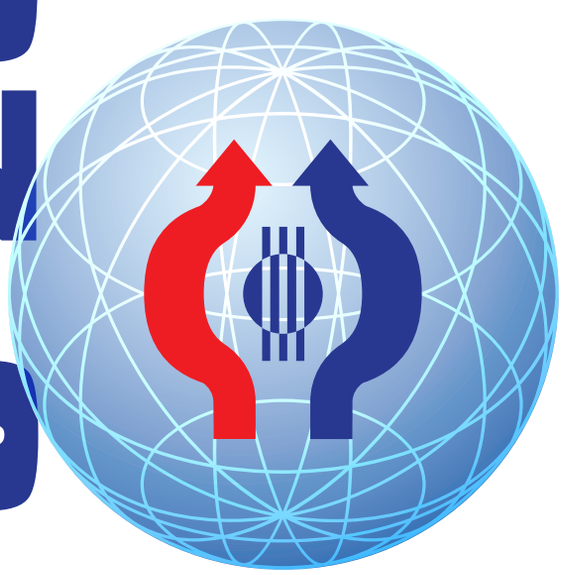
ISS2016 Program & Abstracts

29th INTERNATIONAL SYMPOSIUM ON SUPERCONDUCTIVITY

December 13–15, 2016

Tokyo International Forum, Tokyo, Japan

ISS 2016 超伝導



AIST

NATIONAL INSTITUTE OF
ADVANCED INDUSTRIAL SCIENCE
AND TECHNOLOGY (AIST)

Greetings

It is my great pleasure to announce that the 29th International Superconductivity Symposium (ISS2016) will be held this year, organized by the National Institute of Advanced Industrial Science and Technology (AIST) for the first time. The ISS was launched back in 1988 after the discovery of copper-oxide-based high-temperature superconductors and held annually sponsored by the International Superconductivity Technology Center (ISTEC) until last year.

At present, superconducting technologies are already used in a variety of fields. The most popular application is MRI (Magnetic Resonance Imaging) devices that are installed in almost all major hospitals. Superconducting magnets for generating high magnetic fields are also used in NMR (Nuclear Magnetic Resonance) machines and maglev trains. The discovery of oxide-based high-temperature superconductors in 1986 tremendously expanded the possibility of applications. In recent years, the urgent societal need for energy saving enhances the desire for reliable superconducting technologies. For example, superconducting power transmission cables are to be introduced in railway feeder cables.

This year, 2016 is the thirtieth year from the discovery of high-temperature superconductors. In this commemorative year, AIST has inaugurated a new research consortium on superconductivity: the Applied Superconductivity Constellations of Tsukuba (ASCOT). ASCOT is composed of 19 private companies and 5 national universities/institutes (including AIST). ASCOT aims to develop superconducting technologies into practical products and systems used in our society, and to foster young researchers who may contribute to the future of this technology. In this context, ASCOT supports ISS2016 as well.

I sincerely hope that this renewed symposium will gather many scientists, engineers, academic students, corporate executives and other participants from all over the world, and will facilitate fruitful discussions to promote superconductivity technologies.

May 26, 2016

Toshihiko Kanayama
General Chair, ISS2016

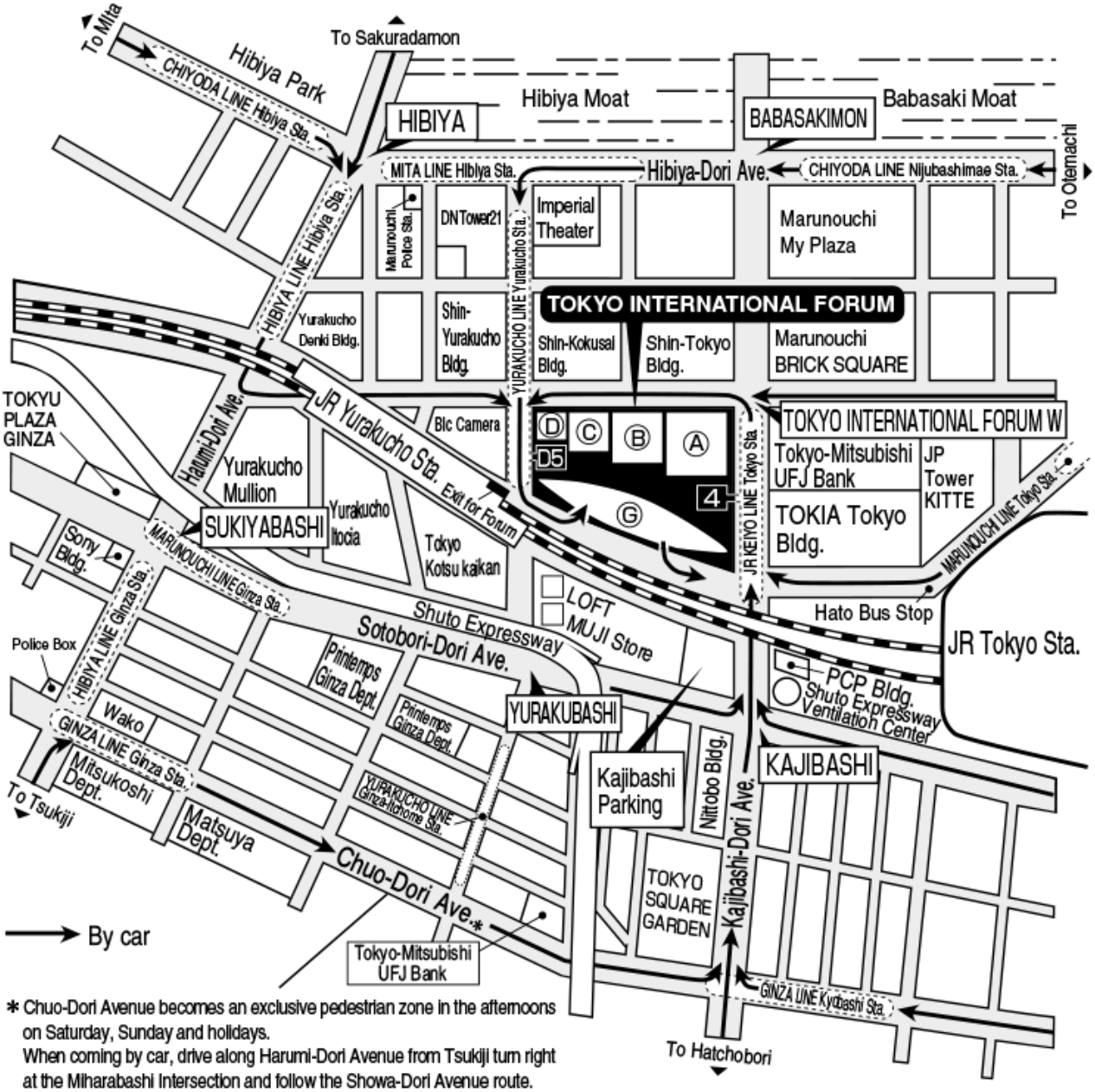
Venue

Tokyo International Forum, Chiyoda-ku, Tokyo, Japan

Hall B5 (B Block)

Rooms G401–G410 in the Glass building (G block)

Phone: 03-5221-9000, Web site: https://www.t-i-forum.co.jp/en/



* Chuo-Dori Avenue becomes an exclusive pedestrian zone in the afternoons on Saturday, Sunday and holidays.
When coming by car, drive along Harumi-Dori Avenue from Tsukiji turn right at the Miharabashi Intersection and follow the Showa-Dori Avenue route.

CONTENTS

General information

■ Period

December 13–15, 2016

■ Official language

English

■ On-site registration

Tuesday, Dec. 13,	9:15–15:00	Hall B5 Lobby
	15:00–18:00	G4 Lobby (G Block 4F)
Wednesday, Dec. 14,	8:45–18:00	G4 Lobby
Thursday, Dec. 15,	9:00–13:00	Rm G401 (G Block 4F)

■ Submission of proceedings manuscript

November 18–December 13 (Online submission only)

■ Banquet

Tokyo International Forum
Rooms G409 & G408 (Glass building 4F)
Tuesday, December 13, 18:15–20:00

■ Web site

https://www.tia-nano.jp/ascot/iss2016/index.html

■ Internet service

Free Wi-Fi service is available at B5 Lobby and G4 Lobby.
SSID: tif-free-wifi (No password needed)

■ Name card

On the resistration desk, you will obtain your name card. You are requested to **wear your name card** in the symposium sites all the time.

■ Scope

The 29th International Symposium on Superconductivity (ISS2016) will consist of oral and poster sessions, covering the latest findings and related topics in the following research fields of superconductivity science and technology.

(a) **Physics and Chemistry (PC)**
Novel Materials, Material chemistry, Fundamental physical properties (bulk, single crystal and thin film), Vortex physics, Theory

(b) **Wires and Bulk (WB)**
Materials and processing, critical currents, mechanical properties, AC Loss and electro-magnetic stability for wires, tapes and bulk superconductors, including artificial pinning centers, multi-filamentary approach and superconducting joints

(c) **Electronic Devices (ED)**
Digital and mixed-signal circuits, Detectors and readout, SQUIDs, High-frequency devices, Quantum information technology, Novel devices, Materials and fabrication, System applications

(d) **Large Scale System Applications (AP)**
Magnets (for high energy physics, medical systems etc.), Rotating machines, Magnetic levitation and propulsion, Electric power devices, Medical systems etc. using HTS and LTS materials

Information for presentation

■ Instruction for oral presentation

The official language of the symposium is **English**. Only papers presented by authors are considered for publication in the proceedings. **An LCD projector** will be available in each session room. You can use **your own computer with mini Dsub-15 I/O pins**, or **the computer prepared by the secretariat**. Requirements for author's own computers and installed software on the computer prepared by the secretariat are as follows.

Requirements for your own PC

I/O connector	RGB mini D-sub 15 pins
Display resolution	XGA (1024x768)*
Electric power supply	AC 100V (50Hz), Flat-pin, two-prong plugs

*Other resolutions such as WXGA (1280x800) may be used for the projector, but the presenter must confirm normal operations beforehand.

Installed software on the secretariat's computer

OS	Windows 10 Pro (English, 64 bit)
Application software	MS Power Point 2013, Adobe Acrobat Reader

If you plan to use the secretariat's computer, you are strongly recommended to install your data in the secretariat's computer before starting the session or during the coffee break. Please contact a staff member at a session room or the ISS2016 headquarter if you have any questions.

Presentation times for various presentations are described as follows.

Presentation times

Plenary lectures	40 min	Including 5 min discussion
Invited talks (PC, ED)	25 min	
Invited talks (WB, AP)	30 min	
Contributed presentations (ED)	20 min	
Contributed presentations (others)	15 min	Including 3 min discussion

■ Instructions for Poster Presentation

Only papers presented by authors are considered for publication in the proceedings. The attendance should be confirmed by chairpersons of the poster session.

The available space is 90 cm wide and 210 cm high. Please mount your material on the panel that your presentation ID is posted on. All the material should be described in English. Captions are required for all figures, photographs and tables. Thumbtacks will be available from the symposium secretariat.

Schedule for poster presentations

	December 13	December 15
Mounting	14:30–16:00	12:30–14:00
Poster session	16:00–18:00	14:00–16:00
Removing	18:00–18:30	16:00–16:30

■ Withdrawal

If you want to withdraw your presentation for some reasons, please inform the ISS2016 secretariat in advance.

Organization

■ General chair

Dr. Toshihiko Kanayama
Senior-Vice-President, National Institute of Advanced Industrial Science and Technology (AIST)

■ Local organizing committee

Secretary-General:
Michiya Okada, TIA Central Office, AIST

Members:
Haruhiko Obara, Fumio Takemura, Teruhisa Horita, Mitsuho Furuse (Department of Energy and Environment, AIST)

Satoshi Haraichi, Masataka Ohkubo, Mutsuo Hidaka, Yoshiyuki Yoshida, Hiraku Ogino (Department of Electronics and Manufacturing, AIST)

Kenshiro Oki, Hirofumi Yamasaki, Kiyoshi Takagi, Susumu Ogawa (TIA Central Office, AIST)

■ Supported by

Applied Superconductivity Constellations of Tsukuba (ASCOT)

TIA—a platform for open innovation

Ministry of Economy, Trade and Industry (METI)

New Energy and Industrial Technology Development Organization (NEDO)

Cryogenics and Superconductivity Society of Japan (CSSJ)

The Institute of Electrical Engineers of Japan (IEEJ)

■ ASCOT members (as of October 28, 2016)

Applied Superconductivity Constellations of Tsukuba (ASCOT)

—founded by the National Institute of Advanced Industrial Science and Technology (AIST) in May 2016

Private Companies:

Hitachi, Ltd.
Mitsubishi Electric Corporation

JEOL Ltd.;
Tokyo Electric Power Company Holdings, Inc.
Tohoku Electric Power Co., Inc.
The Kansai Electric Power Co., Inc.
Chubu Electric Power Co., Inc.
The Chugoku Electric Power Co., Inc.
Kyushu Electric Power Co., Inc.
Fujikura Ltd.
SWCC Showa Cable Systems Co., Ltd.
Sumitomo Electric Industries, Ltd.
Furukawa Electric Co., Ltd.
Sumitomo Heavy Industries, Ltd.
Suzuki Shokan Co., Ltd.
MAYEKAWA MFG. Co., Ltd.
Taiyo Nippon Sanso Corporation
JECC TORISHA Co., Ltd.
Fujihira Co., Ltd.
Central Research Institute of Electric Power Industry

Academic Members:

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Kyoto University
Kyushu University
University of Tsukuba
Nagoya University
Yokohama National University
Kobe University
National Institute for Materials Science (NIMS)
National Institute for Fusion Science (NIFS)

Committees

■ International advisary committee

Naoyuki Amemiya (Kyoto Univ.)
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Bob Buckley (Victoria Univ. of Wellington)
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Bernhard Holzapfel (Karlsruhe Inst. of Technology)
Teruo Izumi (AIST)
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Wai-Kwong Kwok (Argonne National Laboratory)
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Qiang Li (Brookhaven National Laboratory)
Mathias Noe (Karlsruhe Inst. of Technology)
Xavier Obradors (Inst. Ciencia de Materials de Barcelona)
Masataka Ohkubo (AIST)
Hiroyuki Ohsaki (The Univ. of Tokyo)
Satoshi Okuma (Tokyo Inst. of Technology)
Minwon Park (Changwon National Univ.)
Christopher M. Rey (Energy-to-Power Solutions)
Horst Rogalla (Univ. of Colorado at Boulder)
Venkat Selvamanickam (Univ. of Houston)
Michael Sumption (Ohio State Univ.)
Setsuko Tajima (Osaka Univ.)
Keiichi Tanabe (SUSTERA)
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■ Program Committee

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Sub-Chair: Hiraku Ogino (AIST)

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Shigeo Sato (Tohoku Univ.)
Naoto Sekiya (Yamanashi Univ.)
Masamitsu Tanaka (Nagoya Univ.)
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Kazuhiro Kajikawa (Kyushu Univ.)
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Naoko Nakamura (MAYEKAWA MFG. Co., Ltd.)
Taketsune Nakamura (Kyoto Univ.)
Shoichi Yokoyama (Mitsubishi Electric Corporation)
Tomonori Watanabe (Chubu Electric Power Co., Inc.)

Scientific program

■ Plenary lectures

Tabea Arndt (Siemens)
Toru Hara (National Inst. for Materials Science)
Xavier Obradors (Inst. Ciencia de Materials de Barcelona)
Michiya Okada (AIST)
Katsuya Shimizu (Osaka Univ.)
Hubertus W. Weijers (Nat. High Magnetic Field Laboratory)

■ Invited speakers (PC)

Ryotaro Arita (RIKEN)
Tomoteru Fukumura (Tohoku Univ.)
Akira Iyo (AIST)
Wai-Kwong Kwok (Argonne National Laboratory)
Kosuke Nakayama (Tohoku Univ.)
Kenya Ohgushi (Tohoku Univ.)
Shuuichi Ooi (National Inst. for Materials Science)
Carsten Putzke (Univ. of Bristol)
Yu Saito (The Univ. of Tokyo)
Junichi Shiogai (Tohoku Univ.)

■ Invited speakers (WB)

John Durrell (Univ. of Cambridge)
Amit Goyal (The State Univ. of New York)
Kohei Higashikawa (Kyushu Univ.)
Yasuhiro Iijima (Fujikura Ltd.)
Teruo Izumi (AIST)
Hiroaki Kumakura (National Inst. for Materials Science)
Sergey Lee (SuperOx Japan LLC)
Kaname Matsumoto (Kyushu Inst. Tech.)
Tomoyuki Naito (Iwate Univ.)
Venkat Selvamanickam (Univ. of Houston)
Jun-ichi Shimoyama (Aoyama Gakuin Univ.)
Kohei Yamazaki (Sumitomo Electric Ind., Ltd.)

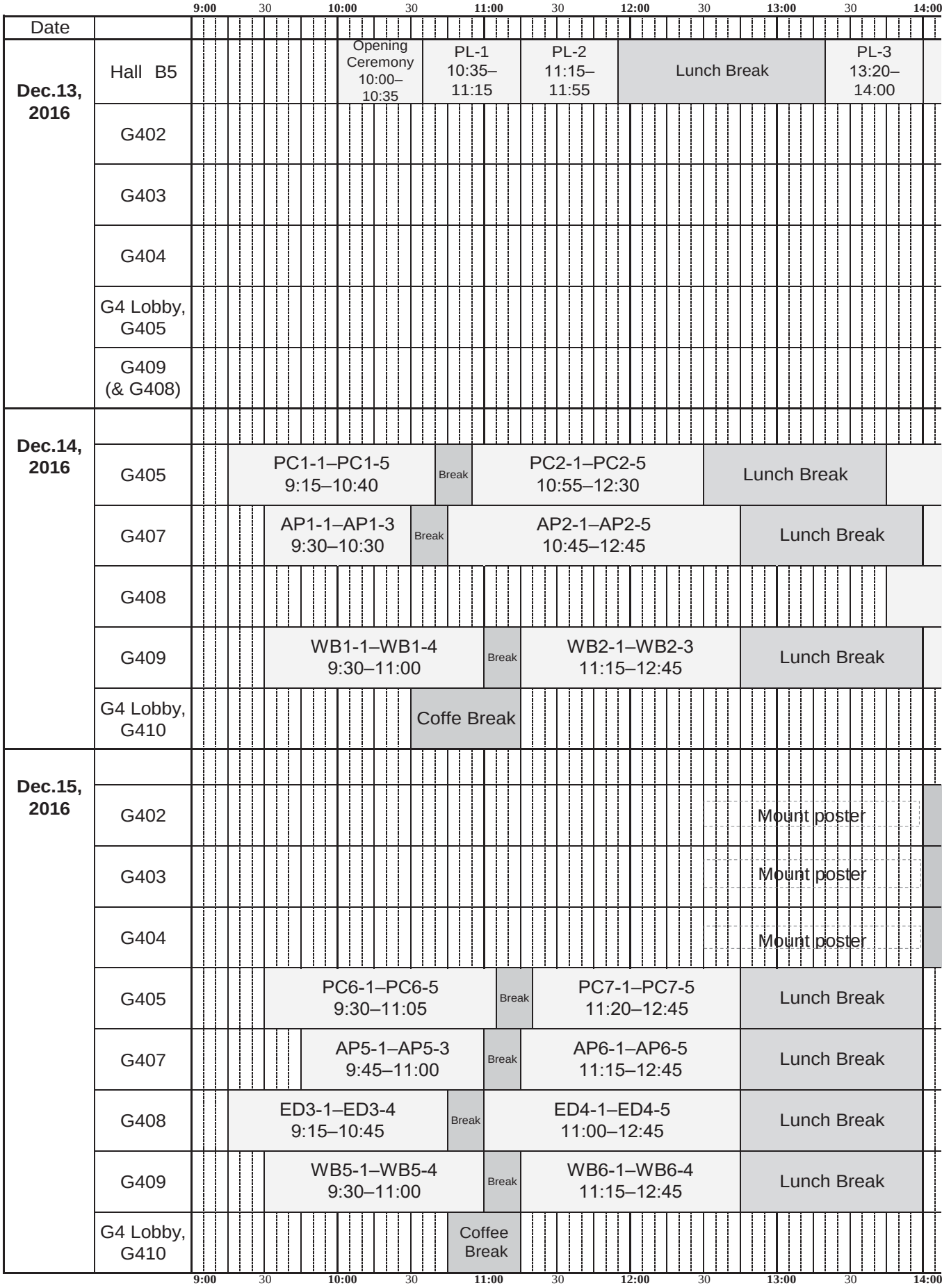
■ Invited speakers (ED)

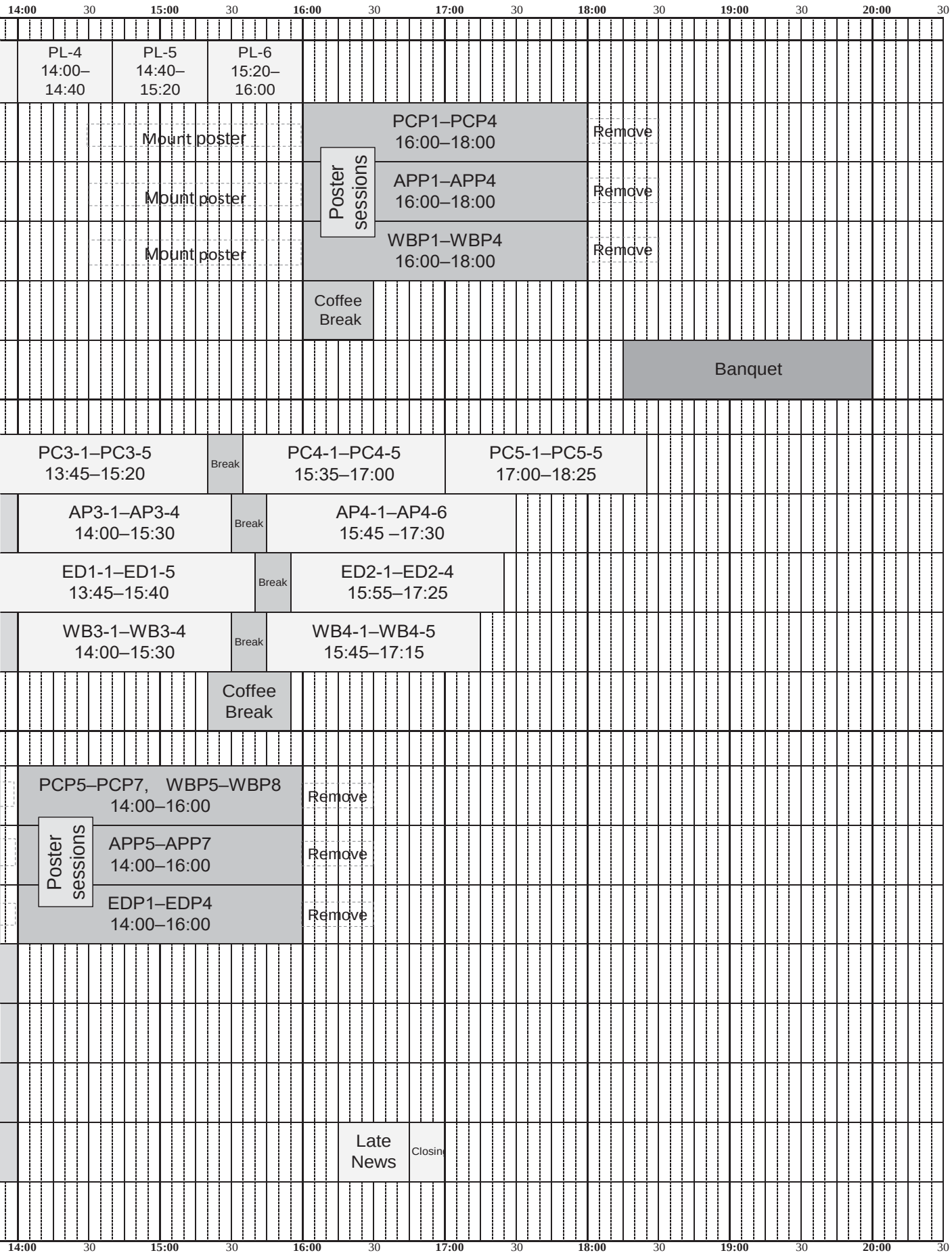
Christopher Ayala (Yokohama National Univ.)
Tsunehiro Hato (Superconducting Sensing Technology Research Association)
Kunihiro Inomata (RIKEN)
Takafumi Kojima (National Astronomical Observatory of Japan)
Zhirong Lin (RIKEN)
Eva Olsson (Chalmers Univ. of Technology)
Masamitsu Tanaka (Nagoya Univ.)
Saburo Tanaka (Toyohashi Univ. of Technology)

■ Invited speakers (AP)

Satoshi Awaji (Tohoku Univ.)
Amalia Ballarino (CERN)
Kazuhiro Kajikawa (Kyushu Univ.)
Antonio Morandi (Univ. of Bologna)
Toru Ogitsu (High Energy Accelerator Research Organization)
Minwon Park (Changwon National Univ.)
Santiago Sanz (Tecnalia)
Shigeki Takayama (Toshiba Corporation)
Hiroshi Ueda (Okayama Univ.)
Shoichi Yokoyama (Mitsubishi Electric Corporation)

Schedule and timetable

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PL-4
14:00–
14:40
PL-5
14:40–
15:20
PL-6
15:20–
16:00
Mount poster
Mount poster
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Poster sessions
PCP1–PCP4
16:00–18:00
APP1–APP4
16:00–18:00
WBP1–WBP4
16:00–18:00
Remove
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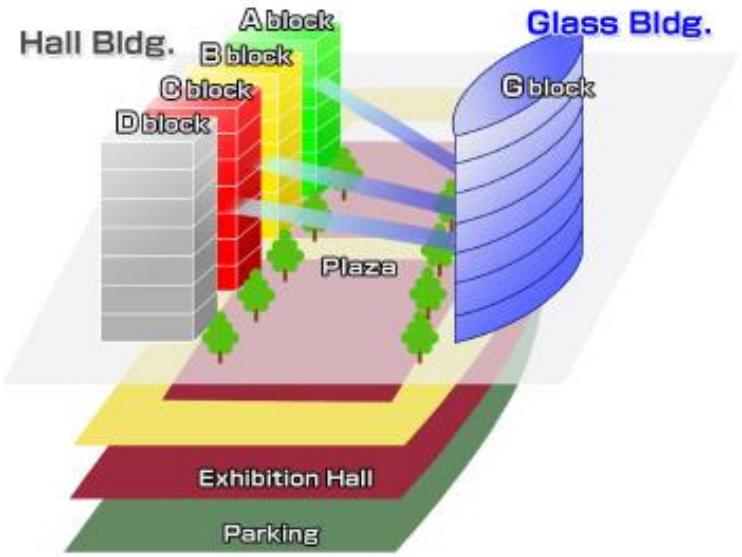
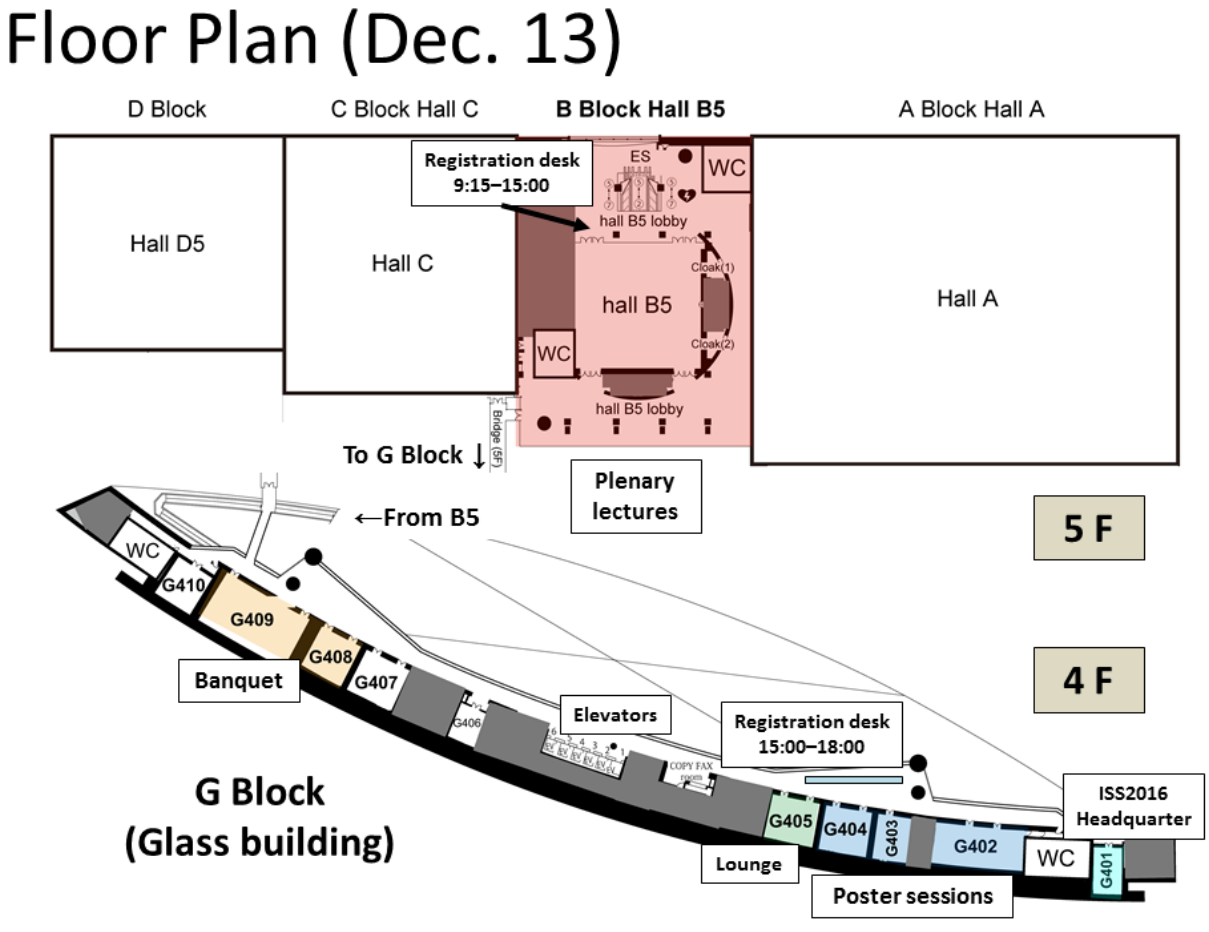
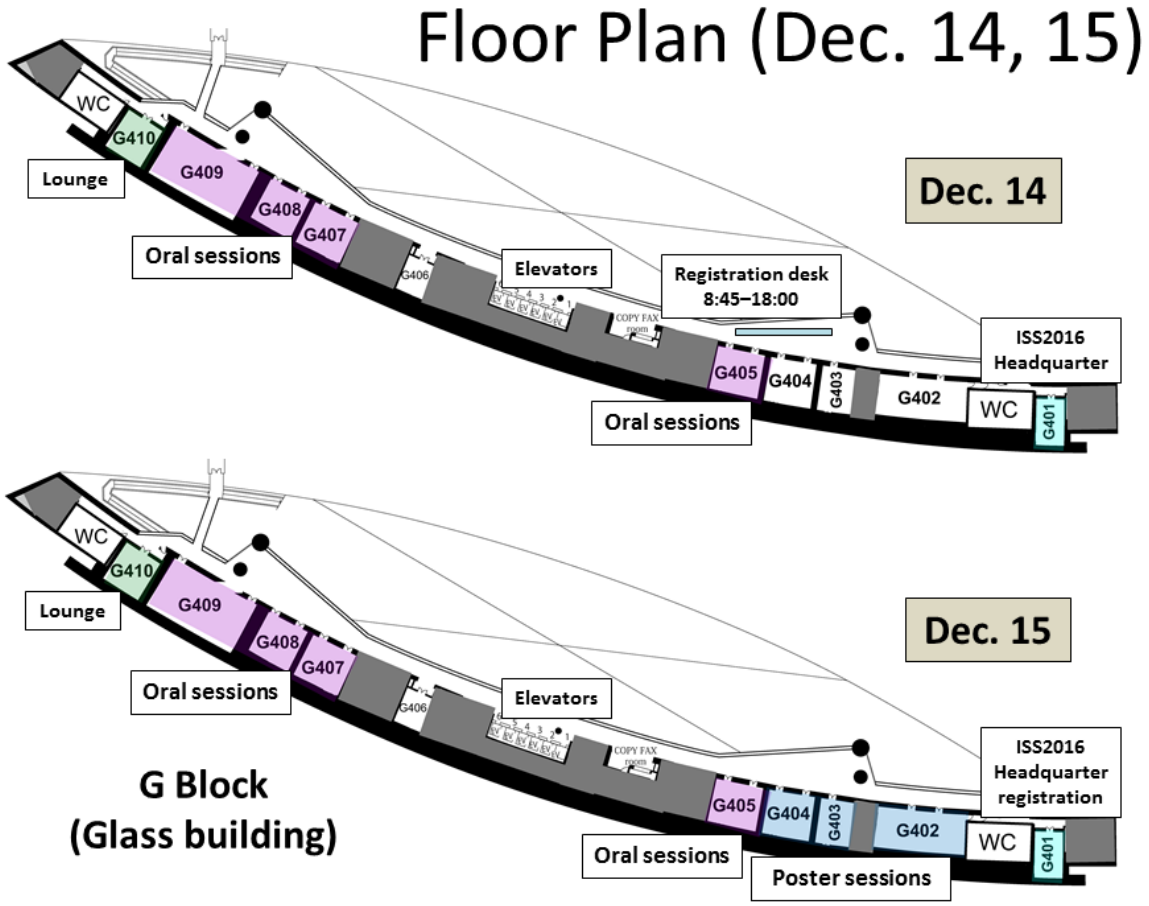
Coffee Break
Banquet
PC3-1–PC3-5
13:45–15:20
Break
PC4-1–PC4-5
15:35–17:00
PC5-1–PC5-5
17:00–18:25
AP3-1–AP3-4
14:00–15:30
Break
AP4-1–AP4-6
15:45 –17:30
ED1-1–ED1-5
13:45–15:40
Break
ED2-1–ED2-4
15:55–17:25
WB3-1–WB3-4
14:00–15:30
Break
WB4-1–WB4-5
15:45–17:15
Coffee Break
PCP5–PCP7, WBP5–WBP8
14:00–16:00
APP5–APP7
14:00–16:00
EDP1–EDP4
14:00–16:00
Poster sessions
Remove
Remove
Remove
Late News
Closing

Floor plan of the symposium site

The opening ceremony and plenary lectures of ISS2016 are held in the **Hall B5** (B block) of Tokyo International Forum. Other sessions (oral and poster) are held in **conference rooms on the forth floor of the glass building** (G block). Participants can walk from the Hall B5 to the glass building through a bridge.







■ How to get to the symposium site

From the ground level to the Hall B5

You may walk in through **the B block entrance** and go up to the fifth floor using escalators.

From the ground level to the conference rooms (G401–G410)

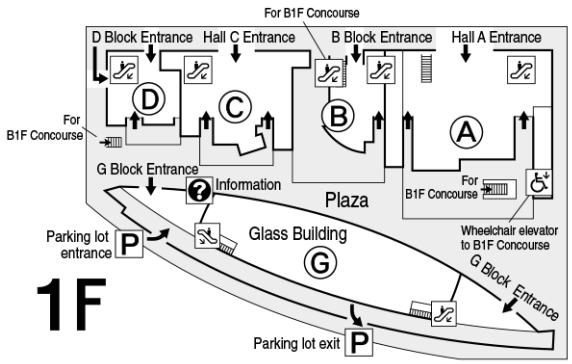
You may walk in through **the G block entrance** and **go down to the B1 floor** using an escalator, and then use **an elevator for conference rooms** to go up to the forth floor.

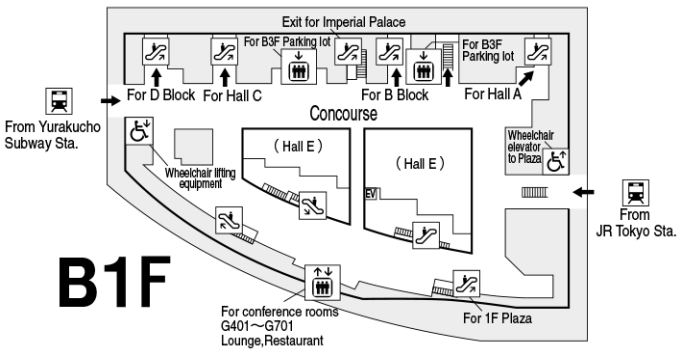
From the B1F level to the Hall B5

You may use **escalators for B block** and go up to the fifth floor.

From the B1F level to the conference rooms (G401–G410)

You may use **an elevator for conference rooms** to go up to the forth floor.





Oral Session

Dec. 13 (Tue.) Opening Ceremony | Hall B5

Chairperson: Haruhiko Obara (AIST)

Opening address 10:00–10:05
Toshihiko Kanayama
Senior Vice-President of AIST

Congratulatory address 1 10:05–10:10
Shin Hosaka
Deputy Director-General, Industrial Science and Technology Policy and Environment Bureau, METI

Congratulatory address 2 10:10–10:15
Shigenobu Watanabe
Director General, Energy Conservation Technology Department, NEDO

Special Talk 10:15–10:35
Reconstruction of R&D for HTS in Japan toward Radical Innovations of Industry
Toshihiko Kanayama (AIST)

Dec. 13 (Tue.) Plenary Lectures | Hall B5

Chairperson: Nobuyuki Sadakata (Fujikura)

PL1-INV 10:35–11:15
Progress in the Development of Nanostructured Coated Conductors in Europe

*Xavier Obradors

Institut Ciencia de Materials de Barcelona

PL2-INV 11:15–11:55
Construction and Test of the NHMFL 32 T Superconducting Magnet

*Hubertus Wilhelmus Weijers, W. D. Markiewicz, A. J. Voran, S. R. Gundlach, Y. L. Viouchkov, A. V. Gavrilin, P. D. Noyes, T.A. Painter, B. Jarvis, W.R. Sheppard, G. Sheppard, T.P. Murphy

National High Magnetic Field Laboratory

Lunch Break 11:55–13:20

Chairperson: Mutsuo Hidaka (AIST)

PL3-INV 13:20–14:00
High Pressure Superconductivity in Sulfur Hydride

*Katsuya Shimizu[1], M. Einaga[1], M. Sakata[1], H. Nakao[1], M. Eremets[2], A. Drozdov[2], I. Troyan[2], N. Hirao[3], Y. Ohishi[3]

1. KYOKUGEN, Grad. Sch. Eng. Sci., Osaka University; 2. Max Planck Institute for Chemistry; 3. JASRI

PL4-INV 14:00–14:40

Application of Transition Edge Sensor as an X-ray Spectrometer for Scanning Transmission Electron Microscope

*Toru HARA[1], Keiichi TANAKA[2], Keisuke MAEHATA[3], Kazuhisa MITSUDA[4], Yoshihiro YAMANAKA[5], Mutsuo HIDAKA[6]

1. National Institute for Materials Science; 2. Hitachi High-Tech Science Corporation; 3. Kyushu University; 4. Japan Aerospace Exploration Agency; 5. Taiyo Nippon Sanso Corporation; 6. National Institute of Advanced Industrial Science and Technology

Chairperson: Shoichi Honjo (TEPCO)

PL5-INV 14:40–15:20

R&D in Electric Power Devices based on Superconducting Technology in Europe

*Tabea Arndt

Siemens AG, CT REE PEM, Germany

PL6-INV 15:20–16:00

Recent Progress on the Development of Superconducting Technology in Japan

*Michiya Okada

AIST

New materials

Chairpersons: Kenya Ohgushi (Tohoku University) and Ryotaro Arita (RIKEN)

PC1-1-INV 9:15–9:40

New Iron-Based Superconductors AeAFe$_4$As$_4$ (Ae = Ca, Sr, Eu, A = K, Rb, Cs)

*Akira Iyo[1], Kenji Kawashima[1,2], Tatsuya Kinjo[1,3], Taichiro Nishio[1,3], Shigeyuki Ishida[1], Hiroshi Fujihisa[1], Yoshito Gotoh[1], Kunihiro Kihou[1], Hiroshi Eisaki[1], Yoshiyuki Yoshida[1]

1. AIST; 2. IMRA Material R&D Co., Ltd.; 3. Tokyo Univ. of Science

PC1-2 9:40–9:55

New iron-based superconducotor (Eu,La)FeAs$_2$

*Hiraku Ogino[1,2], Alberto Sala[1], Hayato Tanaka[2], Kohji Kishio[2], Yoshito Goto[1], Kunimitsu Kataoka[1], Akira Iyo[1], Hiroshi Eisaki[1]

1. AIST; 2. University of Tokyo

PC1-3 9:55–10:10

Enhanced superconductivity at the structural phase boundary of $Sr_{1-x}Ba_xNi_2P_2$

Kazutaka Kudo, Yutaka Kitahama, Keita Iba, Masaya Takasuga, *Minoru Nohara

Okayama University

PC1-4 10:10–10:25

The Electronic Phase Diagram of Superconductor $BaTi_2(Sb_{1-x}Bi_x)_2O$

*Wataru Ishii, Takeshi Yajima, Zenji Hiroi

ISSP, University of Tokyo

PC1-5 10:25–10:40

Superconductivity of Transition Metal Dichalcogenides Co-Intercalated with Alkali Metal and Organic Molecules

*Kazuki Sato, Takashi Noji, Takehiro Hatakeda, Takayuki Kawamata, Masatsune Kato, Yoji Koike

Department of Applied Physics, Graduate School of Engineering, Tohoku University

Iron-based superconductors

Chairpersons: Minoru Nohara (Okayama University) and Hiraku Ogino (AIST)

PC2-1-INV 10:55–11:20

Superconductivity in Fe-based ladder material $BaFe_2S_3$

*Kenya Ohgushi

Tohoku University

PC2-2-INV 11:20–11:45

First-principles Study of the Iron-based Ladder Superconductor $BaFe_2S_3$

*Ryotaro Arita

RIKEN CEMS

PC2-3 11:45–12:00

Origin of 44 K Superconductivity in $K_xFe_{2-y}Se_2$ with Nano-Scale Phase Separation

*Masashi Tanaka[1], Yusuke Yanagisawa[1,2], Hiroyuki Takeya[1], Yoshihiko Takano[1,2]

1. MANA, Natinal Institute for Materials Science; 2. Tsukuba Univ.

PC2-4 12:00–12:15

Non-magnetic Nematic Quantum Criticality In $FeSe_{1-x}S_x$ Superconductors

*Suguru Hosoi[1], Kohei Matsuura[1], Kosuke Ishida[1], Hao Wang[1], Yuta Mizukami[1], Tatsuya Watashige[2], Shigeru Kasahara[2], Yuji Matsuda[2], Takasada Shibauchi[1]

1. Department of Advanced Materials Science, University of Tokyo; 2. Department of Physics, Kyoto University

PC2-5 12:15–12:30

Transport properties of MBE grown NdFeAs(O,F) thin films

*Takahiro Urata, Taito Ohmura, Yousuke Ishimasa, Takafumi Hatano, Kazumasa Iida, Hiroshi Ikuta

Department of Crystalline Materials Science, Nagoya University

Lunch Break 12:30–13:45

Unconventional superconductors

Chairpersons: Takasada Shibauchi (The University of Tokyo) and Carsten Putzke (University of Bristol)

PC3-1-INV 13:45–14:10

Electronic Structure of Iron-Based High-T_c Superconductors

*Kosuke Nakayama

Department of Physics, Tohoku University

PC3-2-INV 14:10–14:35

Electrochemical etching induced high temperature superconductivity in FeSe electric double layer transistors

*Junichi Shiogai, Tomoki Miyakawa, Yukihiro Ito, Tsutomu Nojima, Atsushi Tsukazaki

Institute for Materials Research, Tohoku University

PC3-3 14:35–14:50

Critical temperature variation with a thickness tuned by electrochemical etching in $FeSe_{1-x}Te_x$ thin film on various substrates

Shunsuke Kohno, Daisuke Asami, Fuyuki Nabeshima, Yoshinori Imai, Atsutaka Maeda, *Kazunori Ueno

Department of Basic Science, University of Tokyo

PC3-4 14:50–15:05

Searching for Gap Nodes in the Heavy-fermion Superconductor $CeCu_2Si_2$ from Specific-heat Measurement

*Shunichiro Kittaka[1], Yuya Aoki[1], Yasuyuki Shimura[1], Toshiro Sakakibara[1], Silvia Seiro[2,3], Christoph Geibel[2], Frank Steglich[2], Yasumasa Tsutsumi[4], Hiroaki Ikeda[5], Kazushige Machida[5]

1. Institute for Solid State Physics, University of Tokyo; 2. Max Planck Institute for Chemical Physics of Solids, Germany; 3. Department of Chemistry and Physics of Materials, University of Salzburg, Austria; 4. Department of Basic Science, University of Tokyo; 5. Department of Physics, Ritsumeikan University

PC3-5 15:05–15:20

Fully-gapped s_{++}-wave Pairing in the Heavy-Fermion Superconductor $CeCu_2Si_2$

*Takaaki Takenaka[1], Takuya Yamashita[2], Yoshifumi Tokiwa[2], Joe A Wilcox[3], Yuta Mizukami[1], Daiki Terazawa[2], Yuichi Kasahara[2], Marcin Konczykowski[4], Silvia Seiro[5], Hirale S Jeevan[5], Christoph Geibel[5], Carsten Putzke[3], Takafumi Onishi[2], Hiroaki Ikeda[6], Antony Carrington[3], Yuji Matsuda[2], Takasada Shibauchi[1]

1. University of Tokyo; 2. Kyoto University; 3. University of Bristol; 4. Ecole Polytechnique; 5. Max Planck Institute for Chemical Physics of Solids; 6. Ritsumeikan University

Vortex physics 1

Chairpersons: Shuuichi Ooi (NIMS) and Takekazu Ishida (Osaka Prefecture University)

PC4-1-INV 15:35–16:00

Vortex Studies on a Hybrid Superconducting/Magnetic Spin Ice System

*Wai-Kwong Kwok[1], Yonglei Wang[1,2], Jing Xu[3], Zhili Xiao[1,3], Alexey Snezhko[1], Leo E Ocola[4], Ralu Divan[4], John E Pearson[1], George W Crabtree[1,5]

1. Materials Science Division, Argonne National Laboratory, USA.; 2. Department of Physics, University of Notre Dame, USA.; 3. Department of Physics, Northern Illinois University, USA.; 4. Center for Nanoscale Materials, Argonne National Laboratory, USA.; 5. Departments of Physics, Electrical and Mechanical Engineering, University of Illinois at Chicago, USA

PC4-2 16:00–16:15

Effects of Proton Irradiation on Pinning and Dynamics of Vortices in Isovalently Substituted $BaFe_2(As,P)_2$ Single Crystals

*Tsuyoshi Tamegai[1], Akiyoshi Park[1], Sunseng Pyon[1], Ivan Veshchunov[1], Hisashi Kitamura[2]

1. Department of Applied Physics, The University of Tokyo; 2. National Institute of Radiological Sciences

PC4-3 16:15–16:30

Shape dependence of effects of twin boundaries on half-quantized vortices in d-dot

*Norio Fujita, Masaru Kato, Takekazu Ishida

Osaka Prefecture University

PC4-4 16:30–16:45

Thin Film Growth of Doped NEG-123 Superconductor on STO Substrate by PLD

Shiv Jee Singh[1], *Paolo Mele[1], Miryala Muralidhar[2]

1. Muroran Institute of Technology; 2. Shibaura Institute of Technology

PC4-5 16:45–17:00

High critical current density and pinning potential in YBCO films with synergetic pinning centres

*Adrian Crisan[1], Ion Ivan[1], Alina M Ionescu[1], Lucica Miu[1], Van-Son Dang[2], Paolo Mele[3], Jesus Mosqueira[4]

1. National Institute for Materials Physics Bucharest, Romania; 2. Nano and Energy Center, VNU Hanoi University of Science, Hanoi, Vietnam; 3. Muroran Institute of Technology, Materials Science Research Unit, Muroran, Japan; 4. University of Santiago de Compostela, Department of Condensed Matter Physics, Santiago de Compostela, Spain

Vortex physics 2

Chairpersons: Wai-Kwong Kwok (Argonne National Laboratory) and Tsuyoshi Tamegai (The University of Tokyo)

PC5-1-INV 17:00–17:25

Vortex states in micron-sized crystals

*Shuuichi Ooi, Takashi Mochiku, Minoru Tachiki, Kazuto Hirata

National Institute for Materials Science

PC5-2 17:25–17:40

Physics of Lorentz Force on Supercurrent

*Takafumi Kita, Hikaru Ueki, Wataru Kohno

Department of Physics, Hokkaido University

PC5-3 17:40–17:55

Memory Formation in the Transient State of a Periodically Driven Vortex System

*Mihaly Dobroka, Yasuki Kawamura, Tetsuya Kaji, Koichiro Ienaga, Shin-ichi Kaneko, Satoshi Okuma

Department of Physics, Tokyo Institute of Technology

PC5-4 17:55–18:10

Study of microwave-induced phase switches from the finite voltage state in $Bi_2Sr_2CaCu_2O_y$ intrinsic Josephson junctions

*Haruhisa Kitano, Ayami Yamaguchi, Yusaku Takahashi, Daiki Kakehi, Shin-ya Ayukawa

Department of Physics and Mathematics, Aoyama Gakuin University

PC5-5 18:10–18:25

Investigation of the flux lines motion in superconductors in a longitudinal magnetic field by the computer simulation using the Time-Dependent Ginzburg-Landau equations

*Kento Adachi, Yusuke Ichino, Yuji Tsuchiya, Yutaka Yoshida

Nagoya University

Dec. 14 (Wed.) Wires and Bulk **G409**

HTS 1

Chairpersons: Amit Goyal (The State University of New York at Buffalo) and Yasuhiro Iijima (Fujikura)

WB1-1-INV 9:30–10:00

Status of high performance REBCO coated conductors for high field applications

*Venkat Selvamanickam

University of Houston

WB1-2-INV 10:00–10:30

Optimal, Nanodefect Configurations via Strain-Mediated Assembly for Optimized Vortex-Pinning in Superconducting Wires from 4.2K-77K

*Amit Goyal

University at Buffalo; The State University at New York

WB1-3 10:30–10:45

Statistical Behavior of Positional Variation of Critical Current Density in Long RE-123 Coated Conductors

*Takanobu Kiss[1], Kohei Higashikawa[1], Takahiro Fukuzaki[1], Yuta Onodera[1], Takumi Suzuki[1], Masayoshi Inoue[1], Takato Machi[2], Akira Ibi[2], Teruo Izumi[2]

1. Dept. of Electrical Engineering, Kyushu University; 2. National Institute of Advanced Industrial Science and Technology

WB1-4 10:45–11:00

Correlated Study between Critical Current Density at 77 K and That of Low Temperature In-Filed Conditions of Various REBCO Coated Conductors

*Masayoshi Inoue[1], Kazutaka Imamura[1], Takumi Suzuki[1], Shogo Ichimura[1], Takahiro Fukuzaki[1], Kohei Higashikawa[1], Teruo Izumi[2], Takanobu Kiss[1]

1. Kyushu University; 2. AIST

HTS 2

Chairpersons: Venkat Selvamanickam (University of Houston) and Kaname Matsumoto (Kyushu Institute of Technology)

WB2-1-INV 11:15–11:45

Development of Uniform and Productive Process for BMO-Doped REBCO Coated Conductor by Hot Wall-PLD on IBAD Template Technique

*Yasuhiro Iijima, Kazuomi Kakimoto, Mitsunori Igarashi, Shinji Fujita, Wataru HIrata, Shogo Muto, Tomo Yoshida, Yutaka Adachi, Kunihiro Naoe

Fujikura Ltd.

