced magnetic noise characteristics, operated externally utilizing an infrared remote-control command. An FLL circuit (Hitachi-manufactured) with the wireless LAN interface is mounted onto the dewar and simultaneously feeds rotational positions and SQUID signals to a PC. Real-time subtraction can therefore be performed on a PC. The continuous rotation enables simultaneous measurements of dBz/dx and dBz/dy with averaging technique.

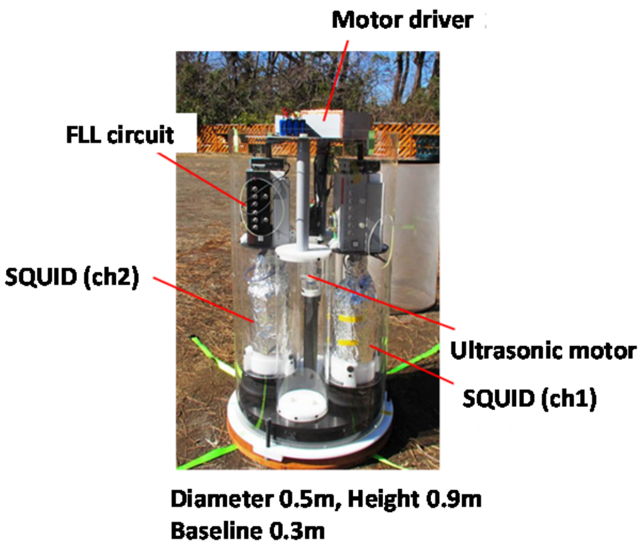

Fig. 2 Prototype HTS gradiometer using 2-SQUID rotation mechanism

This research was supported by Japan Oil, Gas and Metals National Corporation (JOGMEC), as part of a mineral exploration technology development project funded by the Ministry of Economy, Trade and Industry.

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Feature Article: SQUID Application
- System Designed to Visualize Electrochemical Reactions Using HTS-SQUID Gradiometer

Toshihiko Kiwa, Associate Professor
Graduate School of Natural Science and Technology
Okayama University

Measurements of the electrochemical reactions between electrodes and electrolyte have long since been essential for the diverse fields of science and engineering. The important roles played by such measurements in recent years have contributed to analytical chemistry, surface nano-science, and energy systems including highly efficient batteries and fuel cell developments. Amongst the number of methods available, voltammetry is most frequently used as an electro-analytical technique. The method employs three electrodes (a working electrode, a counter electrode and a reference electrode) placed in an electrolyte, and the current between the working and counter electrodes is measured as a function of the electrical potential. The measured current is typically not proportional to the difference between the electrical potential, but instead exhibits non-linear features that are attributed to redox reactions at the electrode/electrolyte interface. By analyzing such features therefore allows the identification of materials contained within the electrolyte as well as an understanding of the nano-region surface morphology of the electrode. However, electrochemical reaction measurements are influenced by a variety of factors such as the ion movement in the electrolyte and the electrode shape etc. Measuring ion currents in an electrolytic cell are essential to address these issues, and therefore there have been an array of R&D activities involved. For example, a technique employing a minute magnetic loop array mounted in the electrolytic cell to detect magnetic fields generated by the ion currents has been applied [1]. However, the inserted coil disrupts the ion currents. To study this further, the author and his research group have constructed a noncontact measurement system employing an HTS-SQUID gradiometer that visualizes the magnetic fields generated by the ion currents in an electrolytic cell.

Figure 1 shows a schematic image of the electrolytic cell used in the experiment. A solution of 0.5 mM-$K_3[Fe(CN)_6]$ dissolved in 0.5 M-Na_2SO_4 was prepared. The depth profile of the cell is around 5mm, sufficiently small compared to the spatial resolution of magnetic measurement system and thus the depth profile of the ion current is negligible. The HTS-SQUID gradiometer employed here was a ramp-edge Josephson junction, comprising ISTEC's $La_{0.1}Er_{0.95}Ba_{1.95}Cu_3O_y$ and $SmBa_2Cu_3O_y$ electrode layers. The HTS-SQUID is mounted onto a planar gradiometer with a long baseline of 7.5mm, both of which are prepared on the same surface plane. For device details, please refer to **2) ~ 4)**. Figure 2 (a)~(d), shows the distribution of the ion currents in the electrolytic cell when the electric potentials of working electrode vs. the reference electrode were +0.15 V, +0.80 V, +348 V, and -0.295 V, respectively. The vector component shown in the figure indicates the magnitude of the currents calculated from the magnetic signals. The magnetic signals from two independent directions in the cell were measured and the magnitudes of the ion current vectors were mapped corresponding to the ion current distribution. The figure shows that the direction of current vector shifts according to the electrical potential caused by a redox reaction between the electrodes. Also, the current distribution can be observed around the working electrode [6].