WB2-2-INV 11:45–12:15

Recent progress of manufacturing HTS tapes and its applications at SuperOx

*Sergey Lee[1], Valery Petrykin[1], Naoyuki Hirata[1], Juhyun Chung[1], Miyuki Nakamura[1], Shinya Hasuo[1], Alexei Mankevich[2], Vsevolod Chepikov[2], Anton Markelov[2], Mikhail Moyzykh[2], Alexander Molodyk[2], Sergey Samoilenkov[2]

1. Superox Japan LLC; 2. CJSC SuperOx

WB2-3-INV 12:15–12:45

Recent development of DI-BSCCO wire

*Kohei Yamazaki, Shin-ichi Kobayashi, Goro Osabe, Tomohiro Kagiyama, Masashi Kikuchi, Takayoshi Nakashima, Soichiro Takeda, Takuro Kadoya, Tomoyuki Okada, Kazuhiko Hayashi, Takeshi Kato

Sumitomo Electric Industries, Ltd.

Lunch Break 12:45–14:00

Superconducting bulk materials

Chairpersons: Tomoyuki Naito (Iwate University) and Muralidhar Miryala (Shibaura Institute of Technology)

WB3-1-INV 14:00–14:30

The generation of high fields in (RE)$Ba_2Cu_3O_{7-\delta}$ and MgB_2 bulk superconductors

*John H. Durrell

University of Cambridge, Department of Engineering

WB3-2-INV 14:30–15:00

Potential of RE123 bulks from viewpoints of materials science

*Jun-ichi Shimoyama[1], Takumi Sato[1], Takanori Motoki[1], Yui Setoyama[2], Kazuya Matsumoto[2], Kohji Kishio[2]

1. Aoyama Gakuin University; 2. University of Tokyo

WB3-3 15:00–15:15

Microstructure and Trapped Field of YBCO Bulk Superconductors Fabricated by Interior Seeding.

*Pavel Diko[1], Monika Radušovská[1], Samuel Piovarči[1], Chan-Joong Kim[2], B.-H. Jun[2], S.-D. Park[2]

1. Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovakia; 2. Korea Atomic Energy Research Institute, Daejeon, Korea

WB3-4 15:15–15:30

Two directional growth of a Y123 grain in melt-processed YBCO bulk superconductor with interior seeding

*Chan Joong Kim[1], Soon Dong Park[1], Byung Huk Jun[1], Sang Heon Lee[2]

1. Neutron Utilization Technology Division, Korea Atomic Energy Research Institute; 2. Department of Electronc Engineering, Sunmoon University

Characterization, fabrication and new materials

Chairpersons: Jun-ichi Shimoyama (Aoyama Gakuin University) and Sergey Lee (SuperOx Japan)

WB4-1-INV 15:45–16:15

Spatially Resolved Measurements on Critical Current in Coated Conductors and MgB_2 Wires

*Kohei Higashikawa[1], Masayoshi Inoue[1], Shinji Fujita[2], Mitsunori Igarashi[2], Kazuomi Kakimoto[2], Yasuhiro Iijima[2], Zhenan Jiang[3], Rodney Badcock[3], Nicholas Long[3], Robert Buckley[3], Teruo Izumi[4], Akiyoshi Matsumoto[5], Hiroaki Kumakura[5], Takanobu Kiss[1]

1. Kyushu University; 2. Fujikura Ltd.; 3. Robinson Research Institute, Victoria University of Wellington; 4. National Institute of Advanced Industrial Science and Technology; 5. National Institute for Materials Science

WB4-2 16:15–16:30

Evaluation of low electric field characteristics in multi-filamentary Bi-2223 tape under high magnetic fields

*YUTA ONODERA, KOHEI HISAJIMA, SHYAM MOHAN, KAZUTAKA IMAMURA, TAKUMI SUZUKI, KOHEI HIGASHIKAWA, MASAYOSHI INOUE, TAKANOBU KISS

Kyushu University

WB4-3 16:30–16:45

Carrier-Doping Dependence of Critical Current Density in $Ba_{1-x}K_xFe_2As_2$ Single Crystals and Superconducting Wires

*Sunseng Pyon, Takahiro Suwa, Tsuyoshi Tamegai

Dept. of Appl. Phys., Univ. of Tokyo

WB4-4 16:45–17:00

Development of Scribing Technique to Fabricate Multi-Filamentary Structure of Coated Conductors

*Takato Machi, Akira Ibi, Teruo Izumi

AIST

WB4-5 17:00–17:15

Calculation of Magnetic Force on Magnetic Levitation Tool with Superconducting Bulks by Finite Element Method

*Yuta Hiramatsu, Yu Takahashi, Edmund Soji Otabe, Keisuke Suzuki, Yuki Tanaka, Masaru Kiuchi

Kyushu Institute of Technology

Dec. 14 (Wed.) Electronic Devices **G408**

Device physics

Chairpersons: Eva Olsson (Chalmers University of Technology) and Mutsuo Hidaka (AIST)

ED1-1-INV 13:45–14:10

Single Microwave Photon Detector

*Kunihiro Inomata[1], Zhirong Lin[1], Kazuki Koshino[2], William D Oliver[3], Jaw-Shen Tsai[1,4], Tsuyoshi Yamamoto[5], Yasunobu Nakamura[1,6]

1. RIKEN Center for Emergent Matter Science; 2. College of Liberal Arts and Sciences, Tokyo Medical and Dental University; 3. MIT Lincoln Laboratory; 4. Department of Physics, Tokyo University of Science; 5. NEC IoT Device Research Laboratories; 6. Research Center for Advanced Science and Technology, The University of Tokyo

ED1-2-INV 14:10–14:35

Josephson parametric amplifier/oscillator and its application to quantum information processing

*Zhirong Lin[1], Kunihiro Inomata[1], Kazuki Koshino[2], Jaw-Shen Tsai[1,3], Tsuyoshi Yamamoto[4], Yasunobu Nakamura[1,5]

1. Center for Emergent Matter Science (CEMS), RIKEN; 2. Tokyo Medical and Dental University; 3. Tokyo University of Science; 4. NEC Corporation; 5. The University of Tokyo

ED1-3-INV 14:35–15:00

Direct Observation of the Thickness Distribution and Atomic Structure of Ultra Thin AlOx Barriers in Al/AlOx/Al Josephson Junctions

Lunjie Zeng, *Eva Olsson

Department of Physics, Chalmers University of Technology, Gothenburg, Sweden

ED1-4 15:00–15:20

Niobium SIS Junction Technology for Sub-mm Wave Mixers

*Matias Kroug, Mizuki Ikeya, Takafumi Kojima, Takeshi Noguchi

National Astronomical Observatory of Japan

ED1-5 15:20–15:40

Elemental Intermixing and Gap States at the Substrate Interfaces of Al Based Josephson Junctions

*Lunjie Zeng[1], Tine Greibe[2], Philip Krantz[2], Per Delsing[2] and Eva Olsson[1]

1. Department of Physics, Chalmers University of Technology, Sweden; 2. Department of Microtechnology and Nanoscience, Chalmers University of Technology

Digital systems

Chairpersons: Nobuyuki Yoshikawa (Yokohama National University) and Christopher L. Ayala (Yokohama National University)

ED2-1-INV 15:55–16:20

Design methodologies toward large-scale adiabatic quantum-flux-parametron integrated circuits

*Christopher L. Ayala[1], Qiuyun Xu[2], Yuki Murai[2], Ro Saito[2], Naoki Takeuchi[1], Yuki Yamanashi[1,2], Thomas Ortlepp[1,3], Nobuyuki Yoshikawa[1,2]

1. Institute of Advanced Sciences, Yokohama National University, Japan; 2. Department of Electrical Engineering and Computer Engineering, Yokohama National University; 3. CiS Research Institute for Microsensor Systems GmbH, Erfurt, Germany

ED2-2-INV 16:20–16:45

Energy-Efficient, High-Performance Microprocessors Based on Single-Flux-Quantum Logic

*Masamitsu Tanaka[1], Ryo Sato[1], Yuki Hatanaka[1], Yuki Ando[2], Takahiro Kawaguchi[2], Koki Ishida[3], Akira Fujimaki[1], Kazuyoshi Takagi[2], Naofumi Takagi[2], Takatsugu Ono[3], Koji Inoue[3]

1. Nagoya University; 2. Kyoto University; 3. Kyushu University

ED2-3 16:45–17:05

Run-to-Run Yield Evaluation of Improved Nb 9-layer Advanced Process using SFQ Shift Register Chip Including 68,990 Josephson Junctions

*Shuichi Nagasawa, Mutsuo Hidaka

National Institute of Advanced Industrial Science and Technology (AIST)

ED2-4 17:05–17:25

Thermally-Fluctuated Single-Flux-Quantum Pulse Intervals Reflected in Input-Output Characteristics of a Double-Flux-Quantum Amplifier

*Yoshinao Mizugaki, Yoshiaki Urai, Hiroshi Shimada

The University of Electro-Communications

High field magnet / Cooling system

Chairpersons: Kazuhiro Kajikawa (Kyushu University) and Hiroshi Ueda (Okayama University)

AP1-1-INV 9:30–10:00

Development of high field cryogen-free superconducting magnets at Tohoku University - 25T-CSM and future prospect –

*Satoshi Awaji

High Field Laboratory for Superconducting Materials, IMR, Tohoku University

AP1-2 10:00–10:15

A 9.4 T 64 mm Bore Conduction-Cooled All-HTS Magnet

Jaemin Kim[1], Seungyoung Hahn[2], Kang Hwan Shin[1], Sangwon Yoon[1], *Kyekun Cheon[1], Young Jin Hwang[3], Jae Young Jang[3], SangGap Lee[3], Hankil Yeom[4], Hunju Lee[1], Seung-Hyun Moon[1]

1. SuNAM Co., LTD; 2. National High Magnetic Field Laboratory; 3. Korea Basic Science Institute; 4. Korea Institute of Machinery and Materials

AP1-3 10:15–10:30

Comparison of Simulated and Experimental Results of Temperature Distribution in a Closed Two-Phase Thermosyphon Cooling System

*Erasmus Shaanika, Ken Nishimura, Kota Yamaguchi, Motohiro Miki, Tetsuya Ida, Mitsuru Izumi

Tokyo University of Marine Science and Technology

HTS magnet / Magnetic bearing

Chairpersons: Satoshi Awaji (Tohoku University) and Kyekun Cheon (SuNAM)

AP2-1-INV 10:45–11:15

Development of REBCO Magnet for MRI

*Shoichi Yokoyama[1], Masayoshi Oya[1], Tetsuya Matsuda[1], Tatsuya Inoue[1], Ryo Eguchi[1], Toshinari Nagahiro[1], Hajime Tanabe[1], Akihiro Daikoku[1], Taketsune Nakamura[2], Yasuyuki Shirai[2], Daisuke Miyagi[3], Makoto Tsuda[3]

1. Mitsubishi Electric Corporation; 2. Kyoto University; 3. Tohoku University

AP2-2-INV 11:15–11:45

Reduction of Screening-Current-Induced Fields by Applying Shaking Fields

*Kazuhiro Kajikawa

Kyushu University

AP2-3-INV 11:45–12:15

Electromagnetic Analysis on Screening-Current-Induced Magnetic Field in REBCO Coil

*Hiroshi Ueda

Okayama University

AP2-4 12:15–12:30

Load test of Superconducting Magnetic Bearing for MW-class Flywheel Energy Storage System

*Shinichi Mukoyama[1], Kengo Nakao[1], Hisaki Sakamoto[1], Ken Nagashima[2], Masafumi Ogata[2], Tomohisa Yamashita[2], Kazufumi Miyazaki[3], Hideki Shimizu[4], Hidetsugu Sawamura[4]

1. Furukawa Electric: 2. Railway Technical Research Institute; 3. Yamanashi Prefectural; 4. Mirapro

AP2-5 12:30–12:45

Vibrational characteristics of a superconducting magnetic bearing employed for a prototype polarization modulator

*Yuki Sakurai[1], Tomotake Matsumura[2], Hajime Sugai[1], Nobuhiko Katayama[1], Hiroyuki Ohsaki[3], Yutaka Terao[3], Yusuke Terachi[3], Hirokazu Kataza[2], Shin Utsunomiya[1], Ryo Yamamoto[2]

1. Kavli IPMU, The University of Tokyo; 2. ISAS/JAXA; 3. Graduate School of Frontier Sciences, The University of Tokyo

Lunch Break 12:45–14:00

Generator / Power grid

Chairpersons: Antonio Morandi (University of Bologna) and Minwon Park (Changwon National University)

AP3-1-INV 14:00–14:30

SUPRAPOWER Project: Towards a 10 MW MgB_2 Wind Power Generator

*Santiago Sanz[1], Gustavo Sarmiento[1], José Mari Merino[1], Ainhoa Pujana[1], Jiuce Sun[2], Victor Zermeño[2], Holger Neumann[2], Matteo Tropeano[3], Davide Nardelli[3], Gianni Grasso[3], Tupac Canosa[4], Iker Marino[1]

1. TECNALIA. Parque Tecnológico de Bizkaia, Spain; 2. Institute for Technical Physics Karlsruhe Institute of Technology, Germany; 3. Columbus Superconductors SpA. Via delle Terre Rosse, Italy; 4. Solute Ingenieros, Spain

AP3-2-INV 14:30–15:00

Current Status of HTS Power Applications in Korea

*Minwon Park

Changwon National University

AP3-3 15:00–15:15

Hardware integration and performance analysis of a 10 kW HTS wind power generator with brushless exciter

*Hae-Jin Sung[1], Byeong-Soo Go[1], Minwon Park[1], Olly Pantoja[2], Zhenan Jiang[2], Rodney Badcock[2], In-Keun Yu[1]

1. Changwon National University; 2. Robinson Research Institute, Victoria University of Wellington

AP3-4 15:15–15:30

HTS Materials for Large-Scale Applications as possible drivers to integrate Superconducting Devices in conventional Electric Power Grids

*Yutaka Yamada[1], Giuliano Angeli[2], Marco Bocchi[2], Luciano Martini[2]

1. Shibaura Institute of Technology, SIT; 2. RSERicerca sul Sistema Energetico – RSE S.p.A.

Magnetic field applications

Chairpersons: Shigehiro Nishijima (Osaka University) and Satoshi Fukui (Niigata University)

AP4-1-INV 15:45–16:15

Saturated induction heating of magnetic metals: concepts and possible implementation

*Antonio Morandi, Massimo Fabbri, Pier Luigi Ribani

University of Bologna - DEI, Dep. of Electrical, Electronic and Information Engineering

AP4-2 16:15–16:30

Volume Reduction of Cesium Contaminated Soil by High Gradient Magnetic Separation Using Superconducting Magnet

*Shigehiro Nishijima[1], Kazuki Yukumatsu[1], Hiroki Horie[1], Naoki Nomura[1,4], Yoko Akiyama[1], Fumihito Mishima[2], Tomio Sekiyama[3], Seiichiro Mitsui[3], Mitsugu Kato[3]

1. Graduate School of Engineering, Osaka University; 2. Department of Nuclear Technology Application, Fukui University of Technology; 3. Japan Atomic Energy Agency (JAEA); 4. Life Environment Division, Fukushima Prefecture

AP4-3 16:30–16:45

Study on Volume Reduction of Cesium Contaminated Soil by Magnetic Separation ~Pretreatment of Soil Organic Matter~

*Hiroki Horie[1], Kazuki Yukumatsu[1], Fumihito Mishima[2], Yoko Akiyama[1], Shigehiro Nishijima[1]

1. Osaka University; 2. Fukui University of Techology

AP4-4 16:45–17:00

SEPARATION OF FLAME AND NONFLAME-RETARDANT PLASTICS UTILIZING MAGNETO-ARCHIMEDES METHOD

*Kohei Misawa[1], Takayuki Kobayashi[1], Tatsuya Mori[1], Fumihito Mishima[2], Yoko Akiyama[1], Shigehiro Nishijima[1]

1. Osaka University; 2. Fukui University of Technology

AP4-5 17:00–17:15

The separation of structural isomer using Magneto-Archimedes method

*Tatsuya Mori[1], Takayuki Kobayashi[1], Fumihito Mishima[2], Yoko Akiyama[1], Shigehiro Nishijima[1]

1. Graduate School of Engineering, Osaka University; 2. Fukui University of Technology

AP4-6 17:15–17:30

Influence of Food Elements by Superconducting Wireless Power Transfer System via Strong Electromagnet Resonance Coupling

*Yoon Do CHUNG[1], Young Gun PARK[2], Bong Soo NOH[3], Eun Young PARK[4]

1. Suwon Science College; 2. Yonsei University; 3. Seoul Women's University; 4. Korea Christian University

Novel materials

Chairpersons: Kosuke Nakayama (Tohoku University) and Junichi Shiogai (Tohoku University)

PC6-1-INV 9:30–9:55

Bi^{2-} square net superconductivity in Y_2O_2Bi

*Tomoteru Fukumura

Tohoku University

PC6-2-INV 9:55–10:20

Highly-crystalline 2D superconductors and beyond

*Yu Saito

The University of Tokyo

PC6-3 10:20–10:35

Paramagnetic and Diamagnetic Pair-Breaking Effect in Electric-Field-Induced Surface Superconductivity under Parallel Magnetic Fields

*Masanori Ichioka[1,2], Masahiro Nabeta[1], Kenta K. Tanaka[1], Seiichiro Onari[1,2]

1. Department of Physics, Okayama University; 2. Research Institute for Interdisciplinary Science, Okayama University

PC6-4 10:35–10:50

Bulk superconductivity induced by in-plane chemical pressure effect in the $Eu_{0.5}La_{0.5}FBiS_{2-x}Se_x$ system

*Gen Jinno[1], Rajveer Jha[2], Akira Yamada[2], Ryuji Higashinaka[2], Tatsuma D. Matsuda[2], Yuji Aoki[2], Masanori Nagao[3], Osuke Miura[1], Yoshikazu Mizugchi[1]

1. Department of Electrical and Electronic Engineering, Tokyo Metropolitan University; 2. Department of Physics, Tokyo Metropolitan University; 3. Center for Crystal Science and Technology, University of Yamanashi

PC6-5 10:50–11:05

Superconducting state of the single crystals of $La(O,F)Bi(S_{1-x}Se_x)_2$

*Naoki Kase[1], Yusuke Terui[1], Tomohito Nakano[1], Naoya Takeda[2]

1. Graduate school of science and technology, Niigata University; 2. Department of materials science, Niigata University

Novel states of matter

Chairpersons: Akira Iyo (AIST) and Tsutomu Nojima (Tohoku University)

PC7-1-INV 11:20–11:45

Correlation strength and T_c: quantum oscillations in $YBa_2Cu_4O_8$ under hydrostatic pressure

*Carsten Putzke[1], L. Malone[1], S. Badoux[2], W. Tabis[2], D. Vignolles[2], B. Vignolle[2], P. Walmsley[1], M. Bird[1], N. E. Hussey[1], C. Proust[2], A. Carrington[1]

1. University of Bristol, UK; 2. LNCMI-Toulouse, France

PC7-2 11:45–12:00

Improvement of superconducting properties in Ba_2SmNbO_6 and $BaHfO_3$ co-doped $SmBa_2Cu_3O_y$ thin films under low and high magnetic field

*Yuma Kusafuka[1], Yusuku Ichino[1], Yuji Tsuchiya[1], Yutaka Yoshida[1], Ichinose Ataru[2]

1. Department of Energy Engineering and Science, Nagoya University; 2. CRIEPI

PC7-3 12:00–12:15

Elastoresistance measurements as a probe of nematic fluctuations in cuprate superconductors

*Kousuke Ishida[1], Suguru Hosoi[1], Yuta Mizukami[1], Yuki Teramoto[2], Tomohiro Usui[2], Takao Watanabe[2], Takasada Shibauchi[1]

1. The University of Tokyo; 2. Hirosaki University

PC7-4 12:15–12:30

Surface spintronics of the chiral d-wave pairing state in the Kane-Mele metal SrPtAs

*Jun Goryo[1], Yoshiki Imai[2], Andreas Schnyder[3], Manfred Sigrist[4]

1. Hirosaki University; 2. Saitama University; 3. Max Planck Institute, Stuttgart; 4. ETH Zurich

PC7-5 12:30–12:45

Spontaneous orbital-selective Mott transitions and the Jahn-Teller metal of A3C60

*Shintaro Hoshino[1], Philipp Werner[2]

1. RIKEN CEMS; 2. University of Fribourg

Dec. 15 (Thu.) Wires and Bulk **G409**

Flux pinning

Chairpersons: Xavier Obradors (ICMAB/CSIC) and Takanobu Kiss (Kyushu University)

WB5-1-INV 9:30–10:00

Flux pinning in REBCO thin films doped with artificial pinning centers

*KANAME MATSUMOTO[1], Tadaya Nishihara[1], Tomoya Horide[1], Alok Jha[1], Yutaka Yoshida[2], Satoshi Awaji[3], Ataru Ichinose[4]

1. Kyushu Institute of Technology; 2. Nagoya University; 3. Tohoku University; 4. CRIEPI

WB5-2-INV 10:00–10:30

Recent Activities on R&D of Coated Conductors in JAPAN

*Teruo IZUMI

AIST (National Institute of Advanced Industrial Science and Technology)

WB5-3 10:30–10:45

Characterization of $YBa_2Cu_3O_y$ coated conductors with $BaHfO_3$ nanoparticle flux pinning centers by metal organic deposition

*Ryo Teranishi[1], Hiroshi Horita[1], Yukio Sato[1], Kenji Kaneko[1], Teruo Izumi[2], Satoshi Awaji[3]

1. Kyushu University; 2. National Institute of Advanced Industrial Science and Technology;
3. Tohoku University

WB5-4 10:45–11:00

Development of Artificial Pinning Center Introduced Coated Conductor by MOD Method Using a New Raw Material Solution

*Kazunari Kimura[1], Ryusuke Hironaga[1], Tatsunori Nakamura[1], Kyo Takahashi[1], Yasuo Hikichi[1], Yasuo Takahashi[1], Tsutomu Koizumi[1], Takayo Hasegawa[1], Koichi Nakaoka[2], Teruo Izumi[2]

1. SWCC Showa Cable Systems Co., Ltd.; 2. National Institute of Advanced Industrial Science and Technology (AIST)

MgB_2

Chairpersons: John H. Durrell (University of Cambridge) and Hideki Tanaka (Hitachi)

WB6-1-INV 11:15–11:45

Recent development of MgB_2 wires and $(Ba,K)Fe_2As_2$ tapes in NIMS

*Hiroaki Kumakura, Shujun Ye, Zhaoshun Gao, Akiyoshi Matsumoto, Kazumasa Togano

National Institute for Materials Science

WB6-2-INV 11:45–12:15

Trapped Field Properties of MgB_2 Superconducting Bulks Magnetized by Field-cooled and Pulsed Field Magnetizations

*Tomoyuki Naito, Arata Ogino, Yuhei Takahashi, Hidehiko Mochizuki, Hiroyuki Fujishiro

Iwate University

WB6-3 12:15–12:30

Record critical current density in bulk MgB_2 using carbon-coated amorphous boron and optimum sintering conditions

*Muralidhar Miryala[1], Masaki Higuchi[1], Kazuo Inoue[1], Pavel Diko[2], Miles Jirsa[3], Masato Murakami[1]

1. Graduate School of Science and Engineering, Shibaura Institute of Technology; 2. Institute of Experimental Physics, SAS, Slovak Republic; 3. Institute of Physics, Czech Academy of Sciences, Praha, Czech Republic

WB6-4 12:30–12:45

The performance improvement of MgB_2 prepared by the Mg diffusion method with the MgB_4 addition

*Hong Zhang[1], Lei Li[1], Yong Zhao[1,2], Yong Zhang[1]

1. Key Laboratory of Maglev Train and Maglev Technology of Ministry of Education, Superconductivity and New Energy R&D Center, Southwest Jiaotong University, China; 2. School of Physical Science and Technology, Southwest Jiaotong University, China

Dec. 15 (Thu.) Electronic Devices **G408**

SQUID

Chairpersons: Akihiko Kandori (Hitachi) and Masahiro Ukibe (AIST)

ED3-1-INV 9:15–9:40

Ultra-Low Field MRI Application of High-Tc SQUID Magnetometer

*Saburo TANAKA

Toyohashi University of Technology

ED3-2-INV 9:40–10:05

Wide-area induction logging system using HTS-SQUID as a highly-sensitive magnetometer

*Tsunehiro Hato[1], Akira Tsukamoto[1], Seiji Adachi[1], Yasuo Oshikubo[1], Hidehisa Watanabe[2], Hidehiro Ishikawa[2], Chikara Okada[2], Ayato Kato[3], Makoto Harada[3], Keita Yoshimatsu[3], Yousuike Kunishi[3], Keiichi Tanabe[1]

1. SUSTERA; 2. MINDECO; 3. JOGMEC

ED3-3 10:05–10:25

Research on HTS-SQUID NDE technique for pipes based on ultrasonic guided wave

*Yoshimi Hatsukade, Natsuki Masutani, Shouta Teranishi, Ken Masamoto, Shouya Kanenaga

Kindai University, Faculty of Engineering

ED3-4 10:25–10:45

QUANTITATIVE AND HIGH-RESOLUTION MAGNETIC IMAGES OBTAINED BY STM-SQUID MICROSCOPE WITH DISTANCE MODULATION TECHNIQUE

*Tsutau Yokocho, Hideo Sato Akaba, Yuji Miyato

Osaka University

Detectors

Chairpersons: Takafumi Kojima (National Astronomical Observatory of Japan) and Hirotake Yamamori (AIST)

ED4-1-INV 11:00–11:25

Superconducting Receivers for ALMA Radio Telescope and Future Development

*Takafumi Kojima[1], Alvaro Gonzalez[1], Matthias Kroug[1], Yasunori Fujii[1], Keiko Kaneko[1], Wenlei Shan[1], Shinichiro Asayama[1], Yoshinori Uzawa[2], Kazumasa Makise[2], Hirotaka Terai[2], Zhen Wang[2]

1. National Astronomical Observatory of Japan; 2. National Institute of Information and Communications Technology

ED4-2 11:25–11:45

Development of Superconducting Detectors for Dark Matter Searches using Liquid Helium

*Hirokazu Ishino[1], Atsuko Kibayashi[1], Yosuke Kida[1], Naoto Hidehira[1], Yosuke Yamada[1], HIrotake Yamamori[2], Fuminori Hirayama[2], Satoshi Kohjiro[2]

1. Okayama University; 2. National Institute of Advanced Industrial Science and Technology (AIST)

ED4-3 11:45–12:05

GroundBIRD - quest for the begin of the Universe by using cutting-edge superconducting detectors, KIDs

*Jun'ya Suzuki, Osamu Tajima

High Energy Accelerator Research Organization (KEK)

ED4-4 12:05–12:25

Development of Iridium-Based Small TES

*Hiroyuki Takahashi, Masashi Ohno

The University of Tokyo

ED4-5 12:25–12:45

Delay line current-biased kinetic inductance detector for imaging

*Takekazu Ishida[1], Yuya Miki[1], Hiroyuki Yamaguchi[1], Hiroaki Shishido[1], Shigeyuki Miyajima[2], Mutsuo Hidaka[3], Tomio Koyama[4]

1. Osaka Prefecture University; 2. National Institute of Information and Communications Technology; 3. National Institute of Advanced Industrial Science and Technology; 4. Institute for Materials Research, Tohoku University

Dec. 15 (Thu.) Large Scale System Applications **G407**

Accelerator / Fusion

Chairpersons: Amalia Ballarino (CERN) and Tetsuhiro OBANA (NIFS)

AP5-1-INV 9:45–10:15

Future Plan of Large Accelerators and Requiments to Superconducting Magnets

*Toru Ogitsu

KEK

AP5-2-INV 10:15–10:45

Design and Test Results of Superconducting Magnet for Heavy-Ion Rotating-Gantry

*Shigeki Takayama[1], Kei Koyanagi[1], Hiroshi Miyazaki[1], Shohei Takami[1], Tomofumi Orikasa[1], Yusuke Ishii[1], Tsutomu Kurusu[1], Yoshiyuki Iwata[2], Koji Noda[2], Kento Suzuki[3], Toru Ogitsu[3], Naoyuki Amemiya[4]

1. Toshiba Corporation; 2. National Institute of Radiological Science; 3. High Energy Accelerator Research Organization; 4. Faculty of Engineering, Kyoto University

AP5-3 10:45–11:00

Stability Analysis of the 100 kA-class HTS Conductor for the Helical Fusion Reactor FFHR-d1

*Yoshiro TERAZAKI[1], Nagato YANAGI[2], Satoshi ITO[3], Shinji HAMAGUCHI[2], Hitoshi TAMURA[2], Toshiyuki MITO[2], Hidetoshi HASHIZUME[3], Akio SAGARA[2]

1. The Graduate University for Advanced Studies; 2. National Institute for Fusion Science; 3. Tohoku University

Power application

Chairpersons: Santiago Sanz (TECNALIA) and Akihisa Miyazoe (Hitachi)

AP6-1-INV 11:15–11:45

Current status of MgB_2 cable applications in Europe

*Amalia Ballarino

CERN, European Organization for Nuclear Research, Geneva, Switzerland

AP6-2 11:45–12:00

Detection of Local Temperature Change on HTS Cables via Time-Frequency Domain Reflectometry

*Su Sik Bang[1], Geon Seok Lee[1], Gu-Young Kwon[1], Yeong Ho Lee[1], Gyeong Hwan Ji[1], Songho Sohn[2], Kijun Park[2], Yong-June Shin[1]

1. School of Electrical and Electronic Engineering, Yonsei University; 2. Korea Electric Power Corporation Research Institute

AP6-3 12:00–12:15

Experimental and Analytical Investigation of Transient Properties of RE-123 Coated Conductors in Fault Current Limiting Operation

*Shogo Urasaki[1], Masahiro Tajima[1], Kohei Higashikawa[1], Masayoshi Inoue[1], Yusuke Fukumoto[2], Masaru Tomita[2], Takanobu Kiss[1]

1. Kyushu University; 2. Railway Technical Research Institute

AP6-4 12:15–12:30

Development Progress of a 220kV Resistive-type Superconducting Fault Current Limiter

*Shaotao Dai[1], Liye Xiao[2], Jingye Zhang[2], Yuping Teng[2], Bangzhu Wang[1], Liangzhen Lin[2]

1. Beijing Jiaotong Univeristy; 2. Institute of Electrical Engineering, CAS

AP6-5 12:30–12:45

Applying Energy-Based Control Strategy to SMES System in Microgrids for Eddy Current Losses Reduction

*Rui Hou[1, 2], Thai-Thanh Nguyen[1], Hak-Man Kim[1], Huihui Song[2], Yanbin Qu[2]

1. Incheon National University, Korea; 2. Harbin Institute of Technology (Weihai), China

Dec. 15 (Thu.) Late News **G409**

Chairperson: Yoshiyuki Yoshida (AIST)

LN-1 16:15–16:30

Infrared Spectroscopic Studies of the Phonon Dynamics in Iron-based Superconductors

R. Yang, B. Xu, *X.G. Qiu

Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences

LN-2 16:30–16:45

Fabrication and Transport Property of 100 m Class Pnictide Wires

Xianping Zhang[1], *Chao Yao[1], Chiheng Dong[1], Dongliang Wang[1], Yanwei Ma[1], Hidetoshi Oguro[2], Satoshi Awaji[2], Kazuo Watanabe[2]

1. Key Laboratory of Applied Superconductivity, Institute of Electrical Engineering, Chinese Academy of Sciences; 2. High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University

Dec. 15 (Thu.) Closing **G409**

Poster Session

Dec. 13 (Tue.) Physics and Chemistry **G402**

Iron-based superconductors 2

Chairperson: Takao Sasagawa (Tokyo Institute of Technology)

PCP1-1 16:00–18:00

Synthesis and Superconductivity of New FeSe-Based Intercalation Compounds $A_x(C_8H_{11}N)_yFe_{1-z}Se$ (A = Li, Na) with the Largest Interlayer Spacings

*Takehiro Hatakeda, Takashi Noji, Kazuki Sato, Takayuki Kawamata, Masatsune Kato, Yoji Koike

Department of Applied Physics, Graduate School of Engineering, Tohoku University

PCP1-2 16:00–18:00

Dome-Shaped Magnetic Order in High-Pressure Phase Diagram of FeSe Superconductor

*Kohei Matsuura[1], Jianping Sun[2], Guangzhou Ye[2,3], Yuta Mizukami[1], Masaaki Shimozawa[4], Kazuyuki Matsubayashi[5], Minoru Yamashita[4], Tatsuya Watashige[6], Shigeru Kasahara[6], Yuji Matsuda[6], Jiaqiang Yan[7,8], Brian C Sales[7], Yoshiya Uwatoko[4], Jinguang Cheng[2], Takasada Shibauchi[1]

1. Department of Advanced Materials Science, University of Tokyo; 2. Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences; 3. School of Physical Science and Technology, Yunnan University; 4. The Institute for Solid State Physics, The University of Tokyo; 5. Department of Engineering Science, The University of Electro-Communications; 6. Department of Physics, Kyoto University; 7. Materials Science and Technology Division, Oak Ridge National Laboratory; 8. Department of Materials Science and Engineering, University of Tennessee

PCP1-3 16:00–18:00

Synthesis of Te substituted Iron Chalcogenide Thick Films by Electrochemical Method

*Nobuaki Watanabe[1], Takahiko Masui[2], Takahiro Osafune[1], Yuusuke Kasai[1], Kouhei Kiuchi[1], Shoma Koike[1]

1. Kanto Gakuin Univ.; 2. Kinki Univ.

PCP1-4 16:00–18:00

Synthesis of Electrodeposited $FeSe_{1-x}Te_x$ ($0 \leq x \leq 0.5$) Superconductors

*Takahiro Osafune[1], Nobuaki Watanabe[1], Takahiko Masui[2], Yuusuke Kasai[1], Kouhei Kiuchi[1], Shoma Koike[1]

1. Kanto Gakuin Univ.; 2. Kinki Univ.

PCP1-5 16:00–18:00

Synthesis of Electrodeposited $FeSe_{1-x}Te_x$ $(0.5 \leq x \leq 1)$ Superconductors

*Yusuke Kasai[1], Nobuaki Watanabe[1], Takahiko Masui[2], Takahiro Osafune[1], Kouhei Kiuchi[1], Shoma Koike[1]

1. Kanto Gakuin Univ.; 2. Kinki Univ.

PCP1-6 16:00–18:00

Gap features of Fe(Se,Te) found by tunneling spectroscopy below and above the superconducting transition

*Toshikazu EKINO[1], Akira Sugimoto[1], Alexander M. Gabovich[2]

1. Hiroshima University; 2. National Academy of Sciences of Ukraine

PCP1-7 16:00–18:00

Two-gap features revealed by specific heat measurements in FeSe

*Jing Ting Chen, Yue Sun, Tatsuhiro Yamada, Sunseng Pyon, Tsuyoshi Tamegai

The University of Tokyo

PCP1-8 16:00–18:00

High-Resolution ARPES Study of FeSe Thin Films

*Giao Ngoc Phan[1], Kosuke Nakayama[1], Shota Kanayama[1], Masato Kuno[1], Katsuaki Sugawara[2], Takafumi Sato[1], Takahiro Urata[1], Yoichi Tanabe[1], Katsumi Tanigaki[1,2], Fuyuki Nabeshima[3], Yoshinori Imai[3], Atsutaka Maeda[3], Takashi Takahashi[1,2]

1. Department of Physics, Tohoku University; 2. WPI Research Center, Advanced Institute for Materials Research, Tohoku University; 3. Department of Basic Science, the University of Tokyo

PCP1-9 16:00–18:00

Chemical-substitution effect on c-axis transport properties of $BaFe_2As_2$

*Masahiko Nagafuchi, Masamichi Nakajima, Shigeki Miyasaka, Setsuko Tajima

Osaka-unversity

PCP1-10 16:00–18:00

Angle-Resolved Photoemission Spectroscopy Study of Fermi Surface and Superconducting Gap in NdFeAs(O,F)

*Zi How Tin[1], Toru Adachi[1], Akira Takemori[1], Shigeki Miyasaka[1], Setsuko Tajima[1], Shin-ichiro Ideta[2,3], Kiyohisa Tanaka[2,3]

1. Department of Physics, Osaka University; 2. UVSOR, Institute for Molecular Science; 3. The Graduate University for Advanced Studies

PCP1-11 16:00–18:00

Field-driven Transition Revealed by Vortex Dynamics in $Ba_{1-x}K_xFe_2As_2$ with Splayed Columnar Defects

*Nozomu Ito[1], Akiyoshi Park[1], Sunseng Pyon[1], Tadashi Kambara[2], Tsuyoshi Tamegai[1]

1. Department of Applied Physics, The University of Tokyo; 2. Nishina Center, RIKEN

PCP1-12 16:00–18:00

EFFECT OF OXYGEN VACANCIES ON ELECTRONIC STATE IN $Sr_4V_2O_6Fe_2As_2$

*Hiroaki Yokota, Masamichi Nakajima, Shigeki Miyasaka, Setsuko Tajima

Osaka University

New superconductors

Chairperson: Kazunori Ueno (The University of Tokyo)

PCP2-1 16:00–18:00

Search for superconductiveity in chromium thin films

Masahiro Miyagawa[1], *Masashi Ohashi[1], Masaki Sawabu[1], Kohei Ohashi[1], Takahide Kubota[2], Koki Takanashi[2]

1. Kanazawa University; 2. IMR, Tohoku University

PCP2-2 16:00–18:00

Electrical resistivity of Chromium thin film

*Masaki Sawabu[1], Kohei Ohashi[1], Masahiro Miyagawa[1], Masashi Ohashi[1], Takahide Kubota[2], Koki Takanashi[2]

1. Kanazawa University; 2. Tohoku University

PCP2-3 16:00–18:00

Thin Film Synthesis of Palladates with the Nd_2CuO_4 Structure

*Yoshiko Nanao, Riku Ito, Hayato Inaba, Michio Naito

Tokyo Univ. of Agri. and Tech.

PCP2-4 16:00–18:00

Impurity effects on critical temperatures of nano-structured superconductors; Size and shape dependence.