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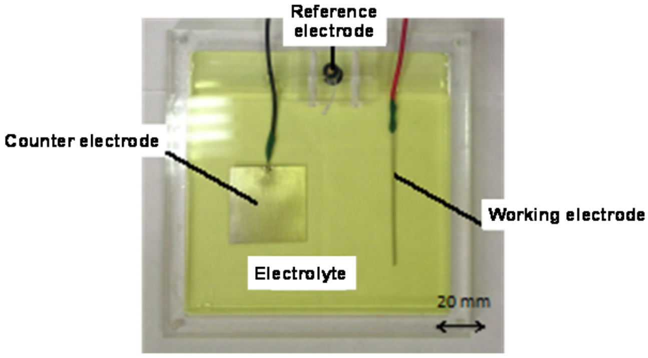

Fig. 1 Electrolytic cell used in the experiment

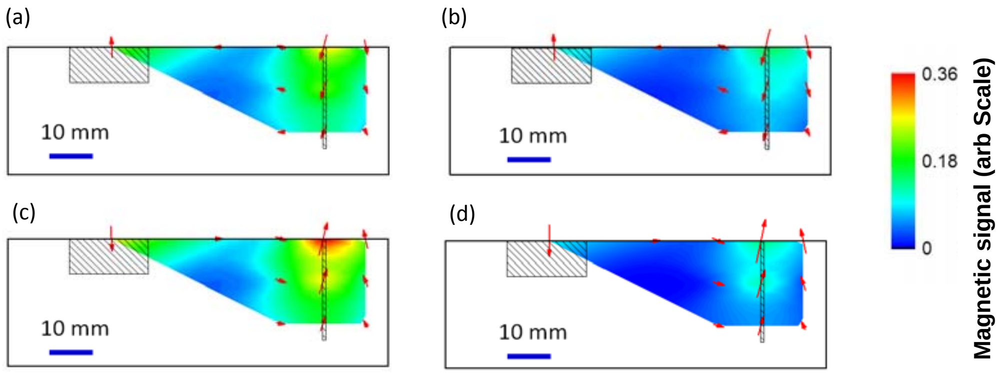

Fig. 2 Distribution of the ion currents in the electrolytic cell when the electric potentials vs. the reference electrode, respectively, (a) +0.15V, (b) +0.8V, (c) +348V, and (d) -0.295 V

Additionally, the magnetic signal response was successfully observed when a pulsed electrical potential was applied [7]. The author considers that transient responses of electrochemical reactions can be visualized in the future, and measurements incorporating an HTS-SQUID gradiometer will become a valuable tool in analyzing electrochemical reaction mechanisms.

Reference:

1) Ch. Wieser,*et al*., J. Appl. Electrochem. 2000; 30: pp. 803-807.
2) S. Adachi, *et al*., 2008; 468: pp. 1936-1971.
3) H. Wakana, *et al*., IEEE Trans. Appl. Supercond. 2009; 19: pp. 782-785.
4) K. Sakai, *et al*., Supercond. Sci. Technol. 2012; 25: 045005.
5) K. Tsukada, *et al,* Rev. Sci. Instrum. 2006; 77: 067303.
6) T. Kiwa *et al*., IEEE Trans. Appl. Supercond., 2013, 12: 1600804.
7) T. Kiwa *et al*., Physica C, 2014, In press

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Feature Article: SQUID Application
- Recent Progress in SQUID Detection System for Metallic Contaminants

Saburo Tanaka, Professor
Department of Environmental and Life Sciences
Graduate School of Engineering, Toyohashi University of Technology

The author and his research group have long since been advancing the development of metallic contaminants detection systems designed for food products. Up to now, a joint R&D collaboration with industry has successfully realized a system incorporating a high-temperature superconducting DC-SQUID for processed cheese block product applications. The system has now been in operation at a food-processing factory for more than ten years. With an aim to design improved reliability, R&D has been progressively initiated via a "The Knowledge Hub of Aichi" project (5yr-term) back in 2011.

SQUID detection, eddy current tests and X-ray methods are currently employed to detect foreign matter contamination in food products. Amongst these methods, eddy current testing is widely employed for food product testing applications. However, its sensitivity is influenced by metallic contaminant conductivity or the conductivity of the food product itself. Although X rays are also a valuable technology and extensively employed, they have a minimum detection limit of around 1mm and have other drawbacks associated with food product ionization, extermination of good bacteria and deterioration in food flavor. These issues can be overcome by employing SQUIDs. The principle of contaminant detection is shown in Figure 1 and is based upon the detection of remnant magnetization of metallic contaminants using a SQUID magnetometer. Figure 2 shows an outline of the system developed in 2014.

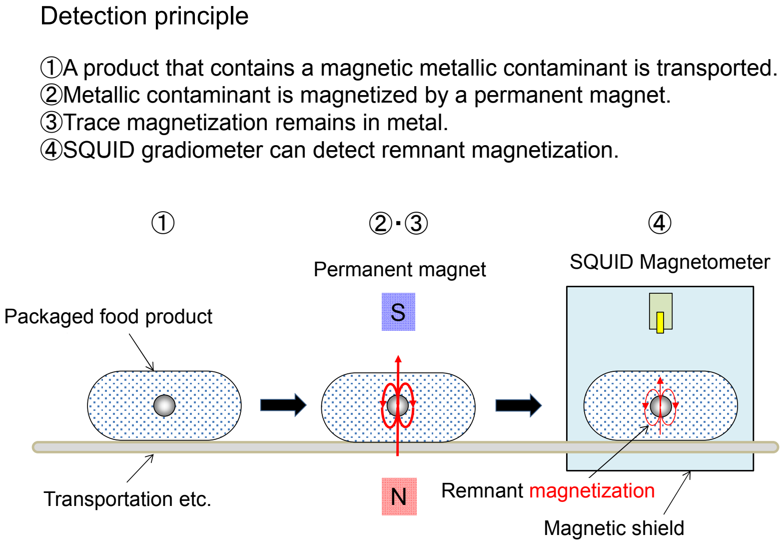

Fig. 1 Principle of contaminant detection

Fig. 2 Appearance of system

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With special considerations for practicality and reliability, an RF-SQUID was selected as part of the Aichi prefecture project. High-temperature superconducting SQUIDs require an everyday top-up of liquid nitrogen. Here, some moisture entering the system during liquid nitrogen filling is unavoidable and regular maintenance is therefore necessary to defrost and eradicate the moisture. Cable deterioration and failure cannot be avoided in long-term DC-SQUID operations of more than ten years. Instead, an RF-SQUID comprising of a single coaxial cable is proposed since it performs with relatively greater reliability (cable deterioration over the long term is not clear since there is no installation track record). The magnet was designed having a maximum flux density of 0.34T (0.1T for conventional systems), and exceed 0.3T along all the parts of the 150mm-width belt conveyor. A liquid nitrogen (LN_2) dewar comprising of individual three glass dewars maintained the RF-SQUID temperature at 77K, as shown in Figure 3. In this way the base of the dewar can be further thinned compared to an integrated large dewar, thereby reducing the distance between the magnetometer and the specimen. The outputs from the RF-SQUIDs are recorded with a low pass filter having a 20Hz cut-off frequency and a high pass filter (HPF) having a 0.2Hz cut-off frequency, and later sent to an A/D converter.

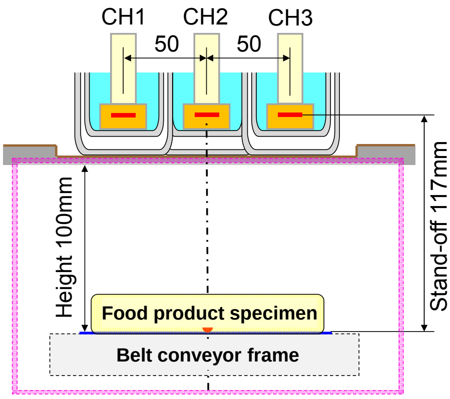

Fig. 3 Cross-sectional diagram of detection system

Figure 4 (a) shows the time-domain magnetic signals from three SQUID magnetometers. These signals were measured when the standoff distance (distance between the iron ball and the SQUID array) was set at 64 mm. The amplitude signal from ch2 is greater than the signal from the other two magnetometers since the iron ball passes just below. A signal to noise ratio (SNR) of >3 was measured for an iron ball larger than ϕ0.4 mm, and a SNR>2 was obtained for a ϕ0.3 mm-iron ball. Figure 4 (b) shows the relationship between the specimen diameter and the measured peak signal amplitude of the SQUID magnetometer. The signal increases three-times the diameter of the specimen, implying that this is proportional to the volume of the specimen.