*Masaki Umeda[1], Masaru Kato[1], Osamu Sato[2]

1. Osaka Prefecture University; 2. Osaka Prefecture University Colledge of Technology

PCP2-5 16:00–18:00

Anisotropic Superconducting Properties in Single Crystals of $ZrTe_3$

*Masaki Onishi, Kenjiro Okawa, Kazumune Tachibana, Takao Sasagawa

Laboratory for Materials and Structures, Tokyo Institute of Technology

PCP2-6 16:00–18:00

Scanning Tunneling Microscopy Measurements in $ZrTe_{3-x}Se_x$

*Ryota Ishio, Satoshi Demura, Yuita Fujisawa, Naoki Ishida, Hideaki Sakata

Department of physics, Tokyo University of Science

PCP2-7 16:00–18:00

Enhancement of superconductivity induced by Se doping in *2H*-TaS_2

*Takahiro Iwasaki, Yuita Fujisawa, Takahiro Fujita, Jun Iwashita, Kouki Kishimoto, Mitsuhiko Nakada, Satoshi Demura, Hideaki Sakata

Department of Physics, Tokyo University of Science, Japan

PCP2-8 16:00–18:00

Effect of Fe-doping on the CDW state in 1*T*-TaS_2 investigated by STM/STS

*Yuita Fujisawa, Tatsunari Shimabukuro, Hiroyuki Kojima, Kai Kobayashi, Satoshi Demura, Hideaki Sakata

Department of Physcis, Tokyo University of Science

PCP2-9 16:00–18:00

A Study on the Vibrational and Superconducting Properties in Granular Boron Doped Diamond Film

*Dinesh Kumar, M.S. Ramachandra Rao

Department of physics, IIT Madras, Chennai, India

PCP2-10 16:00–18:00

Exploration of Topological Superconductors in Au-Pb-Bi Compounds

*Kazumune Tachibana, Kenjiro Okawa, Hiromasa Namiki, Takao Sasagawa

MSL, Tokyo Institute of Technology

PCP2-11 16:00–18:00

Superconductivity of the Sr-intercalated Bi_2Se_3

*Kakeru Nagai[1], Haruka Mastuzaki[2], Naoki Kase[2], Tomohito Nakano[2], Naoya Takeda[1]

1. Department of Materials Science and Technology,Niigata University; 2. Graduate School of Science and Technology, Niigata University

PCP2-12 16:00–18:00

Superconducting gap symmetry of the single crystal of β-$PdBi_2$

*Haruka Matsuzaki[1], Kakeru Nagai[2], Naoki Kase[1], Tomohito Nakano[1], Naoya Takeda[2]

1. Graduate School of Science and Technology, Niigata University; 2. Department of Materials Science and Technology, Niigata University

PCP2-13 16:00–18:00

Large Upper-Critical Field of the Se-doped BiS_2-based Superconductor

*Yusuke Terui[1], Naoki Kase[1], Tomohito Nakano[1], Naoya Takeda[2]

1. Graduate School of Science and Technology, Niigata University; 2. Department of Materials Science and Technology, Niigata University

PCP2-14 16:00–18:00

Growth and characteristics of BiS_2-based superconducting single crystals

*Masanori Nagao[1], Satoshi Watauchi[1], Yoshihiko Takano[2], Isao Tanaka[1]

1. University of Yamanashi; 2. MANA National Institute for Materials Science

PCP2-15 16:00–18:00

Effect of Lead and Antimony Substitution on $LaO_{0.5}F_{0.5}BiS_2$

*Satoshi Otsuki, Yuto Sakai, Satoshi Demura, Yuita Fujisawa, Hideaki Sakata

Tokyo University of Science

PCP2-16 16:00–18:00

Evaluation of Bi Defects in BiS_2-based superconductors by Scanning Tunneling Microscopy and Spectroscopy

*Satoshi Demura, Naoki Ishida, Yuita Fujisawa, Hideaki Sakata

Tokyo University of Science

PCP2-17 16:00–18:00

Anomalous Temperature Dependence of Resistivity in $LaO_{1-x}F_xBiSe_2$ Single Crystals

*Naoki Ishida, Satoshi Demura, Yuita Fujisawa, Hideaki Sakata

Tokyo University of Science

PCP2-18 16:00–18:00

Evolution of superconductivity and metallic conductivity by chemical pressure effect in $REO_{0.5}F_{0.5}BiCh_2$ superconductors

*Kohei Nagasaka, Osuke Miura, Yoshikazu Mizuguchi

Tokyo Metropolitan University

Theory, new method

Chairperson: Takashi Yanagisawa (AIST)

PCP3-1 16:00–18:00

Novel Diamond Anvil Cell with B-doped Diamond Electrodes

*Ryo Matsumoto[1,2], Yosuke Sasama[1,2], Masashi Tanaka[1], Hiroyuki Takeya[1], Yoshihiko Takano[1,2]

1. MANA, NIMS; 2. Univ. of Tsukuba

PCP3-2 16:00–18:00

Examination of the Position Estimation Method for The Magnetic Metal Contaminant Detection

*Yutaro Tsuzuki, Ken Sakuta

University of Shiga Prefecture Japan

PCP3-3 16:00–18:00

Evolution of the CDW gap in Valence Skipper $RbTlX_3$ (X=F,Cl,Br): A First-principle study

*Izumi Hase[1], Takashi Yanagisawa[1], Kenji Kawashima[2]

1. AIST; 2. IMRA Material R&D Co.Ltd.

PCP3-4 16:00–18:00

Partial-Initiated Surface Flashover Characteristics of Ribbed Surface Insulator in Cryogenic Environment

*Jae-Hong Koo, Dong Hun Oh, Jin Yong Na, Bang Wook Lee

Hanyang University

PCP3-5 16:00–18:00

Interplay between staggered flux and *d*-wave superconducting states in Hubbard model

*Kenji Kobayashi[1], Hisatoshi Yokoyama[2]

1. Chiba Institute of Technology; 2. Tohoku University

PCP3-6 16:00–18:00

Effects of Impurity Potential on Antiferromagnetic and *d*-wave Superconducting States in Hubbard Model

*Hisatoshi Yokoyama[1], Ryo Sato[1], Kenji Kobayashi[2], Masao Ogata[3]

1. Department of Physics, Tohoku University; 2. Department of Natural Science, Chiba Institute of Technology; 3. Department of Physics, University of Tokyo

PCP3-7 16:00–18:00

Theory of high-temperature superconductivity in strongly correlated fermions system

*Kazuhisa Nishi

University of Hyogo

Cuprate related

Chairperson: Satoshi Okuma (Tokyo Institute of Technology)

PCP4-1 16:00–18:00

Impurity Effects on T_c and Electronic Transport Properties in the Undoped Superconductor T'-$La_{1.8}Eu_{0.2}CuO_4$

*Koki Ohashi[1], Takayuki Kawamata[1], Tomohisa Takamatsu[1], Tadashi Adachi[2], Masatsune Kato[1], Shuma Naito[1], Kei Hayashi[1], Yuzuru Miyazaki[1], Yoji Koike[1]

1. Department of Applied Physics, Graduate School of Engineering, Tohoku University, Japan; 2. Department of Engineering and Applied Sciences, Sophia University, Japan

PCP4-2 16:00–18:00

An effective Hamiltonian and its phase diagram for T'-structure cuprates

*Kunito Yamazaki[1], Takuya Yoshioka[1], Hiroki Tsuchiura[1], Masao Ogata[2]

1. Department of Applied Physics, Tohoku University, Japan; 2. Department of Physics, University of Tokyo, Japan

PCP4-3 16:00–18:00

OPTICAL STUDY OF ELECTRON-DOPED CUPRATE $Pr_{1.3-x}La_{0.7}Ce_xCuO_{4+\delta}$ IN UNDER-DOPED REGION

*Ryota Ohnishi[1], Masamichi Nakajima[1], Sigeki Miyasaka[1], Setsuko Tajima[1], Tadashi Adachi[2], Taro Ohgi[3], Akira Takahashi[3], Yoji Koike[3]

1. Osaka University; 2. Sophia University; 3. Tohoku University

PCP4-4 16:00–18:00

Magnetron sputtering growth of strain-controlled infinite-layer $Sr_{1-x}La_xCuO_2$ thin films with high T_c

*Keita Sakuma[1], Masataka Ito[2], Tetsuya Hajiri[2], Kenji Ueda[2], Masashi Miura[1], Hidefumi Asano[2]

1. Seikei University; 2. Nagoya University

PCP4-5 16:00–18:00

Theoretical Calculations of Superconductive Transition in Ladder Cuprate $SrCu_2O_3$

*Kenji Toyoda[1], Ryotaro Arita[2], Kazuhiko Kuroki[3], Hiroki Takeuchi[1], Yuji Zenitani[1]

1. Advanced Research Division, Panasonic Corporation; 2. Center for Emergent Matter Science, RIKEN; 3. Department of Physics, Osaka University

MOD

Chairperson: Ryo Teranishi (Kyushu University)

WBP1-1 16:00–18:00

Fabrication of (Y,Gd)$Ba_2Cu_3O_{6+y}$ Coated Conductor Containing Refined $BaZrO_3$ Particles by TFA-MOD Method Using Reel-to-Reel System

*Koichi Nakaoka, Akira Ibi, Takato Machi, Yukie Usui, Keisuke Wada, Teruo Izumi

National Institute of Advanced Industrial Science and Technology

WBP1-2 16:00–18:00

The influence of the grain-boundary angle on flux pinning properties in TFA-MOD (Y,Gd)BCO CCs

*Michio Sato[1], Tomonori Murakami[1], Masashi Miura[1], Akira Ibi[2], Koichi Nakaoka[2], Teruo Izumi[2]

1. Seikei University; 2. AIST

WBP1-3 16:00–18:00

The effect of intermediate heating treatment on in-field J_c in TFA-MOD BZO doped (Y,Gd)BCO wires

*Tomonori Murakami[1], Michio Sato[1], Masashi Miura[1], Akira Ibi[2], Koichi Nakaoka[2], Teruo Izumi[2]

1. Seikei University;.AIST

WBP1-4 16:00–18:00

Effect of $BaZrO_3$ nanoparticle on critical current density in the longitudinal magnetic field for $REBa_2Cu_3O_y$ wires by TFA-MOD

*TASUKU KUSAMA[1], MICHIO SATO[1], MASASHI MIURA[1], AKINORI IBI[2], KOICHI NAKAOKA[2], TERUO IZUMI[2]

1. SEIKEI UNIVERCITY; 2. AIST

WBP1-5 16:00–18:00

The effect of oxygen annealing temperature on in-field J_c of TFA-MOD (Y,Gd)BCO CCs

*Koki Agatsuma[1], Michio Sato[1], Masashi Miura[1], Akinori Ibi[2], Koichi Nakaoka[2], Teruo Izumi[2]

1. Seikei University; 2. AIST

WBP1-6 16:00–18:00

Effects of La addition on the fabrication of fluorine-free MOD-REBCO films

*Seiya Kato[1], Ryusuke Kita[1], Natsuki Kobayashi[2], Osuke Miura[2]

1. Shizuoka University; 2. Tokyo Metropolitan University

WBP1-7 16:00–18:00

Flux pinning properties of hafnium doped Gd123 films fabricated by fluorine-free MOD method

*Natsuki Kobayashi[1], Ryusuke Kita[2], Osuke Miura[3]

1. Tokyo Metropolitan University; 2. Shizuoka University; 3. Tokyo Metropolitan University

Coated conductor 1

Chairperson: Masayoshi Inoue (Kyushu University)

WBP2-1 16:00–18:00

Influence of chemical etching and partial melting heat treatment on the structure and superconducting properties of YGdBCO coated conductors

*Ming Jiang Wang[1], Wen Tao Wang[1], Lian Liu[1], Bao Lei Huo[1], Bing Cai Wu[1], Zhi Bin Liu[1], Yong Zhang[1], Cui Hua Cheng[3], Yong Zhao[1,2]

1. Key lab of Magnetic Levitation Technologies and Maglev Trains (Ministry of Education of China), Superconductivity and New Energy R&D Center, Southwest Jiaotong University, China; 2. School of Physical Sicence and Technology, Southwest Jiaotong University; 3. School of Materials Science and Engineering, University of New South Wales, Australia.

WBP2-2 16:00–18:00

Stability diagram of $GdBa_2Cu_3O_{7-\delta}$ for an off-set composition in low oxygen pressures with oxide refinement process

*Insung Park[1], Won-Jae Oh[1], Jae-Hun Lee[2], Seung-Hyun Moon[2], Sang-Im Yoo[1]

1. Department of Material Science and Engineering, Research Institute of Advanced Materials (RIAM), Seoul National University; 2. Superconductor, Nano & Advanced Materials Corporation (SuNAM Co.) Ltd

WBP2-3 16:00–18:00

The thermal and mechanical Stresses during Al alloy coating on 2nd generation superconducting coated conductor

*Ho-Sup Kim, Byung-Geol Kim, Jeong-Hyeon Jo, Chang-Hwan Lee

Korea Electrotechnology Research Institute

WBP2-4 16:00–18:00

The post-annealing effect of GdBa2Cu3O7-δ coated conductors by RCE-DR process

*Won-Jae OH[1], Insung Park[1], Jae-Hun Lee[2], Seung-Hyun Moon[2], Sang-Im Yoo[1]

1. Seoul National University; 2. Superconductor, Nano & Advanced Materials Corporation (SuNAM Co.) Ltd

WBP2-5 16:00–18:00

Particles in $GdBa_2Cu_3O_{7-\delta}$ Film Prepared by Pulsed Laser Deposition

*Tatsuya Murakami, Ryo Teranishi, Yukio Sato, Kenji Kaneko

Department of Materials Physics and Chemistry, Kyushu University

WBP2-6 16:00–18:00

Grain growth and surface modification of epitaxial CeGdZrO film on NiW substrate

*Jia Jialin, Jin Lihua, Feng Jianqing, Wang Yao, Li Chengshan, Zhang Pingxiang

Northwest Institute for Nonferrous Metal Research

WBP2-7 16:00–18:00

Phase stability and superconducting property of Cu excess SmBCO coated conductors

*Hongsoo HA[1], Younghoon Oh[1,2], Younguk Han[1], Sanghyun Lee[1], Seunghyun Moon[3], Sangsoo Oh[1]

1. Korea Electrotechnology Research Institute; 2. Sungkyunkwan University; 3. SuNAM Co Ltd

WBP2-8 16:00–18:00

Electro-mechanical properties of GdBCO coated conductor laminated with Al alloy tape

*Hongsoo HA[1], Sangsoo Oh[1], Younguk Han[1], Jeonwook Cho[1], Heonjoo Lee[2], Alking Gorospe[3], Hyungseop Shin[3]

1. Korea Electrotechnology Research Institute; 2. SuNAM Co. Ltd.; 3. Andong National University

WBP2-9 16:00–18:00

Fabrication of $YBa_2Cu_3O_{7-x}$ Thin Films with $BaHfO_3$ by Inkjet Printer

*Sei Katagi, Ryo Teranishi, Yukio Sato, Kenji Kaneko

Kyushu University

Coated conductor 2

Chairperson: Takato Machi (AIST)

WBP3-1 16:00–18:00

Development of long BMO doped REBCO coated conductors with high in-field properties by PLD method

*Akira Ibi, Koichi Nakaoka, Takato Machi, Teruo Izumi

National Institute of Advanced Industrial Science and Technology (AIST)

WBP3-2 16:00–18:00

TENSILE STRAIN CHARACTERISTICS OF BMO DOPED REBCO COATED CONDUCTORS

*Shinji Fujita, Shogo Muto, Tomo Yoshida, Hiroki Sato, Mitsunori Igarashi, Kazuomi Kakimoto, Yasuhiro Iijima, Kunihiro Naoe

Fujikura Ltd.

WBP3-3 16:00–18:00

Critical Current Density of YBCO Films with Different Configurations of Columnar Defects in Longitudinal Magnetic Field

*Tetsuro Sueyoshi, Yasuya Iwanaga, Takafumi Kai, Takanori Fujiyoshi

Kumamoto University

WBP3-4 16:00–18:00

Introduction of pinning centers into SmBCO Coated Conductor by Reactive Co-evaporation Method

*Gwan tae Kim[1], Ho-Sup Kim[1], Dong-Woo Ha[1], Kook-Chae Chung[2], Shinde Kiran[2]

1. Korea Superconductivity Research Center, Korea Electrotechnology Research Institute; 2. Functional Nano-materials Research Department, Korea Institute of Materials Science

WBP3-5 16:00–18:00

Deployment of a high-temperature superconductivity application research project of Leading Initiative for Excellent Young Researchers (LEADER) in Muroran Institute of Technology

*Xinzhe Jin[1,2]

1. Muroran Institute of Technology; 2. RIKEN Center for Life Science Technologies

WBP3-6 16:00–18:00

Joint of $REBa_2Cu_3O_y$ Coated Conductors Using Metal Organic Deposition Method

*kazuya hiramatsu, Ryo Teranishi, Yukio Sato, Kenji Kaneko

Kyushu University

WBP3-7 16:00–18:00

Nanostructural Characterization of Low Resistance Joints Using Ag Pastes for $GdBa_2Cu_3O_y$ Coated Conductor

Tomohiro Kato[1], Takato Machi[2], Daisaku Yokoe[1], Ryuji Yoshida[1], *Takeharu Kato[1], Teruo Izumi[2], Tsukasa Hirayama[1], Yuh Shiohara[3]

1. Nanostructures Research Laboratory, Japan Fine Ceramics Center; 2. Research Institute for Energy Conservation, Department of Energy and Environment, National Institute of Advanced Industrial Science and Technology; 3. Industrial Superconductivity Technology Research Association

WBP3-8 16:00–18:00

A study on Electromechanical Properties of a Novel Twisted Soldered-Stacked-Square (3S) HTS Wire with 1 mm Width

*Zeng Lin Xie, Min Hu, Zhu Yong Li, Yong Kang Zhou, Dao Yu Hu, Li Lin Sun, Zhi Jian Jin, Zhi Yong Hong

Academy of electrical engineering, Shanghai Jiao Tong University

WBP3-9 16:00–18:00

The Property of Hot-Dip Aluminizing for HTS Coated Conductor

*ByungGeol Kim, JeongHyeon Cho, HoSup Kim, ChangHwan Lee

Korea Electrotechnology Research Institute

WBP3-10 16:00–18:00

Numerical Investigation on Detection of Internal Crack in HTS Film by Using Contactless Method for Measuring j_C

*Teruou Takayama, Ayumu Saitoh, Atsushi Kamitani

Yamagata University

Characterization

Chairperson: Kohei Higashikawa (Kyushu University)

WBP4-1 16:00–18:00

Determining Pinning Parameters in Flux Creep-Flow Model for E-J characteristics of High Temperature Superconductors by using Differential Evolution

*Edmund Soji Otabe[1], Takuto Taguchi[1], Yuuki Tsuruda[1], Ryohei Funaki[2]

1. Kyushu Institute of Technology; 2. Kyushu University

WBP4-2 16:00–18:00

Evaluation of self-magnetic field of oxide superconducting tapes with ferromagnetic shielding

*Kei Kashiwagi[1], Vladimir Vyatlin[2], Edmund Soji Otabe[1], Yuta Hiramatsu[1], Masaru Kiuchi[1], Satarou Yamaguchi[2]

1. Kyushu Institute of Technology; 2. Chubu University

WBP4-3 16:00–18:00

Numerical Reproduction of Screening-Current-Induced Fields in HTS Tape Windings Using Finite Element Method

*Yuma OKABE, Tomokazu Honda, Kazuhiro Kajikawa

Kyushu University

WBP4-4 16:00–18:00

Reduction of Screening-Current-Induced Fields Using New Structure of HTS Coil

*Tomokazu HONDA, Yuma Okabe, Kazuhiro Kajikawa

Kyushu University

WBP4-5 16:00–18:00

Ac and dc characterizations of striated and copper-plated coated conductors

*Ryuki Toyomoto[1], Takuma Nishimoto[1], Naoyuki Amemiya[1], Satoshi Yamano[2], Hisaki Sakamoto[2]

1. Kyoto University; 2. Furukawa Electric Co., Ltd.

WBP4-6 16:00–18:00

Magnetic Microscopy for the Characterization of Magnetic Relaxation in Multi-filamentary Bi-2223 Tape with DC Transport Current and External Magnetic Field

*Kohei Hisajima, Kohei Higashikawa, Takumi Suzuki, Kazutaka Imamura, Masayoshi Inoue, Takanobu Kiss

Kyushu University

WBP4-7 16:00–18:00

Electomagnetic properties of YBCO ceramic oxides system for magnetic force

*Sang Heon Lee

Department of Electronic Engineering, Sunmoon University, Asan, Korea

WBP4-8 16:00–18:00

Analytical and Experimental Evaluation of DC Insulation Characteristics of PPLP/LN_2 Composite Insulation System according to The Variation of Overlapping Rate

*Jin-Yong Na, Ryul Hwang, Ik-Soo Kwon, Bang-Wook Lee

Hanyang University, Ansan, Korea

WBP4-9 16:00–18:00

Improved Delamination Properties of Coated Conductors

*Kenji Suzuki, Masaru Tomita

Railway Technical Research Institute, Kokubunji-Shi, Tokyo, Japan

Magnet protection

Chairperson: Tsuyoshi Wakuda (Hitachi)

APP1-1 16:00–18:00

Detection Method of Normal transitions in a High Temperature Superconducting Coil wound with a plurality of YBCO superconductors by the Active Power Method and H-coils

*Ryo Kadowaki, Nozomu Nanato

Okayama University

APP1-2 16:00–18:00

Locating of Normal Transitions in A Bi2223 High Temperature Superconducting Coil by Using Capacitor Type Voltage Terminals and the Active Power Method

*Kohei Okura, Nozomu Nanato, Yasunobu Kumagai, Hiroki Aoyama

Okayama University

APP1-3 16:00–18:00

Detection of Normal Transitions in a Hybrid Single-phase Bi2223 High Temperature Superconducting Transformer by using the Active Power Method and a Magnetic Flux Detection Coil

*Shingo Nakamura, Nozomu Nanato, Shinichi Tanaka

Okayama University

APP1-4 16:00–18:00

Protection System for Normal Transitions in a Single-phase 1 kA Class Bi2223 High Temperature Superconducting Transformer by Using the Active Power Method

*Noriyuki Koide, Nozomu Nanato, Takaaki Ono, Takahumi Adachi

Okayama University

APP1-5 16:00–18:00

Quench Behaviors and Characteristics of the Metal-Insulated 2G HTS Coil with Parallel Resistors

*Beomyong Eom, Myung-Hwan Sohn, Kideok Sim, Haejong Kim Kim, Kichul Seong

Korea Electrotechnology Research Institute

APP1-6 16:00–18:00

Conduction Cooling System based Design and the Experimental analysis of A Metal Insulated HTS Magnet

*Jongho Choi, Chan-Kyeong Lee, Sung-Kyu Kim, Minwon Park, In-Keun Yu

Changowon National University

APP1-7 16:00–18:00

Study on the Control of Current Bypassing and the Thermal Behavior in the Non-Insulated HTS Coil

*Kentaro Tami, Daiseki Kanenoto, SeokBeom Kim, Hiroshi Ueda

Okyayama University

NMR

Chairperson: Shoichi Yokoyama (Mitsubishi Electric)

APP2-1 16:00–18:00

Study on the Permanent Current Switch in HTS Coils Wound with 2G Wire for Compact NMR Magnets

*Keito Sugo, SeokBeom Kim, Hiroshi Ueda, Ryo Saito

Okayama University

APP2-2 16:00–18:00

Study on the magnetic field homogeneity and shimming method of Halbach arrayed permanent magnets for compact NMR relaxometry

*Ryota Nomura, Katuya Hojo, Susumu Fukada, Shinya Ohara, SeokBeom Kim,, Hiroshi Ueda

Okayama University

APP2-3 16:00–18:00

Numerical study to obtain the improved field homogeneity of HTS bulk magnet with enlarged inner diameter for compact NMR relaxometry

*Susumu Fukada, SeokBeom Kim, Hiroshi Ueda, Katsuya Hojo

Okayama University

Magnetic field application

Chairperson: Mitsuho Furuse (AIST)

APP3-1 16:00–18:00

Side-suspended High-T_c Superconducting Maglev Prototype Vehicle Running at a High Speed in an Evacuated Circular Test Track

Dajin Zhou[1], Chenyu Cui[1], Lifeng Zhao[1], Yong Zhang[1], Xiqing Wang[1], *Yong Zhao[1,2]

1. Key Laboratory of Magnetic Levitation Technologies and Maglev Trains, Ministry of Education of China, and Superconductivity and New Energy R&D Center, Southwest Jiaotong University; 2. School of Physical and Science Technology, Southwest Jiaotong University

APP3-2 16:00–18:00

Study of Running Stability in Side-Suspended HTS-PMG Maglev Circular Line System

*Dajin Zhou[1], Linbo Li[1], Chenyu Cui[1], Yong Zhang[1], Yong Zhao[1,2]

1. Key Laboratory of Magnetic Levitation Technologies and Maglev Trains (Ministry of Education of China), Superconductivity and New Energy R&D Center, Southwest Jiaotong University, China; 2. School of Physical Science and Technology, Southwest Jiaotong University

APP3-3 16:00–18:00

Nonlinear Vibration Behavior of High-Tc Superconducting Bulks Above a Permanent Magnetic Guideway

*Jipeng Li[1], Haitao Li[1], Botian Zheng[1,2], Huan Huang[1], Jun Zheng[1], Zigang Deng[1]

1. Applied Superconductivity Laboratory, State Key Laboratory of Traction Power, Southwest Jiaotong University, China; 2. School of Electrical Engineering, Southwest Jiaotong University

APP3-4 16:00–18:00

Curve Negotiation Ability of High Temperature Superconducting Maglev Above Different Permanent Magnet Guideways

*Haitao Li, Zigang Deng, Jipeng Li, Hengpei Liao, Jun Zheng, Botian Zheng

Applied Superconductivity Laboratory, State Key Laboratory of Traction Power, Southwest Jiaotong University

APP3-5 16:00–18:00

Numerical Analysis of Fundamental Characteristics of Superconducting Magnetic Bearings for a Polarization Modulator

Yusuke Terachi[1], *Hiroyuki Ohsaki[1], Yutaka Terao[1], Yuki Sakurai[2], Tomotake Matsumura[3], Hajime Sugai[2], Shin Utsunomiya[2], Hirokazu Kataza[3], Ryo Yamamoto[3]

1. Graduate School of Frontier Sciences, The University of Tokyo, Japan; 2. Kavli IPMU, The University of Tokyo, Japan; 3. ISAS/JAXA, Japan

APP3-6 16:00–18:00

Fundamental study on the magnetic field control method using multiple HTS coils for Magnetic Drug Delivery System

*Ryoma Hirano, Takuya Nakagawa, Yoshikazu Tomisaka, Hiroshi Ueda, SeokBeom Kim

Okayama University

APP3-7 16:00–18:00

Power Transfer Characteristics by Different Multi Antennas of Wireless Power Charging System for Superconducting MAGLEV Train

*Yoon Do CHUNG[1], Chang Young LEE[2], Young Gun PARK[3]

1. Dept. of Electrical Engineering, Suwon Science College; 2. Korea Railroad Research Institute; 3. Dept. of Electrical & Electronics Engineering, Yonsei University

Magnet system

Chairperson: Shinji Matsumoto (NIMS)

APP4-1 16:00–18:00

Microstructure observations on butt joint for JT-60SA CS coil

*Tetsuhiro Obana[1], Masayuki Tokitani[1], Kazuya Takahata[1], Kaname Kizu[2], Haruyuki Murakami[2]

1. NIFS; 2. QST

APP4-2 16:00–18:00

An effective cryostat design of conduction-cooled HTS magnets for a 300 kW-class HTS DC induction furnace

*Chankyeong Lee[1], Jongho Choi[1], Minwon Park[1], In-keun Yu[1], Seokho Kim[1], Kiduk Sim[2]

1. Changwon National University; 2. Korea Electrotechnology Research Institute

APP4-3 16:00–18:00

Optimal design and fabrication of a high current HTS DC reactor with conduction cooling system

*Van Quan Dao, Taekue Kim, Jongho Choi, Minwon Park, In-Keun Yu

Changwon National University

Cuprate

Chairperson: Tomoteru Fukumura (Tohoku University)

PCP5-1 14:00–16:00

Superconducting properties of polycrystalline $FeSr_2ErCu_2O_{6+y}$

*Isamu Iida[1], Yoshiaki Hata[1], Takashi Mochiku[2], Hiroshi Yasuka[1]

1. Department of Applied Physics, National Defense Academy; 2. Neutron Scattering Group, Research Center for Advanced Measurement and Characterization, National Institute for Materials Science

PCP5-2 14:00–16:00

Cu substitution for Nb in $NbSr_2GdCu_2O_z$ ($z \approx 8$)

*Toshihiko Maeda, Tatsuya Mitani, Takashi Akesaka, Takanori Okazaki

Kochi University of Technology

PCP5-3 14:00–16:00

Substitution effect of some lanthanoid elements in $Y(Sr,Ba)_2(Cu,Mo)_3O_z$

*Takanori Okazaki, Takashi Akesaka, Toshihiko Maeda

Kochi University of Technology

PCP5-4 14:00–16:00

Effect of Tb substitution on properties of $FeSr_2YCu_2O_{6+\delta}$ magnetic superconductor

*Takashi Mochiku[1], Yoshiaki Hata[2], Isamu Iida[2], Akinori Hoshikawa[3], Toru Ishigaki[3], Hiroshi Yasuoka[2], Kazuto Hirata[1]

1. National Institute for Materials Science; 2. National Defense Academy; 3. Ibaraki University

PCP5-5 14:00–16:00

Oxidation and reduction effects of successive superconducting transitions in ultra-fine $YBa_2Cu_4O_8$ ceramics

*Akihiko Hisada[1,2], Kie Muranaka[2], Kuniyuki Koyama[1,2], Ko-ichi Magishi[1,2], Takahito Saito[2,3], Makoto Hagiwara[4]

1. Faculty of Science and Technology, Tokushima University; 2. Graduate School of Integrated Arts and Sciences, Tokushima University; 3. Institute of Liberal Arts and Sciences, Tokushima University; 4. Faculty of Engineering and Design, Kyoto Institute of Technology

PCP5-6 14:00–16:00

Field-Temperature Phase Diagram of Intergrain Ordering in Superconductive Ceramic YBCO

*Hiroyuki Deguchi[1], Ryusei Warabino[1], Syunkun Ka[1], Masaki Mito[1], Makoto Hagiwara[2], Kuniyuki Koyama[3]

1. Faculty of Engineering, Kyusyu Institute of Technology; 2. Faculty of Engineering and Design, Kyoto Institute of Technology; 3. Faculty of Science and Technology, Tokushima University

PCP5-7 14:00–16:00

Double pair breaking peak in triple layer cuprate Bi2223

*Giulio Vincini[1], Lennart Sobirey[1], Kiyohisa Tanaka[2], Toru Adachi[1], Naoki Murai[1], Shigeki Miyasaka[1], Setsuko Tajima[1], Shintaro Adachi[3], Takao Watanabe[3]

1. Department of Physics, Osaka University; 2. Institute for Molecular Science; 3. Graduate School of Science and Technology, Hirosaki University

PCP5-8 14:00–16:00

STS measurement of Ni impurity effect in Bi2212

*Akito Nakagawa, Tomohiro Sakaidani, Yuta Kiguchi, Tatsuro uto, Azusa Matsuda

Waseda University

PCP5-9 14:00–16:00

Spin injection effect in thin Bi2212 single crystal

*Kenichiro Murata, Kazuto Otaka, Kazuhiro Yamaki, Akinobu Irie

Utsunomiya University

PCP5-10 14:00–16:00

And-renormalization effects on antiferromagnetism and d-wave superconductivity in two-dimensional t-J model

*Ryo Sato, Hisatoshi Yokoyama

Tohoku University

Vortex physics 3

Chairperson: Atsutaka Maeda (The University of Tokyo)

PCP6-1 14:00–16:00

Detecting Vortex Motion with Scanning Tunneling Microscopy

*Koshiro Kato[1], Koichiro Ienaga[1], Shin-ichi Kaneko[1], Hideaki Sakata[2], Satoshi Okuma[1]

1. Department of Physics, Tokyo Institute of Technology;
2. Department of Physics, Tokyo University of Science

PCP6-2 14:00–16:00

Non-equilibrium depinning transition driven by dc current and vortex density

*Tetsuya Kaji, Yasuki Kawamura, Koichiro Ienaga, Shin-ichi Kaneko, Satoshi Okuma

Dept. of Physics, Tokyo Institute of Technology

PCP6-3 14:00–16:00

Random organization of vortices under anisotropic conditions

*Koichiro Ienaga, Yudai Shirahata, Mihaly Dobroka, Yasuki Kawamura, Shin-ichi Kaneko, Satoshi Okuma

Department of Physics, Tokyo Institute of Technology

PCP6-4 14:00–16:00

Spin-polarized Local Density of States around Vortex in Helical p-wave Superconductors

*Kenta Tanaka[1], Masanori Ichioka[1,2], Seiichiro Onari[1,2]

1. Department of Physics, Okayama University; 2. Research Institute for Interdisciplinary Science, Okayama University

PCP6-5 14:00–16:00

Spin-current induced around half-quantum vortices in chiral p-wave superconducting states

*Rui Asaoka[1], Hiroki Tsuchiura[1], Manfred Sigrist[2]

1. Tohoku University; 2. Eidgenössisch Technische Hochschule

PCP6-6 14:00–16:00

Temperature Distribution and Critical Current of Long HTS Cables Cooled with Subcooled Liquid Nitrogen

*Vladimir Vyatkin[1], Yury Ivanov[1,2], Hirofumi Watanabe[1,2], Noriko Chikumoto[1,2], Satarou Yamaguchi[1,2]

1. Chubu University, Kasugai, Japan; 2. Ishikari Superconducting DC Power Transmission System Research Association, Yokohama, Japan

PCP6-7 14:00–16:00

Manipulation of Magnetic Flux States in Superconducting Squares with Artificial Pinning Sites

*Kohei Kitano[1], Satoru Okayasu[2], Tsutomu Nojima[3], Takahiko Sasaki[3], Nobuhito Kokubo[1]

1. Department of Engineering Science, University of Electro-Communications; 2. Advanced Science Research Center, Japan Atomic Energy Agency; 3. Institute for Materials Research, Tohoku University

PCP6-8 14:00–16:00

Magnetic field dependence of most stable vortex states in the chiral helimagnet / superconductor bilayer system

*Saoto Fukui, Masaru Kato, Yoshihiko Togawa

Osaka Prefecture University

PCP6-9 14:00–16:00

Simulations of vortices in a star-shaped plate with an artificial pin

*Hiroki Miyoshi[1], Atsuki Ito[1], Vu The Dang[1,2], Ho Thanh Huy[1,2], Masahiko Hayashi[2], Masaru Kato[1,3,4], Takekazu Ishida[1,4]

1. Department of Physics and Electronics, Osaka Prefecture University; 2. University of Sciences, Vietnam National University HCMC, Ho Chi Minh, Viet Nam; 3. Department of Mathematical Science, Osaka Prefecture University; 4. Institute for Nanofabrication Research, Osaka Prefecture University

PCP6-10 14:00–16:00

Molecular Dynamics Simulation on Vortex Lattice Melting in Meso-scopic Superconductors

*Masaru Kato, Harutaka Kitago

Department of Mathematical Sciences, Osaka Prefecture University

PCP6-11 14:00–16:00

A variety of vortex state solutions of Ginzburg-Landau equation on superconducting mesoscopic plates

*Osamu Sato[1], Masaru Kato[2]

1. Department of Liberal Arts, Osaka Prefecture University College of Technology; 2. Department of Mathematical Sciences, Osaka Prefecture University

PCP6-12 14:00–16:00

Numerical restoration of surface vortices in Nb films measured by a scanning SQUID microscope

*Atsuki Ito[1], Ho Thanh Huy[1,2], Vu The Dang[1,2], Hiroki Miyoshi[1], Masahiko Hayashi[3], Takekazu Ishida[1]

1. Osaka Prefecture University; 2. Vietnam National University HCMC; 3. Akita University

PCP6-13 14:00–16:00

Magnetism, Fluctuations and Superconductivity in Cuprate High-Temperature Superconductors

*Takashi Yanagisawa[1], Izumi Hase[1], Mitake Miyazaki[2], Kunihiko Yamaji[1]

1. National Institute of Advanced Industrial Science and Technology; 2. Hakodate National College of Technology

PCP6-14 14:00–16:00

Equilibrium and dynamic vortex phase diagrams near absolute zero in a thick amorphous film

*Satoshi Okuma[1], Aguri Ochi[1], Naoya Sohara[1], Koichiro Ienaga[1], Shin-ichi Kaneko[1], Nobuhito Kokubo[2]

1. Department of Physics, Tokyo Institute of Technology; 2. Dept. of Engineering Science, The University of Electro-Communications

PCP6-15 14:00–16:00

Dynamic Melting of Anisotropic Vortex Lattices

*Inoue Toshiki[1], Aguri Ochi[1], Yasuki Kawamura[1], Mihaly Dobroka[1], Koichiro Ienaga[1], Shin-ichi Kaneko[1], Nobihito Kokubo[2], Satoshi Okuma[1]

1. Dept. of Physics, Tokyo Institute of Technology; 2. Dept. of Engineering Science, The University of Electro-Communications

PCP6-16 14:00–16:00

Simulation of Critical Current Density of Bulk High Tc Superconducting Materials with a Thermally Activated Flux Motion

*Santosh Miryala[1], Michael Koblischka[2]

1. University of Toronto; 2. Saarland University

PCP6-17 14:00–16:00

Microscopic calculation of the flux-flow Hall effect in a superconductor with an isolated vortex

*Hikaru Ueki, Wataru Kohno, Takafumi Kita

Department of Physics, Hokkaido University, Sapporo, Japan

PCP6-18 14:00–16:00

Charging due to the Lorentz force, Kopnin force and slope in the density of states in superconductors

*Marie Ohuchi, Hikaru Ueki, Takafumi Kita

Department of Physics, Hokkaido University

PCP6-19 14:00–16:00

Hall effect in the Abrikosov lattice of type-II superconductors

*Wataru Kohno, Hikaru Ueki, Takafumi Kita

Hokkaido University

Application

Chairperson: Paolo Mele (Muroran Institute of Technology)

PCP7-1 14:00–16:00

Fabrication of Low Temperature LPE-$NdBa_2Cu_3O_y$ Films without Nd/Ba Substitution via Phase Decomposition Process

*Shuhei Funaki, Yugo Miyachi, Keisuke Soeda, Yasuji Yamada

Shimane University

PCP7-2 14:00–16:00

Preparation of $EuBa_2Cu_3O_{7-\delta}$ Films Decomposed From $EuBa_2Cu_4O_8$ Films Deposited by Molten Hydroxide Method

*Yugo Miyachi, Shuhei Funaki, Keisuke Soeda, Yasuji Yamada

Shimane University

PCP7-3 14:00–16:00

Measurements of Shielding Current Decay in YBCO Tapes Formed into One Turn Coil

*Keita Matsuura[1], Akifumi Kawagoe[1], Masataka Iwakuma[2]

1. Kagoshima univercity; 2. Kyushu univercity

PCP7-4 14:00–16:00

Enhancement of J_c in-field for $YBa_2Cu_3O_y$ Coated Conductors Using Vapor-Liquid-Solid Growth Method by Introducing Y_2BaCuO_5

*Shuya Tajiri[1], Yusuke Ichino[1], Yuji Tsuchiya[1], Ataru Ichinose[2], Yutaka Yoshida[1]

1. Department of Energy Engineering and Science, Nagoya University; 2. Central Research Institute of Electric Power Industry

PCP7-5 14:00–16:00

Carrier Density Dependence of the Critical Temperature in $BaHfO_3$ doped $SmBa_2Cu_3O_y$ Films

*Shun Sato, Yusuke Ichino, Yuji Tsuchiya, Yutaka Yoshida

Department of Energy Engineering and Science, Nagoya University

PCP7-6 14:00–16:00

Improvement of In-Field J_c of $YBa_2Cu_3O_y$ + $BaHfO_3$ Thin Films by Modified Crystallization Process in TFA-MOD Method

*Hiroshi Horita[1], Ryo Teranishi[1], Yukio Sato[1], Kenji Kaneko[1], Satoshi Awaji[2], Teruo Izumi[3]

1. Kyushu Univershity; 2. Tohoku University; 3. National Institute of Advanced Industrial Science and Technology

PCP7-7 14:00–16:00

Study of the superconducting coil effect on current density distribution in BSCCO tape after an over-current pulse

*Tallouli Mohamed[1], Oleg Shyshkin[2], Satarou Yamaguchi[3]

1. Center of Applied Superconductivity and Sustainable Energy Research Center, Chubu University; 2. V. N Karazin National University, Ukraine; 3. Center of Applied Superconductivity and Sustainable Energy Research Center, Chubu University

PCP7-8 14:00–16:00

High-Speed Shielding Current Analysis in Cracked HTS Film: Implementation of H-Matrix Method and Variable Reduction Method

*Atsushi Kamitani, Teruou Takayama, Ayumu Saitoh

Yamagata University

PCP7-9 14:00–16:00

Study on Oxygen In-diffusion in Joint Configuration

*Xinyang Wu, Zhiwei Zhang, Yue Zhao, Wei Wu, Junliang Zuo, Yunhao Pan, Zhuyong Li, Zhiyong Hong, Zhijian Jin

Department of Electrical Engineering, Shanghai Jiao Tong University, Shanghai, China

PCP7-10 14:00–16:00

Epitaxial growth of superconducting MgB_2 thin films with a Mg buffer layer at 110°C

*Hiroaki Shishido[1,2], Takatoshi Nakagami[1,2], Takuya Yoshida[1], Takekazu Ishida[1,2]

1. Department of Physics and Electronics, Graduate School of Engineering, Osaka Prefecture University; 2. Institute for Nanofabrication Research, Osaka Prefecture University

PCP7-11 14:00–16:00

Upper critical fields and critical current densities of Nb_3Sn doped with (Ti,Ta) of (Ti,Ga)

*Yuya Tanabe[1], Masaru Kiuchi[1], Edmund Soji Otabe[1], Teruo Matsushita[1], Yoshiyuki Monju[2], Taiji Mizuta[2], Kyoji Tachikawa[3], Kozo Osamura[4]

1. Kyushu Institute of Technology; 2. Osaka Alloying Works; 3. National Institute for Materials Science, Tokai University; 4. Research Institute for Applied Sciences

PCP7-12 14:00–16:00

Fabrication and Properties of Nb_3Al Superconductor sintered after hot-pressing

Wen Jia Lin[1], Ping Yuan Li[2], Li Yuan Xu[1], Zhou Yu[1], Yong Liang Chen[1], Xi Feng Pan[2], Guo Yan[2], Yong Zhao[1,3], *Yong Zhang[1]

1. Key Laboratory of Magnetic Levitation Technologies and Maglev Trains, Ministry of Education of China, and Superconductivity and New Energy R&D Center, Southwest Jiaotong University; 2. Western Superconducting Technoligies Co., Ltd.; 3. School of Physical and Science Technology, Southwest Jiaotong University

Dec. 15 (Thu.) Wires and Bulk **G402**

MgB_2 wire

Chairperson: Akiyoshi Matsumoto (NIMS)

WBP5-1 14:00–16:00

Development of MgB_2 wire and coil for the next generation of MRI magnet

*Minoru Maeda[1], Dipak Patel[2], Md Shahriar Al Hossain[2], Seyong Choi[3], Jung Ho Kim[2]

1. Nihon University; 2. University of Wollongong; 3. Korea Basic Science Institute

WBP5-2 14:00–16:00

Spatially Resolved Measurement of Local Critical Current Density Distribution and Compositional Variation in MgB_2 Thick Film

*Kazutaka Harada[1], Kohei Higashikawa[1], Masayoshi Inoue[1], Takanobu Kiss[1], Hideaki Tanaka[2]

1. Department of Electrical Engineering, Kyushu University; 2. Research & Development Group, HITACHI Ltd.

WBP5-3 14:00–16:00

Numerical Simulations of Operations of Parallel-Type Superconducting Level Sensors for Liquid Hydrogen Using Experimental Results of Electrical Resistivity

*Jumpei Koshio[1], Kazuhiro Kajikawa[1], Yutaka Yamada[2], Momoko Makino[3], Itsuo Aoki[3]

1. Kyushu University; 2. Tokai University; 3. Jecc Torisha Co., Ltd.

WBP5-4 14:00–16:00

Numerical Analysis of In-Field Magnetization in Mono-core MgB2 Wire with Magnetic Sheath

*Hiroshi Tatara[1], Kohei Higashikawa[1], Masayoshi Inoue[1], Shyam Mohan[1], Akiyoshi Matsumoto[2], Hiroaki Kumakura[2], Takanobu Kiss[1]

1. Kyushu University; 2. NIMS

New materials

Chairperson: Yoshiyuki Yoshida (AIST)

WBP6-1 14:00–16:00

Preparation and transport properties of superconducting $Sr_2VFeAsO_{3-\delta}$ wires fabricated by *ex-situ* powder-in-tube process

*Suguru IWASAKI, Yoichi KAMIHARA, Masanori MATOBA

Keio University

WBP6-2 14:00–16:00

The angular dependence of irreversibility line in $BaZrO_3$ nanoparticles doped $BaFe_2(As_{0.66}P_{0.33})_2$ films

*Akinori Okubo[1], Michio Sato[1], Masashi Miura[1], Keiichi Tanabe[2]

1. Seikei University; 2. SUSTERA

WBP6-3 14:00–16:00

Development of Fe-based superconducting wires for liquid hydrogen level sensors

*Shigeyuki Ishida, Yoshinori Tsuchiya, Yasunori Mawatari, Hiroshi Eisaki, Akihiro Nakano, Yoshiyuki Yoshida

National Institute of Advanced Industrial Science and Technology (AIST)

WBP6-4 14:00–16:00

Large and field-insensitive critical current densities in $(Sr,Na)Fe_2As_2$ superconducting tapes

*Takahiro Suwa[1], Sunseng Pyon[1], Akiyoshi Park[1], Tsuyoshi Tamegai[1], Yuji Tsuchiya[2], Satoshi Awaji[2], Kazuo Watanabe[2]

1. Department of Applied Physics, The University of Tokyo: 2. High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University

REBCO bulk

Chairperson: Yasunori Mawatari (AIST)

WBP7-1 14:00–16:00

Magnetic flux invasion in REBCO bulk magnets with varying pre-magnetized flux distributions in multiple-PFM processes

Tetsuo Oka[1], Kensuke Hara[1], Akira Takeda[1], Jun Ogawa[1], Satoshi Fukui[1], Takao Sato[1], *Kazuya Yokoyama[2], Akira Murakami[3]

1. Niigata University; 2. Ashikaga Institute of Technology; 3. Ichinoseki National College of Technology

WBP7-2 14:00–16:00

Influence of Artificial Defects on Trapped Field Performance in a Superconducting Bulk Magnet

*Kazuya Yokoyama[1], Kulawansha Eranda[2], Yuanding Zhao[2], Atsushi Katsuki[2], Atsuro Miura[2], Tetsuo Oka[3]

1. Ashikaga Institute of Technology; 2. Graduate School of Engineering, Ashikaga Institute of Technology; 3. Niigata University

WBP7-3 14:00–16:00

Effect of resin impregnation on Y-Ba-Cu-O bulk superconductors

*Atsuhiro Ono, Kazuo Inoue, Muralidhar Miryala, Masato Murakami

Shibaura Institute of Technology

WBP7-4 14:00–16:00

Effects of Carbon Nanotube Addition on Superconductivity in Y-Ba-Cu-O Bulk Superconductors

*Kazuo Inoue, Yuya Miyake, Muralidhar Miryala, Masato Murakami

Shibaura Institute of Technology

WBP7-5 14:00–16:00

Effect of growth temperature on superconducting properties of bulk GdBa2Cu3Oy bulk superconductors grown by IG process

*Yuta Nakanishi, Miryala Muralidhar, Kazuo Inoue, Masato Murakami

Department of Materials Science and Engineering, Shibaura Institute of Technology, Japan

WBP7-6 14:00–16:00

Superconducting Performance, Microstructure and SEM by EDX Analysis of IG Processed $YBa_2Cu_3O_y$ Bulk Superconductors by Top and Interior Seeding Methods

*Naoki Ide[1], Miryala Muralidhar[1], Monika Radusovska[2], Diko Pavel[2], Jirsa Milos[3], Masato Murakami[1]

1. Department of Materials Science and Engineering, Shibaura Institute of Technology; 2. Institute of Experimental Physics, Slovak Academy of Sciences, Material Physics Laboratory; 3. Institute of Physics ASCR

WBP7-7 14:00–16:00

Property of the GdBCO-Ag Bulk Superconductors Fabricated by Cooling-Rate-Controlled-Melt-Growth

*Ryo Matsuumi[1], Mitsuru Izumi[1], Xin Yao[2]

1. Tokyo University of Marine Science and Technology; 2. Shanghai Jiao Tong University

WBP7-8 14:00–16:00

Stress-strain behavior of Gd123 superconducting bulk material under repeated loading

*Ryuto Kubo[1], Akira Murakami[1], Akifumi Iwamoto[2]

1. National Institute of Technology, Ichinoseki College; 2. National Institute for Fusion Science

WBP7-9 14:00–16:00

Mechanical properties of EuBaCuO superconducting bulk material at liquid nitrogen temperature

*Akira Murakami[1], Akifumi Iwamoto[2]

1. National Institute of Technology, Ichinoseki College; 2. National Institute for Fusion Science

MgB_2 bulk

Chairperson: Hiroshi Ikuta (Nagoya University)

WBP8-1 14:00–16:00

Bending properties of spark plasma sintered MgB_2 superconducting bulk materials

*Shinya Chiba[1], Akira Murakami[1], Jacques Noudem[2], Akifumi Iwamoto[3]

1. National Institute of Technology, Ichinoseki College; 2. CRISMAT-CNRS/UNICAEN-ENSICAEN; 3. National Institute for Fusion Science

WBP8-2 14:00–16:00

Effects of Ag content on bending strength of MgB_2 superconducting bulk material

*Akira Murakami[1], Miryala Muralidhar[2], Akifumi Iwamoto[3]

1. National Institute of Technology, Ichinoseki College; 2. Shibaura Institute of Technology; 3. National Institute for Fusion Science

WBP8-3 14:00–16:00

Improved Critical Current Densities in Bulk MgB_2 Fabricated using Nano Amorphous Boron Combined with Optimal Processing Conditions

Muralidhar Miryala[1], *Kotaro Kitamoto[1], Higuchi Masaki[1], Michael Rodolf Koblischka[2], Masato Murakami[1]

1. Graduate School of Science and Engineering, Shibaura Institute of Technology; 2. Experimental Physics, Saarland University

WBP8-4 14:00–16:00

Production and Characterization of Bulk MgB_2 Material made by the Combination of Crystalline and Carbon Coated Amorphous Boron Powders

*Hiroki Kobayashi[1], Muralidhar Miryala[1], Koblischka Rudolf Michael[2], Masato Murakami[1]

1. Superconducting Materials Laboratory, Department of Materials Science and Engineering, Shibaura Institute of Technology; 2. Experimental Physics, Saarland University

WBP8-5 14:00–16:00

Microstructure and critical current densities in bulk MgB_2 using carbon-coated amorphous boron

*Masaki Higuchi[1], Miryala Muralidhar[1], Pavel Diko[2], Masato Murakami[1]

1. Superconducting Materials Laboratory, Department of Materials Science and Engineering, Shibaura Institute of Technology; 2. Institute of experimental Physics, SAS

WBP8-6 14:00–16:00

Influences of Co substitution on FeSe Superconductors with High-Energy Ball milling Aided Sintering Process

*Feng Jianqing, Zhang Shengnan, Liu Jixing, Li Chengshan, Zhang Pingxiang

Northwest Institute of Nonferrous Metal Research

WBP8-7 14:00–16:00

Growth of $FeTe_{0.6}Se_{0.4}$ bulk single crystals and critical current properties under high magnetic field

*Yuji Tanaka, Yoshikazu Mizuguchi, Osuke Miura

Tokyo Metropolitan University

Dec. 15 (Thu.) Electronic Devices **G404**

SQUID 2

Chairperson: Yoshimi Hatsukade (Kindai University)

EDP1-1 14:00–16:00

Defect detection of pipes using ultrasonic guided wave and HTS-SQUID

*Natsuki Masutani, Shouta Teranishi, Ken Masamoto, Shouya Kanenaga, Yoshimi Hatsukade

Kindai University

EDP1-2 14:00–16:00

Vector Scanning SQUID system for High Spatial Resolution

*THE DANG VU[1,2], Thanh Huy Ho[1,2], Shigeyuki Miyajima[1], Hiroaki Shishido[1,3], Masaaki Maezawa[4], Mutsuo Hidaka[4], Masahiko Hayashi[5], Takekazu Ishida[1,3]

1. Department of Physics and Electronics, Osaka Prefecture University; 2. University of Sciences, Vietnam National University HCMC, VietNam; 3. Institute for Nanofabrication Research, Osaka Prefecture University; 4. National Institute of Advanced Industrial Science and Technology; 5. Faculty of Education and Human Studies, Akita University

EDP1-3 14:00–16:00

Ultra-low Field SQUID-NMR using LN_2 Cooled Cu Polarizing Field coil

*Kazuma Demachi, Satoshi Kawagoe, Seiichiro Ariyoshi, Saburo Tanaka

Toyohashi University of Technology

EDP1-4 14:00–16:00

2D-MPI System using HTS-SQUID

*Kazuya Kobayashi, Yusaku Sanada, Seiichiro Ariyoshi, Saburo Tanaka

Toyohashi University of Technology

EDP1-5 14:00–16:00

Investigation of readout coil for performance improvement of high-T_c rf-SQUID

*Yuji Miyato

Osaka University

Device systems 2

Chairperson: Masamitsu Tanaka (Nagoya University)

EDP2-1 14:00–16:00

Experimental and simulation results of a symmetrical pad to reduce a stray ground current in superconducting integrated circuits

*Hideo Suzuki, Tomohiro Ono, Nobuyuki Yoshikawa

Yokohama National University

EDP2-2 14:00–16:00

Simulation and Measurement of Influence of Flux Quantum Trapped in Moat on Superconducting Circuit

*Hibiki Imai, Yuki Yamanashi, Nobuyuki Yoshikawa

Yokohama National University

EDP2-3 14:00–16:00

Design and Evaluation of Adiabatic-Quantum-Flux-Parametron Autocorrelators for Submillimeter-Wave Spectrometry

*Saki Kobako, Yuki Yamanashi, Nobuyuki Yoshikawa

Yokohana National University

EDP2-4 14:00–16:00

High-Speed Superconductive Decimation Filter for Sigma-Delta Analog to Digital Converter

*Tomu Wakamatsu, Yuki Yamanashi, Nobuyuki Yoshikawa

Yokohama National University

EDP2-5 14:00–16:00

Evaluation of Bit Error Probabilities for an Integrated Quantum Voltage Noise Source for Johnson Noise Thermometry

*Takahiro Yamada, Masaaki Maezawa, Chiharu Urano

National Institute of Advanced Industrial Science and Technology

EDP2-6 14:00–16:00

Implementation of a Double-Active-Layered AQFP Cell Library Using Double Gate Process

*Takumi Ando[1], Naoki Tsuji[1], Fumihiro China[1], Naoki Takeuchi[2,3], Shuichi Nagasawa[4], Mutsuo Hidaka[4], Yuki Yamanashi[1,2], Nobuyuki Yoshikawa[1,2]

1. Department of Electrical and Computer Engineering, Yokohama National University; 2. Institute of Advanced Sciences, Yokohama National University; 3. PRESTO, Japan Science and Technology Agency; 4. National Institute of Advanced Industrial Science and Technology

EDP2-7 14:00–16:00

Implementation of a Look-Up Table Based on Phase Shift Elements and Dual-Rail SFQ Circuits

*Soya Taniguchi[1,2], Hiroshi Ito[1], Takuya Kurihara[1], Masamitsu Tanaka[1], Hiroyuki Akaike[1], Akira Fujimaki[1]

1. Nagoya University; 2. JSPS Research Fellow

EDP2-8 14:00–16:00

A random access memory cell using quantum flux parametron

*Hiroshi Takayama[1], Naoki Tsuji[1], Naoki Takeuchi[2,3], Yuki Yamanashi[1,2], Nobuyuki Yoshikawa[1,2]

1. Department of Electrical and Computer Eng., Yokohama National University; 2. Institute of Advanced Sciences, Yokohama National University; 3. PRESTO, Japan Science and Technology Agency

Detectors 2

Chairperson: Masashi Ohno (The University of Tokyo)

EDP3-1 14:00–16:00

THz detection using Substrate Absorption Type STJ with Position Resolution

*Masahiko Sone[1], Naoki Igarashi[1], Masato Naruse[1], Hiroaki Myoren[1], Yoshiaki Sasaki[2], Chiko Otani[2], Tohru Taino[1]

1. Saitama University; 2. RIKEN

EDP3-2 14:00–16:00

Development of large-scale array of superconducting detectors for the CMB polarization measurement

*Ryo Koyano[1], Munehisa Semoto[1], Satoru Mima[2], Kenji Kiuchi[2], Masato Naruse[1], Hiroaki Myoren[1], Chiko Otani[2,3], Osamu Tajima[4], Shugo Oguri[4], Tohru Taino[1]

1. Saitama University; 2. RIKEN; 3. Tohoku University; 4. KEK

EDP3-3 14:00–16:00

Development of STJ for neutron detector on Si-LBO hybrid substrate by surface-activated room-temperature bonding

*So Endo[1], Go Fujii[2], Masahiro Ukibe[2], Hideki Takagi[2], Masataka Ohkubo[2], Masato Naruse[1], Hiroaki Myoren[1], Chiko Otani[3], Tohru Taino[1]

1. Saitama University; 2. AIST; 3. RIKEN

EDP3-4 14:00–16:00

Fabrication method of superconducting TSV for STJ detector using 3D integration technique

*Kohei Morita[1], Soki Hatakeyama[1], Masahiro Aoyagi[2], Masato Naruse[1], Hiroaki Myoren[1], Tohru Taino[1]

1. Saitama University; 2. AIST

EDP3-5 14:00–16:00

Development of LEKID detectors for Light Dark Matter Searches using Liquid Helium

*Yosuke Kida[1], Hirokazu Ishino[1], Atsuko Kibayashi[1], Yosuke Yamada[1], Kunimoto Komatsu[1], Naoto Hidehira[1], Masashi Hazumi[2], Nobuaki Sato[2], Satoshi Kohjiro[3], Hirotake Yamamori[3], Fuminori Hirayama[3]

1. Department of Physics, Okayama University; 2. Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK); 3. Nanoelectronics Research Institute, National Institute of Advanced Industrial Science and Technology

EDP3-6 14:00–16:00

Combined operation of two TESs for low-energy photon applications

*Hiroyuki Takahashi, Yuki Mitsuya, Taisei Fujimori, Masashi Ohno

The University of Tokyo

EDP3-7 14:00–16:00

Stress Control of Reactively Sputtered Thick NbN Film on Si Wafer Changing the Location of the Substrate Si Wafer Against the Nb Target on a Magnetron Cathode

*Yasuhiro Suzuki[1], Nobuhiro Iguchi[1], Kazuhiro Adachi[1], Tatsumi Hioki[1], Akihisa Ichiki[1], Tomoyoshi Motohiro[1], Che-Wei Hsu[2], Shinya Kumagai[2], Minoru Sasaki[2]

1. Institutes of Innovation for Future Society, Graduate School of Engineering, Nagoya University; 2. Graduate School of Engineering, Toyota Technological Institute

EDP3-8 14:00–16:00

Capacitance Measurements of Niobium SIS Junctions at Microwave Frequencies

*Konomi Sato[1], Takafumi Kojima[2], Matthias Kroug[2], Takeshi Sakai[1] and Yoshinori Uzawa[2]

1. The University of Electro-Communications; 2. National Astronomical Observatory of Japan; 3. National Institute of Information and Communications Technology

Device physics 2

Chairperson: Naoto Sekiya (University of Yamanashi)

EDP4-1 14:00–16:00

Simulations of chaos generation from Josephson junctions with various junction parameters

*Ryo Hiwatashi, Yukihide Tamura, Hisashi Shimakage

Ibaraki University

EDP4-2 14:00–16:00

Evaluation of detectable angle of mid-infrared slot antennas

*Ryosuke Obara[1], Junsei Horikawa[2], Hisashi Shimakage[1], Akira Kawakami[3]

1. Ibaraki Univ.; 2. NIT, Fukui Col.; 3. NICT

EDP4-3 14:00–16:00

Calculations of superconducting parametric amplifiers performances

*Takashi Goto[1], Hisashi Shimakage[1], Shingo Saito[2], Masanori Takeda[3]

1. Ibaraki University; 2. National Institute of Information and Communications Technology; 3. Shizuoka University

EDP4-4 14:00–16:00

Optical Design of Linearity Measurement System for Superconducting SIS Mixer on Millimeter Band Atmospheric Spectrometer

*Naoki Akiyama[1], Tac Nakajima[1], Akira Mizuno[1], Tomoo Nagahama[1], Kazuji Suzuki[1], Yasunori Fujii[2]

1. Institute for Space-Earth Environmental Research (ISEE), Nagoya University; 2. Advanced Technology Center, National Astronomical Observatory of Japan

EDP4-5 14:00–16:00

Design of compact high pole HTS tri-band bandpass filters

*Takahiro Unno, Naoto Sekiya

University of Yamanashi

EDP4-6 14:00–16:00

Design of high quality factor spiral coil using double-side REBCO wire for RF applications

*Yuki Monjugawa, Naoto Sekiya

University of Yamanashi

EDP4-7 14:00–16:00

Development of High-T_c Superconducting Terahertz Emitter

*Takanari Kashiwagi[1,2], Hiroyuki Kubo[1], Kazuki Sakamoto[1], Takumi Yuasa[1], Yuki Tanabe[1], Chiharu Watanabe[1], Takuya Katsuragawa[1], Taiga Tanaka[1], Yuki Komori[1], Ryusei Ota[1], Genki Kuwano[1], Kento Nakamura[1], Manabu Tsujimoto[1,2], Takashi Yamamoto[3], Ryozo Yoshizaki[1,2], Hidetoshi Minami[1,2], Kazuo Kadowaki[1,2]

1. Graduate School of Pure and Applied Sciences, University of Tsukuba , Japan; 2. Division of Materials Science, Faculty of Pure and Applied Sciences, University of Tsukuba, Japan; 3. Institute for Materials Research (IMO), Hasselt University, Belgium

EDP4-8 14:00–16:00

I-V characteristics and THz radiation properties of Bi2212 mesas

*Akinobu Irie, Yoshihiko Yajima, Takashi Watanabe, Kazuhiro Yamaki

Utsunomiya University

Dec. 15 (Thu.) Large Scale System Applications **G403**

Fault current limiter

Chairperson: Tomoo Mimura (TEPCO)

APP5-1 14:00–16:00

Study on Protection Coordination of Distance Relays for Application of a SFCL in a Power Transmission System

*Sung-Hun Lim[1], Jin-Seok Kim[2] and Jae-Chul Kim[1]

1. Department of Electrical Engineering, Soongsil University, Seoul, Republic of Korea; 2. Department of Electrical Engineering, Seoil University, Seoul, Republic of Korea

APP5-2 14:00–16:00

Fault Current Limiting and Double Quench Characteristics of Transformer Type SFCL with Additionally Coupled Circuit

Seung-Taek Lim[1], Tae-Hee Han[2], *Sung-Hun Lim[1]

1. School of Electrical Engineering, Soongsil University, Republic of Korea; 2. Department of Energy Resources Engineering, Jungwon University, Republic of Korea

APP5-3 14:00–16:00

Magnetizing Characteristics of Transformer Type SFCL Due to Its Winding Direction of Additional Secondary Winding

*Tae-Hee Han[1], Shin-Won Lee[2], Seok-cheol Ko[3] Sung-Hun Lim[4]

1. Department of Aero Materials Engineering, Jungwon University, Republic of Korea;
2. Department of Computer System Engineering, Jungwon University; 3. Chungnam TechnoPark, Policy Planning Agency, Republic of Korea; 4. Department of Electrical Engineering, Soongsil University, Republic of Korea

APP5-4 14:00–16:00

Transient Fault Current Limiting Characteristics of Transformer type SFCL with Two Non-Isolated Secondary Windings using Double Quench

*Tae-Hee Han[1], Shin-Won Lee[2], Sung-Hun Lim[3]

1. Department of Aero Materials Engineering, Jungwon University, Republic of Korea; 2. Department of Computer System Engineering, Jungwon University; 3. Department of Electrical Engineering, Soongsil University, Republic of Korea

APP5-5 14:00–16:00

Application Validity Studies of Various Kinds of Superconducting Fault Current Limiters for HVDC Grids

*Ho-Yun Lee, Kyu-Hoon Park, Jong-Geon Lee, Bang-Wook Lee

Hanyang University

APP5-6 14:00–16:00

Optimal Location of Superconducting Fault Current Limiters (SFCLs) for Fault Current Reduction in the Korean AC Transmission Grid

*Jin Hur[1], Seung Ryul Lee[2]

1. Sangmyung University; 2. Korea Electrotechnology Research Institute

APP5-7 14:00–16:00

Stability Improvement of VSC HVDC system according to Superconductivity combined DC Circuit Breaker

*HYEWON CHOI, INSUNG JEONG, SANGYONG PARK, NOA PARK, SUNHO WHANG, JUNBEOM KIM, HYOSANG CHOI

CHOSUN University

HTS bulk

Chairperson: Kazuya Yokoyama (Ashikaga Institute of Technology)

APP6-1 14:00–16:00

Study on the Method of ON/OFF Field Switching using the HTS Bulks for Medical Applications

*Takuya Nakagawa, Ryoma Hirano, Yoshikazu Tomisaka, SeokBeom Kim, Hiroshi Ueda

Okayama University

APP6-2 14:00–16:00

Study on the Rotation Properties and the Design Issue of Non-Contact Rotating System Using HTS Bulks and Permanent Magnets

*Ryota Okamura, Yusuke Ozaki, SeokBeom Kim, Hiroshi Ueda

Okayama University

APP6-3 14:00–16:00

Development of the Turning System Using Permanent Magnets for the Direction Change from Floor Traveling to Wall Traveling in 3-D Superconducting Actuator

*Takao Yamasaki, Yusuke Hiratsuka, SeokBeom Kim, Hiroshi Ueda

Graduate School of Natural Science and Technology, Okayama University

APP6-4 14:00–16:00

Correlations between magnetic flux and levitation force of HTS bulks above a permanent magnet guideway

*Huan Huang, Jun Zheng, Botian Zheng, Nan Qian, Haitao Li, Jipeng Li, Zigang Deng

Applied Superconductivity Laboratory, State Key Laboratory of Traction Power, Southwest Jiaotong University, China

Power application 2

Chairpersons: Tomonori Watanabe (Chubu Electric Power Co.) and Taketsune Nakamura (Kyoto University)

APP7-1 14:00–16:00

Feasibility study on the brushless HTS exciter of a modularized large-scale HTS wind power generator

*Byeong-Soo Go, Hae-Jin Sung, Minwon Park, In-Keun Yu

Changwon National University

APP7-2 14:00–16:00

Electrical and structured analysis for 15MW REBCO designed wind turbine generators

*Kiwook Yun[1], Masataka Iwakuma[1], Katsuhito Tamura[1], Yoshiji Hase[2], Yuichiro Sasamori[2], Teruo Izumi[3]

1. Kyushu university; 2. Fuji Electric; 3. ISTEC

APP7-3 14:00–16:00

Design and Performance Analysis of a Novel Stator-HTS Squirrel Cage Induction Motor with High Power to Weight Ratio

*Bin Liu[1], Jin Fang[1], Rod Badcock[2], Wenjuan Song[1], Hang Shu[1]

1. School of Electrical Engineering, Beijing Jiaotong University; 2. Robinson Research Institute, Victoria University of Wellington

APP7-4 14:00–16:00

Development of A large AC Current Supply with A Single-phase Air-core Bi2223 High Temperature Superconducting Transformer

*Noriyuki Kishi, Nozomu Nanato, Yuhi Tanaka, Mikishi Kondo

Okayama University

APP7-5 14:00–16:00

Providing a Proper Vacuum Level in the Thermal Insulation Layer of the Long HTS Cable Line

*Yury V Ivanov[1,2], Hirofumi Watanabe[1,2], Noriko Chikumoto[1,2], Vladimir S. Vyatkin[1], Noriyuki Inoue[1,2], Satarou Yamaguchi[1,2]

1. Chubu University; 2. Ishikari Superconducting DC Power Transmission System Research Association

APP7-6 14:00–16:00

A Study on a 10 kVA Single-Phase HTS Transformer with a Cylindrical Central Iron Core

*Lilin Sun, Daoyu Hu, Zenglin Xie, Zhuyong Li, Zhiyong Hong, Zhijian Jin

Shanghai Jiao Tong University

APP7-7 14:00–16:00

Thermal Properties of HTS Coils with Conduction Cooling by Using Heat Pipes

*Jun Tokushige[1], Akifumi Kawagoe[1], Toshiyuki Mito[2], Nagato Yanagi[2], Shinji Hamaguchi[2], Suguru Takada[2], Naoki Hirano[3], Yoshiro Terazaki[4]

1. Kagoshima University; 2. National Insititute for Fusion Science; 3. Chubu Electric Power; 4. Graduate University for Advanced Studies

APP7-8 14:00–16:00

Characteristics of Superconducting WPT by multi-receive coils

*In-Sung Jeong, Hye-Won Choi, Sang-Yong Park, No-A Park, Sun-Ho Hwang, Jun-Beom Kim, Hyo-Sang Choi

Chosun University

■ ABSTRACTS ■

Oral presentation

PL1-INV 10:35–11:15

Progress in the development of nanostructured coated conductors in Europe

*Xavier Obradors

ICMAB / CSIC, Campus UAB, Bellaterra-Catalonia, Spain

Coated conductors is one of the most promising alternatives to reach the performance goals and to reduce the cost/performance ratio down to the levels required to make a reality these technological expectances. Within Europe, a large consortium of academic and industrial partners (EUROTAPES) an extended collaboration is being developed to advance in the demanding challenges of low temperature-ultra high field and intermediate/high temperatures and medium magnetic fields. In this presentation, several topics related to the recent progress in the different aspects covered by the project will be presented. On one hand, I will report on the progress in the efforts in developing more robust enhancing the critical currents under a wide spectrum of conditions using both PLD and chemical solution approaches. I will report particularly on the efforts in increasing the robustness of the ABAD coated conductor architecture using Ink Jet Printing to produce multilayered structures. On the other hand, different approaches related to achieving nanostructured superconducting films with enhanced flux pinning and high magnetic field performances will be also presented. This includes both, chemical solution deposition and PLD thin films and coated conductors on different metallic substrates (RABiT and ABAD).

keywords : Coated conductors, YBa2Cu3O7

PL2-INV 11:15–11:55

Construction and Test of the NHMFL 32 T Superconducting Magnet

*Hubertus Wilhelmus Weijers, W. D. Markiewicz, A. J. Voran, S. R. Gundlach, Y. L. Viouchkov, A. V. Gavrilin, P. D. Noyes, T.A. Painter, B. Jarvis, W.R. Sheppard, G. Sheppard, T.P. Murphy

National High Magnetic Field Laboratory

The 32 T project aims to combine a 15 T LTS magnet with two REBCO double pancake coils generating 17 T to create a 32 T user magnet for the MilliKelvin facility at the NHMFL. Both coil sets operate at 4.2 K using two separate power supplies. First, the construction of the REBCO coils and integration with the LTS magnet and cryostat is described. Additionally, the paper describes the cool down and performance characteristics of the complete magnet. Intended operating modes include ramping the REBCO and LTS coils separately, and synchronized one-hour ramps to full field. Data from voltage taps, pick-up coils, Hall effect sensors and temperature sensors are presented to quantify the performance of the magnet and the magnetic field it generates.

Acknowledgement
This work was supported in part by the U.S. National Science Foundation under Grants No. DMR-0654118, DMR-1157490, DMR-0923070 and the State of Florida

keywords : Coated Conductor, YBCO, High Field Magnet

PL3-INV 13:20–14:00

High Pressure Superconductivity in Sulfur Hydride

*Katsuya Shimizu[1], M. Einaga[1], M. Sakata[1], H. Nakao[1], M. Eremets[2], A. Drozdov[2], I. Troyan[2], N. Hirao[3], Y. Ohishi[3]

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After finding superconductivity in 100 years ago, "room-temperature" superconductor has been long-fascinated target for physicists. Superconductivity above 200K was recently reported in the highly compressed hydrogen sulfide (H_2S) by Drozdov and coworkers[1]. The crystal structure of the superconducting sulfur hydride systems was studied by using the synchrotron x-ray diffraction at room temperature and the superconducting temperature[2]. H_2S and D_2S were compressed to 150 GPa in DAC with same process with the ref.1, and cooled down to 10 K in the cryostat in the x-ray diffractometer in SPring-8. The resistivity was monitored at all cooling process. The critical temperature and zero resistivity were observed around 180 K, and the collected x-ray diffraction data showed good agreement with the theoretically predicted structures of $R3m$ and $Im\text{-}3m$[3]. No structural difference was observed between at 10 K and room temperature. The creation of the high-temperature superconductor was experimentally also confirmed by our Osaka group. H_2S gas was cooled down to around 200 K and liquefied then compressed up to 150 GPa in a diamond-anvil cell (DAC). The resistance decreased with increasing pressure and showed metallic behavior in cooling process. The superconducting transition was observed at 60-70 K with zero resistance. At the second cooling after warmed up to room temperature, the resistance dropped to zero from 180 K.

This work was supported by JSPS KAKENHI Grant Number 26000006 and the European Research Council 2010-Advanced Grant 267777.

[1] A. Drozdov et al., Nature 525, 73 (2015). [2] M. Einaga et al., Nature Physics 12, 835 (2016).
[3] D. Duan et al., Scientific Reports 4, 6968 (2014).

keywords : H2S, High Pressure, hydrogen sulfide

PL4-INV 14:00–14:40

Application of Transition Edge Sensor as an X-ray Spectrometer for Scanning Transmission Electron Microscope

*Toru HARA[1], Keiichi TANAKA[2], Keisuke MAEHATA[3], Kazuhisa MITSUDA[4], Yoshihiro YAMANAKA[5], Mutsuo HIDAKA[6]

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Microstructure evaluation is essentially important to develop new materials. Electron microscopes, such as scanning transmission electron microscope (STEM), plays very important role for such purpose. In addition to microstructure observation, compositional analysis using x-ray spectroscopy is now widely applied in electron microscopes. However, accuracy and/or sensitivity of current x-ray detector is not sufficient against required level from users; for example, advanced heat-resistant steel contains more than 10 elements with their amount of <0.1% each. In order to realize precise x-ray analysis in electron microscopes, we have been developing new x-ray detector using transition-edge sensor (TES) type microcalorimeter. We are trying to apply TES detector with STEM that shows high spatial resolution such as around 0.1nm. The target specs of the developed analytical STEM are as follows: i) x-ray energy resolution: <10eV, ii) detecting x-ray energy range: 0.5-10keV, iii) x-ray counting rate: >5kcps, iv) spatial resolution of x-ray map: <10nm. v) stability of the cooling system : >0.5 year. In order to realize the spec listed above, we developed a new detector system. The characteristic points of the detector are: i) multipixel detector: 64 pixels to increase countrate, ii) applying multicapillary x-ray lens to increase detecting solid-angle, iii) developing compact Liq.He free cooling system for high stability. As the results, we have assembled the new STEM with a TES detector and succeeded to obtain high energy-resolution x-ray spectra with multipixel TES detector.

keywords : x-ray microanalysis, electron microscopy, transition edge sensor, energy resolution

PL5-INV 14:40–15:20

R&D in Electric Power Devices based on Superconducting Technology in Europe

*Tabea Arndt

Siemens AG, CT REE PEM, Germany

Now being 30 years since the discovery of the high-temperature superconducting materials, several important milestones in technical superconductivity have been passed: the availability of relevant long lengths of practical 1G-HTS wires (roughly in 1996), the discovery and availability of relevant lengths of powder-in-tube MgB2 wires for magnet production (roughly in 2003) and the steadily increasing availability of long lengths of 2G-HTS wires (since 2000 on).
This progress from materials to technical wires has motivated intensive R&D on energy technology worldwide. In Europe, there is a considerable number of installed prototypes and first (nearly) commercial devices in the field stating the increasing high level of maturity of the technology.
Nevertheless, energy technology is a very conservative business reluctant to allow the introduction of new technologies in the sensitive environment requiring high reliability.
So, besides reporting on recent results in Europe (and in the R&D at Siemens) we will comment on the hurdles and entry reports remaining to superconducting technology in power devices. In addition to technical challenges, there is the “educational task" to make engineers aware of chances and of relevance of (perceived) risks – the latter is not to be underrated.
Finally we will give an outlook of near future and long term perspective for HTS technology in power devices.

keywords : HTS, Power Devices, Energy Technology, Demonstrators

PL6-INV 15:20–16:00

Recent Progress on the Development of Superconducting Technology in Japan

*Michiya Okada

AIST

The major Research and Development (R&D) projects relating with superconducting technology in Japan will be reviewed. At the moment, three major projects are in progress, and a new R&D consortium in private funds has been started.
(1)“Superconducting Systems"/ALCA/JST:
“Superconducting Systems" is a R&D Program focused on technology transfer in the Research Area of the Advanced Low Carbon Technology Research and Development Program(ALCA), supported by JST. Under the ALCA, MgB2 wire and the applications are under development.
(2)"Superconductivity System"/S-INNOVATION/JST :
Strategic Promotion of Innovative Research and Development (S-INNOVATION), creating innovation with industry and academia hand in hand on the R&D themes with high impact on society. Under the program, next-generation NMR, high-efficient railway technologies, HTS SQUID etc. are under development.
(3) “Project for the Promotion to the Commercialization of High-Temperature Superconductivity Technology"/NEDO:
This new project has just started in FY2016, focusing to develop the HTS system applications, i.e. the HTS MRI Magnet and the HTS Power Transmission Cable Systems.
(4)ASCOT
A new R&D consortium for superconducting technology have recently established in private funds. The details of the consortium ASCOT would also to be introduced.

keywords : Superconductivity, System Application, Superconducting cable, Superconducting device

PC1-1-INV 9:15–9:40

New Iron-Based Superconductors *AeA*Fe_4As_4 (*Ae* = Ca, Sr, Eu, *A* = K, Rb, Cs)

*Akira Iyo[1], Kenji Kawashima[1,2], Tatsuya Kinjo[1,3], Taichiro Nishio[1,3], Shigeyuki Ishida[1], Hiroshi Fujihisa[1], Yoshito Gotoh[1], Kunihiro Kihou[1], Hiroshi Eisaki[1], Yoshiyuki Yoshida[1]

1. AIST
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3. Tokyo Univ. of Science

Fe-based superconductors attract research interest because of their rich structural variety, which is due to their layered crystal structures. Here, we report new-structure-type Fe-based superconductors *AeA*Fe_4As_4 (*Ae* = Ca, Sr, Eu, *A* = K, Rb, Cs) [1,2], which can be regarded as hybrid phases between *Ae*Fe_2As_2 and *A*Fe_2As_2. Unlike solid solutions such as $(Ba_{1-x}Kx)Fe_2As_2$ and $(Sr_{1-x}Nax)Fe_2As_2$, the *Ae* and *A* do not occupy crystallographically equivalent sites, owing to large differences between their ionic radii. Rather, the *Ae* and *A* layers are inserted alternately between the Fe_2As_2 layers in the c-axis direction in *AeA*Fe_4As_4 (*AeA*1144). The ordering of the *Ae* and *A* layers causes a change in space group from *I4/mmm* to *P4/nmm*, which is clearly apparent in powder X-ray diffraction patterns. *AeA*1144 is the first known structure among not only Fe-based superconductors, but also other materials. The *AeA*1144 is formed as a stoichiometric compound. Therefore, each *AeA*1144 has its own superconducting transition temperature of approximately 31-36 K. An anomalous magnetic transition appears at approximately 15 K in Eu*A*Fe_4As_4 (*A* = Rb, Cs), suggesting the coexistence of superconductivity and a magnetic ordered state formed by the Eu^{2+} ions.

[1] A. Iyo *et al.* J. Am. Chem. Soc. **138** (2016) 3410.
[2] K. Kawashima *et al.* J. Phys. Soc. Jpn. **85** (2016) 064710.

keywords : Fe-based superconductors, New materials, New structure, Stoichiometric compounds

PC1-2 9:40–9:55

New iron-based superconducotor (Eu,La)$FeAs_2$

*Hiraku Ogino[1,2], Alberto Sala[1], Hayato Tanaka[2], Kohji Kishio[2], Yoshito Goto[1], Kunimitsu Kataoka[1], Akira Iyo[1], Hiroshi Eisaki[1]

1. AIST
2. University of Tokyo

Since 2008, series of iron-based superconductors such as REFeAsO have been developed. Recently new iron-based superconductor (Ca,RE)$FeAs_2$ have been discovered. The compounds show superconductivity above 40 K is reported. Crystal structure of the (Ca,RE)$FeAs_2$ is composed of Ca(RE) planes, Fe_2As_2 layer and As_2 layer. In As_2 layer of (Ca,RE)$FeAs_2$, closest As-As distance is ~2.60 Å, suggesting existence of two As-As bonding for each As atom, which is the first example in iron-based superconductors. Anisotropy of the compound is lower than that of REFeAsO, though distance between superconducting layers of this compound is longer than that of REFeAsO. We have explored relative compounds of (Ca,RE)$FeAs_2$ and discovered new iron-based superconductor $EuFeAs_2$. The compound also contains As_2 chain which is similar to that of (Ca,RE)$FeAs_2$. Sysnthesis and physical properties of the compound will be presented.

keywords : Iron-based superconducotor, New superconductor

PC1-3 9:55–10:10

Enhanced superconductivity at the structural phase boundary of $Sr_{1-x}Ba_xNi_2P_2$

Kazutaka Kudo, Yutaka Kitahama, Keita Iba, Masaya Takasuga, *Minoru Nohara

Okayama University

We report on the evolution of crystal structure and superconductivity of the 122-type solid solution $Sr_{1-x}Ba_xNi_2P_2$. The partial P-P dimer formation between the adjacent NiP layers is present in $SrNi_2P_2$, which results in an orthorhombic structure. An orthorhombic to tetragonal structural phase transition occurs upon Ba substitution at x = 0.5, and a superconducting phase with a maximum T_c = 2.85 K emerges. T_c decreases monotonically upon Ba substitution and T_c = 2.5 K results for the end member $BaNi_2P_2$. Our observation shows that dimer breaking is a good mean to enhance superconductivity.

keywords : BaNi2P2, SrNi2P2

PC1-4 10:10–10:25

The Electronic Phase Diagram of Superconductor $BaTi_2(Sb_{1-x}Bi_x)_2O$

*Wataru Ishii, Takeshi Yajima, Zenji Hiroi

ISSP, University of Tokyo

Titanium pnictide oxides, $BaTi_2Sb_2O$ and $BaTi_2Bi_2O$, exhibit superconductivity at 1.2 K and 4.6 K, respectively [1, 2]. Superconductivity has also been observed in the solid solution of $BaTi_2(Sb_{1-x}Bi_x)_2O$ except for $0.35 \leq x \leq 0.55$ (region B), resulting that two superconducting phases, $0 \leq x \leq 0.3$ (region A) and $0.6 \leq x \leq 1$ (region C), are observed in the electronic phase diagram of the solid solution. Such a two-dome structure has also been reported in the high-T_c ¬cuprate and the iron pnictide superconductor [4, 5], therefore much attention has been paid to the origin of a two-dome structure of the $BaTi_2(Sb_{1-x}Bi_x)_2O$. However, the origin has not been clarified yet because only x dependence of Tc down to 1.85 K has been reported in previous work.

In this work, we found superconductivity at around 1 K in region B by using specific heat capacity measurements down to 0.5 K. In region B, T_c is much less than that in region A though the Sommerfeld coefficients γ are almost the same, implying the superconductivity in region B is suppressed by other ordered phase. The exponents of the temperature dependence of the resistivity below 20 K in region B deviates from two, indicating anomalous metallic state is realized in region B. In the vicinity of region B and C, Tc drasrically increases from 1 K (x = 0.55) to 3.6 K (x = 0.6) though γ decreases from 17.6 to 7.1. This means the supercoductivity changes from weak-coupling (region A and B) to strong coupling (region C). In the presentation, we will show the detail of experimental results and discuss the complicated electronic phase diagram of $BaTi_2(Sb_{1-x}Bi_x)_2O$.

[1] T. Yajima et al., J. Phys. Soc. Jpn. 81 (2012) 103706.
[2] T. Yajima et al., J. Phys. Soc. Jpn. 82 (2013) 013703.
[3] T. Yajima et al., J. Phys. Soc. Jpn. 82 (2013) 033705.
[4] C. C. Homes et al., Phys Rev B. 85 (2012) 134510.
[5] N. Fujiwara et al., Phys Rev Lett 111(2013) 097002.

keywords : Titanium pnictide oxide, two-dome structure, strong-coupling superconductivity

PC1-5 10:25–10:40

Superconductivity of Transition Metal Dichalcogenides Co-Intercalated with Alkali Metal and Organic Molecules

*Kazuki Sato, Takashi Noji, Takehiro Hatakeda, Takayuki Kawamata, Masatsune Kato, Yoji Koike

Department of Applied Physics, Graduate School of Engineering, Tohoku University

Several transition metal dichalcogenides (TMD's) MX_2 (M = transition metal, X = S, Se, or Te) exhibit intriguing phenomena such as anisotropic superconductivity and charge density wave (CDW), owing to their two-dimensional electronic structure. It is also known that a variety of metal atoms and organic molecules are intercalated between weakly bound MX_2 layers, leading to drastic changes of the physical properties.

Recently, we have succeeded in making co-intercalation of Li and ethylenediamine, $C_2H_8N_2$, or hexamethylenediamine, $C_6H_{16}N_2$, into semimetallic $TiSe_2$ exhibiting a CDW transition and semiconducting $MoSe_2$. It has been found that both $Li_x(C_2H_8N_2)_yTiSe_2$ and $Li_x(C_6H_{16}N_2)_yTiSe_2$ show superconductivity with T_c = 4.2 K. Moreover, it has been found that Li_xTiSe_2 and $(C_2H_8N_2)_yTiSe_2$ also show superconductivity with T_c = 2.2 K and 2.5 K, respectively. These results indicate that the electron doping due to the Li intercalation and the expansion of the interlayer spacing between MX_2 layers due to the intercalation of organic molecules suppress the CDW transition, leading to the appearance superconductivity.

As for $Li_x(C_2H_8N_2)_yMoSe_2$ and $Li_x(C_6H_{16}N_2)_yMoSe_2$, they have also shown superconductivity with T_c = 4.2 K and 3.2 – 6.0 K, respectively. It has been found the T_c values are related to not the interlayer spacing but the carrier density increased by the electron doping due to the Li intercalation.

keywords : superconductivity, intercalation, transition metal dichalcogenide, lithium

PC2-1-INV 10:55–11:20

Superconductivity in Fe-based ladder material $BaFe_2S_3$

*Kenya Ohgushi

Tohoku University

All the iron-based superconductors identified so far share a square lattice composed of iron atoms as a common feature. In copper-based high-Tc materials, the superconducting phase emerges not only in square-lattice structures but also in ladder structures, which give nice hints for elucidating the microscopic mechanism of the superconductivity. Here, we report the discovery of pressure-induced superconductivity in the iron-based ladder material $BaFe_2S_3$, a Mott insulator with striped-type magnetic ordering below 120 K. On the application of pressure, this compound exhibits a metal–insulator transition at about 11 GPa, followed by the appearance of superconductivity below T_c = 24 K. Our findings indicate that square lattice is not the necessary ingredients of the superconductivity and that not only the spin and orbital fluctuations but also the charge fluctuations could play a key role in the emergence of the superconductivity in iron-based superconductors.

[1] Y. Nambu, et al., Phys. Rev. B 85, 064413 (2012).
[2] F. Du, et al., Phys. Rev. B 85, 214436 (2012).
[3] F. Du, et al., Phys. Rev. B 90, 085143 (2014).
[4] T. Hawai, et al., Phys. Rev. B 91, 184416 (2015).
[5] H. Takahashi, et al., Nat. Mater. 14, 1008 (2015).
[6] Y. Hirata, et al., Phys. Rev. B 92, 205109 (2015).
[7] T. Yamauchi, et al., Phys. Rev. Lett. 115, 246402 (2015).

keywords : Fe-based superconductors

PC2-2-INV 11:20–11:45

First-principles Study of the Iron-based Ladder Superconductor $BaFe_2S_3$

*Ryotaro Arita

RIKEN CEMS

Since the discovery of superconductivity in fluorine doped LaFeAsO [1], a variety of iron pnictides and chalcogenides have been found to exhibit superconductivity at high transition temperatures (T_c). In these compounds, Fe ions commonly form a two-dimensional (2D) network. This fact raises an intriguing question whether the square network is essential for the high-T_c superconductivity and what happens in different geometries. Recently, it has been found that a ladder compound $BaFe_2S_3$ becomes a superconductor under high pressure ~10GPa [2]. In the phase diagram, the superconducting phase resides next to a magnetic insulating phase and the maximum T_c is as high as 24 K [3].
Motivated by this discovery, we performed ab initio electronic structure calculation for $BaFe_2S_3$ [4,5]. We show that the complex band structure around the Fermi level is represented only by the Fe $3d_{xz}$ (mixed with $3d_{xy}$) and $3d_{x2-y2}$ orbitals. We also estimate the interaction parameters such as the Hubbard U, and we and show that the system is more correlated than the 1111 family of iron-based superconductors. Provided the superconductivity is mediated by spin fluctuations, the $3d_{xz}$-like band plays an essential role, and the gap function changes its sign between the Fermi surface around the Γ point and that around the Brillouin-zone boundary.
This work was done in collaboration with H. Ikeda, M-T. Suzuki and S. Sakai.
[1] Y. Kamihara, T. Watanabe, M. Hirao and H. Hosono, J. Am. Chem. Soc. 130, 3296 (2008).
[2] H. Takahashi et al., Nature Materials, 14, 1008 (2015).
[3] T. Yamauchi et al., Phys. Rev. Lett. 115, 24602 (2015).
[4] M-T. Suzuki, R. Arita and H. Ikeda, Phys. Rev. B 92, 054515 (2015).
[5] R. Arita, H. Ikeda, S. Sakai and M-T. Suzuki, Phys. Rev. B 92, 085116 (2015)

keywords : first-principles calculation, iron-based ladder compound, electronic structure, pairing mechanism

PC2-3 11:45–12:00

Origin of 44 K Superconductivity in $K_xFe_{2-y}Se_2$ with Nano-Scale Phase Separation

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1. MANA, Natinal Institute for Materials Science; 2. Tsukuba Univ.