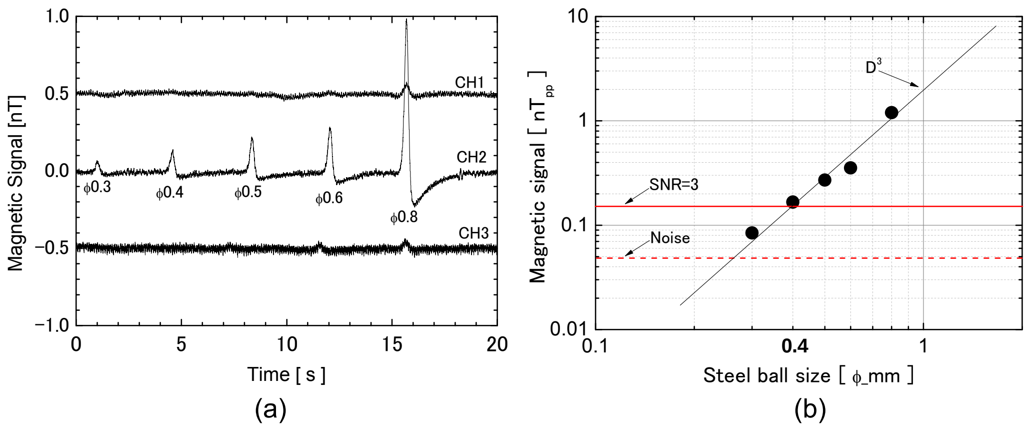

Fig. 4 (a) Time-domain magnetic signal, (b) Relationship between the measured signal amplitude and diameter of contaminated specimen

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Feature Article: SQUID Application - STM-SQUID Microscope

Hideo Itozaki, Professor
Graduate School of Engineering Science
Osaka University

Magnetic microscopy is one of the SQUID application research themes. A session of the SQUID microscope took place at the International Superconductive Electronics Conference (ISEC) 2013, held in Boston. We reported on an STM-SQUID microscope, receiving high acclaim due to its uniqueness and high resolution.

The SQUID microscope presented here has two significant attributes; ① a probe with high permeability and uniquely sharpened sub-micron tip (Figure 1), along with a capability that can transfer the captured local magnetic fields on the sample surface to the SQUID, and ② the application of a DC voltage to the probe that allows a controlled and constant flow of tunnel current when the probe gets close to the sample surface. This behaves as a scanning tunneling microscope (STM), able to maintain a nano-scale distance between the sample surface and the tip of probe. In addition, it is simultaneously able to observe both the roughness and magnetic field of the sample surface.

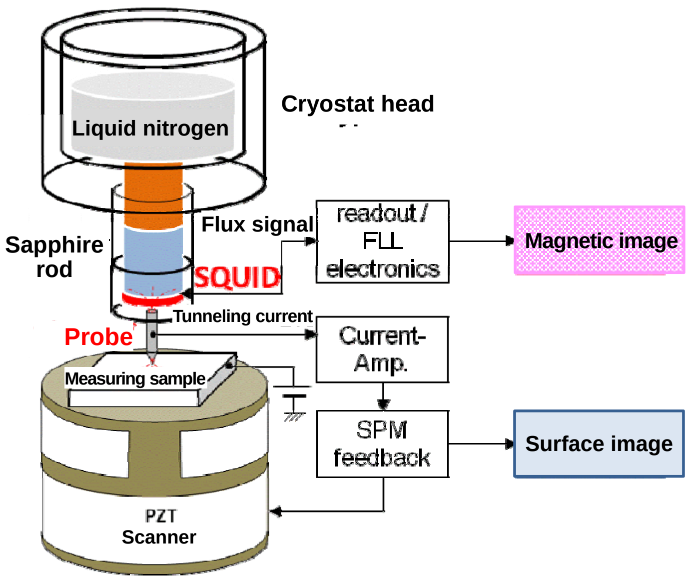

Fig.1 Conceptual diagram of STM-SQUID microscope

Figure 2 shows an arrangement of the SQUID, the needle and the sample of the STM-SQUID microscope A SQUID is attached to a sapphire rod, which is cooled to liquid nitrogen temperatures by placing it at the bottom of a liquid nitrogen vessel. One side of the probe needle is located near the SQUID which is in vacuum and its sharpened tip is located in outside of vacuum and close to the sample at room temperature.

The sample is attached on a 3D XYZ piezo-scanner. The XY scanner scans the surface of the sample and its surface morphology and magnetic field can be observed by Z scanner.

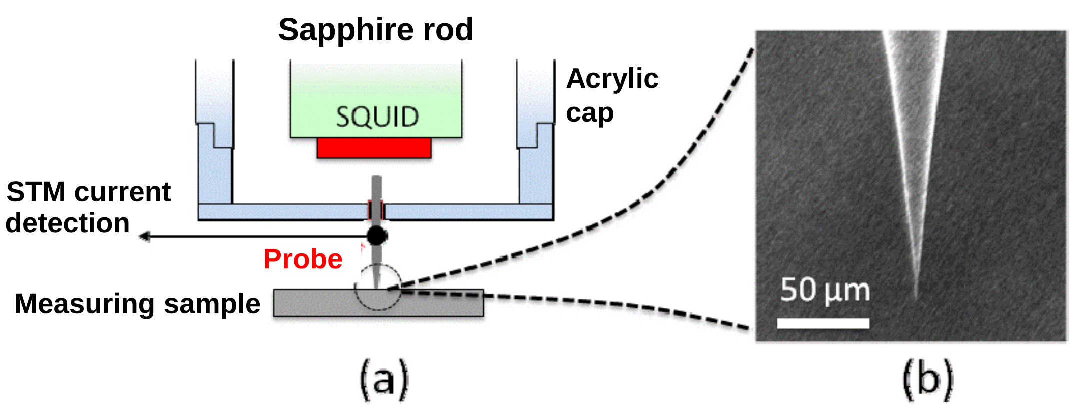

Fig. 2 Probe positioned for magnetic measurements and the SEM image of the probe tip

Figure 3 shows example images of the magnetic domains of Ni thin films (1µm film thickness), together with its STM image of the surface roughness, both of which were simultaneously observed. The surface is almost flat although a nano-scale roughness exists. The magnetic image clearly shows the magnetic domains of Ni thin films.

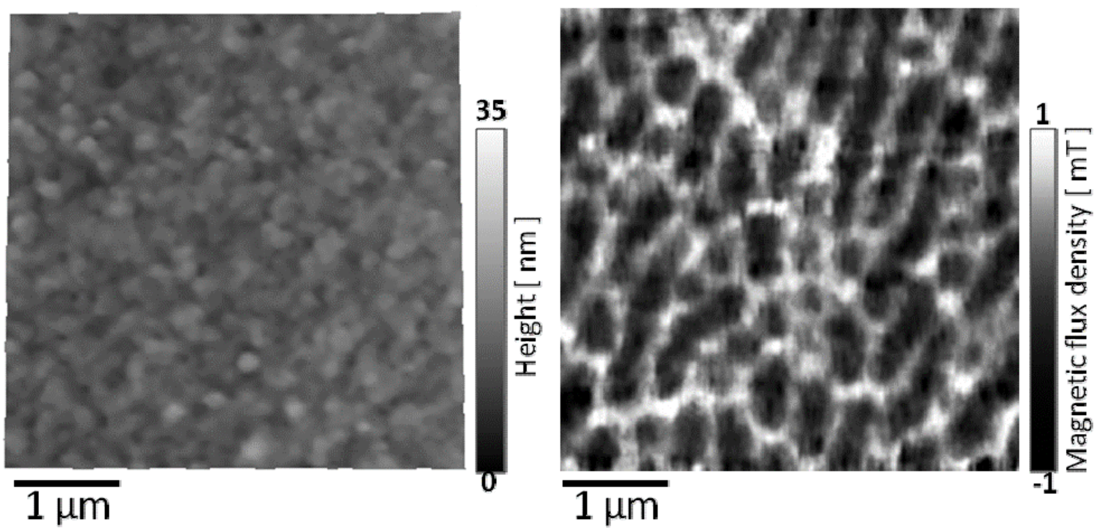

Fig. 3 STM image (left) and magnetic field distribution image (right) of the Ni thin film surface

There is a problem measuring insulating materials since the STM requires a tunnel current to flow between the probe and the sample, and thus the technique is limited to only conductive samples. In its place, an AFM-SQUID microscope is currently undergoing development and will progressively permit observations of insulating magnetic materials.