Layer structured iron selenide, FeSe has the simplest crystal structures among iron-based superconductors. It shows superconductivity with transition temperature (T_c) around ~10 K under ambient pressure. The T_c increases up to 37 K by applying high pressure [1-3]. When potassium is intercalated between FeSe layers, the T_c increases more than 30 K, and it has been reported as potential superconductors with T_c's of 30-48 K. However, there is no clear answer to identify the relationship between the surface morphology, compositional ratio and its crystal structure, mainly due to its intrinsic phase separation. In this study, we have been investigated growth mechanism and superconducting properties of single crystalline $K_xFe_{2-y}Se_2$.
Single crystals of $K_xFe_{2-y}Se_2$ were prepared by a “one-step method" [4] with quenching at various temperatures. The superconducting properties and surface morphology were strongly affected by the quenching temperature. And it was found that slow-cooling treatment process realizes a higher T_c around 44 K with a creation of island-like morphology on the surface of single crystals. *In-situ* high-temperature single crystal X-ray diffraction measurements provide us a hint as to how to generate such a higher T_c phase [5]. TEM measurements supported by a micro-sampling technique directly revealed that the island-like parts corresponds to the $K_xFe_2Se_2$ structure having a perfect FeSe layers. The higher T_c phase is formed with the aid of the growth of $K_2Fe_4Se_5$ phase [6].
[1] Y. Mizuguchi et al., Appl. Phys. Lett. 93, 152505 (2008).
[2] S. Margadonna et al., Phys. Rev. B 80, 064506 (2009).
[3] S. Masaki et al., J. Phys. Soc. Jpn. 78, 063704 (2009).
[4] T. Ozaki et al., Euro. Phys. Lett., 98, 27002 (2012).
[5] M. Tanaka et al. J. Phys. Soc. Jpn. 85, 044710 (2016).
[6] M. Tanaka et al. arXiv. 1609.03151.

keywords : Fe-based superconductor, High-temperature X-ray diffraction, Micro-sampling technique

PC2-4 12:00–12:15

Non-magnetic Nematic Quantum Criticality In $FeSe_{1-x}S_x$ Superconductors

*Suguru Hosoi[1], Kohei Matsuura[1], Kosuke Ishida[1], Hao Wang[1], Yuta Mizukami[1], Tatsuya Watashige[2], Shigeru Kasahara[2], Yuji Matsuda[2], Takasada Shibauchi[1]

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2. Department of Physics, Kyoto University, Kyoto, Japan

Relationships between nematicity and superconductivity have been one of the central issues in the physics of iron-based superconductors. To approach this problem, an elegant experimental method using elastoresistance measurements has been developed, which enables us to evaluate the nematic susceptibility [1]. In iron-pnictide superconductors, the nematic susceptibility shows Curie-Weiss-like temperature dependence, and especially near the optimally doped regime the nematic fluctuations diverge towards 0 K revealing a nematic quantum critical point (QCP) [2]. Superconductivity is enhanced around the nematic QCP, which suggests the intimate relationships between nematicity and superconductivity. However, it is difficult to clarify the effect of nematic fluctuations on superconductivity because of the coexistence with magnetism. $FeSe_{1-x}S_x$ is a suitable system to investigate the effects of nematic quantum criticality without contamination of magnetic orders, since nematic transition temperatures can be controlled by isovalent substitution S into Se sites while there are no signs of magnetism for all samples. Our recent elastoresistance measurements reveal strong enhancement of nematic fluctuations around $x \sim 0.17$ where nematic transition is completely suppressed, which indicates the existence of nematic QCP [3]. Here, we report these behaviors of nematic fluctuations and discuss the relation to superconductivity in this system.

keywords : electronic nematicity, quantum critical point, iron-based superconductors, nematic susceptibility

PC2-5 12:15–12:30

Transport properties of MBE grown NdFeAs(O,F) thin films

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Department of Crystalline Materials Science, Nagoya University

*Ln*FeAs(O,F) (*Ln*: Lanthanoid) systems have the highest superconducting transition temperature (T_c) in the iron based superconductors. Nevertheless, due to difficulties of growing high quality single crystals, their electronic structures have not been fully investigated. We have succeeded to grow single crystal thin films of NdFeAsO by molecular beam epitaxy [1], and F doping was achieved by depositing NdOF layer on the top of the surface [2]. NdFeAs(O,F) thin films were grown by this method on several substrates, in which we found that T_c of the thin film grown on MgO substrate was somewhat lower than that on CaF_2 substrate [3]. In the present study, magnetotransport measurements were performed in order to examine the electronic structure and the reason why T_c was lower on MgO substrates. In the non-doped parent phase, we found a weak localization effect in the zero field resistance and finite transverse magnetoresistance. On the other hand, the weak localization behavior was absent in the superconducting film, possibly due to an electron screening effect caused by enhanced carrier density. In addition, both the magnetoresistance and Hall coefficient were small, indicating that a large amount of electrons were doped by our F doping method. We will report detailed analyses of these results, as well as of thermoelectric properties, and discuss their link to the electronic structure and superconducting properties.

[1] T. Kawaguchi *et al.*, Appl. Phys. Express **2**, 093002 (2009).
[2] T. Kawaguchi *et al.*, Appl. Phys. Express **4**, 083102 (2011).
[3] H. Uemura *et al.*, Solid State Commun. **152**, 735 (2012).

keywords : Iron based superconductor, transport property, thin film

PC3-1-INV 13:45–14:10

Electronic Structure of Iron-Based High-T_c Superconductors

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Department of Physics, Tohoku University

A recent report on high-temperature (T_c) superconductivity in a monolayer FeSe film on $SrTiO_3$ substrate [1] has generated significant attention, because the T_c value is very high, close to the liquid-nitrogen temperature, and the material is an atomically thin (a few angstrom thick) film. One of key questions is how the high-T_c superconductivity evolves from bulk to film, since bulk FeSe exhibits T_c no higher than 10 K. In this presentation, we report the high-resolution angle-resolved photoemission spectroscopy (ARPES) results on the electronic structure of bulk and thin films of FeSe [2,3] and demonstrate the evolution of the electronic structure from bulk to one monolayer. We also report a novel approach to control the surface carrier density, that is, an in situ deposition of potassium (K) atoms onto the surface. Using this technique, we have succeeded in accessing the heavily electron-doped region and found evidence of the emergence of high-T_c superconductivity not only in one-monolayer film but also in multilayer films. We present the electronic phase diagram of FeSe as a function of thickness and electron doping, and discuss the implications for high-T_c superconductivity.

[1] Q.-Y. Wang *et al.*, Chin. Phys. Lett. **29**, 037402 (2012).
[2] K. Nakayama *et al.*, Phys. Rev. Lett. **113**, 237001 (2014).
[3] Y. Miyata *et al.*, Nature Mater. **14**, 775 (2015).

keywords : Iron-based superconductors, Electronic structure, Angle-resolved photoemission spectroscopy

PC3-2-INV 14:10–14:35

Electrochemical etching induced high temperature superconductivity in FeSe electric double layer transistors

*Junichi Shiogai, Tomoki Miyakawa, Yukihiro Ito, Tsutomu Nojima, Atsushi Tsukazaki

Institute for Materials Research, Tohoku University

Among variety of iron-based superconductors, 11-system FeSe (Tc ~ 8 K in bulk) has been intensively studied on electronic structure and paring interaction because of its simple crystal structure [1]. Moreover, the discovery of a high-T_c superconductivity (HTS) in monolayer (ML) FeSe on $SrTiO_3$ with gap closing temperature of 65 K *in in-situ* spectroscopy [2-7] and the onset T_c reaching 40 K in *ex-situ* transport measurements, triggered much variety of investigations in thin films. Although it has been proposed that its HTS originates from the interfacial effects between the film and substrate including electronic band modulation [3], charge transfer [4], and electron-phonon coupling [5], understanding the main contribution to HTS remains unsolved issue at present.

In this study, we investigate the interfacial effect on HTS in FeSe thin films on $SrTiO_3$, MgO and $KTaO_3$ substrates using the electrochemical etching technique based on electric double layer transistors (EDLT) [6]. It was found that the Hall coefficient in normal state and T_c revealed the universal relationship regardless of film thickness and substrate materials. Our results point out the importance of proper charge balance between electron and hole density for emergence of FeSe HTS.

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keywords : FeSe, Electric double layer transistor

PC3-3 14:35–14:50

Critical temperature variation with a thickness tuned by electrochemical etching in $FeSe_{1-x}Te_x$ thin film on various substrates

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Superconductivity on FeSe ultra-thin film attracts considerable attention after a report of an enhancement of critical temperature T_c from 8 K in a bulk to 109 K in a FeSe monolayer/$SrTiO_3$(STO) substrate.[1] Recently, T_c enhancement to around 40 K was also reported on a FeSe thin film on STO with a thickness below 10 nm. Electrochemical etching and electric field-effect were used for tuning a thickness and carrier density, respectively, by an electric double layer transistor configuration. [2] On the other hand, we have reported on T_c of 23 K and 19 K on thick $FeSe_{1-x}Te_x$ films on CaF_2 (CaF) and $LaAlO_3$ (LAO) substrates, respectively.[3] In this presentation, we report on T_c variation on $FeSe_{0.8}Te_{0.2}$ films on STO, LAO and CAF substrates by the electric double layer transistor configuration.
The films with a thickness of 50-80 nm were fabricated on (001) surfaces of various substrates by a PLD method.[3] Electric double layer transistor with a Hall-bar shaped channel was fabricated with ionic liquid DEME-TFSI and Pt gate. The film was electrochemically etched at 245-250 K with a gate bias V_G of 5 V. After the etching, a sample was cooled with a gate bias of 0 V or 5 V.
On STO, T_c of the film was gradually increased from 8 K to 38 K for V_G of 5 V, and the film shows T_c of 38 K with a thickness less than 13 nm. In contrast, on CaF and LAO, T_c of the film was rapidly increased to 38 K with decreasing a thickness to around 50 nm for V_G of 5 V. A film with a thickness of 41 nm shows T_c of 12 K for V_G of 0 V and T_c of 38 K for V_G of 5 V. In addition, Hall coefficient was reversed from positive and negative where T_c of 38 K is observed for the LAO and CaF. These results strongly suggest that the T_c enhancement comes from electrostatic carrier accumulation on the film.
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keywords : FeSe, thin film, Electric field effect, Electrochemical etching

PC3-4 14:50–15:05

Searching for Gap Nodes in the Heavy-fermion Superconductor $CeCu_2Si_2$ from Specific-heat Measurement

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5. Department of Physics, Ritsumeikan University, Kusatsu, Japan

The discovery of the first heavy-fermion superconductor $CeCu_2Si_2$ [1] had great impact because strong Coulomb repulsion disturbs the formation of Cooper pairs by the conventional electron-phonon interaction. Until recently, $CeCu_2Si_2$ had been a good candidate for a *d*-wave superconductor mediated by spin fluctuations associated with an antiferromagnetic quantum critical point. Such pairing possesses nodes in the superconducting gap and can avoid strong Coulomb repulsion. In order to conclude the gap symmetry of $CeCu_2Si_2$, we have performed field-angle-dependent specific heat measurements [2,3] by which the location of gap nodes can be elucidated [4]. Unexpectedly, the low-temperature specific heat of a high-quality single crystal has revealed the absence of gap nodes and supports multiband full-gap superconductivity, which is unprecedented in the heavy-fermion system. These findings have opened a new door for the research on unconventional superconductivity.
[1] F. Steglich *et al.*, Phys. Rev. Lett. **43**, 1892 (1979).
[2] S. Kittaka *et al.*, Phys. Rev. Lett. **112**, 067002 (2014).
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keywords : unconventional superconductor, CeCu2Si2, gap symmetry, specific heat

PC3-5 15:05–15:20

Fully-gapped s_{++}-wave Pairing in the Heavy-Fermion Superconductor $CeCu_2Si_2$

*Takaaki Takenaka[1], Takuya Yamashita[2], Yoshifumi Tokiwa[2], Joe A Wilcox[3], Yuta Mizukami[1], Daiki Terazawa[2], Yuichi Kasahara[2], Marcin Konczykowski[4], Silvia Seiro[5], Hirale S Jeevan[5], Christoph Geibel[5], Carsten Putzke[3], Takafumi Onishi[2], Hiroaki Ikeda[6], Antony Carrington[3], Yuji Matsuda[2], Takasada Shibauchi[1]

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$CeCu_2Si_2$ is a prototypical heavy-fermion superconductor with transition temperature $T_c \sim 0.6$ K [1]. The superconducting gap structure is a direct consequence of the pairing mechanism. In $CeCu_2Si_2$, the gap has been believed to be of *d*-wave type, which implies unconventional pairing mechanisms with repulsive interactions such as magnetic fluctuations. It has been shown that slight variations of stoichiometry lead to '*A*-type' and '*S*-type' crystals; the former exhibits only antiferromagnetic order and the latter shows superconductivity without magnetic ordering. Recently, the method to synthesize high-quality *S*-type single crystals was established [2] and specific heat measurements in high-quality *S*-type crystals have been reported. Surprisingly, the low-temperature specific heat shows an exponential behavior that is expected for fully-gapped superconductors [3]. Here we report penetration depth measurements in such high-quality crystals. Penetration depth is sensitive to light quasiparticle excitation in multiband systems and thus it gives information complementary to specific heat that is governed by heavy bands. The result indicates that gap nodes are absent on the light hole bands. Moreover, electron-irradiation experiments reveal very small pair-breaking effect and no extra low-energy excitation by disorders.

These results demonstrate that the gap structure of $CeCu_2Si_2$ is fully-gapped with no sign change. Contrary to the long-standing belief that $CeCu_2Si_2$ is a magnetically-driven superconductor, it rather has an on-site attractive pairing interaction.

[1] F. Steglich *et al.*, Phys. Rev. Lett. **43**, 1892 (1979).; [2] S. Seiro *et al.*, Phys. Status Solidi B **247**, 614-616 (2010).; [3] S. Kittaka *et al.*, Phys. Rev. Lett. **112**, 067002 (2014).

keywords : Pairing Symmetry, Unconventional Superconductors, Heavy-Fermion materials

PC4-1-INV 15:35–16:00

Vortex Studies on a Hybrid Superconducting/Magnetic Spin Ice System

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Hybrid superconducting (SC) and ferromagnetic (FM) systems provide an intriguing combination of two contrasting phenomena and their mutual interaction has been extensively studied to tailor their electromagnetic behavior. Here, we present a novel FM/SC hybrid structure consisting of a unique artificial magnetic charge ice structure deposited onto a superconducting MoGe film. Our magnetic charge ice structure mimics the ground state of a square artificial spin ice structure, with the advantage that long-range ordering of multiple magnetic structures can be easily achieved and manipulated with an in-plane magnetic field [1]. The stray fields emanating from our reconfigurable magnetic nanostructure can affect the behavior of proximal superconducting vortices in the MoGe film. The novelty of the magnetic ice structure and its impact on vortex matching effect and dynamics will be presented. The globally reconfigurable and locally writable magnetic charge ice structure could provide a new setting for designing and controlling the properties of superconducting films and other two-dimensional materials.

This work was supported by the U.S. Department of Energy (DOE), Office of Science, Office of Basic Energy Sciences, Materials Sciences and Engineering Division. Z.-L.X. and J.X. were supported by NSF grant no. DMR-1407175. Use of the Center for Nanoscale Materials, an Office of Science user facility, was supported by the DOE, Office of Science, Office of Basic Energy Sciences, under contract no. DE-AC02-06CH11357. [1] Science 352, 962 (2016)

keywords : Superconductivity, Magnetism

PC4-2 16:00–16:15

Effects of Proton Irradiation on Pinning and Dynamics of Vortices in Isovalently Substituted $BaFe_2(As,P)_2$ Single Crystals

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$BaFe_2(As,P)_2$ is a unique system where intrinsic vortex pinning is very weak due to substitution of isovalent P in less influential site of As [1]. Actually, in contrast to other 122-type iron pnictides, magnetic field dependence of the critical current density (J_c) is dominated by sparse strong pinning centers except at high fields where collective pinning emerges in the form of peak effect. In this study, we have systematically investigated the magnetic field dependence of J_c and its relaxation in proton irradiated optimally doped $BaFe_2(As,P)_2$ single crystals, and compare these results with those in pristine crystal. A clear enhancement of J_c by proton irradiation is observed with a broad maximum of self-field $J_c \sim 4x10^6$ A/cm^2 at 2 K as compared with $J_c \sim 1.3x10^6$ A/cm^2 in pristine crystal. In addition, defects created by proton irradiation produce a peak effect that is distinctly different from that found in pristine crystal. Changes in temperature and magnetic field dependence of magnetic relaxation rate induced by proton irradiation are compared with those in other 122-type iron pnictides [2,3].

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keywords : $BaFe_2(As,P)_2$, proton irradiation, peak effect, critical current density

PC4-3 16:15–16:30

Shape dependence of effects of twin boundaries on half-quantized vortices in d-dot

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A d-dot is a nano-sized composite structure that consists of a *d*-wave superconductor (SC) embedded in an *s*-wave matrix. Since the phase of the superconducting order parameter in the *d*-wave SC depends on direction, phase difference appears at the corner junctions between *d*-wave and *s*-wave SCs in d-dot's. Due to quantization of fluxoids including this phase difference, half-quantized vortices spontaneously appear at the each corner. This is a feature of d-dot's [1]. We can use Pb or Nb as *s*-wave SCs and $YBa_2Cu_3O_{7-\delta}$ (YBCO) as *d*-wave SCs. But it is pointed out that the SHQVs may not appear if there exist some defects, especially twin boundaries (TBs) in YBCO [2]. In order to analyze effects of TBs on spontaneous half-quantized vortices (SHQVs), we introduce orthorhombic structure of YBCO into two-components Ginzburg-Landau(GL) equations [3] in terms of anisotropy of effective mass in YBCO. Using the finite element method [1] and solving these equations self-consistently, we showed that anisotropy of effective mass suppress SHQVs and that fractional SHQVs appear on edges of TBs [3]. In this study, we calculate magnetic field distribution in d-dot model with several TBs and investigate shape dependence of effects of TBs on SHQVs.

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keywords : d-wave superconductor, Ginzburg-Landau equations, finite element method, twin boundary

PC4-4 16:30–16:45

Thin Film Growth of Doped NEG-123 Superconductor on STO Substrate by PLD

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Oxygen controlled melt growth (OCMG) processed (Nd,Eu,Gd)Ba2Cu3Oy “NEG-123" doped with very small amount of nanometer sized particles like TiO3, MoO3 and Nb2O5 exhibited an improvement in pinning performance. As a result, a high critical current density (Jc) value of ~10^5 A/cm^2 was achieved at 90.2 K. Technical applications of high Tc superconductors (HTS) also require the development of simple methods to produce with appropriate superconducting properties. We have studied and optimized the superconducting properties of doped REBa2Cu3Oy “RE123" thin film composites by nanoparticles based on a control of the growth conditions. In this study, we focus on (Nd0.33Eu0.33Gd0.33)Ba2Cu3Oy (NEG-123) + Gd2BaCuO5 (Gd-211), which has reported excellent critical current density (Jc) in the bulk form, and fabricated NEG-123 + Gd-211 thin film with high superconducting properties. NEG-123 + Gd-211 films have grown on STO (SrTiO3) substrate by PLD method. We shall discuss the optimization of growth of thin film on different heating temperature inside chamber in a very broad range of temperature from 700 to 900°C, the distance between target and substrate, and the O2 pressure inside the chamber. A broad spectrum of characterizations involving XRD, SEM, TEM, magneto-resistance, magnetization and specific heat measurements have been undertaken on these films. Our study shows that the grown film at 800°C has showed the transition temperature (Tc) of 93K as similar to that reported value for the polycrystalline sample. We will also demonstrate and discuss the effect of O2 gas annealing of thin film inside the furnace at different pressure and annealing time and will conclude the best conditions to grow the high quality thin film of NEG-123+Gd-211 with high superconducting properties.

keywords : high Tc superconductors, thin films, physical properties

PC4-5 16:45–17:00

High critical current density and pinning potential in YBCO films with synergetic pinning centres

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We have grown by PLD YBCO films with naoengineered pinning centres using a synergetic approach by combining substrate decoration with Ag nanodots, quasi-multilayers with Ag nanodots and targets with BaZrO3 secondary phase nanoinclusions.
From AC multiharmonic susceptibility measurements in DC fields up to 14 T we have studied the frequency-dependent critical current densities and pinning potentials using the approach and theoretical model from Ref. 1.
The values of critical currents and of pinning potentials are quite high, and promising for further developments.
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keywords : Pinning, Nanoengineering, Critical current, Pinning Potential

PC5-1-INV 17:00–17:25

Vortex states in micron-sized crystals

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Large thermal fluctuation, owing to high superconducting transition temperature, short coherence length and quasi-two-dimensionality, brings about a rich variety of vortex phases in $Bi_2Sr_2CaCu_2O_{8+y}$ (Bi2212). In almost past three decades, such vortex states and phase transitions, including melting transition of pancake vortex lattice in the magnetic field perpendicular to the superconducting plane, have extensively studied using bulk single crystals. As a next step, based on current understandings on vortex phase diagram in bulk, it is interesting how the vortex states and the transitions would be modified when vortices are confined in a small-sized crystal. Recently, we have found an oscillating behavior of melting transition temperatures T_m as a function of magnetic field in small squared Bi2212 with a lateral dimension of 5-10 μm [1]. Using advantages of intrinsic Josephson junctions (IJJs), we successfully detected both the melting transition [2] and the series of vorticity change [3] through *c*-axis resistance measurements. In the case of the square-shaped crystals, it seems that T_m is enhanced around the vortex numbers N_v of i^2 (i: integer), indicating a matching of square vortex lattices in the square boundary. However, frustration between vortices, preferring a triangular lattice in bulk crystals of Bi2212, and the square boundary shape complicates the situation. The matching of vortex crystals with a boundary shape is more clearly observed in a triangle-shaped sample.

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keywords : vortex, melting transition, Bi2212, intrinsic Josephson junction

PC5-2 17:25–17:40

Physics of Lorentz Force on Supercurrent

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The Lorentz force on electric currents flowing in magnetic fields has a unique component perpendicular to both the current and field. It generally induces charge redistribution before recovering any steady state to produce the Hall voltage that eventually brings a force balance along the transverse direction. Extensive studies have been performed on this *Hall effect* in metals and semiconductors.

In contrast, we still have quite a poor understanding of the phenomena in superconductors. Indeed, the Lorentz force is missing from the Ginzburg-Landau and Eilenberger equations that have been used extensively in the literature, and can only be reproduced microscopically as a next-to-leading order contribution in the expansion of the Gor'kov equations in terms of the quasiclassical parameter $\delta \equiv 1/k_F \xi_0$ [1,2]. Hence, physics of the Lorentz force in superconductors remains mostly unexplored theoretically.

In this talk, I first outline how to incorporate the Lorentz force in the quasiclassical equations of superconductivity, where due care to the gauge invariance of the equations is necessary [1,2]. Next, I focus on the first category mentioned above on the Hall effect. We here report our theoretical results on (i) charging near edges in the Meissner state due to the shielding current [3], (ii) charging of an isolated vortex due to circulating supercurrents [2], and (ii) vortex-core charging in type-II superconductors as a function of the magnetic field [4].

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keywords : Lorentz force, Hall effect, charging

PC5-3 17:40–17:55

Memory Formation in the Transient State of a Periodically Driven Vortex System

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When an ac shearing force is applied to many particle systems with a random distribution and the number (n) of the shear cycle is increased, the particles gradually self-organize to avoid future collisions and transform into an ordered structure [1-3]. This is called random organization. It has been studied theoretically and experimentally that the information of the input shear amplitude is memorized in the particle configuration and it is readable by a subsequent readout experiment with different shear amplitudes. This phenomenon belongs to a type of memory effect and is observed not only for the steady state with $n\rightarrow\infty$ but also for the transient state with finite n. These memory effects have been actually observed in the colloidal particle systems [4,5], while it remains unclear whether they are unique to the colloidal system or universal in many particle systems.
In this work, we study this problem by using a superconducting vortex system driven by ac forces. We employ strip-shaped amorphous Mo_xGe_{1-x} films, where the reordering of the vortices is exclusively determined by the local shear due to the random pinning potential. The system remembers the created vortex configuration and the information of the input amplitude is distinguishable from the read-out experiments. The information is readable not only for the configuration in the steady state but also for the configuration in any previous steps, i.e., in the transient state. Our results provide insight into the general issue on how the system initially in a disordered configuration evolves to the ordered structure during the random organization process.
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keywords : Non-equilibrium phenomena, memory effect, random organization

PC5-4 17:55–18:10

Study of microwave-induced phase switches from the finite voltage state in $Bi_2Sr_2CaCu_2O_y$ intrinsic Josephson junctions

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The phase switching dynamics in the current-biased intrinsic Josephson junctions (IJJs) of high-Tc cuprates has much attention as a promising candidate for the quantum information processing, since the discovery of the macroscopic quantum tunneling (MQT) in IJJs. Not only a gigantic critical current density but a perfectly smooth tunnel junction in IJJs is also expected to be favor in the implementation of superconducting quantum bits (qubits) at higher temperatures than a temperature (typically less than 100 mK) at which the conventional Al- or Nb-based Josephson qubits are operated. The most distinct property of IJJs is a multiple-branched current-voltage characteristic, which is attributed to the strong coupling between Josephson junctions neighboring in an atomic scale with each other. Thus, the investigation of the phase switches from the finite voltage state in IJJs is quite important to understand the strong interaction between junctions and to implement the IJJ qubits.
Here, we report a study on the microwave-induced phase dynamics of the underdamped IJJs made of single crystalline $Bi_2Sr_2CaCu_2O_y$ (Bi-2212). Successfully, we observed the resonant double-peak structure in the switching current distribution for the phase switches from the finite voltage state. This feature is found to be well explained by a quantum mechanical model where the strong microwave field effectively suppresses the potential barrier for the phase switch. We also present the detailed analyses of the phase escape from a potential well and the multiple-phase retrapping under the microwave irradiation. These results suggest that the discrete energy state expected in the MQT state is survived up to ~10 K in the phase switches from the finite voltage state although it is strongly modified by the microwave irradiation.

keywords : Intrinsic Josephson junction, Macroscopic quantum tunneling

PC5-5 18:10–18:25

Investigation of the flux lines motion in superconductors in a longitudinal magnetic field by the computer simulation using the Time-Dependent Ginzburg-Landau equations

*Kento Adachi, Yusuke Ichino, Yuji Tsuchiya, Yutaka Yoshida

Nagoya University

The quantized flux lines (flux quanta, FQs) penetrate into superconductors and are subjected to the Lorentz force which is given by a cross product of a current density and a magnetic flux density. If the current is applied parallel to the magnetic field, the configuration is called as a longitudinal magnetic field (LMF) state. In the LMF state, the Lorentz force on the FQs becomes negligible and hardly works on the FQs. Therefore, some peculiar effects have been reported in the LMF state. For example, a critical current density (J_c) in a superconducting film with artificial pinning centers (APCs) increases in a magnetic field more than the one at zero field. However, it has not been understood about the LMF effects in detail. In our study, we visualize the FQs motion in the LMF state by the numerical simulation solving the three-dimensional Time-Dependent Ginzburg-Landau (TDGL) equations to clarify the origin of the LMF effect.

We numerically calculated time development of the order parameter by solving the TDGL equations in order to visualize the FQs motion in superconductors. All boundaries contact with vacuum. Moreover, we introduced the randomly distributed- nano-particles in the normal state as APC.

We were able to visualize the FQs motion in the superconductor with the APCs in the LMF state. The FQs penetrated into the superconductor and were distorted in a spiral shape by a current-induced magnetic field. The motion of the FQs is suppressed by the APCs. With increasing the current, the FQs went out of the APCs and continued moving. We also investigate the motion of the FQs with various shapes and densities of the APCs. We will calculate the J_c in each condition and discuss the contribution of the APCs on the LMF effect.

keywords : Superconductor, Longitudinal magnetic field, TDGL

PC6-1-INV 9:30–9:55

Bi^{2-} square net superconductivity in Y_2O_2Bi

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Tohoku University

$ThCr_2Si_2$-type layered oxide Y_2O_2Bi was firstly synthesized in a polycrystalline form [1]. This compound was difficult to be grown as an epitaxial thin film, but reductive solid phase epitaxy enabled to grow the epitaxial thin film [2], and multilayer solid phase epitaxy realized the much higher crystallinity [3]. As a result, intrinsic properties of Bi^{2-} square net were unveiled. Our recent result is discovery of 2 K superconductivity in Y_2O_2Bi polycrystal, reflecting two dimensionality of Bi^{2-} square net [4]. Intriguingly, pristine Y_2O_2Bi shows no superconductivity, but Y_2O_2Bi with excess oxygen shows superconductivity as a result of expanded c-axis, implying hidden interstitial oxygen site.

This work was in collaboration with Ryosuke Sei, Suguru Kitani, Hitoshi Kawaji, Tetsuya Hasegawa, and was supported by CREST, JST.

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keywords : Bi2- square net, Y2O2Bi, two dimensional superconductivity, oxygen incorporation

PC6-2-INV 9:55–10:20

Highly-crystalline 2D superconductors and beyond

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Recent technological advances in controlling materials have developed methods to produce idealized two-dimensional (2D) electron systems, which are highly-crystalline with less disorder in common. Here, we introduce the recent developments of highly-crystalline 2D superconductors and a series of unprecedented physical properties discovered in these systems. First of all, we highlight the quantum phase transitions, i.e., quantum metallic state (or possible metallic ground state) [1] and the quantum Griffiths phase [2] in out-of-plane magnetic fields, both of which is the evidence of universal quantum phase in highly-crystalline 2D superconductors. In addition, we focus two novel phenomena owing to broken inversion symmetry of the crystal structure coupled with spin-orbit coupling in ion-gated MoS2: one is the enhanced in-plane upper critical field by Zeeman-type spin-valley locking [3] and the other is the large nonreciprocal superconducting current [4], latter of which is later theoretically expected to be universal phenomena in noncentrosymmetric superconductors [4]. These series of unprecedented phenomena suggest that highly-crystalline 2D superconductors evidently offer tremendous opportunities to unveil the intrinsic quantum phase and exotic nature of superconductors, leading to a new era of superconductivity.
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[4] R. Wakatsuki* and Y. Saito* et al. submitted.

keywords : 2D superconductors, quantum phase transition, spin-orbit coupling, broken inversion symmetry

PC6-3 10:20–10:35

Paramagnetic and Diamagnetic Pair-Breaking Effect in Electric-Field-Induced Surface Superconductivity under Parallel Magnetic Fields

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By strong electric field of the field-effect-transistor or the electric-double-layer-transistor, carriers are induced and trapped in the confinement potential of the electric field near the surface of insulators or semiconductors. In the surface metallic states, superconductivity appears at low temperature, such as in $SrTiO_3$. A unique nature of the surface metallic state is that sub-bands are formed by the quantum confinement of carriers near the surface. The surface superconductivity is expected to have multi-gaps depending on the sub-bands [1].

We theoretically study electronic states when magnetic fields are applied parallel to the surface, in order to find phenomena reflecting the multi-gap superconductivity in the electric-field-induced surface metallic state. Wave functions in the superconducting states are calculated from Bogoliubov-de Gennes equation, assuming s-wave pairing interaction. As the effects of magnetic field, we consider both contributions of paramagnetic and diamagnetic pair-breaking. Under the magnetic field, paramagnetic moment appears due to Zeeman effect, and diamagnetic screened current flows near the surface. We study the magnetic field dependence of the superconducting state. There, contribution of a sub-band to the zero-energy density of states appears above each effective critical field, which is lower for higher sub-band. The multi-gap states of sub-bands are related to the depth-dependence of the superconducting state. The magnetic field dependence may be a key feature to identify the multi-gap structure of the surface superconductivity.

[1] Y. Mizohata, M. Ichioka, and K. Machida, Phys. Rev. B **87**, 014505 (2013).

keywords : Electric-Field-Induced Surface Superconductivity, Magnetic Fields dependence, Bogoliubov-de Gennes theory, Quantum confinement

PC6-4 10:35–10:50

Bulk superconductivity induced by in-plane chemical pressure effect in the $Eu_{0.5}La_{0.5}FBiS_{2-x}Se_x$ system

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$Eu_{0.5}La_{0.5}FBiS_2$ is a $BiCh_2$-based layered superconductor with a crystal structure consisting of the BiS_2 superconducting layer and the (Eu,La)F blocking layer. $Eu_{0.5}La_{0.5}FBiS_2$ shows superconductivity with an onset transition temperature T_c^{onset} = 2.3 K, and Tc increases up to 10 K under high pressure. The huge pressure effect on T_c is quite similar to that of $LaO_{0.5}F_{0.5}BiS_2$. In $LaO_{0.5}F_{0.5}BiS_2$, isovalent substitution of S by Se generates in-plane chemical pressure, and bulk superconductivity is induced in $LaO_{0.5}F_{0.5}BiS_{2-x}Se_x$. Thus, we expected the similar in-plane chemical pressure effect and the appearance of superconductivity in the $Eu_{0.5}La_{0.5}FBiS_2$ system as well. Here, we report the successful synthesis of new superconducting phase $Eu_{0.5}La_{0.5}FBiS_{2-x}Se_x$ with the highest T_c of 3.8 K for $x = 0.8$.
We have prepared polycrystalline samples of $Eu_{0.5}La_{0.5}FBiS_{2-x}Se_x$ with x = 0, 0.2, 0.4, 0.6, 0.8, and 1 by the solid state reaction method. With increasing x, a-axis is largely expanded, therefore in-plane chemical pressure is enhanced. For $x \geq 0.4$, superconductivity is observed in magnetic susceptibility measurements, and the highest T_c is 3.8 K for $x = 0.8$. From electrical resistivity measurements, a zero-resistivity state is observed for all the samples (including $x = 0$ and 0.2), and the highest T_c^{zero} of 3.8 K is observed for x = 0.8. With increasing Se concentration, characteristics of electrical resistivity change from semiconducting-like to metallic, suggesting that the evolution of superconductivity is linked with the enhanced metallicity. A superconductivity phase diagram of $Eu_{0.5}La_{0.5}FBiS_{2-x}Se_x$ superconductor is established. Temperature dependence of electrical resistivity shows an anomalous two-step transition under high magnetic field. These resistivity data are analyzed with assuming in-plane anisotropy of upper critical field.

keywords : in-plane chemical pressure, BiCh2-based layered superconductor, bulk superconductivity

PC6-5 10:50–11:05

Superconducting state of the single crystals of $La(O,F)Bi(S_{1-x}Se_x)_2$

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2. Department of materials science, Niigata University

Recently, superconductivity of the BiCh_2-based layered compound La(O,F)BiCh_2 (Ch = S, Se) has much attention [1,2]. The crystal structure consists of the LaO layer and $BiCh_2$ layer, which is very similar to the FeAs-based high-T_c superconductor. By replacing variety elements, many superconductors are found in $LaOBiCh_2$ system.
However, there is little report on the superconducting gap symmetry, because synthesized single crystals are very small. To overcome the problem, we constructed a hand-made sensitive calorimeter, which is effective to reveal the superconducting symmetry. In this presentation, we discuss the superconducting properties and superconducting gap symmetry of $La(O,F)Bi(S_{1-x}Se_x)_2$.
We confirm that bulk nature of superconductivity from specific heat measurements. Weak jump in $C(T)$ is observed at T_c = 3.2 K below x = 0.2, suggesting superconductivity is not bulk nature. Above 0.3, clear jump is observed above x = 0.3. Thus, superconductivity becomes bulk nature above x = 0.3. Temperature dependence of the electronic specific heat $C_e(T)$ shows exponential dependence above x = 0.3. Field dependence of the electronic specific heat $C_e(H)$ behaves as H-linear dependence. These results indicate that superconductivity is fully gapped. In addition, we found that $\Delta C/\gamma T_c$ and $2\Delta(0)/k_B T_c$ increase with x from specific heat measurements. In addition, Electronic specific heat coefficient (γ) and Debye temperature (Θ_D) slightly increase with x. This result indicates that T_c depends on $N(E_F)$ and Θ_D.
[1] Y. Mizuguchi et al., J. Phys. Soc. Jpn. 81, 114725 (2012).
[2] H. Takafumi et al,. J. Phys. Soc. Jpn. 84, 024723 (2015).

keywords : BiCh2-based superconductor, superconductivity, specific heat

PC7-1-INV 11:20–11:45

Correlation strength and T_c: quantum oscillations in $YBa_2Cu_4O_8$ under hydrostatic pressure

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The unusual normal state electronic structure of the cuprates is widely believed to be at the heart of understanding high-temperature superconductivity in these materials. Recent quantum oscillation measurements in $YBa_2Cu_3O_{7-\delta}$ (Y123) have found a strong increase in the quasiparticle effective mass close to two separate critical points in the temperature-doping phase diagram[1]. Here we present a study of quantum oscillations in the double chain cuprate superconductor $YBa_2Cu_4O_8$ (Y124). Instead of varying the doping by changing δ (in Y123) we study the evolution of the quantum oscillations under hydrostatic pressure. Pressure increases T_c by around 0.6K/kbar, primarily, it is thought, by increasing charge transfer between the chains and planes. Unlike in Y123, where the increase in T_c close to optimal doping is accompanied by a strong increase in quasiparticle mass, in Y124 we find that the mass decreases. Our results suggest that the mechanism that leads to the mass enhancement in the cuprates (most likely the emergence of a competing charge density wave instability) does not directly lead to an enhancement of the superconducting critical temperature.

References:
[1] B.J. Ramshaw *et al.* Science 348, 6232 (2014)

keywords : Superconductivity, Cuprates, Pressure, Quantum Criticality

PC7-2 11:45–12:00

Improvement of superconducting properties in Ba_2SmNbO_6 and $BaHfO_3$ co-doped $SmBa_2Cu_3O_y$ thin films under low and high magnetic field

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2. CRIEPI

Superconducting properties of $REBa_2Cu_3O_y$ (REBCO) films in magnetic fields are improved by doping Ba-M-O (BMO: M = Zr, Sn, Hf etc.) nanorods[1]. These nanorods shape are depending on deposition condition, and these diameters are several nanometers. On the other hand, we observed that Ba_2SmNbO_6 (BSNO) makes the diameter wider and number of nanorods less than other BMO nanorods[2]. The nanorods number density and diameter were about 250 /μm2 and 33 nm, respectively and that a superconducting property was especially good at lower magnetic field.

In this study, we fabricated SmBCO thin films with wide nanorods and narrow ones by doping both BHO and BSNO to improve the superconducting property from low magnetic field to high magnetic field. These films were fabricated by pulsed laser deposition (PLD) method on $LaAlO_3$ (100) single crystalline substrates.

As a result, we confirmed both wide and narrow nanorods of which diameters were about 29.3 nm and 7.5 nm, respectively in a BSNO 32 vol.% and BHO 8.5 vol.% co-doped SmBCO film from the TEM observation. This film shows two types of plateau at low and high magnetic field in the J_c-B curve. It indicats that wide and narrow nanorods trap flux quanta at each matching field. This film shows Fpmax of 20.7 GN/m^3, and it is higher than each BSNO and BHO doped-SmBCO film prepared in the same deposition conditions.

This work was partly supported by a Grant-in-Aid for Scientific Research (23226014, 15H04252, 15K14301, 15K14302), NU-AIST alliance project and JST-ALCA.

keywords : Thin film, nanorods, SmBCO, BHO

PC7-3 12:00–12:15

Elastoresistance measurements as a probe of nematic fluctuations in cuprate superconductors

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2. Hirosaki University

The pseudogap state in cuprate superconductors has been considered to be a key to understanding the mechanism of the high-temperature superconductivity. Recently, electronic nematicity, characterized by four-fold rotational symmetry breaking in CuO_2 planes, has been suggested as a key signature inside the pseudogap regime from several measurements such as thermal transport [1], neutron scattering [2] and scanning tunneling spectroscopy [3]. However, whether the pseudogap onset temperature T* is a nematic phase transition temperature or not remains an open issue. Here we report elastoresistance measurements in Pb-doped $Bi_2Sr_2CaCu_2O_{8+y}$ with suppressed structural modulation along the *b* axis, which allow us to evaluate the nematic susceptibility. The nematic susceptibility is defined as the in-plane anisotropy change with respect to the orthorhombic distortion induced by piezoelectric device, and is directly connected with the charge nematic fluctuations [4]. This measurement is bulk sensitive and very useful to probe the rotational symmetry breaking. We find that the temperature dependence of the nematic susceptibility shows the Curie-Weiss-like enhancement toward the pseudogap temperature T*, below which a deviation from the hightemperature dependence is observed. This result supports the existence of a transition to a charge nematic state below T* in the cuprates. At the presentation we will discuss the hole doping dependence of the nematic susceptibility and discuss the electronic nematic phase in the phase diagram of the cuprate superconductors.
[1] R. Daou *et al.*, Nature **463**, 519 (2010).; [2] V. Hinkov *et al.*, Science **319**, 597 (2008).; [3] M. J. Lawler *et al.*, Nature **466**, 347 (2010).; [4] J. H. Chu *et al.*, Science **337**, 710 (2012).

keywords : pseudogap, electronic nematicity, high-temperature superconductivity

PC7-4 12:15–12:30

Surface spintronics of the chiral d-wave pairing state in the Kane-Mele metal SrPtAs

*Jun Goryo[1], Yoshiki Imai[2], Andreas Schnyder[3], Manfred Sigrist[4]

1. Hirosaki University; 2. Saitama University; 3. Max Planck Institute, Stuttgart; 4. ETH Zurich

We point out a novel surface spintronics spontaneously induced in the chiral d-wave superconductor with a spin-orbit coupling. This work is motivated by the superconductivity of SrPtAs [1]. The unit cell contains two honeycomb-like PtAs layers distinguished by the exchanged location of Pt and As cites. The crystal symmetry allows the spin-orbit coupling equivalent to the one in the Kane-Mele topological insulator. The term yields the spin-dependent effective magnetic field and causes the spin-dependent cyclotron motion of an electron. We therefore have a spontaneous spin current at the sample surface in the normal state. SrPtAs shows the superconductivity below Tc=1.5K [1]. The MuSR measurement observed spontaneous magnetization below Tc [2], which implies the time-reversal-symmetry breaking due to the pairing. Some theoretical works [3,4] suggest that one of the most plausible candidates of pairing symmetry is the chiral d-wave state with topologically protected chiral surface state. Although its amount is sensitive to the surface geometry, the state carriers charge current. We then have spontaneous flow of charge and spin at the surface in the superconducting state, and this coexistence causes spin polarization [5]. We analyzed this effect for zigzag and armchair surfaces by using Bogoliubov-de Gennes approach, and found that the spin magnetization in the armchair case is significantly enhanced. This system would provide us a new mechanism of the spontaneous spin magnetism in the honeycomb system.
[1] Y. Nishikubo, K. Kudo, and M. Nohara, JPSJ 80, 055002 (2011); [2] H. Biswas, et al. PRB 87, 180503 (2013) ; [3] J. Goryo, M. Fischer, and M. Sigrist, PRB86, 100507(2012), M. Fischer and J. Goryo, JPSJ 84, 054705(2015); [4] M. Fischer, et al. PRB 89. 020509(R) (2014); [5] M. Imai, K. Wakabayashi, and M. Sigrist, PRB 85, 174532(2012), PRB 88, 144503(2013)

keywords : spontaneous flow of spin and charge, spontaneous spin polarization, chiral d-wave pairing, Kane-Mele model

PC7-5 12:30–12:45

Spontaneous orbital-selective Mott transitions and the Jahn-Teller metal of A3C60

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2. University of Fribourg

The alkali-doped fullerides A3C60 are half-filled three-orbital Hubbard systems which exhibit an unconventional superconducting phase next to a Mott insulator. An unusual property of these compounds is the effectively negative Hund coupling J produced by anisotropic (Jahn-Teller) phonons. In contrast to transition metal (d-electron) systems, which have a positive Hund coupling of the order of 1 eV, the bare Hund coupling in fullerides is much smaller (~ 30 meV) because of the spatially extended molecular orbitals, so that the screening by phonons can lead to a sign inversion of the effective J. While the pairing in fulleride compounds is understood to arise from an effectively negative Hund coupling, the highly unusual Jahn-Teller metal near the Mott transition, featuring both localized and itinerant electrons, has not been understood [R.H. Zadik et al., Science Advances 1, e1500059 (2015)]. This property is consistently explained by a previously unrecognized phenomenon: the spontaneous transition of multiorbital systems with negative Hund coupling into an orbital-selective Mott state. This symmetry-broken state, which has no ordinary orbital moment, is characterized by an orbital-dependent two-body operator (the double occupancy) or an orbital-dependent kinetic energy, and may also be regarded as a diagonal-order version of odd-frequency superconductivity. We propose that the recently discovered Jahn-Teller metal phase of A3C60 is an experimental realization of this novel state of matter [S. Hoshino and P. Werner, arXiv:1609.00136 (2016)].

keywords : fulleride superconductors, orbital-selective Mott state, Jahn-Teller metal

WB1-1-INV 9:30–10:00

Status of high performance REBCO coated conductors for high field applications

*Venkat Selvamanickam

University of Houston

Heavily-doped REBCO coated conductors have been demonstrated with excellent properties in magnetic fields of 2 – 30 T over a temperature range of 4.2 K to 77 K. REBCO conductors with zirconium addition up to 25 mol% exhibit critical current densities exceeding 20 MA/cm^2 at 30 K, 3 T and pinning forces over 1000 GN/m^3 at 20 K. Combining these heavily-doped REBCO with thicker films, engineering current densities above 2200 A/mm^2 have been achieved at 4.2 K in 15 T field oriented perpendicular to the tape plane, which is twice and thrice respectively better than the performance levels of Nb_3Sn and Bi-2212 wires at this field. The factors affecting the consistency in the in-field performance of the heavily-doped REBCO conductors have been studied in detail by compositional analysis and high resolution X-ray Diffraction. Based on a strong linear correlation that was found between the I_c at 77 K, 3 T and I_c at fields above 3 T at all temperatures from 20 to 77 K, a reel-to-reel in-field critical current measurement system has been constructed and used for qualifying the variability in in-field I_c of long REBCO tapes. Using an Advanced superconductor deposition tool, further refinement of nanoscale defects has yielded record high lift factors of 9 in critical current (I_c) at 30 K, 2.5 T. The latest progress in the development of high performance REBCO coated conductors for high field applications will be presented.
This work was supported by the Office of Naval Research, Advanced Research Projects Agency-Energy and the DOE Office of High Energy Physics.

keywords : coated conductors, REBCO, magnetic field, pinning

WB1-2-INV 10:00–10:30

Optimal, Nanodefect Configurations via Strain-Mediated Assembly for Optimized Vortex-Pinning in Superconducting Wires from 4.2K-77K

*Amit Goyal

University at Buffalo; The State University at New York

Engineered nanoscale defects within REBa2Cu3O7-δ (REBCO) based coated conductors are of great interest for enhancing vortex-pinning, especially in high-applied magnetic fields. We have conducted extensive research to optimize vortex-pinning and enhance Jc via controlled introduction of various types of nanoscale defects ranging from simple rare-earth oxides and Ba-based perovskites to double perovskite rare-earth tantalates and niobates (Ba2RETaO6 and Ba2RENbO6). This talk will provide an overview on how density, morphology, and composition of these engineered nanoscale defects affects vortex-pinning in different temperature, field and angular regimes. Detailed microstructural and superconducting properties coated conductors with these engineered defects will be presented. It will be shown that certain nanodefect configurations that provide the best performance at high-operating temperatures also provide the optimal properties at low operating temperatures out to high-applied magnetic fields.

keywords : Flux-pinning, Coated-conductors, Columnar defects, Self-assembly

WB1-3 10:30–10:45

Statistical Behavior of Positional Variation of Critical Current Density in Long RE-123 Coated Conductors

*Takanobu Kiss[1], Kohei Higashikawa[1], Takahiro Fukuzaki[1], Yuta Onodera[1], Takumi Suzuki[1], Masayoshi Inoue[1], Takato Machi[2], Akira Ibi[2], Teruo Izumi[2]

1. Dept. of Electrical Engineering, Kyushu University
2. National Institute of Advanced Industrial Science and Technology

Current transport properties is one of the most fundamental characteristics of superconducting materials. To design practical devices such as coil windings and/or magnets, we usually measure critical current, Ic, using a short sample. Especially in case of high Ic sample, we often adopt a micro-bridge for the measurements in order to suppress test currents. However, the relationship between such local measurements and the global current-voltage characteristics in long HTS tapes have not yet fully established. To understand the current transport properties in long RE-123 coated conductors (CCs), we have investigated statistical behavior of positional variation of local critical current density, Jc, in multiple scale of long CCs by use of reel-to-reel scanning Hall probe microscopy and transport four-probe measurements. While an intrinsic Jc fluctuation is strongly influenced by the interaction between vortices and pinning centers in mesoscopic scale, current blocking obstacles also cause a spatial variation of Jc in macroscopic scale. In this study, the influence of spatial resolution of the measurements have been discussed based on the measurements and theoretical analysis within a frame work of percolation transition model [1]. We have succeeded in separating intrinsic- and extrinsic-distribution. We also found a scaling behavior of probability density function of Jc, i.e., the statistical Jc distribution follows power law at around threshold value of Jc. These understandings are very important to establish a reliable model to describe current transport properties in the long CCs.
Acknowledgements: This work was supported by “JSPS KAKENHI (16H02334)", “METI and AMED", and “JST-ALCA".
Reference [1] K. Yamafuji and T. Kiss, Physica C, Vol.258, No.3-4, pp.197-212 (1996)

keywords : Critical Current, Statistical Distribution, Pinning, Coated Conductor

WB1-4 10:45–11:00

Correlated Study between Critical Current Density at 77 K and That of Low Temperature In-Filed Conditions of Various REBCO Coated Conductors

*Masayoshi Inoue[1], Kazutaka Imamura[1], Takumi Suzuki[1], Shogo Ichimura[1], Takahiro Fukuzaki[1], Kohei Higashikawa[1], Teruo Izumi[2], Takanobu Kiss[1]

1. Kyushu University; 2. AIST

Critical current density (Jc) of CCs is often characterized at 77 K and self-field (s.f.) condition because of the easiness for the measurement, however, practical operation conditions of the CCs are usually lower temperature, T, and in-field, B, conditions. In fact, the measurement at lower T and in-field conditions are time consuming and difficult especially for recent advanced CCs where in-field critical current has been increased significantly by introducing APCs and making thicker superconducting layer. From practical point of view, a prediction of Jc at low T and in-field condition by using those at high T around 77 K is interested in very much. The ratio between Jc (s.f., 77 K) and Jc (B, T) is known as lift-factor. However, it is also pointed out that the correlation between Jc (s.f., 77 K) and Jc (B, T) is not good whereas Jc (3 T, 77 K) has a linear correlation with Jc (3 T, 30 K) [1]. Furthermore, the influence of spatial variation in the same sample and sample-to-sample variation is not yet fully understood. In this study, we have carried out E-J measurement in wide range of T and B, and then investigate the correlation between Jc at 77 K and in-field Jc at lower temperature of various REBCO CCs. We have confirmed that Jc (10 T, 50 K) shows good linear correlation with Jc (1 T, 77 K) or Jc (3 T, 77 K) among non-doped REBCO CCs, such as PLD-GdBCO CC, CVD-YBCO CC, and TFA-MOD REBCO CC, as well as $BaHfO_3$ doped REBCO CCs, whereas there is no correlation between Jc (s.f., 77 K) and Jc (10 T, 50 K). Based on these measurements, we will discuss an appropriate metric to obtain a reliable lift-factor. Also the influence of the spatial- and sample-to-sample-variation of Jc will be discussed.
Acknowledgment: This work was supported by “AMED and METI as a Project for Development of HTS Coiling Technology" and “JSPS: KAKENHI (26420273, 16H02334)".
[1] V. Selvamanickam, et al., SuST 27 (2014) 055010

keywords : in-field Jc, REBCO, coated conductor

WB2-1-INV 11:15–11:45

Development of Uniform and Productive Process for BMO-Doped REBCO Coated Conductor by Hot Wall-PLD on IBAD Template Technique

*Yasuhiro Iijima, Kazuomi Kakimoto, Mitsunori Igarashi, Shinji Fujita, Wataru HIrata, Shogo Muto, Tomo Yoshida, Yutaka Adachi, Kunihiro Naoe

Fujikura Ltd.