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Active R&D related to SQUID microscopes are currently being undertaken in Europe and the USA. The unique method of probe by Osaka University group in Japan can realize higher resolutions and simultaneously observe the surface morphologies of samples at ambient temperature. It therefore demonstrates its superior characteristics.

The SQUID microscopes have a promising future as research tools for the observation of magnetic materials exhibiting a variety of microstructures.

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Feature Article: SQUID Applications
- Non-destructive SQUID-Based Testing for Railway Applications

Yoshiki Miyazaki, Assistant Senior Reseacher
Cryogenic Systems, Maglev Systems Technology Division
Railway Technical Research Institute

A friction between a rail and wheels during acceleration and braking can lead to the formation of a thermally-transformed hard but fragile structure on the surface of the rail, a so-called white etching layer (WEL). The area around the WEL triggers the formation of micro-cracks that expand easily leading to rail damage by the delamination on the surface of the rail. WEL is considered one of the causes of rail damage and investigations to better understand the relationships are being actively pursued.

In this study, the author and his research group have confirmed that the SQUID-eddy current technique can be employed to investigate the formation of WEL on the rails. Our initial system, however, demagnetized the specimen in advance and was completely magnetically shielded in order to eliminate the remanent magnetism of the rail.

Having a system that is magnetically shielded completely is not feasible for rail field measurements. A prior process to demagnetize the rail is also undesirable because of increased detection times. To overcome this, a prototype rail testing system comprising a SQUID has been specifically designed for field tests, as shown in Figure 1. Figure 2 shows the measurement principle. The only detection probe, comprising of a bridge circuit, is placed closer to the rail allowing the SQUID to obtain signals from the input coil. Also, this allows for the SQUID to be completely housed in a magnetic shield enclosure and placed several distance from the rail. The prototype system performs consistent measurements that eliminate the influence of the remanent magnetism of the rail.

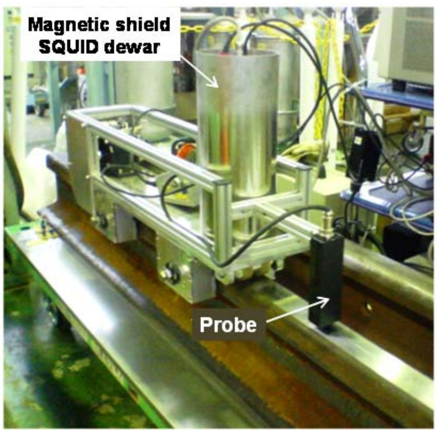

Fig. 1 SQUID-rail testing system

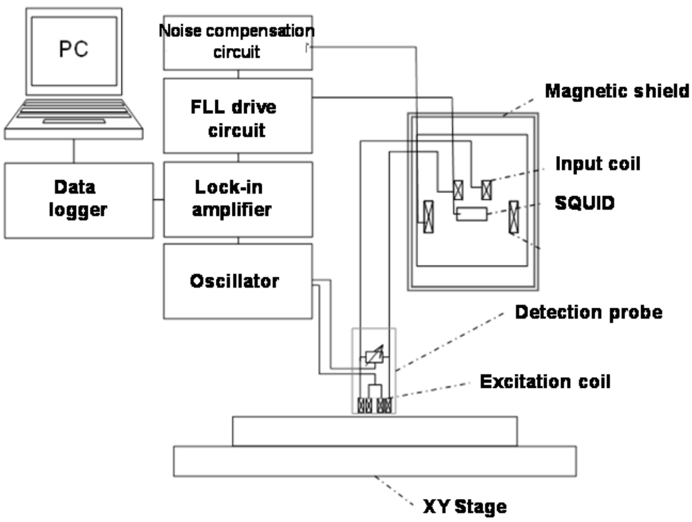

Fig. 2 The principle of SQUID-rail testing

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The measurement system specifically designed for outdoor use was installed and tested on a rail scanning system, performing measurements of an actual WEL. At a scanning speed of 5mm/sec, a WEL with an approximate thickness of 15μm was successfully detected. The system validated the prospect of determining WEL formation using a SQUID (Figure 3).