In order to construct industrial REBCO wire processes with long length uniformity, high-throughput and reproducibility, vapour-phase production lines were developed by using ion-beam-assisted-deposition (IBAD), and hot-wall pulsed-laser-deposition (PLD), which have furnace-like, nearly equilibrium growth zone, with work lengths over 500 m and typical I_c over 1000 A/cm at 30 K in 2T [1]. 30km long 4mm wide tapes were shipped for test coils for a MRI prototype, which had very stable field homogeneity within 2ppm at 3T [2]. Moreover, recent results of in-field performance for $BaMO_3$ (BMO, M：Zr or Hf) -doped REBCO tape samples also indicated strong and uniform performances by the hot-wall PLD system, though multiplied deposition parameters come from nano-rod BMO growth should cause narrower process windows [3]. Very high pinning force density (F_p) of 1.6TN/m^3 was observed at 4.2K, 15T, for a sample of RE=Eu, M=Hf, deposited with growth rate of ~5 nm/sec. 50m long class uniform EuBCO tapes were formed with productive high growth rate over 20nm/sec, being consistent with commercial non-doped conductors, which had also large I_c of 1687A/cm and F_p of 0.96TN/m^3 at 4.2K, 15T. and 1883A/cm at 30K, 2T. Randomly distributed pinning centers were effective in both samples, which were more obvious compared to c-axis correlated ones in lower operation temperatures. Current perspective for 1 km long production lines would be presented. This Paper includes the results supported by the New Energy and Industrial Technology Development Organization (NEDO).
[1] Y. Iijima, et al., *IEEE Tran.s. Appl. Supercond.*, vol. 25, no. 3 (2015) , Art. no. 6604104.
[2] S. Yokoyama, et.al., presented in *ASC2016*, Denver, USA, 2016, 2LPo2J05.
[3] Y. Iijima, et al., presented in *ASC2016*, Denver, USA, 2016, 4MOr3A03.

keywords：Coated Conductor, REBCO, Artificial Pining Center, Pulsed Laser Deposition

WB2-2-INV 11:45–12:15

Recent progress of manufacturing HTS tapes and its applications at SuperOx

*Sergey Lee[1], Valery Petrykin[1], Naoyuki Hirata[1], Juhyun Chung[1], Miyuki Nakamura[1], Shinya Hasuo[1], Alexei Mankevich[2], Vsevolod Chepikov[2], Anton Markelov[2], Mikhail Moyzykh[2], Alexander Molodyk[2], Sergey Samoilenkov[2]

1. Superox Japan LLC
2. CJSC SuperOx

In this presentation I will give a brief overview of main results obtained during past 5 years since the establishment of SuperOx Japan LLC and during 10 years since foundation of SuperOx company in Russia.
At first the new structure of SuperOx group of companies will be introduced and after that I will describe our company strategy and vision on future development of 2G HTS wires production and applications.
Than I will focus on SuperOx activities for up-scaling of manufacturing facilities to increase the production throughput and yield, improve the performance of 2G HTS wires and to provide a wider range of customization for our product tapes.
Based on our cost analysis model I will discuss the potential pathways to reduce the final price of our wires, which based on the magnetron-IBAD-PLD production scheme and discuss the main obstacles and possible competitiveness of this approach in comparison with other techniques.
In conclusion I will present an overview of ongoing and prospective projects aimed on the development of new materials, wire architectures, construction of pilot scale devices and electrical equipment where our 2G HTS tapes were used.

keywords：coated conductors (CC), pulsed laser deposition (PLD), ion beam assisted deposition (IBAD), superconducting tapes

WB2-3-INV 12:15–12:45

Recent development of DI-BSCCO wire

*Kohei Yamazaki, Shin-ichi Kobayashi, Goro Osabe, Tomohiro Kagiyama, Masashi Kikuchi, Takayoshi Nakashima, Soichiro Takeda, Takuro Kadoya, Tomoyuki Okada, Kazuhiko Hayashi, Takeshi Kato

Sumitomo Electric Industries, Ltd.

Sumitomo Electric has been developing the silver-sheathed Bi2223 wires since the discovery of Bi-based superconductor. These wires are called as 'DI-BSCCO' (Dynamically Innovative BSCCO). Recently, a strength-type wire is commercialized for high-field applications. This type wire is Type HT-NX, laminated with Ni alloy tapes which have higher strength than stainless steel tapes. The mechanical properties of Type HT-NX with 30 μm-thick Ni alloy tapes are 400MPa for the tensile strength at 77K, 0.5% for the tensile strain at 77K and 40mm diameter for bending performance at room temperature. In terms of mechanical properties, this strength wire is expected to be used for high field applications.
The development of longer Type HT-NX also has been conducting. There are two efforts to make longer wire. First method is to improve unit length of Type HT-NX itself by modifying lamination technique, and second method is to splice Type HT-NX wires. For splicing, when Type HT-NX wires is simply spliced, the splice resistance becomes so high because Ni alloy material has high resistance. So, a new splice structure, which has good mechanical properties and low splice resistance, has been developing. The recent progress on development of DI-BSCCO, especially Type HT-NX, will be shown in the presentation.

keywords : Bi2223 wire

WB3-1-INV 14:00–14:30

The generation of high fields in (RE)$Ba_2Cu_3O_{7-\delta}$ and MgB_2 bulk superconductors

*John H. Durrell

University of Cambridge, Department of Engineering

Bulk superconductors offer a potentially straightforward and economical way to achieve high magnetic fields outside the bore of a superconducting solenoids. In essence they act like high performance permanent magnets, albeit with key differences in how the magnetic field is generated.
In 2003 Tomita and Murakami set the record for the trapped field in a bulk superconductor of a shade over 17 T. In 2014, not without significant effort, this record was raised to 17.6T . This apparently slow progress is due to the fact that achieving high fields in bulk superconductors is limited not only by critical current but by other more traditional materials considerations such as thermal stability and tensile strength .
In this lecture I will review the progress made to date in the Bulk Superconductivity Group at the University of Cambridge, and around the world, in pushing the high field performance envelope of both (RE)$Ba_2Cu_3O_{7-\delta}$ and the rapidly developing MgB_2 bulk superconductors. I will also discuss potential applications and the challenges of charging such materials.

keywords : Bulk Superconductor, High Magnetic Fields

WB3-2-INV 14:30–15:00

Potential of RE123 bulks from viewpoints of materials science

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Excellent flux pinning properties of RE123 ($REBa_2Cu_3O_y$) materials are originated in its small electromagnetic anisotropy resulting in relatively large pinning volume and various kinds of effective pinning centers. Very high potential for high field generating materials has been well recognized for RE123 coated conductors. On the other hand, RE123 bulks grown by the melt-solidification method have been opening new superconducting applications, such as flywheels, magnetic separation, drug delivery, levitating mixer and compact NMR, though their Jc is more than one order of magnitude lower than that of coated conductors. However, the engineering J_c, J_e, is almost comparable between coated conductors and melt-solidified bulks. This means that RE123 bulks has basically high potential for high field applications. In the recent decade or more, high performance RE123 bulks have been developed mainly through improvements of mechanical strength and homogeneity of J_c and microstructures, while precise controls of chemical composition and dispersed non-superconducting precipitates of RE123 crystals are found to be effective for further enhancement of critical current properties.
Possibilities of applying these techniques for large products and approaches for higher field trapping properties will be discussed.

keywords : RE123 bulk

WB3-3 15:00–15:15

Microstructure and Trapped Field of YBCO Bulk Superconductors Fabricated by Interior Seeding.

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The influence of the seed position at interior seeding [1] on the macro and microstructure of YBCO single-grain bulks superconductors is presented in this study. The position of the inner seed in the sample is significantly influencing distribution of pinning centers in the form of Y211 particles. The concentration of Y211 is advantageously higher at the top surface of the sample. Another important microstructural feature of these bulks which is influenced by the position of the inner seed is the size and volume fraction of pores. They promote oxygenation of the sample but reduce cross-section for supercurrent. The Y211particle and porosity distribution influenced measured trapped field on the top and bottom side of the studied bulks.
Acknowledgment. This work was financially supported by the National Research Foundation Grant funded by the Ministry of Science, ICT and Future Planning (MSIP) of Republic of Korea (Project Number: NRF-2013M2A8A1035822) and by projects New Materials and Technologies for Energetic (ITMS 26220220061), Research and Development of Second Generation YBCO Bulk Superconductors (ITMS 26220220041), APVV No. 0330-12, VEGA No. 2/00121/16.
[1] C-J Kim, S-D Park, H-W Park and B-H Jun, Supercond. Sci. Technol. 29 (2016) 034003 (7pp).

keywords : YBCO bulk, Interior seeding, Microstructure, Trapped field

WB3-4 15:15–15:30

Two directional growth of a Y123 grain in melt-processed YBCO bulk superconductor with interior seeding

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2. Department of Electronc Engineering, Sunmoon University

For the fabrication of signle grain YBCO superconductor, Sm123 seed was inserted in the interior of YBCO powder compact. Growth nature of a Y123 grain in melt-processed YBCO bulk superconductors with interior seeding was investigated. It was found that a Y123 grain grew from the seed up and down simultaneously. As a result of the two directional growth of the Y123 grain, a large a/c growth sector was developed on the top and bottom of the YBCO sample, which is comparable to the lage a/b growth sector of the top surfcae of the conventional top seeded melt growth processed YBCO superconductors. The magnetic levitation forces and trapped magnetic field of the top/bottom of the sample were compared with the center region.

keywords : Growth, Y123 grain, bulk superconductor, Interior seeding

WB4-1-INV 15:45–16:15

Spatially Resolved Measurements on Critical Current in Coated Conductors and MgB_2 Wires

*Kohei Higashikawa[1], Masayoshi Inoue[1], Shinji Fujita[2], Mitsunori Igarashi[2], Kazuomi Kakimoto[2], Yasuhiro Iijima[2], Zhenan Jiang[3], Rodney Badcock[3], Nicholas Long[3], Robert Buckley[3], Teruo Izumi[4], Akiyoshi Matsumoto[5], Hiroaki Kumakura[5], Takanobu Kiss[1]

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Local critical current distributions in superconducting wires become crucial information for (1) the clarification of their performance limiting obstacles, (2) product inspection, and (3) determination of design criteria of practical applications. In other words, spatially resolved measurements on local critical current distributions will play a key role in the developments not only of wires but also of applications. In fact, Hall-probe measurements have been working well in recent years for them. However, in case of RE-123 coated conductors (CCs), the practical applications requires not only wide and straight conductors but also more sophisticated geometries: narrow, multi-filamentary and transposed ones. Furthermore, such magnetic measurements does not simply work for superconducting wires with magnetic materials especially seen in recent high-performance MgB_2 wires. In this talk, we will report recently updated functions of our Hall-probe measurements as follows:
- in-field critical current distribution in long CCs
- applicability to long-length multi-filamentary CCs
- applicability to Roebel strands
- applicability to MgB_2 wires with magnetic materials.
These functions gave crucial information which could not be obtained by the conventional methods. Furthermore, they were all developed as non-destructive characterization methods which could be applicable to future product inspections. We believe that our efforts strongly contribute to further development of sophisticated superconducting wires and promote their application to practical devices.
This work was supported by “JSPS KAKENHI (16H02334, 16K14216)", “METI and AMED", and “JST-ALCA".

keywords : critical current distribution, coated conductor, MgB2, SHPM

WB4-2 16:15–16:30

Evaluation of low electric field characteristics in multi-filamentary Bi-2223 tape under high magnetic fields

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Because of its wide and flat geometry, a large magnetic moment will be induced in HTS tapes against perpendicular component of external magnetic field. Moreover, a relaxation of the magnetic moment is significant due to flux creep. Such magnetization in a tape strand is relevant for magnet applications because it will distort spatial- and temporal- stability in HTS based magnet. One of the advantages of a multi-filamentary Bi-2223 tape is its fast relaxation of the magnetic moment due to 2-dimensional nature. However, it is not yet clear the influence of filament coupling and field-, temperature-dependences. Magnetic moment measurement in a whole sample is often used to characterize flux creep properties in a superconductor, however, in such a multi-filamentary sample, it is inevitable to clarify spatial distribution of magnetization current. In this study, we have carried out in-field scanning Hall probe microscopy (SHPM) to investigate remanent state in a multi-filamentary Bi-2223 tape. From the relaxation, electric field (E) vs. current density (J) characteristics at low electric field ranges have been estimated. Combining these results with four probe measurement, we have successfully obtained wide-range of E-J characteristics from 10^{-10} to 10^{-3} V/m. We also obtained analytical expression of the E-J characteristics taking into account J_c distribution and flux hopping within the framework of percolation transition model [1]. From the comparison between the experimental results and the analytical expression, it has been shown that the flux creep can be estimated from flux flow property measured by the four-probe measurements.

This work was partly supported by the "METI and AMED: Development of Fundamental Technology for HTS Coils" and "JSPS: KAKENHI (24760235)". [1] T. Kiss et al., Physica C 392-396 (2003) 1053-1062.

keywords : Bi-2223, E-J characteristics

WB4-3 16:30–16:45

Carrier-Doping Dependence of Critical Current Density in $Ba_{1-x}K_xFe_2As_2$ Single Crystals and Superconducting Wires

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Iron-based superconductors (IBS) are of great interest for applications due to their large upper critical fields and low anisotropies. In particular, high critical current density, J_c, is realized in superconducting wires or tapes using 122-type IBS of $A_{1-x}K_xFe_2As_2$ (A = Ba, Sr) [1-4]. In these report, K content x in the staring materials for superconducting wires and tapes are 0.4 where T_c is optimized. In contrast, recently, Song *et al.* reported distinct doping dependence of J_c and T_c in $Ba_{1-x}K_xFe_2As_2$ single crystals, which is synthesized by KAs self-flux method [5]. The x-dependence of J_c is characterized by a peak at $x = 0.3$, which corresponds to the under-doped region. This result implies that higher J_c may also be achieved at under doped region in 122-type superconducting wires and tapes.

In this work, we focused on carrier-doping dependence of J_c in $Ba_{1-x}K_xFe_2As_2$ single crystals and superconducting wires. $Ba_{1-x}K_xFe_2As_2$ single crystals ($0.24 < x < 0.4$) are synthesized by commonly used FeAs self-flux method. $Ba_{1-x}K_xFe_2As_2$ wires are fabricated by powder-in-tube (PIT) method and hot isostatic pressing (HIP) technique, using polycrystalline $Ba_{1-x}K_xFe_2As_2$ ($0.25 < x < 0.4$) prepared by solid state reaction and silver and copper tubes. Their magnetic J_c is characterized by magnetization measurement. We found that the x-dependence of J_c in our single crystals also shows the peak in under-doped region around $x \sim 0.3$. In HIP wire, although significant peak is not observed, J_c shows a broad plateau in a wide doping region of $0.3 < x < 0.4$. These results may expand the doping level of starting materials for high-J_c superconducting wires and tapes.

[1] J. D. Weiss *et al.*, Nat. Mater. **11** (2012) 682.; [2] S. Pyon *et al.*, Supercond. Sci. Technol. **27** (2014) 095002.; [3] Z. Gao *et al.*, Sci. Rep. **4** (2014) 4065.; [4] H. Lin *et al.*, Sci. Rep. **4** (2014) 6944.; [5] D. Song *et al.*, Sci. Rep. **6** (2016) 26671.

keywords : Iron-based superconductor,, Ba1-xKxFe2As2, Critical current density, Single crystal

WB4-4 16:45–17:00

Development of Scribing Technique to Fabricate Multi-Filamentary Structure of Coated Conductors

*Takato Machi, Akira Ibi, Teruo Izumi

AIST

It is important to reduce the effect of shielding current and AC-loss in the case of magnet applications of $REBa_2Cu_3O_{7-\delta}$ (RE123) coated conductors (CCs) with high homogeneity and stability of magnetic field, such as Magnetic Resonance Imaging (MRI) and medical accelerator coils. As well known in the low temperature superconducting magnet, the multi-filamentary structure is indispensable for reducing the effect of shielding field and the AC-loss. For realizing similar structure in CCs, we have been developing the laser scribing technique as a method of fabricating the multi-filamentary CCs. In this presentation, it will be reported about the progress in R&D of laser scribing techniques for realization of higher production rate of scribing process and the improvement of quality of slot shape. And the characterized results will be shown such as magneto-optical images, magnetic properties, transport properties, etc.
This work was supported by METI, AMED and NEDO.

keywords : multi-filament, coated conductors, laser scribing

WB4-5 17:00–17:15

Calculation of Magnetic Force on Magnetic Levitation Tool with Superconducting Bulks by Finite Element Method

*Yuta Hiramatsu, Yu Takahashi, Edmund Soji Otabe, Keisuke Suzuki, Yuki Tanaka, Masaru Kiuchi

Kyushu Institute of Technology

Recently, some types of process technology are used. Hollow machining process is one of the technologies. Many technologies like 3D printer and die casting method have some problems, for example, long process time and difficult usage of hard metal. To solve these problems, magnetic levitation tool using magnetic floating force by superconducting bulk is effective. Magnetic levitation tool is the machine that permanent magnet is fixed floating by magnetic force of superconducting bulk, and slaves and grinds the object by driving force caused by rotating superconductor. In this study, magnetic floating force and driving force of permanent magnet are calculated by finite element method (FEM).
FEM calculation by JMAG-Designer 15.0 was performed using permanent magnet and superconductor, and observed J_c - B property of $YBa_2Cu_3O_7$ superconducting bulk at 77.3 K [1]. In this calculation, permanent magnet is 4-poles NdFeB ring magnet. Four superconducting quadrangular bulks are put under ring magnet. In this study, magnet is levitated at 10 mm above superconducting bulks.
For evaluation of magnetic floating force, attractive force and torque of ring magnet are calculated in case of field cooled magnetization (FCM). First, permanent magnet is fixed at 10 mm above the surface of the superconducting bulks. Then, the temperature of the bulks decreases to 77.3 K. It is confirmed that the attractive force occurs to magnet when the distance of bulks and magnet increases from equilibrium point. On the other hand, the repulsive force occurs to magnet when the distance of bulks and magnet decreases from equilibrium point. Thus, it is found that the calculation result roughly agrees well with experimental result. It is necessary for the calculation result to approximate the experimental result.
[1] W. Zhai *et al*, Cryst. Growth Des., (2015) **15** 907 - 914

keywords : Magnetic levitation tool, Superconducting bulk, Finite element method

WB5-1-INV 9:30–10:00

Flux pinning in REBCO thin films doped with artificial pinning centers

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4. CRIEPI

Nanoparticle doped GdBCO thin films were prepared on single crystal and IBAD-MgO substrates by alternating pulsed laser deposition using REBCO target and BaHfO3 (BHO) target as APCs. Volume fraction of APCs was tuned in the range of 3-10 vol. % by varying the supply of BHO. Crystallinity and microstructure of the films were investigated by x-ray diffraction and by transmission electron microscopy, and superconducting properties were measured by PPMS. Maximum global pinning force, Fpmax (=Jc×B, B || c), of the 5 vol. % doped film reached 18 GN/m3 at 77 K and 80 GN/m3 at 65 K, although the properties of 10 vol. % doped film were degraded severely at 77 K. We found, however, the low temperature properties of these films were excellent. Fp values (B || c) of the 5 vol. % film reached 350 GN/m3 at 40 K and 750 GN/m3 at 20 K, and exceeded 1000 GN/m3 at 10 K. These data are comparable to the best results obtained by the films containing self-assembled nanorods such as BaZrO3 or BHO, but plateau-like behavior of Fp-B curves typically observed in the naorods doped films were not identified for the present films. In addition, no maximum Fp peaks at 10 K and 20 K were observed in Fp-B curves below 9 T. We believe that periodically deposited BHO was randomly dispersed in the GdBCO films as nanoparticles instead of nanorods. We will discuss the flux pinning mechanism of these films based on the results of microstructure observation and the time-dependent Ginzburg-Landau flux pinning simulation.

keywords : Flux pinning, Critical current, Thin film, Coated conductor

WB5-2-INV 10:00–10:30

Recent Activities on R&D of Coated Conductors in JAPAN

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AIST (National Institute of Advanced Industrial Science and Technology)

Coated conductors (CCs) are expected for many applications because of its high potentials such as “high in-field performance”, “low AC loss”, “reduction of shielding current”, “high mechanical strength”. Through the several national projects in Japan, the CCs have been developed for electric power applications and medical ones etc., and lots of marvelous results have been achieved. The control technologies of artificial pinning centers (APCs) have been developed in Pulsed Laser Deposition and Metal Organic Deposition processes. In the both processes, worldwide level performance of Ic(B)/Jc(B) were realized, and the results make us image the real operation of several magnetic applications in liquid nitrogen. On the other hand, the scribing technique and the uniformity of 2-dimentional Ic distribution have been improved for lowering AC losses and control of the shielding current. Additionally, simple joint technique with low electric resistance has been developed. The paste including nano-sized metal particles were employed and the jointing at 150 ºC for 1 hr in air atmosphere were carried out and the resistance of nano-ohm level were confirmed.

The development of CCs has been continued and progressed. In this paper, the recent progress in Japan will be reviewed.

This work was supported by METI, AMED and NEDO.

WB5-3 10:30–10:45

Characterization of $YBa_2Cu_3O_y$ coated conductors with $BaHfO_3$ nanoparticle flux pinning centers by metal organic deposition

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$REBa_2Cu_3O_y$ (REBCO, RE = rare earth elements) coated conductors (CCs) have been considered as the prime materials for the electric power applications towards the next generation, due to its high current properties. Metal organic deposition (MOD) is the most appropriate process to fabricate REBCO-CCs because of its inexpensiveness, high material yield and facileness. The composition of starting solution of MOD can easily be controlled, so that to introduce artificial pinning centers (APC) into REBCOs, for the enhancement of critical current density (Jc) in magnetic fields. In this work, YBCO films with $BaHfO_3$ (BHO) as APC were fabricated by MOD and the influences of additional heating process on Jc in magnetic fields were investigated.
The starting solution was prepared by dissolving Y and Ba-trifluoroacetates, and Cu-octylate in the organic solvent with the Hf salts of 1 mol%. The solution was deposited on two $CeO_2/LaMnO_3/MgO/Gd_2Zr_2O_7$/Hastelloy substrates using a spin-coating method. The coated films were heated up to 703 K in a humid oxygen atmosphere to obtain the precursor films. After the cooling of precursor films, one sample was crystallized by conventional heating process at 1053 K for 150 min, the other one was done by additional heating process at 823 K in prior to the conventional heating process. As a result, in-field Jc of the film was increased more than 50% from 1.4×10^5 A/cm^2 to 2.2×10^5 A/cm^2 at 77.3 K in 3 T, after the introduction of additional heating temperature.

keywords : TFA-MOD, Jc property, Microstructure

WB5-4 10:45–11:00

Development of Artificial Pinning Center Introduced Coated Conductor by MOD Method Using a New Raw Material Solution

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Superconducting technology has been applied to devices such as MAGLEV and MRI utilized as a practical industries. When considering practical devices, in particular ones using high magnetic fields, it is necessary for coated conductor (CC) to be introduced artificial pinning center (APC) in order to realize high magnetic field properties. We have developed a CC in which $BaZrO_3$ nano-particles were uniformly dispersed in the superconducting layer. The J_c value was 0.2 MA/cm^2 at 77 K and 3 Teslas, and we have been developing various kinds of current lead which could be used in high-field magnets. However, the required properties in magnetic fields are increasing in a particular use. For the purpose of further improvement of magnetic properties, the material for APC was changed to other materials. Nakaoka et al. reported that Hf element was effective for a raw material of APC. Particles of $BaHfO_3$ were dispersed in the superconductor finer and more uniform compared with the conventional $BaZrO_3$ and it significantly improved the performance in magnetic fields.
In this report, we could obtain the J_c value of 4 MA/cm^2 at 77 K in self-field, which was nearly twice of the J_c in the case of $BaZrO_3$ APC. Dependence between the manufacturing conditions and superconducting properties, and results of long-length production will be reported.

keywords : Coated conductor, Artificial Pinning Center, MOD Method, Magnetic field properties

WB6-1-INV 11:15–11:45

Recent development of MgB_2 wires and $(Ba,K)Fe_2As_2$ tapes in NIMS

*Hiroaki Kumakura, Shujun Ye, Zhaoshun Gao, Akiyoshi Matsumoto, Kazumasa Togano

National Institute for Materials Science

MgB_2 is expected to operate under helium-free condition at ~20K to replace the practical metal superconducting wires in liquid helium condition. Internal Mg diffusion (IMD) method is an effective method in increasing filling factor of MgB_2 and enhancing Jc values of MgB_2 wires. High Jc values of ~1,500A/mm^2 in 4T and ~700A/mm^2 in 5T at 20K are obtained for these IMD wires with carbon substitution for B site. Je values higher than 100A/mm^2 at 4.2K and 10T are obtained for these IMD wires. Estimation of local Jc by the scanning Hall probe microscope(SHPM) indicates that there is some local Jc variation along the wire length for IMD processed MgB_2 wires. The minimum local Jc of the wire obtained by the SHPM is nearly equal to the transport Jc of the wires measured by the four-probe resistive method, suggesting that there is still room to improve Jc values. Fabrication of 100m-class IMD wires are now in progress.
The iron-based superconductors of K-doped $(Ba,K)Fe_2As_2$(Ba-122) are potentially useful for high field applications due to their high upper critical fields of over 50T and small anisotropy. However, improvement of Jc is still required to PIT processed Ba-122 tapes for such applications. Two important factors that much influence Jc of PIT Ba-122 tapes are the density and c-axis grain orientation of Ba-122 core in the tapes. Recently, we succeeded in obtaining large improvement of Jc values applying stainless steel(SS)/(Ag-Sn) double sheath materials. The Jc reaches to the practical level of 1,000A/mm^2 in magnetic fields up to 10T for flat rolled SS/(Ag-Sn) double sheathed tapes. These higher Jc values than those for pure Ag sheath and SS/Ag double sheath should be attributed to the more improved density and c-axis grain orientation of Ba-122 core together with the smoother interface between Ba-122 core and the Ag-Sn inner sheath.

keywords : critical current density, filling factor, c-axis orientation

WB6-2-INV 11:45–12:15

Trapped Field Properties of MgB_2 Superconducting Bulks Magnetized by Field-cooled and Pulsed Field Magnetizations

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Iwate University

MgB_2 superconducting bulk magnets have been intensively studied for the past five years. Since it is well known that the grain boundaries are predominant pinning centers for MgB_2, the refinement of grains and/or the densification have improved the trapped field properties. A hot pressed (HPed) MgB_2 bulk using the ball-milled nano-powder trapped 5.4 T at 12 K by field-cooled magnetization (FCM) [1]. The trapped field of 4.6 T by FCM was obtained at 14 K for the doubly stacked Ti-doped bulks fabricated by a hot isostatic pressing (HIPing) method [2]. The dense MgB_2 bulks can also be synthesized by an infiltration method without pressing and specific furnace, contrary to the HP and HIP methods. Recently, we succeeded in fabricating the high quality infiltration-processed MgB2 bulk trapping 2.4 T at 16.2 K, which was comparable with those of the HPed and HIPed bulks [4]. On the other hand, the trapped field by the pulsed field magnetization was still lower than that by FCM. The record-high trapped field of 1.1 T was achieved for the HIPed bulk using a split-type magnetizing coil equipped with a soft-iron yoke [5]. In this presentation, we discuss the recent progress in the MgB_2 bulk magnets.
Acknowledgements:
This work was partly supported by JSPS KAKENHI Grant Numbers JP15K04718, JP15K04646.
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keywords : MgB_2, bulk magnet

WB6-3 12:15–12:30

Record critical current density in bulk MgB_2 using carbon-coated amorphous boron and optimum sintering conditions

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We report on the synthesis and characterization of a sintered bulk MgB_2 material produced at an optimized sintering temperature with a varying content of carbon-encapsulated boron. The MgB_2bulk was prepared from commercial powder of Mg metal (99.9% purity) and 0%, 1.5%, 2.8%, 4.5%, 7.3%, 12% and 16.5% of carbon-encapsulated boron using a single-step solid state reaction at 805°C for 3 h in pure argon atmosphere. XRD results proved that the main phase was MgB2 for all samples. In the samples with 12% of carbon-encapsulated boron, Mg and MgB_2C_2 formation was also observed. The temperature dependence of magnetization confirmed a sharp superconducting transition with onset Tc at around 38.4 K, decreasing with increasing carbon content, reaching 25 K in the samples with 16.5 % of carbon-encapsulated boron. Scanning electron microscopy (SEM) by EDX analysis showed a homogenous carbon distribution in the whole samples produced with low contents of the carbon-encapsulated boron. The highest Jc values of 470 kA/cm^2 and 310 kA/cm^2, in the self-field and 1 T, respectively, were achieved at 20 K, in the MgB_2 sample with 1.5% of carbon-encapsulated boron. The present results clearly demonstrate that the optimized sintering temperature combined with the appropriate amount of the carbon-coated boron is able to improve the entire critical current performance of the bulk MgB_2 material.
This work was supported by Grant-in-Aid FD research budget code: 112261, Shibaura Institute of Technology and by APVV No.0330-12, VEGA 2/0121/16.

keywords : MgB2, carbon-encapsulated boron, high critical current density, flux pinning

WB6-4 12:30–12:45

The performance improvement of MgB_2 prepared by the Mg diffusion method with the MgB_4 addition

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The Mg diffusion method with the MgB_4 doping is developed to improve the MgB_2 application performance. The precursor powders are uniformly mixed with compositions$(1- 4x)$mol % of B + x mol % of MgB_4 (x = 0, 1, 2, 5, 10 and 20) and pressing into bulks, together with excessive amounts of Mg powders into the iron tube for heat treatment under pure argon atmosphere. The high-quality MgB_2 bulks are achieved with higher density and smaller grains when x = 2. The superconducting critical temperature decreases slightly with the increase of MgB_4, and the critical current density increases for the samples with x = 2 and 5. These results suggest that the Mg diffusion method with a right amount of MgB_4 doping could be a good alternative to manufacture MgB_2 bulks with excellent performance. This method also provides a way to improve the internal Mg diffusion (IMD) process with the increase of the Mg diffusion distance and the decrease of the un-reacted B particles amount. However, there is almost no porosity introduced in the process.

keywords : MgB2, Mg diffusion method, MgB4 doping

ED1-1-INV 13:45–14:10

Single Microwave Photon Detector

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1. RIKEN Center for Emergent Matter Science; 2. College of Liberal Arts and Sciences, Tokyo Medical and Dental University; 3. MIT Lincoln Laboratory; 4. Department of Physics, Tokyo University of Science; 5. NEC IoT Device Research Laboratories; 6. Research Center for Advanced Science and Technology, The University of Tokyo

Single-photon detection is essential to many quantum-optics experiments, enabling photon counting and its statistical and correlational analyses [1]. It is also an indispensable tool in many protocols for quantum communication and quantum information processing [2]. In the optical domain, various kinds of single-photon detectors are commercially available and commonly used [1,3]. However, the detection of a single microwave photon in an itinerant mode remains a challenging task due to its correspondingly small energy. In this presentation, we demonstrate an efficient and practical single microwave-photon detector based on the deterministic switching in an artificial Λ-type three-level system implemented using the dressed states of a driven circuit-quantum electrodynamics system [4]. The detector operates in a time-gated mode and features a high quantum efficiency 0.66 ± 0.06, a low dark-count probability 0.014 ± 0.001, a bandwidth ~2π x 16 MHz, and a fast reset time ~400 ns. The efficiency limited by a relaxation time (T_1) of the qubit can readily exceed 0.9 by improving T_1 [5]. It can be readily integrated with other components for microwave quantum optics.

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keywords : circuit quantum electrodynamics, impedance-matched Λ system, superconducting flux qubit, microwave photon detector

ED1-2-INV 14:10–14:35

Josephson parametric amplifier/oscillator and its application to quantum information processing

*Zhirong Lin[1], Kunihiro Inomata[1], Kazuki Koshino[2], Jaw-Shen Tsai[1,3], Tsuyoshi Yamamoto[4], Yasunobu Nakamura[1,5]

1. Center for Emergent Matter Science (CEMS), RIKEN; 2. Tokyo Medical and Dental University; 3. Tokyo University of Science; 4. NEC Corporation; 5. The University of Tokyo

Superconducting circuits are demonstrated to be a very promising platform for constructing large scale quantum processor. Meanwhile, Josephson parametric amplifier (JPA) has become an important resource for superconducting quantum information experiments. We incorporated a flux-driven JPA [1] as a preamplifier in our setup for the readout of superconducting qubits. This led to drastic improvement in the signal to noise ratio and enabled us to achieve single-shot readout and observation of quantum jumps [2]. Same circuit of the flux-driven JPA can also work as a parametric phase-locked oscillator (PPLO) at the pump power above the oscillation threshold. Using a PPLO, we demonstrated a fast, high-fidelity, and non-destructive readout [3]. The new readout scheme combines the advantages of several disparate schemes developed. The developed qubit-readout technique with PPLO was applied to itinerant microwave-photon detection of single-microwave photon, which remains a challenging task due to its correspondingly small energy [4].

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keywords : superconducting circuit, quantum information

ED1-3-INV 14:35–15:00

Direct Observation of the Thickness Distribution and Atomic Structure of Ultra Thin AlOx Barriers in Al/AlOx/Al Josephson Junctions

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The thinnest region in the barrier of a Josephson junction will be the preferential tunneling channel for the charge carriers and give rise to the highest tunnel current due to the exponential increase of tunnel current with decreasing barrier thickness. As a consequence, even small variations, on the individual atom plane length scale, will result in inhomogeneity of the tunnel current across the barrier. There are several earlier experimental indirect indications that only a small fraction of the junction area is active. We have used high resolution annular dark field scanning transmission electron microscopy imaging to directly determine the thickness distribution along the oxide barrier in Al/AlOx/Al Josephson junctions. The barrier thickness is about 1-2 nm. The thickness distribution shows that less than 10% of the junction area dominates the electron tunneling. We have also studied how the distribution varies with oxygen pressure and oxidation time. In addition, we have determined the atomic structure and coordination of Al atoms within the oxide barrier layer. A lower Al coordination is observed at the metal/oxide interface compared to the interior of the oxide barrier.

[1] L.J. Zeng, S. Nik, T. Greibe, P. Krantz, P. Delsing and E. Olsson, “Direct Observation of the Thickness Distribution of Ultra Thin AlOx Barriers in Al/AlOx/Al Josephson Junctions”, J. Phys. D: Appl. Phys.48 (2015) 395308
[2] L.J. Zeng, D.T. Tran, C.-W- Trai, G. Svensson and E. Olsson, “Atomic Structure and Oxygen Deficiency of the Ultrathin Aluminium Oxide Barrier in Al/AlOx/Al Josephson Junctions”, Sci. Rep. 6 (2016) 29679.

keywords : Al/AlOx/Al Josephson junctions, oxide barrier thickness variation, atomic structure within oxide barrier

ED1-4 15:00–15:20

Niobium SIS Junction Technology for Sub-mm Wave Mixers

*Matias Kroug, Mizuki Ikeya, Takafumi Kojima, Takeshi Noguchi

National Astronomical Observatory of Japan

Future heterodyne receivers for radio astronomy are expected to show improved performance in areas such as ultra-wide RF bandwidth, low noise and multi-pixel coupling schemes. At NAOJ we are developing various types of SIS junction technologies to meet these requirements. Here we will present results on Nb junctions with critical current densities j_c=10-30 kA/cm^2 *and* low leakage. Owing to their shorter time constant, high current density junctions are potentially interesting for SIS mixers where a large fractional bandwidth is required. We have fabricated and characterized junctions based on two types of try-layers: Nb/Al,AlO_x/Nb, the standard in most SIS circuits, and Nb/Al,AlO_x/Al/Nb where a second layer of aluminium, coined Al cap layer, has been added. Its thickness is about 3-4 nm, roughly half of that of the Al over layer. When comparing characteristics of the two types of junctions, fabricated under identical conditions with respect to oxide barrier formation, we make three major observations: Al cap layer type junctions (1) have a lower current density, (2) their sub-gap leakage is substantially reduced and (3) the gap voltage decreases by 0.05–0.1 mV. We speculate that if the Nb counter electrode is deposited directly onto the ultra-thin AlO_x barrier, niobium reacts with oxygen thereby making the insulating layer `thinner`, e.g. more transparent. It also can create additional defects resulting in deteriorated junction quality. Mixers based on high quality cap-layer type junctions, with j_c~25 kA/cm^2 and sub-gap to normal-state resistance ratios of 20 or better, have successfully been tested in a 400 – 500 GHz receiver.

keywords : SIS junctions, niobium, aluminium oxide, ultra-thin barrier

ED1-5 15:20–15:40

Elemental Intermixing and Gap States at the Substrate Interfaces of Al Based Josephson Junctions

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1. Department of Physics, Chalmers University of Technology, Gothenburg, Sweden
2. Department of Microtechnology and Nanoscience, Chalmers University of Technology

In recent years, significant research effort has been devoted to identifying the origin of noise and how to diminish it in superconducting quantum devices [1]. The charge noise in single electron transistors made from Josephson junctions is understood to originate from the dielectric environment of the junctions [2]. Decoherence in superconducting qubits may also be caused by noise originating from defects accommodated at the qubit/dielectric interfaces [3]. Hence, studying the microstructure at the interface between the Josephson junction and the dielectric substrates is of great importance for the determination of possible sources of noise in Josephson junction based superconducting devices. We have studied the detailed structure of the junction/substrate interfaces of Al/AlO_x/Al Josephson junctions fabricated on SiO_2 and Si substrates by transmission electron microscopy (TEM). We have found that there is an intermixing layer with a thickness of around 5 nm at the Al/SiO_2 interfaces of junctions grown on SiO_2/Si substrates [4]. The layer contains alumina with the aluminium atoms being octahedrally coordinated rather than tetrahedrally coordinated, which is the most common type in amorphous alumina. Depth profiles of the Al-O and Si-O bonding characteristics were also determined. They show the presence of defect states, within the band gap of SiO_2, at the interface region and the states can be related to the elemental intermixing. Also for junctions grown on Si substrates, an amorphous layer with a thickness of ~ 5 nm was found between the bottom Al electrode and HF-treated Si substrates [5]. It results from intermixing between Al, Si and O. The alumina formed at the Al/Si substrate interface shows the tetrahedral Al-O coordination in contrast to that found at Al/SiO_2 substrate interfaces.

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keywords : Al Josephson junctions, noise, junction substrate interface, microstructure

ED2-1-INV 15:55–16:20

Design methodologies toward large-scale adiabatic quantum-flux-parametron integrated circuits

*Christopher L. Ayala[1], Qiuyun Xu[2], Yuki Murai[2], Ro Saito[2], Naoki Takeuchi[1], Yuki Yamanashi[1,2], Thomas Ortlepp[1,3], Nobuyuki Yoshikawa[1,2]

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2. Department of Electrical Engineering and Computer Engineering, Yokohama National University, Japan
3. CiS Research Institute for Microsensor Systems GmbH, Erfurt, Germany

Adiabatic quantum-flux-parametron (AQFP) logic is an emerging technology in superconducting electronics that shows promise towards building extremely energy efficient computing systems with bit energies approaching $100k_BT$ and has already demonstrated circuits consisting of more than 1000 Josephson junctions. To push forward for larger, more complex AQFP digital logic circuits, a systematic design approach and an electronic design automation (EDA) toolchain need to be established. First, a minimalist AQFP logic cell library has been developed, whose core components consist of only a buffer cell, NOT cell, branch cell, and constant-1/-0 cells. Each core component has been optimized and designed modularly such that one can mix-and-match pieces together to form any Boolean logic operator. Next, the AQFP logic cells have been modeled using Verilog HDL (hardware description language) infused with transport delays and timing windows extracted from analog simulation to help the designer perform timing closure. Automated wiring tools have been developed to speed up the design flow of the interconnect between layers of AQFP logic. By combining the cell library, HDL models, and wiring tools, a basic logic synthesis flow has been put together to transform a high-level description of a digital circuit in Verilog/VHDL into its physical layout. With this basic design flow in place, we have the key elements that will enable us to design higher complexity AQFP circuits.

keywords : aqfp, superconductor electronics, vlsi, digital logic

ED2-2-INV 16:20–16:45

Energy-Efficient, High-Performance Microprocessors Based on Single-Flux-Quantum Logic

*Masamitsu Tanaka[1], Ryo Sato[1], Yuki Hatanaka[1], Yuki Ando[2], Takahiro Kawaguchi[2], Koki Ishida[3], Akira Fujimaki[1], Kazuyoshi Takagi[2], Naofumi Takagi[2], Takatsugu Ono[3], Koji Inoue[3]

1. Nagoya University; 2. Kyoto University; 3. Kyushu University

We present recent progress in study on microprocessors based on single-flux-quantum (SFQ) logic. The rapid single-flux-quantum (RSFQ) logic is promising for future LSIs because of sub-terahertz-clock-frequency operation. Its energy-efficient derivatives with reduced- or zero-static power consumption were recently proposed and demonstrated, by which the superconductor digital circuits become more attractive for high-performance computing.
Bit-serial processing is a unique approach for SFQ circuits, by which we can achieve ultrafast clock frequencies with a minimal hardware cost. We have demonstrated 100-GHz, 1-mW operation of a bit-serial microprocessor with a mixed-voltage design, in which we carefully selected the bias voltages depending on the targeting operating frequencies to balance performance and power consumption. Recently, we have started development of bit-serial microprocessors with embedded random access memory, and confirmed successful operation by on-chip high-speed testing. The microprocessor is made up of 10,603 Nb/AlOx/Nb Josephson junctions whose critical currents are reduced by 30%, and consumes 2.52-mW power. The instruction set includes 13 essential instructions to demonstrate small, but real programs, such as finding the highest proper divisor and greatest common divisor.
Much higher performance is achieved by introducing parallelized processing. We have already demonstrated 50-GHz operation of a 4-bit bit-slice arithmetic logic unit (ALU). We also report the latest design of an 8-bit bit-parallel ALU which realizes 50-GHz gate-level pipelining.
Acknowledgements: This work was supported by JST-ALCA, JSPS KAKENHI (26220904, 16H02796) and partly by VDEC, University of Tokyo in collaboration with Cadence Design Systems, Inc. The circuits were fabricated in the AIST CRAVITY.

keywords : single-flux-quantum logic, microprocessor, energy-efficiency, computing

ED2-3 16:45–17:05

Run-to-Run Yield Evaluation of Improved Nb 9-layer Advanced Process using SFQ Shift Register Chip Including 68,990 Josephson Junctions

*Shuichi Nagasawa, Mutsuo Hidaka

National Institute of Advanced Industrial Science and Technology (AIST)

We have been developing a Nb 9-layer advanced process (ADP2) for large-scale single flux quantum (SFQ) circuits [1]. In the ADP2, the bias-sputtering SiO_2 had been used for an inter-layer insulator, however we replaced the bias-sputtering SiO_2 with a plasma-enhanced chemical vapor deposition (PECVD) SiO_2, which has advantages such as good step coverage, low film stress, lower temperature process, and fewer particles. At first, although there were several problems to apply PECVD SiO_2 for the actual device structure, we could eliminate the problems due to the surface profile of the PECVD SiO_2 by adding an ion-milling process. The reliability of ADP2 was evaluated by the operating yield of the SFQ shift registers (SRs). The SRs with six different bit sizes from 16 to 2560 were designed to evaluate the circuit size dependency of their yields. Total number of SRs is 16, and total number of junctions becomes 68,990 per chip. By introducing the PECVD SiO_2 insulator, we could obtain a high operating yield of more than 80% even for large scale 2560bit shift registers having junctions of more than 10, 000. Moreover, we could obtain nine perfect chips within 26 measured chips for the recent fabrication runs using PECVD. The perfect chip means that all SRs of the chip were successfully operated. From these results, we believe that fabrication yield of our Nb 9-layer advanced process is close to a level of 100, 000 Josephson junction circuits.
This work is supported by ALCA-JST project, and fabrications were performed in the clean room for analog-digital superconductivity (CRAVITY) of AIST.
[1] S. Nagasawa, K. Hinode, T. Satoh, M. Hidaka, H. Akaike, A. Fujimaki, N. Yoshikawa, K. Takagi, N. Takagi, IEICE Trans. Electron., vol. E97-C, no. 3, pp. 132-140, Mar. 2014.

keywords : Superconductivity, Fabrication process, SFQ, PECVD SiO2

ED2-4 17:05–17:25

Thermally-Fluctuated Single-Flux-Quantum Pulse Intervals Reflected in Input-Output Characteristics of a Double-Flux-Quantum Amplifier

*Yoshinao Mizugaki, Yoshiaki Urai, Hiroshi Shimada

The University of Electro-Communications

Over-biasing a Josephson transmission line is a simple method for feeding single-flux-quantum (SFQ) pulse trains into Josephson circuits. We refer to this method as an "over-biasing method" and employ it for evaluation of double-flux-quantum amplifiers (DFQAs) [1], especially for determination of their maximum input voltage (V_{IN_MAX}) and the corresponding frequency (f_{IN_MAX}) [2,3]. We have recently found that there is always slight difference between the experimental and numerical input-output (IO) characteristics near V_{IN_MAX}, where the input SFQ pulses are fed by the over-biasing method in experiments and by periodic current pulses in simulation.
In this paper, we present experimental IO characteristics of a 100-fold DFQA on Nb IC and compare them with numerical results. Numerical simulation including thermal noise of 4.2 K [4] suggests that thermally-fluctuated pulse intervals gradually deteriorate IO characteristics of a DFQA near V_{IN_MAX} when the over-biasing method is employed for feeding SFQ pulses.
This work was partially supported by VDEC, the University of Tokyo in collaboration with Cadence Design Systems, Inc. The circuits were fabricated in the CRAVITY of AIST with the STP2.
[1] Q. P. Herr, IEEE Trans. Appl. Supercond., 15 (2005) 259.
[2] Y. Sato, et al., Physics Procedia, 45 (2013) 221.
[3] Y. Mizugaki, et al., Jpn. J. Appl. Phys., 53 (2014) 053101.
[4] J. Satchell, IEEE Trans. Appl. Supercond., 7 (1997) 3315.

keywords : Josephson effects, Stochastic, histogram, Nb/AlO_x/Nb

ED3-1-INV 9:15–9:40

Ultra-Low Field MRI Application of High-Tc SQUID Magnetometer

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Toyohashi University of Technology

We developed an Ultra-Low Field (ULF) MRI system using a flux transformer and a high temperature superconductor (HTS) superconducting quantum interference device (SQUID) for use in commercial food inspection. A ULF MRI system has several advantages: small size, low cost and a moderate magnetic field uniformity requirement. However, there is a drawback in that the signal is extremely small. As a result, the low signal to noise ratio (SNR) is lower [1]. In this paper, we describe the improvement of the SNR of the nuclear magnetic resonance (NMR) signal and the improved results of 2D MR images.
A special cryostat made of G-10 fiber glass epoxy, which had a room temperature bore was designed and made. A Cu wound flux transformer, which was composed by a differential pickup coil and an input coil cooled at 77 K by liquid nitrogen, was installed in the cryostat. In an LC resonant mode a capacitor with proper capacitance was inserted into the flux transformer circuit. A modified Helmholtz coil for measurement field was designed and prepared to improve field distribution. A water phantom, which consisted of multiple cells was pre-polarized in the permanent magnet and transferred to one side of the pickup coil. After repeating proper sequences, spin-echo signals were obtained for twenty four projections. Finally a 2D-MR image was reconstructed from the grid processing raw data using the 2D fast Fourier transform method. As a result, each small cell was able to be clearly identified.

[1] S. Kawagoe, H. Toyota, J. Hatta, S. Ariyoshi and S. Tanaka, “Ultra-Low Field MRI Food Inspection System Prototype", Physica C: Superconductivity and its applications (2016), http://dx.doi.org/10.1016/j.physc.2016.02.015

keywords : SQUID, Low field MRI, detection

ED3-2-INV 9:40–10:05

Wide-area induction logging system using HTS-SQUID as a highly-sensitive magnetometer

*Tsunehiro Hato[1], Akira Tsukamoto[1], Seiji Adachi[1], Yasuo Oshikubo[1], Hidehisa Watanabe[2], Hidehiro Ishikawa[2], Chikara Okada[2], Ayato Kato[3], Makoto Harada[3], Keita Yoshimatsu[3], Yousuike Kunishi[3], Keiichi Tanabe[1]

1. SUSTERA; 2. MINDECO; 3. JOGMEC

We have tried to develop a wide-area induction logging system utilizing high-temperature superconducting quantum interference devices (HTS-SQUIDs) to monitor CO_2 behavior in Enhanced Oil Recovery (EOR) technology. CO_2-EOR technology is a promising technique for efficient production of petroleum. Recently, a new technique of changing CO_2 to CH_4 based on biotechnology has also attracted attention. CO_2-EOR is important not only for oil producing countries but also environmental conservation of the earth. To control the EOR, it is important to improve accuracy of monitoring technique of CO_2 behavior in reservoir. Though the seismic exploration technique is useful to detect the reservoir structure, the electromagnetic method with highly-sensitive magnetometer is expected to provide improvement of monitoring technology.
Based on these backgrounds, we prospected a possibility of SQUID system to monitor the CO_2 movement in reservoir by simulation, and we found the sensitivity of HTS- SQUID is useful to this objective. Then, we confirmed the stable operation of SQUID through a 3000 m-long optical fiber, stable cooling of SQUIDs using long release tubes for evaporated N_2, and prepared a vessel made of carbon fiber reinforced plastic (CFRP) with pressure tightness of 70 MPa and heat-resistance of 200 ^oC. By using the SQUID system placed at a depth of 300 m in a steel-cased borehole filled with water, magnetic signals from a transmitter coil in another borehole were successfully measured. And the SQUID in borehole detected large enough magnetic signal from the transmitter coil on the ground at a distance of 800 m successfully. These results suggested a possibility of wide-area induction logging monitoring system for CO_2-EOR.
This study was conducted under the JOGMEC Technical Solutions Project.

keywords : HTS-SQUID, Induction logging, CO2-EOR, monitoring

ED3-3 10:05–10:25

Research on HTS-SQUID NDE technique for pipes based on ultrasonic guided wave

*Yoshimi Hatsukade, Natsuki Masutani, Shouta Teranishi, Ken Masamoto, Shouya Kanenaga

Kindai University, Faculty of Engineering

This paper describes research on novel remote HTS-SQUID NDE technique for pipes based on ultrasonic guided waves. We constructed HTS-SQUID NDE system for pipes based on ultrasonic guided wave testing, while utilizing magnetostrictive effects. Using the system, we investigated effects of changing parameters, such as direction of a HTS-SQUID gradiometer, liftoff distance, and intensity and frequency of input current fed to a magnetostrictive transmitter, that generated T(0,1) mode ultrasonic guided waves ranging 10 to 100 kHz. We clarified limitations of detectable length and liftoff, direction of generated magnetic signals, and dependencies of the generated magnetic signals on the intensity and frequency of the input current.

keywords : HTS-SQUID, ultrasonic guided wave, magnetostrictive effects, pipe

ED3-4 10:25–10:45

QUANTITATIVE AND HIGH-RESOLUTION MAGNETIC IMAGES OBTAINED BY STM-SQUID MICROSCOPE WITH DISTANCE MODULATION TECHNIQUE

*Tsutau Yokocho, Hideo Sato Akaba, Yuji Miyato

Osaka University

We have developed an STM-SQUID microscope, in which a scanning tunneling microscope (STM) is combined with an rf-SQUID. The feature of our SQUID microscope is to use a probe with high-magnetic permeability for an STM probe as well as for a flux guide to transfer local magnetic flux over a sample into the SQUID. Hence, the tomographic and magnetic images are obtained simultaneously by our microscope. However, our conventional magnetic image wasn't perfectly the same as the ideal magnetic field distribution on the sample surface. This was because the probe transferred the magnetic flux not only from the tip but also from the side of the probe. It means the magnetic image was affected not only by the magnetic field on the sample surface, but also by the field far away from the sample, namely the “background field". The influence of the background field tends to appear in the magnetic image as the offset. We calculated and analyzed the magnetic field distribution around the probe in our microscope. Comparing the magnetic field distributions at the different probe positions changed within tens of nanometers, we found that the background field was distributed almost equally among the different positions and the change of the field around the probe tip was significant. For that reason, we focused on the distance modulation technique to our microscope. In this technique, the change of SQUID output signal was detected while the distance between the sample and the probe was modulated in a constant amplitude. As a result, the influence of the background field was canceled out, and the magnetic information near the sample surface was largely extracted. Thus, we successfully obtained the quantitative magnetic images with sub-100 nm spatial resolution by using distance modulation technique.

keywords : rf-SQUID, SQUID microscopy, magnetic microscopy, distance modulation

ED4-1-INV 11:00–11:25

Superconducting Receivers for ALMA Radio Telescope and Future Development

*Takafumi Kojima[1], Alvaro Gonzalez[1], Matthias Kroug[1], Yasunori Fujii[1], Keiko Kaneko[1], Wenlei Shan[1], Shinichiro Asayama[1], Yoshinori Uzawa[2], Kazumasa Makise[2], Hirotaka Terai[2], Zhen Wang[2]

1. National Astronomical Observatory of Japan
2. National Institute of Information and Communications Technology

The Atacama Large Millimeter/submillimeter Array (ALMA) is the largest ground-based radio-astronomical telescope located in the Atacama desert, 5,000 m above sea level in northern Chile, South America, it is a collaboration between East Asia, Europe, and North America. The telescope consists of 66 antennas and covers atmospheric windows in the frequency range from 35 GHz to 950 GHz which is divided into 10 bands. One of Japan's roles in the ALMA project is the development, manufacturing and delivering of Band 4 (125-163 GHz), Band 8 (385-500 GHz), and Band 10 (787-950 GHz) heterodyne receivers to be installed in all the antennas. In total, 73 receivers including 7 spares are required for each frequency band. The ALMA heterodyne receivers met the noise performance of less than 3-5hf/k_B for 4 K operation, based on superconductor-insulator-superconductor mixers. The delivered receivers have already been installed in all the ALMA antennas and been now used for observations.
Although our receivers have shown the-state-of-the-art performance, future heterodyne receivers for radio astronomy are expected to enhance performance. We have started to upgrade and develop new technologies to extend ALMA such as a supra-terahertz receiver up to 1.6 THz (Band 11), multi-pixel heterodyne receivers, ultra-wideband receivers and so on.
In this presentation, we will summarize the performance of all the production receivers and describe future receiver development for the ALMA.

keywords : SIS mixer, ALMA, submillimeter wave, low noise

ED4-2 11:25–11:45

Development of Superconducting Detectors for Dark Matter Searches using Liquid Helium

*Hirokazu Ishino[1], Atsuko Kibayashi[1], Yosuke Kida[1], Naoto Hidehira[1], Yosuke Yamada[1], HIrotake Yamamori[2], Fuminori Hirayama[2], Satoshi Kohjiro[2]

1. Okayama University; 2. National Institute of Advanced Industrial Science and Technology (AIST)

We report the status of development of superconducting detectors aiming for searches of dark matter particles using liquid helium. The dark matter is considered to be weakly interacting massive particles (WIMPs). Direct searches for the WIMPs have been conducted using Xe, NaI, Ge and Si as target. Those experiments have sensitivity the WIMP mass down to about 10 GeV/c2. No clear signals of the WIMPs have been found. Searching for the light WIMP mass region less than 10 GeV/c2 has been recognized to be very important in recent researches. In 2013, W. Guo and D. N. McKinsey have proposed to use liquid helium as the target. Recoiled helium will produce scintillation light photons with the wavelength of 80 nm (16eV in energy). We propose to use superconducting detectors to detect the photons directly in liquid helium. To have a large acceptance in the dewar, we use LEKIDs that enable us to readout in frequency domain multiplexing, reducing the number of readout cables, thus heat load.

The superconducting detectors are fabricated with photolithographic techniques in clean rooms, CRAVITY at AIST and one at KEK. We optimize the LEKID design so that the cross-talks among the resonators reduce to less than 1% level while fill the detector area as large as possible. We use Nb or NbN for the superconducting material. The detector is evaluated using a visible laser light pulse using cryogenic optical fiber system. We have also developed a customized KID readout system. We employ the KC705 Kintex-7 evaluation board for the firmware development. The firmware generates KID's resonant frequency microwaves and sends them to KID. The returned microwaves are digitized and converted to time-domain. We implement a self-trigger system to extract the pulse signals of KIDs which are then sent to PC through the SiTCP.

keywords : Kinetic Inductance Detector, Dark Matter

ED4-3 11:45–12:05

GroundBIRD - quest for the begin of the Universe by using cutting-edge superconducting detectors, KIDs

*Jun'ya Suzuki, Osamu Tajima

High Energy Accelerator Research Organization (KEK)

The cosmic inflation is a promising scenario to describe the origin of the Big Bang universe. Precise measurements of the cosmic microwave background (CMB) radiation, in particular its polarization patterns larger than one degree-scale, are the best experimental approach to prove the cosmic inflation. The GroundBIRD aims this target based on a unique technology: a combination of high-speed scan modulation and kinetic inductance detectors (KIDs). The scan modulation mitigates effects of 1/f noise due to instruments, atmospheric fluctuation and so on. KID is a cutting edge superconducting detector, and its fast time response is well matching with the high-speed scan. A single pixel consists of millimeter-wave circuits (antennas and transmittance circuits), two superconducting resonators, and a feed-line. We have horn antenna coupled KID arrays in 145 and 220 GHz bands. The signal via each horn is transmitted to the resonators. Single wafer consists of one feed-line, 110 (224) resonators, and 55 (112) millimeter-wave circuits for 145 GHz (220 GHz) band. A combined simulation using three types of simulators allows us to optimize millimeter-wave circuits. In the KID fabrication stage, we employ ``hybrid processing'': a combination of mask aligner and stepper for exposure of the photo-resist. A combination of them fulfills our requirements: coupling of resonators with single feed-line on a full wafer area, and periodic processing of the millimeter-wave circuits. We will present a status of our detector developments as well as other instrumental components.

keywords : Kinetic Inductance Detector, millimeter wave, polarization, cosmology

ED4-4 12:05–12:25

Development of Iridium-Based Small TES

*Hiroyuki Takahashi, Masashi Ohno

The University of Tokyo

We have been studying on iridium TESs since 1996. Transition temperature of iridium is 113 mK and this temperature is suitable for TES operation at popular ultra-low temperature refrigerators. However, poor thermal conductivity of iridium makes it difficult to operate a large area sensor. This drawback is partly compensated by a higher resistance and faster signal compared with TESs of lower normal resistance. We have fabricated many small TESs with different geometry. We found that the TES suffers from unstable baseline noise, which should be controlled. The iridium TES is also promising for near infrared applications. The small heat capacity, in turn, sometimes is not favorable for X-ray applications because of the nonlinear pulse height response. However, such non-linearity could be compensated by an integration of a current pulse signal, which enables this kind of detector in a saturated regime. The advantage of such a direction is towards a timing measurement and extremely simplify the multiplexing approach using a Time over Threshold method and digital readout.

keywords : Transition Edge Sensor, X-ray, Photon

ED4-5 12:25–12:45

Delay line current-biased kinetic inductance detector for imaging

*Takekazu Ishida[1], Yuya Miki[1], Hiroyuki Yamaguchi[1], Hiroaki Shishido[1], Shigeyuki Miyajima[2], Mutsuo Hidaka[3], Tomio Koyama[4]

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A superconducting nanowire meander has an inductance L consisting of a magnetic inductance L_m and a kinetic inductance L_k. A small contribution of kinetic inductance ΔL_k ($<<L_k$.) from an envisaged hot spot gives a voltage of $V = I_b\, d(\Delta L_k)/dt$ induced by a decrease of Cooper pair density. Our current-biased kinetic inductance detector (CB-KID) [1,2,3] can be used for imaging. When a certain amount of energy is dissipated in a hot spot of the nanowire, a signal of positive polarity propagates toward one electrode while a signal of negative polarity propagates toward another electrode. A time difference in the arrival clocks at the two electrodes gives the position of the event by knowing propagation velocity. We succeeded in demonstrating a clear restoration of the University emblem drawn by a focused laser on a CB-KID sensor. We give the Josephson-coupled micro-stripline London model to explain the signal propagation. This method can be applied to various different external stimuli such as photons, neutrons, gamma rays, X-rays, ions, molecules, terahertz radiations, etc.

[1] T. Ishida et al., J. Low Temp. Phys. 167, 447 (2012).
[2] N. Yoshioka et al., IEEE Trans. Appl. Supercond. 23, 2400604 (2013).
[3] Y. Narukami et al., IEEE. Trans. Appl. Supercond. 25, 2400904 (2015).

Acknowledgment
This work is supported by Grant-in-Aid for Scientific Research No. 23226019 and No.16H02450 from JSPS. The devices were fabricated in CRAVITY and were designed by the use of VDEC with the collaboration with Cadence Corporation.

keywords : superconducting imager,, current-biased kinetic inductance detector, delay line, the Josephson-coupled micro-stripline London model

AP1-1-INV 9:30–10:00

Development of high field cryogen-free superconducting magnets at Tohoku University - 25T-CSM and future prospect –

*S. Awaji

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We have developed a 25 T cryogen-free superconducting magnet (25T-CSM) under the “High Magnetic Field Collaboratory in Japan” project established in 2012 at the Science council of Japan. The 25T-CSM consists of the inner HTS, middle Nb_3Sn Rutherford and outer NbTi Rutherford coils. The Nb_3Sn and NbTi (LTS) coils are connected in series and generate a 14 T in a 300 mm bore by an operation current of 854 A. The Nb_3Sn Rutherford cable coil was made by a react-and-wind (R&W) method with the pre-bending treatment, i.e., application of 0.5% repeated double bending strains. The high stress design is possible because the high strength CuNb/Nb_3Sn strands. The maximum hoop stress on the Nb_3Sn coil is about 250 MPa. The LTS coils are cooled by the two GM/JT cryocoolers. For the HTS coils, two HTS coils using Bi2223 and Gd123 tapes were developed. The design field of both HTS coils is 11.5T in the background field of 14 T. We use two 4K-GM cryocoolers for the HTS coil. The HTS coil is thermally separated from the LTS coils so as to allow the temperature rise of the HTS coil. Although the Gd123 coil quenched at 24 T, we successfully achieved 24.6 T using the Bi2223 insert coil in a 52 mm room temperature bore. The future prospects under the projects will be introduced in the presentation.

keywords : High field magnet, Cryogen-free, REBCO, BSCCO

AP1-2 10:00–10:15

A 9.4 T 64 mm Bore Conduction-Cooled All-HTS Magnet

Jaemin Kim[1], Seungyoung Hahn[2], Kang Hwan Shin[1], Sangwon Yoon[1], *Kyekun Cheon[1], Young Jin Hwang[3], Jae Young Jang[3], SangGap Lee[3], Hankil Yeom[4], Hunju Lee[1], Seung-Hyun Moon[1]

1. SuNAM Co., LTD
2. National High Magnetic Field Laboratory
3. Korea Basic Science Institute
4. Korea Institute of Machinery and Materials

A conduction-cooled 9.4 T 100 mm winding bore 2nd generation (2G) high temperature superconducting (HTS) magnet was designed and constructed for a 400 MHz Nuclear Magnetic Resonance system. 48 double pancake (DP) coils were wound with metal-clad 2G HTS tapes, where a 1-μm thick layer of stainless steel was sputter-coated in a hermetic way around the tape. The No-insulation (NI) and multi-width (MW) winding technic was incorporated to enhance the overall magnet current density and yet to become the magnet essentially *self-protecting*. To obtain a target field homogeneity, the “inside-notch" technique was applied, where 18 out of 48 DP coils were wound with different winding radii than that of the other DP coils. The magnet was first tested in a bath of liquid nitrogen at 77 K. From a charging test, we found that the charging time of this metal-clad magnet was reduced by 20 times than that of its no-insulation counterpart. We present the details in design, construction and test together with discussion on the effectiveness and challenges of the metallic cladding technique for the next generation REBCO magnet applications.

keywords : NMR, 2G HTS Tape, Metallic Cladding, Field Homogeneity

AP1-3 10:15–10:30

Comparison of Simulated and Experimental Results of Temperature Distribution in a Closed Two-Phase Thermosyphon Cooling System

*Erasmus Shaanika, Ken Nishimura, Kota Yamaguchi, Motohiro Miki, Tetsuya Ida, Mitsuru Izumi

Tokyo University of Marine Science and Technology

Amongst a host of methods for cooling HTS machinery, thermosyphon-based cooling systems are preferred due to high heat transfer rate and near-constant operating temperature characteristics associated with them. It is therefore essential to study the thermal characteristics of these cryogenic thermosyphons for optimal application.
This work presents a comparison between temperature distribution obtained from a computer simulation and that from experimental results obtained from a two-phase cryogenic thermosyphon cooling system. The experiments were performed on a neon-thermosyphon cooling system which mimics HTS machinery in that it comprises a rotor-like cylindrical evaporator housed in a cryostat. Thermal properties and behavior were investigated by applying a series of heat loads to the evaporator at different filling ratios.
A model of the cryogenic thermosyphon cooling system was then developed and used to simulate temperature distribution. Simulating the thermosyphon at different neon-filling ratios entailed using temperature and the corresponding applied heat flux boundary conditions obtained from the aforementioned experiments. As well as providing an estimate of the expected thermal conditions such as temperature, the model gives insight into heat interaction within the thermosyphon system. The simulation results of temperature distribution compared generally well with experimental data.
1. K. Yamaguchi et al. (2016). Study of HTS Machine System Cooling with a Closed-Loop Thermosyphon: Stability of Unsteady Heat Load and Transient Conduction.
2. Brice et al.(2011). Development of a cryogenic helium-neon gas mixture cooling system for use in a Gd-bulk HTS synchronous motor.

keywords : Thermosyphon,, Superconducting machine, HTS, Effective Emissivity

AP2-1-INV 10:45–11:15

Development of REBCO Magnet for MRI

*Shoichi Yokoyama[1], Masayoshi Oya[1], Tetsuya Matsuda[1], Tatsuya Inoue[1], Ryo Eguchi[1], Toshinari Nagahiro[1], Hajime Tanabe[1], Akihiro Daikoku[1], Taketsune Nakamura[2], Yasuyuki Shirai[2], Daisuke Miyagi[3], Makoto Tsuda[3]

1. Mitsubishi Electric Corporation; 2. Kyoto University; 3. Tohoku University

The current MRI superconducting magnet needed cooling in the liquid helium (4.2K) to use NbTi superconducting wire. For these several years, a price of the liquid helium rise and acquisition-related difficulty become the problem. Therefore we carried out the development of a high-Tc superconducting (HTS) coil dispensing with liquid helium cooling [1]. In this program we succeeded to get high stable magnetic field and imaging with REBCO mini coil [2]. The research and development project of the HTS superconducting magnet for 3T-MRI is restart from this year. In this project, we will produce REBCO HTS model magnets with active-shield coils and 500mm in diameter room temperature bore. This coil is cooled in less than 20K by a G-M refrigerator. We are going to make MR imaging used by the HTS coil field to evaluate the uniformity and stability of the magnetic field.
This presentation is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).
[1] S. Yokoyama et al., “Research and Development of Fundamental Technology for the HTS Coil System having Very Stable Magnetic Field for MRI Application" presented at the 28th International Symposium on Superconductivity, SA-9-Inv, November 16-18, Tokyo, Japan 2015
[2] S. Yokoyama et al., “Research and Development of the High Stable Magnetic Field ReBCO Coil System Fundamental Technology for MRI", presented at The 2016 Applied Superconductivity Conference, 2LPo2J-05, Denver CO, September 7th, 2016

keywords : Superconducting magnet, MRI, Liquid helium free, REBCO coil

AP2-2-INV 11:15–11:45

Reduction of Screening-Current-Induced Fields by Applying Shaking Fields

*Kazuhiro Kajikawa

Kyushu University

The effective methods to eliminate screening-current-induced fields (SCFs) arising in high-temperature superconducting (HTS) tape windings have been proposed [1,2] on the basis of "the abnormal transverse-field effect" [3] or "the vortex shaking effect" [4] observed commonly in type-II superconductors, in which a DC magnetization due to an induced screening current can be reduced by applying an external AC magnetic field (shaking field) in the perpendicular direction and furthermore decays exponentially with time if the applied field amplitude is larger than the full penetration field. There are two typical arrangements of additional coils to apply the shaking fields to an HTS solenoid coil. One is the coaxial arrangement, in which a pair of copper coils are located coaxially inside and outside the HTS coil and connected in the opposite direction, and the shaking field can be applied in the directions axial to the HTS coil and parallel to the individual turns. The other is the toroidal arrangement, in which a copper coil is wound toroidally around the HTS coil, and the shaking field can be azimuthal to the HTS coil and longitudinal to the individual turns. These two arrangements for reductions of SCFs in HTS coils fabricated using coated conductors have been validated experimentally [1,2,5].
[1] K. Kajikawa and K. Funaki: SuST 24 (2011) 125005.
[2] K. Kajikawa and K. Funaki: IEEE TAS 22 (2012) 4400404.
[3] K. Funaki and K. Yamafuji: JJAP 21 (1982) 299.
[4] E.H. Brandt and G.P. Mikitik: SuST 17 (2004) S1.
[5] K. Kajikawa and Y. Okabe: IEEE TAS 26 (2016) 4400504.

keywords : AC field, High temperature superconductor, Magnetization, Screening current

AP2-3-INV 11:45–12:15

Electromagnetic Analysis on Screening-Current-Induced Magnetic Field in REBCO Coil

*Hiroshi Ueda

Okayama University

The superconductor layer of a REBCO tape is very thin with a very high aspect ratio of 10^{-3} to 10^{-4}. In application of REBCO tapes to high field magnet, the screening-current is remarkably induced by the component of the magnetic field perpendicular to the wide face of the REBCO tape. The magnetic field generated by the screening current (hereinafter referred to as screening-current-induced magnetic field) affects the magnetic field distribution in the applications such as NMR (nuclear magnetic resonance), MRI (magnetic resonance imaging), and accelerator in the following issues: (1) field reduction, (2) accuracy of the field distribution, (3) temporal stability, and (4) field repeatability after charge and discharge repetitions. Thus, the screening-current field can deteriorate the field quality. Therefore, the precise computation of current density and magnetic field distributions inside thin REBCO tapes is very important for the prediction and reduction of screening-current-induced magnetic field in the applications such as NMR, MRI, and accelerator. In this study, we report the numerical simulations for the screening current and screening-current-induced magnetic field in REBCO coil.
Acknowledgements
The part of this work was supported by Grant-in-Aid for Scientific Research (C), the Ministry of Education, Science, Sports and Culture (No.25420253 and No.16K06222).

keywords : HTS magnet, Screening current, Irregular magnetic field, Numerical simulation

AP2-4 12:15–12:30

Load test of Superconducting Magnetic Bearing for MW-class Flywheel Energy Storage System

*Shinichi Mukoyama[1], Kengo Nakao[1], Hisaki Sakamoto[1], Ken Nagashima[2], Masafumi Ogata[2], Tomohisa Yamashita[2], Kazufumi Miyazaki[3], Hideki Shimizu[4], Hidetsugu Sawamura[4]

1. Furukawa Electric
2. Railway Technical Research Institute
3. Yamanashi Prefectural
4. Mirapro

A flywheel energy storage system (FESS) stores electrical power as kinetic energy in a rotating flywheel rotor. The storage energy of the FESS is proportional to the weight of the rotor and the square of the rotating speed. However a conventional FESS that used a mechanical bearing limits in both the rotor weight and the rotating speed. A superconducting FESS utilizes a superconducting magnetic bearing (SMB) to levitate and rotate a flywheel rotor of a ton-class weight and a high speed without mechanical contact. A SMB, in the 300 kW FESS demonstrated at Mt. Komekura in Yamanashi prefecture, could levitated the 4-ton rotor. The SMB consisted of high temperature superconducting magnet (HTS magnet) and HTS bulk, and utilized a repulsive force between the HTS magnet and the HTS bulk. During a next development of MW-class FESS, Furukawa confirmed that the SMB levitated and withstood a 10 ton class load by its standalone test. This paper describes the result of the load test of the SMB.
This development was supported by NEDO in a part of 'Development of next generation flywheel energy storage system'.

keywords : Flywheel, Energy Strage, Magnetic bearing, High temperature superconductivity

AP2-5 12:30–12:45

Vibrational characteristics of a superconducting magnetic bearing employed for a prototype polarization modulator

*Yuki Sakurai[1], Tomotake Matsumura[2], Hajime Sugai[1], Nobuhiko Katayama[1], Hiroyuki Ohsaki[3], Yutaka Terao[3], Yusuke Terachi[3], Hirokazu Kataza[2], Shin Utsunomiya[1], Ryo Yamamoto[2]

1. Kavli IPMU, The University of Tokyo
2. ISAS/JAXA
3. Graduate School of Frontier Sciences, The University of Tokyo

We present the vibrational characteristics of a levitating rotor in a superconducting magnetic bearing (SMB) system operating at below 10 K. We develop a polarization modulator that requires a continuously rotating optical element, called half-wave plate (HWP), for a cosmic microwave background polarization experiment. The HWP has to operate at the temperature below 10 K, and thus an SMB provides a smooth rotation of the HWP at the cryogenic temperature at about 10K with minimal heat dissipation. In order to understand the potential interference to the cosmological observations due to the vibration of the HWP, it is essential to characterize the vibrational properties of the levitating rotor of the SMB. We constructed a prototype model that consists of an SMB with an array of high temperature superconductors, YBCO, and a permanent magnet ring. The rotor position is monitored by the laser displacement gage, and the cryogenic Hall sensor via the magnetic field. In this presentation, we present the measurement results of the vibration characteristics using our prototype SMB system. We discuss the spring constant and the magnetic field inhomogeneity of the SMB and sub-components including a rotation frequency monitoring system, a holder mechanism, and drive system. Finally, we discuss the projected performance of this technology toward the use in future space missions.

keywords : Superconducting Magnetic Bearing, Levitation force, Spring characteristics

AP3-1-INV 14:00–14:30

SUPRAPOWER Project: Towards a 10 MW MgB_2 Wind Power Generator

*Santiago Sanz[1], Gustavo Sarmiento[1], José Mari Merino[1], Ainhoa Pujana[1], Jiuce Sun[2], Victor Zermeño[2], Holger Neumann[2], Matteo Tropeano[3], Davide Nardelli[3], Gianni Grasso[3], Tupac Canosa[4], Iker Marino[1]

1. TECNALIA. Parque Tecnológico de Bizkaia, Derio, Spain; 2. Institute for Technical Physics Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany; 3. Columbus Superconductors SpA. Via delle Terre Rosse, Genova, Italy; 4. Solute Ingenieros, San Sebastián de los Reyes, Spain

The offshore wind industry is demanding more powerful machines to reduce the costs of installation and maintenance, and at last the levelized cost of energy (LCOE). On the other hand, some trends points to direct drive machines, where the generator is directly connected to the turbine without an intermediate gearbox. This simplification of the drive train aims to increase the availability, as the gearbox is prone to damage and difficult to repair. However, scaling up of wind turbines to 10 MW and beyond is problematic due to the huge size and weight increase of the generator. By increasing the current and magnetic flux density, superconductivity could be an enabling technology permitting more powerful, compact and lightweight generators.
SUPRAPOWER is an FP7 EU funded collaborative project with the objective to develop the conceptual design of a 10 MW superconducting generator and to validate it in an experiment named Rotating Magnetic Validator (RMV). The concept consists on a partially superconducting salient-poles synchronous generator, where the rotor coils are made of MgB2 material selected in base of its performance and cost. The cooling system chosen has been cryogen-free type with Gifford-McMahon cryocoolers. While the helium compressors are stationary, the cold heads are rotating with the coils. The stationary and rotating helium lines are connected by an especially developed rotary joint.
The project is facing now its last year and most of the activities have been already finished or launched. The main achievements will be presented, as well as the problems met and the learned lessons. The detailed design of the RMV, the manufacturing and testing of the first serial coils, the test of a modular cryostat with a dummy coil, the rotary joint development, the study of the integration of the generator in a wind turbine and the future plans will be shown.

keywords : Offshore wind synchronous salient-pole generator, MgB2 coils, cryogen-free cooling system, Gifford-McMahon cryocoolers

AP3-2-INV 14:30–15:00

Current Status of HTS Power Applications in Korea

*Minwon Park

Changwon National University

The history of the electric power system in the world much synchronizes with the history of increasing the voltage level because of the joule heating loss. The high voltage systems cause some problems such as insulation and environmental problems and a public nuisance. The technology of superconductivity enables to change the direction of that history and solve the problems. And the technology of High Temperature Superconductor (HTS) will much more accelerate the speed of change due to its extremely high current density with no joule heating losses. According to those reasons, so many different types of electric power applications with HTS technology have been being discussed and some of selected items have been developed in Korea. However, the development of technologies in case of engineering point of view has to focus on first the commercialization and next industrialization. Even though, the HTS power applications are amazing and very attractive. the value of technologies are waned and other components are enlarged in order to be commercially available. In this chance, the Korean HTS power applications will be introduced and the bottle neck of the commercialization will also be discussed.

keywords : High Temperature Superconductor, Power application

AP3-3 15:00–15:15

Hardware integration and performance analysis of a 10 kW HTS wind power generator with brushless exciter

*Hae-Jin Sung[1], Byeong-Soo Go[1], Minwon Park[1], Olly Pantoja[2], Zhenan Jiang[2], Rodney Badcock[2], In-Keun Yu[1]

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This paper deals with the performance analysis of a brushless HTS exciter to a 10 kW HTS wind power generator through hardware implementation. To supply DC current into the HTS coils, a brushless exciter was adopted in the generator. The field current of the generator supplied by the brushless exciter passed through the HTS coil without any mechanical connections. The HTS generator, which consisted of 6 pole racetrack type HTS coils for rotor and 36 slots copper windings for stator, was designed and fabricated. All of the field coils were wound by an HTS coated conductor made of 2G GdBCO wire. The HTS coils were mounted in a vacuum vessel integrated into the rotor, and cooled down by thermosyphon cooling method with a cryogenic refrigerator.
Through the physical fabrication of the machine, we confirmed several important results as follows. The rated output power of the generator reached to 10 kW at 300 rpm, and the operating temperature was maintained at 30 K by the cooling method. The brushless exciter supplied the operating field current of 95 A to the HTS coils. The charging time of the current in the brushless exciter was 180 second which was well matched to the simulation result. When the performance results of the conventional power supply and the brushless exciter were compared, the magnetic flux densities of the generators were almost identical, and Total Harmonic Distortion (THD) of the output voltage of the generator using the brushless exciter was 3.2% which is under the IEEE standard limit of 5%. Therefore, it is able to be applied to real wind power systems. The results will be utilized to practical design of a generator with brushless exciter through which the heat loss reduction of the field winding and the simplicity of the structure of a large-scale HTS wind power generator will be achieved.

keywords : Brushless exciter, Rotating machine, Superconducting generator, Wind turbine

AP3-4 15:15–15:30

HTS Materials for Large-Scale Applications as possible drivers to integrate Superconducting Devices in conventional Electric Power Grids

*Yutaka Yamada[1], Giuliano Angeli[2], Marco Bocchi[2], Luciano Martini[2]

1. Shibaura Institute of Technology, SIT
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The core of any High Temperature Superconducting (HTS) device is the HTS tapes used. Nowadays HTS wires have rapidly progressed from being produced in short lengths for laboratory study to being used in large scale electric grid applications. Since several companies are providing 1G and 2G wires, as well as MgB2, it is useful recognizing what wire is suitable for what application. Ricerca sul Sistema Energetico – RSE S.p.A has been carrying-on for several years experimental and theoretical activities aimed at designing and realizing SFCL prototypes based on 1G and 2G tapes and wires. Main results concerned with the developed activities are described and discussed. Along with the aforesaid activity, for what concern the superconducting cables, it has been recently initiated a modeling activity about the thermo-fluid dynamic behavior of cryogenic coolants flowing in forced convection regime inside the flexible cryostat. SFCL and cables have reached a high Technology Readiness Level, therefore investigating their behavior in the every-day grid working condition assume a relevant significance, in particular for what concern the design of the proper cryogenic systems. In the framework of the International Energy Agency (IEA), the 2015-2030 roadmap document for HTS in the electric power sector has been developed to paint a picture of where the industry actually is and what steps it should take to promote widespread adoption of superconducting based devices [1]. The main outcomes from the Roadmap and the most important trends in superconductivity world will be emphasized.
[1] Y. Yamada, B. Marchionini, “High Temperature Superconductivity: A Roadmap for the Electric Power Sector 2015-2030" prepared for IEA HTS IA.

keywords : HTS, HTS wire, Cable, FCL

AP4-1-INV 15:45–16:15

Saturated induction heating of magnetic metals: concepts and possible implementation

*Antonio Morandi, Massimo Fabbri, Pier Luigi Ribani

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Induction heating is largely used in industry for heating non-magnetic metals before hot working. The advantages of the induction heating over the use of gas furnaces include the absence of CO2 emission, fast operation, high surface quality and controllability. However, applicability of induction for the core heating of magnetic metals is prevented, in fact, by the small penetration depth which is obtained due to the high magnetic permeability of this materials. The small penetration depth leads to slow process and low thermal efficiency and is prone to create surface defects.
A method for extending the applicability of induction heating to magnetic work piece has been proposed which consists of applying, beside the AC field produced by a copper coil, a saturating DC magnetic field that reduces the permeability of the material thus increasing the penetration depth. The practical implementation of this saturated heating concept relies on the use of DC superconducting magnets which are able to produce the required field over the bore of the work-piece.
The concept of the saturated heating is presented in this paper. The possible implementation is also discussed with reference to a case of practical interest for industry. In particular, the possible design of the superconducting DC magnet and the copper AC magnets is discussed and their interaction is analyzed. The performance of the saturated induction heater in terms of productivity and temperature uniformity is investigated by numerical simulation and compared with that of conventional induction heaters.

keywords : induction heating, dc superconducting magnets

AP4-2 16:15–16:30

Volume Reduction of Cesium Contaminated Soil by High Gradient Magnetic Separation Using Superconducting Magnet

*Shigehiro Nishijima[1], Kazuki Yukumatsu[1], Hiroki Horie[1], Naoki Nomura[1,4], Yoko Akiyama[1], Fumihito Mishima[2], Tomio Sekiyama[3], Seiichiro Mitsui[3], Mitsugu Kato[3]

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4. Life Environment Division, Fukushima Prefecture

The amount of Cs contaminated soil originating from decontamination work after the accident of Fukushima Dai-ichi Nuclear Power Plant is estimated as large as 20 million m^3 in maximum, and its volume reduction is required to optimize final disposal of the contaminated soil outside Fukushima pref. We have proposed a new method to reduce the volume of the contaminated soil by the combination of wet classification and high gradient magnetic separation (HGMS). Cs ion is mainly adsorbed on the small clay particles with large surface area, thus volume reduction is possible by classification of soil into recyclable low-dose sand gravel and high-dose fine particles. However, the volume reduction rate becomes low in the soil that is rich in silt and clay such as agricultural soil. In this study, the possibility of volume reduction of silt and clay was investigated by applying HGMS to fine particles after wet classification. Among the components of silt and clay, 2:1 type clay and mica strongly adsorbs Cs and show paramagnetism, whereas other components of 1:1 type clay, quartz and feldspar weakly adsorbs Cs and show diamagnetism. Thus, former components can be selectively separated only by HGMS.
Based on the particle trajectory calculation to estimate the separating condition, HGMS by using superconducting solenoidal magnet was conducted in Fukushima pref. with actual contaminated soil after classification. The difference in radioactive concentrations of captured and passed particles showed that magnetic separation is effective for volume reduction of silt and clay. Based on the result, the separating condition to capture superfine particle under 2 μm in diameter for further dose reduction, pretreatment of organic-rich soil for application to variety of soil, and apparatus design to achieve high-throughput were discussed.

keywords : Cesium, Soil, Volume reduction, 2:1 type clay mineral

AP4-3 16:30–16:45

Study on Volume Reduction of Cesium Contaminated Soil by Magnetic Separation ~Pretreatment of Soil Organic Matter~

*Hiroki Horie[1], Kazuki Yukumatsu[1], Fumihito Mishima[2], Yoko Akiyama[1], Shigehiro Nishijima[1]

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By the accident of Fukushima Daiichi Nuclear Power Plant, a large amount of soil was contaminated by radioactive cesium. We developed a new volume reduction method combining classification and magnetic separation. In magnetic separation process, paramagnetic 2:1 type clay minerals, which strongly adsorb cesium, are removed from soil suspension of silt and clay. Thus, contaminated soil is separated into high and low dose soil. However, there is an issue that it is difficult to capture 2:1 type clay minerals selectively, because clay minerals form aggregates by soil organic matter. The purpose of this study is to capture 2:1 type clay minerals more selectively by dispersing aggregates.
In this work, size distribution of silt and clay particles under 75 μm in the soil was measured after shaking in 0.01 mol/L K_2CO_3 solution, which is low environmental load. The result showed that small particles tend to increase, indicating dispersion of aggregates by degradation of soil organic matter.
The dispersed soil was applied into magnetic separation with a superconducting magnet, and the magnetic property of the passed and the captured soil compared with those before separation were investigated. As a result, it was shown that the change in a volume susceptibility of the captured soil against those before separation became relatively large after dispersing aggregates. This result shows that 2:1 type clay minerals were able to separate more selectivity. Therefore, it was shown that pretreatment of soil organic matter is effective for selective soil separation.

keywords : Cesium contaminated soil, Magnetic separation, Clay minerals, Soil organic matter

AP4-4 16:45–17:00

SEPARATION OF FLAME AND NONFLAME-RETARDANT PLASTICS UTILIZING MAGNETO-ARCHIMEDES METHOD

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Physical recycling process has attracted attention due to mass consumption of plastics. The process has sustainability and low environmental load. But quality of recycled plastics made from mixed plastics is low.
In order to solve the problem, we tried to separate flame and nonflame-retardant plastics from toner cartridges as one example of mixed plastics by using magneto-Archimedes method. This method utilizes the differences in the forces acting on each separation object under magnetic field. The force depends on the differences in the specific gravity and the magnetic susceptibility. By using this method, we can separate precisely each separation object which has almost the same specific gravity. However, we found it is difficult to separate each separation object continuously and massively by using this method.
We introduced wet type specific gravity separation, which can separate each separation object massively, before magnetic separation. In addition, we used common medium in specific gravity separation and magnetic separation. We examined continuous and massive separation by introducing the system which can separate the plastics continuously in the flowing fluid. Then, we designed the concentration of medium and the strength of magnetic field so as to separate the plastics. It was found that the plastics are successfully separated by magneto-Archimedes method, which showed possibility of precise and massive separation of general plastics.

keywords : Mixed plastics, Magneto-Archimedes method, Wet type specific gravity separation, Superconducting magnet

AP4-5 17:00–17:15

The separation of structural isomer using Magneto-Archimedes method

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The synthetic processes of organic compounds need the process for separating structural isomers which is formed coincidentally with the objective substance. The existing separation methods of isomers are extraction, recrystallization and distillation. However, environmental burden of existing methods are large because they need large space and energy.