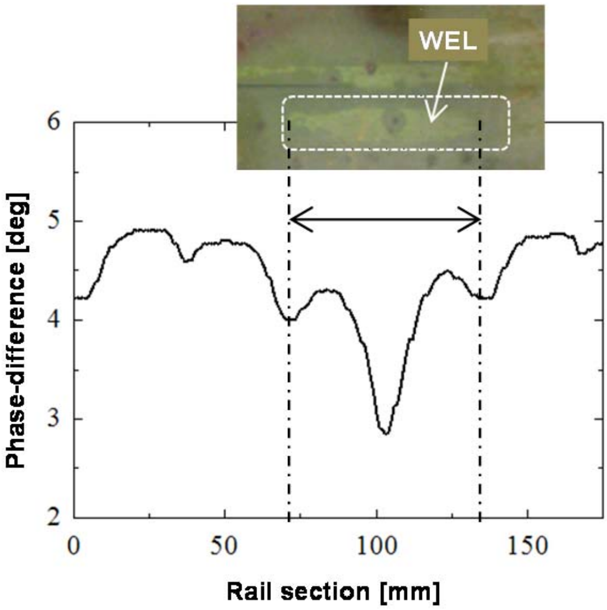

Fig. 3 The detection results measured at a scanning speed of 5mm/sec

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Feature Article: SQUID Application
- Progress in Spinal Cord Diagnostic Systems Employing LTS-SQUID

Yoshiaki Adachi, Associate Professor
Applied Electrons Laboratory
Kanazawa Institute of Technology

The author and his research group have advanced the development of magnetospinogram (MSG), a technique that utilizes a SQUID magnetometer array placed at the body surface to detect feeble magnetic fields accompanying neural activity[1), thereby allowing non-invasive assessment of spinal cord lesions. The MSG system is able to visualize spinal neural activity and provide useful and accurate diagnosis in spinal degeneration due to paralysis and/or numbness of hands and feet. A prototype MSG system is being continuously used at the Department of Orthopaedic Surgery of Tokyo Medical and Dental University, and progressively demonstrates the effectiveness in the diagnosis of spinal cord lesions.

The high operational costs of MSG prevent it from being widely introduced at hospitals since the need to utilize liquid helium, similar to other SQUID-based biomagnetic measurement systems such as magneto-encephalogram and magneto-cardiogram. The author and his research group have performed experiments to minimize the evaporation of liquid helium, employing a pulse-tube cryocooler to cool the thermal radiation shield inside the low temperature vessel using helium gas [2)].

Typically, cryocooler oscillations and magnetic noise significantly impact biomagnetic measurements. However, the magnetic frequency signals associated with the spinal cord range between several 100 Hz to several kHz, and thus the frequency bands do not overlap with the cryocooler noise of less than 10 Hz. Even so, a high-pass filter can be utilized to reduce noise and thus minimize the effects to any measurements.

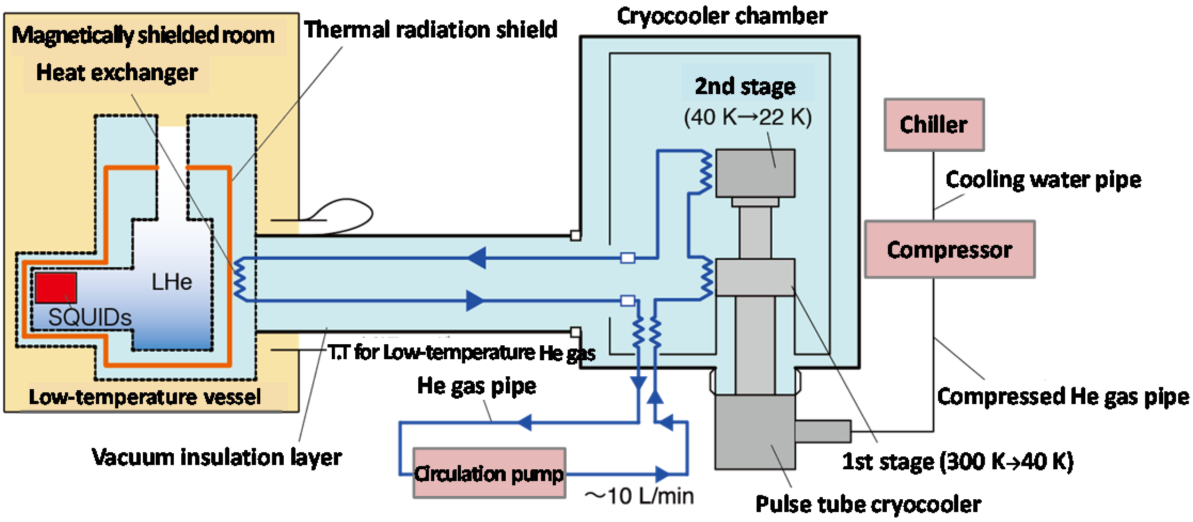

Fig. 1 System configuration of the experiments undertaken to reduce helium evaporation with the use of a cryocooler

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Figure 1 shows the experimental system configuration. A pulse-tube cryocooler with a cooling capacity of 0.5W@4K was employed (Iwatani Corporation, CryoMini PDX05/CW701). The system achieved a 46 % reduction in helium evaporation. As shown in Figure 2, the measured spinal magnetic signals were equivalent to a system equipped without a cryocooler and yet the pulse-tube cryocooler was placed 1.5 m away from the wall of a shielded room.

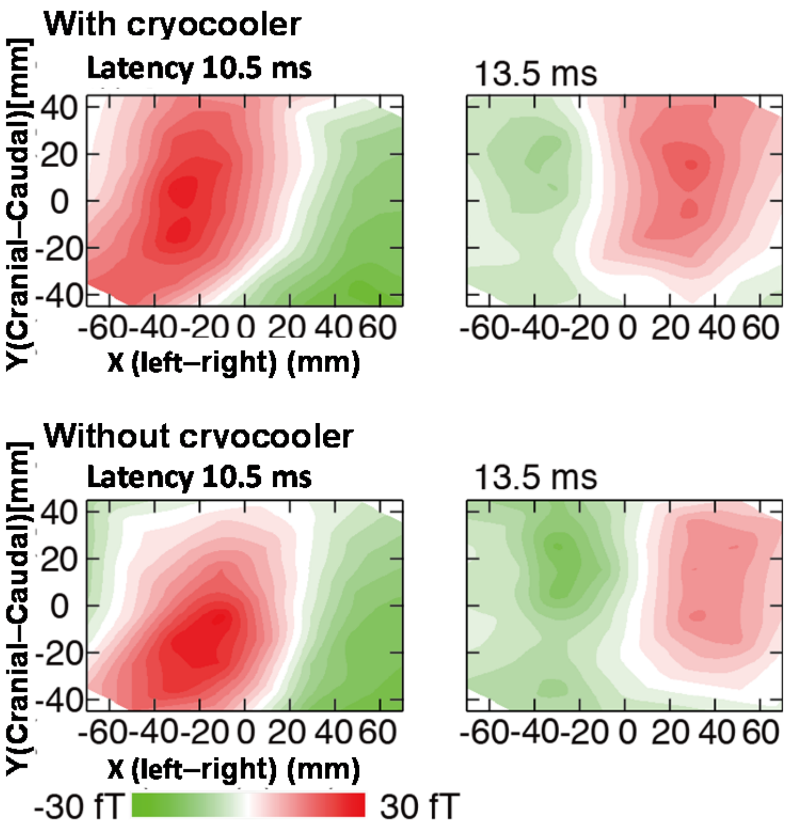

Fig. 2 Comparisons of the cervical spinal cord evoked magnetic fields produced by median nerve stimulation given in left wrist, using a magnetospinography equipped with/without a cryocooler

Reference:

1) Y Adachi *et al*., "Magnetospinography: Instruments and Application to Functional Imaging of Spinal Cords", IEICE Trans Electron, E96-C, 326–333, 2013.
2) Y Adachi *et al*, "Spinal Cord Evoked Magnetic Field Measurement Using a Magnetospinography System Equipped with a Cryocooler", Engineering in Medicine and Biology Society (EMBC), 35th Annual International Conference of the IEEE, 4426–4429, 2013.

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