In this study, a separation method of structural isomers using Magneto- Archimedes method which can separate the substance with smaller device and lower energy was examined. This is a method to separate the materials by the difference of magnetic levitation position depending on their magnetic properties. In this study, powders of 1,6-DDA (1, 6-Decanedicarboxylic Acid, $C_{12}H_{22}O_4$) and 1,10-DDA (1, 10-Decanedicarboxylic Acid) were used as an example of structural isomers which have different industrial applications.

In magneto-Archimedes method, particle aggregation makes selective magnetic separation difficult, thus the type and concentration of medium was controlled based on zeta potentials of the particles so as to disperse the aggregates. Then the magnetic field was designed based on specific gravities and magnetic properties of separation targets and selected medium. Levitation position of particle was calculated from the relation between the distance from the magnet surface and magnetic field product in vertical direction, which suggested that the two structural isomers can be separated.

The experiment based on the calculation confirmed the separation possibility of isomers of 1,6-DDA and 1,10-DDA. Finally, a flow chart for Magneto-Archimedes method that can be generally applied to the variety of structural isomers was proposed.

keywords : Magnetic separation, Magneto-Archimedes method, Particle aggregation, Structural isomer

AP4-6 17:15–17:30

Influence of Food Elements by Superconducting Wireless Power Transfer System via Strong Electromagnet Resonance Coupling

*Yoon Do CHUNG[1], Young Gun PARK[2], Bong Soo NOH[3], Eun Young PARK[4]

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4. Korea Christian University

Recently, the wireless power transfer (WPT) systems using superconducting resonance wires, which is called superconducting WPT (SUWPT), have been promisingly to be applied to the wireless charging for electrical vehicles and trains because the superconducting wires, which have high Q factor resonators and keep high current density, exchange energy at a much higher rate for each resonance coil as well as they are possible to keep much stronger magnetic fields out in the peripheral regions. However, in order to commercialize the SUWPT system, the regulations for the protection of the human body from electromotive force (EMF) exposure are should be examined by national and international levels; the effect of a WPT system on human body varies greatly depending on the operating frequency and the input power. Thus, the specific absorption rate (SAR) as well as the induced electric field inside a human body due to the EMF from the WPT devices must be assessed before the commercialization of the developed devices.

In this paper, authors examine the (activation/inactivation) effect for food elements, instead of human body, by SUWPT via strong resonance coupling method at laboratory scale with a purpose built test stand, under different input power of RF generator, which is 370 kHz, 1KW power rate.

keywords : Food Element Effect, Radio Frequency, Superconducting resonance coil, Wireless power transfer

AP5-1-INV 9:45–10:15

Future Plan of Large Accelerators and Requiments to Superconducting Magnets

*Toru Ogitsu

KEK

In order to search for physics beyond current LHC several plans for large accelerators, including LHC upgrades, are proposed world wide. Many of them require superconducting magnets. The talk summarizes those accelerator plans and presents requirement to superconducting magnets.

keywords : Accelerator

AP5-2-INV 10:15–10:45

Design and Test Results of Superconducting Magnet for Heavy-Ion Rotating-Gantry

*Shigeki Takayama[1], Kei Koyanagi[1], Hiroshi Miyazaki[1], Shohei Takami[1], Tomofumi Orikasa[1], Yusuke Ishii[1], Tsutomu Kurusu[1], Yoshiyuki Iwata[2], Koji Noda[2], Kento Suzuki[3], Toru Ogitsu[3], Naoyuki Amemiya[4]

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Heavy-Ion radiotherapy has a high curative effect for cancer, and also can reduce burden on patients. These advantages have been recognized generally. Furthermore, a rotating gantry can irradiate a tumor with the ions from any direction without changing the position of the patients. It can reduce the physical dose on normal cells, therefore it's commonly used in proton radiotherapy. However, because of the high magnetic rigidity of carbon ions, the weight of the rotating gantry for heavy-ion therapy is about 3 times heavier than one for the proton cancer therapy, according to our estimation.
We developed small and lightweight rotating gantry in collaboration with the National Institute of Radiological Sciences (NIRS). The compact rotating gantry was composed of ten low-temperature superconducting (LTS) magnets that were designed from the viewpoint of beam optics. These LTS magnets have the surface-winding coil-structure and provide both dipole and quadrupole fields. The maximum dipole and quadrupole magnetic field of the magnet were 2.88T and 9.3 T/m, respectively. The rotating gantry was installed at NIRS, and beam commissioning is in progress to achieve the required beam quality.
In the three years since 2013, in a project supported by the Ministry of Economy, Trade and Industry (METI) and the Japan Agency for Medical Research and Development (AMED), we have been developing high-temperature superconducting (HTS) magnets, with the aim of further miniaturization of the rotating gantry. To develop fundamental technologies for designing and fabricating HTS magnets, the model magnet was manufactured. The model magnet composed of 24 saddle-shaped HTS coils and generated a magnetic field of 1.27 T. In the presentation, recent progress of research is reported.

keywords : Rotating-Gantry, Heavy-Ion Therapy, Superconducting Magnet, Accelerator

AP5-3 10:45–11:00

Stability Analysis of the 100 kA-class HTS Conductor for the Helical Fusion Reactor FFHR-d1

*Yoshiro TERAZAKI[1], Nagato YANAGI[2], Satoshi ITO[3], Shinji HAMAGUCHI[2], Hitoshi TAMURA[2], Toshiyuki MITO[2], Hidetoshi HASHIZUME[3], Akio SAGARA[2]

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The conceptual design activities of the LHD-type helical fusion reactor FFHR-d1 are progressing at National Institute for Fusion Science (NIFS). The helical coils of FFHR-d1 have the major radius of 15.6 m and the toroidal magnetic field of 4.7 T [1]. To produce this field, an operating current of 94 kA is required for a conductor of the helical coils at the maximum magnetic field of 11.8 T. We proposed a conductor using the high-temperature superconductor (HTS) as one of the options of the helical coil conductor. This conductor is consisted of simply-stacked REBCO HTS tapes, a copper stabilizer and a rigid stainless-steel structure.
For the development of such a HTS conductor suitable for the FFHR-d1, we fabricated and tested 30 kA-class [2] and 100 kA-class prototype HTS conductors [3], which used 20 and 54 GdBCO tapes, respectively. In the results of experiments the critical current of the sample was measured at various temperature and magnetic field: e.g., 45 kA at 20 K, 6.1 T for the 30 kA-class sample [2] and 72.6 kA at 45 K, 2.8 T for the 100 kA-class sample. At the same time the transport current was successfully reached the critical current in the fast lamp rate of ~1 kA/s without an instability of the lamp rate limitation.
Then, we planned to quantitatively investigate the instability of the conductor to adiabatically solve the coupled electromagnetic-thermal analysis, and then discuss a stability of the conductor. For this analysis, one-dimensional finite element method analysis of the hotspot temperature was performed so far. The details of the results will be reported in the presentation.
[1] A. Sagara et al., Fusion Eng. Des., 89 (2014) 2114–2120
[2] Y. Terazaki et al., IEEE Trans. Appl. Supercond., 24 (2014) 4801305.
[3] S. Ito et al., Plasma and Fusion Research, 9 (2014) 3405086.

keywords : Helical fusion reactor FFHR-d1, Helical coil, HTS, Simply stacked conductor

AP6-1-INV 11:15–11:45

Current status of MgB_2 cable applications in Europe

*Amalia Ballarino

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Since its discovery in early 2001, MgB_2 has generated interest for practical applications. Its availability in the form of multi-filamentary round wire makes it suitable for production of cables, and this, together with relative with high critical temperature and potential low-cost, render it appealing for use in superconducting devices where its limited in-field performance can be tolerated.
The state-of-the- art properties of commercially available wire and the potential of MgB_2 conductor for use in superconducting systems are discussed. An overview of high-current electrical transmission projects where MgB_2 has been proposed as an alternative to conventional Nb-Ti or High Temperature Superconductors is presented.

keywords : Superconductors, MgB2, Superconducting cables

AP6-2 11:45–12:00

Detection of Local Temperature Change on HTS Cables via Time-Frequency Domain Reflectometry

*Su Sik Bang[1], Geon Seok Lee[1], Gu-Young Kwon[1], Yeong Ho Lee[1], Gyeong Hwan Ji[1], Songho Sohn[2], Kijun Park[2], Yong-June Shin[1]

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2. Korea Electric Power Corporation Research Institute

Research of high temperature superconducting (HTS) cables and verification test are actively under-way to apply the HTS cables to the power grid. Especially, reliability of cooling systems are necessary to HTS systems because a failure of the cooling system leads to quench phenomenon which can seriously impact on stability of the power grid. In order to prevent an extreme accident caused by the quench, diagnosis and protection techniques for HTS cables are essential; however these techniques leaves much to be desired because of limitations of experimental setup.

In this paper, a novel simulation model of local temperature change on HTS cables is proposed. In order to improve an accuracy of the simulation, model of HTS cables reflecting temperature and frequency characteristics, which influence on the parameters of the HTS cables is used [1]. Also, we propose a non-destructive diagnostics applying time-frequency domain reflectometry (TFDR) to detect temperature change points. Both TFDR results targeted on the simulation model and the real-world HTS cables are compared to verify performance of the proposed diagnostics.

By utilizing the proposed simulation model, numerous kinds of failure as well as local temperature change on HTS cables, which is hard to emulate in real-world test-bed, will be able to be simulated. It is expected that the analysis of the simulation results will improve the proposed diagnostics and the proposed technique will contribute to prevent accidents by quench in HTS cables in future power grid.

[1] S. S. Bang *et al.*, "Modeling and simulation of HTS cables for scattering parameter analysis," to appear in *Physica C: Superconductivity and its Applications,* doi:10.1016/j.physc.2016.07.013

keywords : High temperature superconducting (HTS) cable, Simulation, Time-frequency domain reflectometry (TFDR), Quench detection

AP6-3 12:00–12:15

Experimental and Analytical Investigation of Transient Properties of RE-123 Coated Conductors in Fault Current Limiting Operation

*Shogo Urasaki[1], Masahiro Tajima[1], Kohei Higashikawa[1], Masayoshi Inoue[1], Yusuke Fukumoto[2], Masaru Tomita[2], Takanobu Kiss[1]

1. Kyushu University; 2. Railway Technical Research Institute

We have investigated transient properties of RE-123 coated conductors in fault current limiting operation based on experimental hardware-in-the-loop simulation, and clarified the phenomena based on an electrically and thermally coupled analysis. Fault current limiting function of superconducting electric power application is attractive to maximize the potential of power system; such a function can be realized by the transition to the resistive state of superconducting wire. On the other hand, it is necessary to model such transient behavior for the reliable design of fault current limiters although the phenomena is relatively complicated: nonlinear current transport properties varying with time-dependent temperature rise. To demonstrate this, we have developed hardware-in-the-loop simulation (HILS) system using real-time digital simulator (RTDS) [1]. This system enabled us to evaluate the real-time responses of a RE-123 coated conductor such as a non-linear properties and thermal behaviors under a power grid network; fault current limiting operation was successfully demonstrated for DC electric railway system. Furthermore, we have succeeded in describing the transient phenomena quantitatively by electrically and thermally coupled analysis taking into account of temperature dependent nonlinear transport properties of the RE-123 coated conductor based on the percolation transition model [2]. This framework will become a fundamental tool for exploring optimal design and introduction of fault current limiters into a practical system.

This work was supported by the Japan Science and Technology Agency (JST) as a project of "S-innovation" and "JSPS: KAKENHI (16K14216).

[1] K. Higashikawa, et al., *IEEE Transactions on Applied Superconductivity* **26** (2016) 5402016
[2] T. Kiss, et al., *Cryogenics* (2016) in press

keywords : Hardware-in-the-loop simulation, Real-time Digital Simulator, Superconducting Fault Current Limiter

AP6-4 12:15–12:30

Development Progress of a 220kV Resistive-type Superconducting Fault Current Limiter

*Shaotao Dai[1], Liye Xiao[2], Jingye Zhang[2], Yuping Teng[2], Bangzhu Wang[1], Liangzhen Lin[2]

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2. Institute of Electrical Engineering, CAS

Short-circuit current rises up when the power gird scale being ever greater and interconnected. Consequently, it becomes very important and dispensable to suppress the large short-circuit current that may exceed the current-breaking capacity of existing breaker. Superconducting fault current limiter (SFCL) is considered as one of the effective technologies to cut down the possible large short-circuit current. A 220kV SFCL is proposed to alleviate the possible threat by short-circuit failure in China. The SFCL adopts a resistive-type principle that takes advantage of physical state transition property of superconductors. By far the design of the SFCL is completed, and the fabrication of the SFCL is under way. This paper will discuss in detail the simulation of the impact of SFCL on the power grid, and the development of the SFCL, including its non-inductive coil, cryogenic container, high-voltage lead, et al.

keywords : Superconducting fault current limiter, Resistive type, Design, Power grid

AP6-5 12:30–12:45

Applying Energy-Based Control Strategy to SMES System in Microgrids for Eddy Current Losses Reduction

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In the microgrids, the superconducting magnetic energy storage (SMES) is a promising energy storage device for sustaining the output power of renewable energy, voltage and frequency regulation. The converter control strategy plays an important role in taking full advantage of SMES and reducing the eddy current losses of the superconducting coil. However, the conventional proportional–integral (PI) control method, which is widely used and researched in SMES system, provides unsatisfactory performance on the DC current harmonic for the superconducting coil, followed by an increasing of the eddy current losses. This will decrease the efficiency and comprehensive performance of the SMES system. Meanwhile, energy-based (EB) method, which is a novel nonlinear robust control based on passivity theory, can achieve superior performance both in transient and steady states. In this study, EB strategy is implemented to control the converter in SMES system for eddy current losses reduction. Detailed step-by-step design method of EB method in SMES system is presented built on interconnection and damping assignment strategy. The control performance of EB method is compared with that of classic PI method. By employing EB control strategy, the DC current harmonic for the superconducting coil is reduced, which leads to the reduction of eddy current losses. In addition, tracking capability and robustness to parameter uncertainty of SMES system are also improved. The correctness and effectiveness of the proposed EB control strategy are verified by the Matlab simulation results.

Keywords : Microgrid, energy-based strategy, eddy current losses, superconducting magnetic energy storage (SMES)

LN-1 16:15–16:30

Infrared Spectroscopic Studies of the Phonon Dynamics in Iron-based Superconductors

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The temperature dependence optical reflectivity has been measurement for $BaFe_2As_2$ doped different sites and $CaKFe_4As_4$. The optical conductivity has been obtained by using the two-Drude component model. It has been found that the phonons show red- or blue-shift in different samples. Interestingly, the phonon conductivity exhibits a Fano lineshape, suggesting possible coupling between phonon and electrons or spin. Based on the temperature evolution of the lineshape and peak shift, we discuss the possible role played by electron-phonon and spin fluctuation in the occurrence of superconductivity in iron-based superconductors.

Keywords: Iron-based superconductors, Infrared spectroscopy, electron phonon coupling

LN-2 16:30–16:45

Fabrication and Transport Property of 100 m Class Pnictide Wires

Xianping Zhang[1], * Chao Yao[1], Chiheng Dong[1], Dongliang Wang[1], Yanwei Ma[1], Hidetoshi Oguro[2], Satoshi Awaji[2], Kazuo Watanabe[2]

1. Key Laboratory of Applied Superconductivity, Institute of Electrical Engineering, Chinese Academy of Sciences; 2. High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University

Pnictide superconductors are very attractive for high magnetic field applications, due to their large upper critical field, small anisotropy, etc. Up to now, high J_c over 10^5A/cm^2 have been reached at 4.2K and 10T in the 122 type pnictide wires. However, there is no study on long pnictide wires, which are necessary for device development. Usually there will be a J_c drop from the short samples to long wires. So how to control the J_c degradation in the long wire is an important work. In this report, 100 m class 7-filamentary $Sr_{0.6}K_{0.4}Fe_2As_2$ wires have been fabricated using the powder-in-tube method for the first time. At 4.2K, 10T, an average J_c ~1.3×10^4 A/cm^2 was achieved on the 115 meter 7-filamentary Sr122 tapes. Good uniformity ~95% was also obtained in this kind Sr122 tapes. Double-pancake coils were made by a wind and reaction technique using the 122 tape. The factors related to the superconducting properties of the coil were discussed in this work.

Keywords: Pnictide, Long wire, Coil, Property

■ ABSTRACTS ■

Poster presentation

PCP1-1 16:00–18:00

Synthesis and Superconductivity of New FeSe-Based Intercalation Compounds $A_x(C_8H_{11}N)_yFe_{1-z}Se$ (A = Li, Na) with the Largest Interlayer Spacings

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We have succeeded in synthesizing new FeSe-based intercalation superconductors, $A_x(C_8H_{11}N)_yFe_{1-z}Se$ (A = Li, Na), with the interlayer spacing between neighboring Fe layers, d, of ~ 19 Å and the superconducting transition temperature T_c = 39 – 44 K via the co-intercalation of alkali metals and 2-phenethylamine (2-PEA), $C_8H_{11}N$, into FeSe [1]. This d value is the largest among those of the FeSe-based intercalation compounds and is understood to be due to the intercalation of two molecules of 2-PEA in series perpendicular to the FeSe layers. By collecting the data of T_c and d of a variety of FeSe-based intercalation superconductors, it has been found that T_c increases with increasing d and then is saturated at ~ 45 K for $d \geq 9$ Å. The saturated value of T_c is comparable to the T_c values of single-layer FeSe films which may be regarded as a kind of FeSe-based intercalation superconductor with infinite d values. Accordingly, the electronic structure of the FeSe-based intercalation superconductors with large d values is inferred to be similar to that of the single-layer FeSe films.

We have also investigated the dependence of T_c on the intercalation temperature (45℃ and 60℃) and the Li content ($0.125 \leq x \leq 1$). It has been found that the distribution of intercalants in the intercalated samples is inhomogeneous and that T_c increases with the increase in the local density of Li, as in the case of $Li_x(C_6H_{16}N_2)_yFe_{2-z}Se_2$ [2]. This is consistent with the calculated one based on the spin-fluctuation-mediated superconductivity by Guterding *et al.* [3] that T_c increases with the increase in the carrier density at $d \geq 8$ Å.

[1] T. Hatakeda *et. al.*, to be published in J. Phys. Soc. Jpn. **85** (2016).; [2] S. Hosono *et. al.*, J. Phys. Soc. Jpn. **85**, 104701 (2016).; [3] D. Guterding *et. al.*, Phys. Rev. B **91**, 041112(R) (2015).

keywords : intercalation, FeSe, alkali metal, organic molecule

PCP1-2 16:00–18:00

Dome-Shaped Magnetic Order in High-Pressure Phase Diagram of FeSe Superconductor

*Kohei Matsuura[1], Jianping Sun[2], Guangzhou Ye[2,3], Yuta Mizukami[1], Masaaki Shimozawa[4], Kazuyuki Matsubayashi[5], Minoru Yamashita[4], Tatsuya Watashige[6], Shigeru Kasahara[6], Yuji Matsuda[6], Jiaqiang Yan[7,8], Brian C Sales[7], Yoshiya Uwatoko[4], Jinguang Cheng[2], Takasada Shibauchi[1]

1. Department of Advanced Materials Science, University of Tokyo; 2. Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences; 3. School of Physical Science and Technology, Yunnan University; 4. The Institute for Solid State Physics, The University of Tokyo; 5. Department of Engineering Science, The University of Electro-Communications; 6. Department of Physics, Kyoto University; 7. Materials Science and Technology Division, Oak Ridge National Laboratory; 8. Department of Materials Science and Engineering, University of Tennessee.

Iron-based superconductors are a group of high transition-temperature (high-T_c) superconductors whose mechanism is beyond the classical BCS theory. The coexistence and competition between superconductivity and electronic orders, such as spin or charge density waves, have been a central issue in high-T_c superconductors. It has been found that most iron-based superconductors share a common feature. The superconductivity emerges near a spin density wave (SDW) accompanied or followed by the tetragonal-to-orthrombic structural transition. So it is believed that the relationship between the superconductivity and magnetism is important. Unlike other iron-based superconductors, FeSe exhibits the structural transition but no magnetic order. Moreover, a pressure-induced fourfold increase of T_c has been reported, which poses a profound mystery. Here we report high-pressure magnetotransport measurements in FeSe up to 15 GPa, which uncover the dome shape of pressure-induced magnetic phase [1]. Above 6 GPa the sudden enhancement of superconductivity (up to T_c=38.3 K) accompanies a suppression of magnetic order, demonstrating their competing nature with very similar energy scales. Above the magnetic dome, we find anomalous transport properties suggesting a possible pseudogap formation, whereas linear-in-temperature resistivity is observed in the normal states of the high-T_c phase above 6GPa. The obtained phase diagram highlights unique features of FeSe among iron-based superconductors, but bears some resemblance to that of high-T_c cuprates.

[1] J. P. Sun, K. Matsuura, G. Z. Ye et al., Nat. Commun. 7, 12146 (2016).

keywords : Iron-based superconductor, FeSe, Pressure effect, Magnetism

PCP1-3 16:00–18:00

Synthesis of Te substituted Iron Chalcogenide Thick Films by Electrochemical Method

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2. Kinki Univ.

$FeSe_{1-x}Te_x$ thick-film superconductors by electrodeposition were presented. The alloy composition is controllable by the deposition potential. The effect of deposition potential on alloy composition, surface morphology, crystal structure and magnetic properties of the samples was investigated. According to the magnetic measurement, the obtained $FeSe_{1-x}Te_x$ showed superconductor. Samples of FeSe1-xTex were prepared by conventional three electrodes method. $Fe_2SO_4 \cdot 7H_2O$, SeO_2 and TeO_2 were used as solution. Preparation conditions were optimized to obtain a stoichiometric composition and a crystal structure for superconductivity. The composition and crystallinity of electrodeposited FeSe were very sensitive to the deposition potential and pH. The results of XRD showed almost the single phase of tetragonal α□-FeSe with PbO-structure under the preparation conditions of pH4.0, 70 oC and -0.75 V (vs. Ag/AgCl). The magnetic susceptibility measurement indicated that the superconductivity transition temperature was 8 K. The maximum film thickness was about 50 μm and the composition of the films is uniform.

keywords : Iron Chalcogenide, Electrodeposition, Tellurium

PCP1-4 16:00–18:00

Synthesis of Electrodeposited $FeSe_{1-x}Te_x$ ($0 \leq x \leq 0.5$) Superconductors

*Takahiro Osafune[1], Nobuaki Watanabe[1], Takahiko Masui[2], Yuusuke Kasai[1], Kouhei Kiuchi[1], Shoma Koike[1]

1. Kanto Gakuin Univ.
2. Kinki Univ.

$FeSe_{1-x}Te_x$ ($0 \leq x \leq 0.5$) superconductors by electrodeposition were presented. The alloy composition is controllable by the deposition potential. The effect of deposition potential on alloy composition, surface morphology, crystal structure and magnetic properties of the samples was investigated. Samples of FeSe1-xTex were prepared by conventional three electrodes method. $Fe_2SO_4 \cdot 7H_2O$, SeO_2 and TeO_2 were used as solution. Preparation conditions were optimized to obtain a stoichiometric composition and a crystal structure for superconductivity. The composition and crystallinity of electrodeposited FeSe were very sensitive to the deposition potential and pH.

keywords : FeSe, Electrodeposition, Tellurium

PCP1-5 16:00–18:00

Synthesis of Electrodeposited $FeSe_{1-x}Te_x$ $(0.5 \leq x \leq 1)$ Superconductors

*Yusuke Kasai[1], Nobuaki Watanabe[1], Takahiko Masui[2], Takahiro Osafune[1], Kouhei Kiuchi[1], Shoma Koike[1]

1. Kanto Gakuin Univ.
2. Kinki Univ.

$FeSe_{1-x}Te_x$ $(0.5 \leq x \leq 1)$ superconductors by electrodeposition were presented. The alloy composition is controllable by the deposition potential. The effect of deposition potential on alloy composition, surface morphology, crystal structure and magnetic properties of the samples was investigated. Samples of FeSe1-xTex were prepared by conventional three electrodes method. $Fe_2SO_4 \cdot 7H_2O$, SeO_2 and TeO_2 were used as solution. Preparation conditions were optimized to obtain a stoichiometric composition and a crystal structure for superconductivity. The composition and crystallinity of electrodeposited FeSe were very sensitive to the deposition potential and pH.

keywords : FeSe, Electrodeposition, Tellurium

PCP1-6 16:00–18:00

Gap features of Fe(Se,Te) found by tunneling spectroscopy below and above the superconducting transition

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We measured $FeSe_xTe_{1-x}$(x = 0.3 - 0.5) single crystals by means of in situ break-junction tunneling spectroscopy (BJTS) and scanning tunneling microscopy/spectroscopy (STM/STS). The superconducting BJTS reveals the gap values 2Δ (4 K) = 3 meV, 5 meV, and 6-7 meV. The broadening energy parameter Γ is not less than ~ 0.1Δ, as stems from the BCS (Bardeen-Cooper-Schrieffer)-Dynes density of states. The maximum superconducting gap scaled by T_c = 15 K is ~ 5, which is consistent with that of the Fe-As oxide with T_c = 48 K [1].

Extending the bias voltages well above the superconducting gap energy reveals the hump structures. They are similar to the well-known dip-hump structures of the layered high-T_c cuprates. The temperature evolution of the BJTS conductance through T_c from 4 K demonstrates the existence of the normal-state gap, which is inherent to the partially gapped charge-density wave (CDW) superconductor [2]. This normal-state gap is gradually smeared out to merge into the background at the characteristic temperature, T^* = 80 K - 125 K, depending on the gap size. The T^*-scaled gap value obeys the gap-to-transition-temperature ratio found for CDWs in high-T_c compounds. Therefore, the background electron spectrum gapping character is common to those two different classes of superconductors. Such a large normal-state gaps are also observed in STS as strongly asymmetric and inhomogeneous conductance features. Their possible origins are discussed on the basis of the observed facts and available theories.

[1] T. Ekino *et al.*, PhysicaC 470 (2010) S358.
[2] A.M. Gabovich *et al.*, Adv. Cond. Mat. Phys. 2010 (2010) 681070.

keywords : FeSeTe superconductor, energy gap, break-junction tunneling spectroscopy, scanning tunneling spectroscopy

PCP1-7 16:00–18:00

Two-gap features revealed by specific heat measurements in FeSe

*Jing Ting Chen, Yue Sun, Tatsuhiro Yamada, Sunseng Pyon, Tsuyoshi Tamegai

The University of Tokyo

The symmetry of superconducting gap is a key to understand the mechanism of superconductivity. Specific heat measurements give us useful information on the gap structure of bulk sample, while Angle-Resolved Photoemission Spectroscopy (ARPES) and Scanning Tunneling Spectroscopy (STS) can only probe the surface property of the crystal. Among iron-based superconductors (IBSs), FeSe has the simplest structure and is most suitable for the understanding of the superconducting mechanism.
The crystal used in the present specific heat experiments is a high-quality single crystal of FeSe (T_c ~ 8.76 K and $\Delta C/\gamma_c T_c$ = 1.62). A sharp jump of specific heat at T_c, and the second drop around 1.2 K are observed. This is a typical behavior for two-gap superconductors such as MgB_2 [1, 2] and $Lu_2Fe_3Si_5$ [3, 4], suggesting the presence of two superconducting gaps in FeSe. Furthermore, the electronic specific heat under zero field can be well fitted by the two-gap model. Moreover, the two-gap nature of FeSe is also supported by the presence of a kink structure in $\gamma(H)$ ($\gamma(H)$: electronic specific coefficient under magnetic field, H) at low temperatures, which is strikingly different from that observed in conventional s-wave and the d-wave superconductors.
[1] H. D. Yang et al., Phys. Rev. Lett. 87, 167003 (2001).
[2] F. Bouquet et al., Phys. Rev. Lett. 87, 047001 (2001).
[3] Y. Nakajima et al., Phys. Rev. Lett. 100, 157001 (2008).
[4] Y. Nakajima et al., Phys. Rev. B 85, 174524 (2012).

keywords : Iron-based superconductor, Specific heat

PCP1-8 16:00–18:00

High-Resolution ARPES Study of FeSe Thin Films

*Giao Ngoc Phan[1], Kosuke Nakayama[1], Shota Kanayama[1], Masato Kuno[1], Katsuaki Sugawara[2], Takafumi Sato[1], Takahiro Urata[1], Yoichi Tanabe[1], Katsumi Tanigaki[1,2], Fuyuki Nabeshima[3], Yoshinori Imai[3], Atsutaka Maeda[3], Takashi Takahashi[1,2]

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Iron selenide (FeSe) is the structurally simplest iron-based superconductor [1]. While the T_c value of bulk FeSe is just 8 K, it can be significantly enhanced by various ways, e.g., by isolating one monolayer on $SrTiO_3$ substrate [2], by doping electron carriers via alkaline-metal coating [3], or by applying compressive in-plane lattice strain [4]. To understand the origin of high-T_c superconductivity in FeSe, we have fabricated high-quality FeSe thin films with various thickness, doping levels, and in-plane lattice strain and investigated their electronic structure by high-resolution angle-resolved photoemission spectroscopy (ARPES). In this presentation, we show the evolution of the fermiology and discuss the relationship with the emergence of high-T_c superconductivity.
[1] F.-C. Hsu *et al.*, Proc. Natl. Acad. Sci. USA **38**, 14262 (2008).
[2] Q. Y. Wang *et al.*, Chin. Phys. Lett. **29**, 037402 (2012).
[3] Y. Miyata *et al.*, Nature Mater. **14**, 775-779 (2015).
[4] F. Nabeshima *et al.*, Appl. Phys. Lett. **103**, 172602 (2013).

keywords : FeSe, electronic structure, Angle-resolved photoemission spectroscopy

PCP1-9 16:00–18:00

Chemical-substitution effect on c-axis transport properties of $BaFe_2As_2$

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Osaka-unversity

Although most iron-based superconductors essentially exhibit two-dimensional electronic properties due to the layered crystal structure, the 122 system (e.g., BaFe2As2) shows a rather three-dimensional nature [1]. To understand the comprehensive electronic state of this system, it is indispensable to study the c-axis properties.

In this study, we investigated the c-axis transport properties of chemically substituted (doped) BaFe2As2. We focused on the impurity effect for various substitutions: Co and Ru for Fe, P for As, and K and Sr for Ba. For the isovalent Ru, P, and Sr substitution, an increase in the residual resistivity with doping is small. On the other hand, Co doping strongly increases the residual resistivity. Remarkably, we observed an anomalous behavior for K doping. The low-temperature c-axis resistivity shows an upturn for slightly K-doped BaFe2As2, resulting in the large residual resistivity. With further doping, the upturn disappears, and the residual resistivity becomes small. This likely arises from the aliovalent substitution of K+ for Ba2+.

[1] M. A. Tanatar et al., Phys. Rev. B 79, 134528 (2009).

keywords : Iron-based superconductor, In-plane and out-of-plane anisotropy, doping effect

PCP1-10 16:00–18:00

Angle-Resolved Photoemission Spectroscopy Study of Fermi Surface and Superconducting Gap in NdFeAs(O,F)

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Since the discovery of the iron-pnictide superconductor, many researchers have made great efforts to clarify its superconducting mechanism. In order to understand the pairing mechanism in iron-based superconducting systems, it is crucial to clarify the Fermi surface and the superconducting gap symmetry. However, the superconducting gap structure and band dispersion from the bulk has not been clear yet.
In this study, we have investigated the Fermi surface and the superconducting gap of NdFeAs(O,F) (1111) using angle-resolved photoemission spectroscopy (ARPES). Regardless of high T_c of NdFeAs(O,F), there are only a few reports of ARPES studies for the related 1111 systems because of the difficulty of single crystal growth. In the present-study, we have successfully synthesized the high quality NdFeAs(O,F) single crystal, which has T_c of 43 K by high pressure method. The Fermi surfaces and superconducting gaps of NdFeAs(O,F) were investigated by ARPES, we observed that the outer and inner hole Fermi surfaces at the Γ point, and the hole FSs do not show any three dimensionality along the k_z direction, i.e. they have a cylindrical shape. Propeller-like or petal-like Fermi surface was observed around the M point. Superconducting gaps on the observed Fermi surfaces were measured in k_x-k_y momentum space. Both two hole Fermi surfaces have a nodeless superconducting gap, of ~16meV-23meV. On the other hand, on each two Fermi surfaces around the M point, the superconducting gaps are ~22meV and 18meV-19meV, respectively. These correspond to large gap ratio, $2\Delta/kT_c$=8.6~12.4.

keywords : NdFeAsOF, 1111, ARPES, Superconducting gap

PCP1-11 16:00–18:00

Field-driven Transition Revealed by Vortex Dynamics in $Ba_{1-x}K_xFe_2As_2$ with Splayed Columnar Defects

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Columnar defects in type-II superconductors serve as artificial pinning centers, which lead to enhancement of critical current density. However, vortex motion in superconductors with columnar defects is not thoroughly understood. It is revealed that field-driven transition occurs in $Bi_2Sr_2CaCu_2O_{8+\delta}$ [1] and $YBa_2Cu_3O_{7-\delta}$ [2] when columnar defects are introduced. Theoretically, a Monte Carlo simulation suggests a field-driven transition with enhancement of vortex trapping rate by columnar defects at 1/3 of matching field, B_Φ [3]. On the other hand, there is no report of field-driven transitions in iron-based superconductors with columnar defects. In this study, we performed detailed magnetization measurements including its relaxation in iron-based superconductors with splayed columnar defects.

$Ba_{0.6}K_{0.4}Fe_2As_2$ single crystals used in this study were synthesized by FeAs flux method, and splayed columnar defects were installed into the crystals by 2.6 GeV $^{238}U^{+}$ irradiation. In order to assess the effectivity of the splayed columnar defects as pinning centers, critical current density and magnetic relaxation rate for the crystals were measured systematically. Field-driven transitions are found near 1/3 of B_Φ when the magnetic field is applied along the average direction of the splayed columnar defects. We discuss possible origins of the field-driven transition comparing it with those in cuprate superconductors.

[1] M. Sato *et al.*, Phys. Rev. Lett. **79**, 3759 (1997).
[2] K. Itaka *et al.*, Phys. Rev. Lett. **86**, 5144 (2001).
[3] R. Sugano *et al.*, Phys. Rev. Lett. **80**, 2925 (1998).

keywords : Ba-122, columnar defects, irradiation, vortex dynamics

PCP1-12 16:00–18:00

EFFECT OF OXYGEN VACANCIES ON ELECTRONIC STATE IN $Sr_4V_2O_6Fe_2As_2$

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In general, superconductivity in iron pnictides emerges in the proximity of an antiferromagnetic-orthorhombic (AFO) phase, and that a role of the AFO phase has been discussed. $Sr_4V_2O_6Fe_2As_2$ is a superconducting material showing a relatively high critical temperature of 37 K without chemical substitution. It is not clear for $Sr_4V_2O_6Fe_2As_2$ whether an ordered phase exists or not.

In this study, we investigated a change in electronic states induced by oxygen vacancies in $Sr_4V_2O_6Fe_2As_2$ and established a phase diagram of $Sr_4V_2O_{6-\δ}Fe_2As_2$. Oxygen vacancy makes the *c* axis longer. With introducing oxygen vacancy, superconductivity is gradually suppressed and abruptly vanishes at *c* = 15.69 Å. Around this composition, we observed an anomaly in magnetic susceptibility at ∼ 100 K, indicating a presence of a magnetic and possibly structural phase transition. Our results suggest that this is a universal feature of iron-pnictide superconductors.

keywords : Iron-based superconductor, oxygen vacancy

PCP2-1 16:00–18:00

Search for superconductiveity in chromium thin films

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In ion beam sputtered chromium (Cr) thin films, suppression of antiferromagnetism and superconductivity has been reported since 40 years ago. It will be remarkable if Cr thin films exhibit bulk superconductivity, because it has not been reported for strongly correlated 3d transition-metal compounds such as Cr-based superconducting compounds, except for CrAs. In this study, we perform precise electrical resistance measurements of Cr thin films to clarify the electronic state in a wide temperature range. Several single-crystal Cr films were prepared using a conventional magnetron sputtering device. The substrate for growing Cr epitaxially (001) MgO. The ρ(T) curve of single-crystal films decrease with decreasing temperature and show humps at around 300 K consistent with the bulk Cr being an itinerant antiferromagnet. Superconducting transition does not occur down to 0.5 K in single-crystal Cr films. On the other hand, polycrystalline Cr films were deposited on silicon substrate using ion beam sputtering. The ρ(T) curves deviate from those of the bulk Cr. Moreover, we observed sudden decrease in the resistance around Tc=1.5 K, which is consistent with the previous report. However, the large residual resistance remains below Tc. It suggests that Cr does not show superconductivity contrary to the previous study. Possible factors are as follows. First, some chromium oxide on a film surface show a superconducting transition. Second, taking into account that no transition is observed at Tc in the single-crystal Cr films, crystalline impurities may be superconducting or show some magnetic transition. Third, aluminum wires as a probe may create grains on Cr. To clarify the transport properties of polycrystalline Cr, more precise experiments are required at low temperature in detail.

PCP2-2 16:00–18:00

Electrical resistivity of Chromium thin film

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Chromium is an antiferromagnet below the Neel temperature T_N= 311 K. Although, Schmidt et al. report that chromium thin film show superconductivity (P. H. Schmidtet al., Physics Letters, **41A**, 367 (1972)), there was no experimental data such as resistivity drop and the Meissner effect. In this study, we studied the electrical resistance of chromium films in order to clarify the previous report. Polycrystalline chromium films were deposited on silicon substrate using ion beam sputtering. The thickness of the chromium oxide layer is obtained to be about 1 nm by X-ray reflectivity measurements. The electrical resistance was measured by a four-point collinear four-probe dc method with the current direction on the film plane. Aluminum wires were bonded on the film plane by wire bonding.The temperature dependence of the electrical resistivity was measured using the Quantum-Design PPMS between 0.5 and 350 K. The $\rho(T)$ curve of polycrystalline films increase with decreasing temperature in low temperature as in semiconductor. Moreover, we observed sudden decrease in the resistance at around 1.5K where the superconducting transition was reported. However, it is difficult to conclude whether a superconducting transition occurs because the electrical resistivity is not zero in all films. No anomaly was detected by resistance measurements around room temperature, and the sudden decrease in the resistance at low temperature may be attributed to the suppression of antiferromagnetic interaction by thinning down the chromium element.

keywords : Cr film, Sheet resistivity, Electrical resistivity, Superconductivity

PCP2-3 16:00–18:00

Thin Film Synthesis of Palladates with the Nd_2CuO_4 Structure

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Tokyo Univ. of Agri. and Tech.

T'-$(R,Ce)_2CuO_4$ was discovered as an electron-doped superconductor in 1989[1]. The superconductivity of T' compounds are very sensitive to oxygen defects: interstitial O atoms at the apical site and oxygen deficiencies in CuO_2 planes. In T' cuprates, Cu^{2+} is surrounded by four O^{2-} in square-planar coordination. Most of transition-metal perovskite oxides prefer octahedral coordination. This contrast reflects the nature of the chemical bond: octahedral for ionic oxides vs square planar for covalent oxides. In this light, square-planar oxides are interesting for potential high-T_c superconductivity. Pd^{2+} oxides are promising which prefer square-planar coordination due to strong Pd-O hybridization. There are a few reports on bulk T' palladates[2-3], but still no report on film T' palladates. The reason for the latter is the difficulty to oxidize Pd: the much tighter phase window for Pd^{2+} (higher oxygen pressure or lower temperature) than that for Cu^{2+}. We synthesized thin films of T'-$(Nd,Ce)_2PdO_4$ with ozone assisted molecular beam epitaxy, and obtained single-phase films of the T' structure. With X-ray diffraction, the *c*-axis lattice parameter of the films was determined and it shortens with Ce content x. We are now optimizing the electrical conductivity. During the growth, strong oxidation by ozone is required for the phase formation, but the vacuum reduction after growth improves the conductivity. The situations are common with bulk samples[3,4] and also quite resemble those of superconducting T'-$(Nd,Ce)_2CuO_4$ films. So far, the lowest resistivity at 295 K is ~ 400 mΩcm for the film with $x = 0.15$ although no trace of superconductivity is yet to be observed.

1) Y. Tokura *et al.*, Nature **337** (1989) 345
2) J.P. Attfield *et al.*, J. Solid State Chem **80** (1989) 286
3) S. Suzuki *et al.*, JPS Conf. Proc. **3** (2014) 017028
4) S. Ayukawa *et al.*, Mater. Sci. Eng. B **148** (2008) 65

keywords : Pd oxide, Covalency, T' structure, Thin film

PCP2-4 16:00–18:00

Impurity effects on critical temperatures of nano-structured superconductors; Size and shape dependence.

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Each superconducting materials have their own critical temperatures. However, for a nano-structured superconductor, the critical temperature depends on size and shape of the superconductor. Nishizaki found that the high pressure torsion enhances the critical temperatures of bulks of Nb, because the torsion makes many fine grains in the bulk which becomes nano-structure of superconductors[1]. However for a bulk of V, critical temperature becomes smaller after the high pressure torsion. Nishizaki discussed that the decrease of critical temperature is caused by impurities in the sample of V.
Previously, we studied critical temperatures of nano-structured superconductors by solving Gor'kov equations with finite element method [2].We found that smaller and narrower nano-structured superconductors show higher critical temperatures [3]. In this talk, we show that impurity effects decrease critical temperatures. This behavior of critical temperatures means the violation of Anderson's theorem of impurity effects on superconductors [4]. Also we discuss about size and shape effects on the impurity effects.

[1] T. Nishizaki , S. Lee , Z. Horita , T. Sasaki, N. Kobayashi. Physica C 493 (2013) 132-135
[2] M. Kato, T. Ishida, T. Koyama, M. Machida. Superconductors-Materials, Properties and Applications. InTech. (2012)319
[3] M. Umeda, M. Kato, O.Sato IEEE Trans. Appl. Supercond. 26 (2016) 8600104
[4] P. W. Anderson J. Phys. Chem. Solids 11 (1959) 26-30

keywords : critical temperature, impurity effect, finite element method, Gor'kov equations

PCP2-5 16:00–18:00

Anisotropic Superconducting Properties in Single Crystals of $ZrTe_3$

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$ZrTe_3$ shows superconductivity (SC) below 2 K and an anisotropic charge-density-wave (CDW) transition at ~70 K reflecting its crystal structure: a stack of quasi-two dimensional layers (the *ab*-planes) with quasi-one dimensional $ZrTe_6$ prisms along the *b*-axis. Interestingly, previous work showed that suppressing the CDW by the Te/Se-substitution led to increasing T_c (~ 4 K), and that multi-band SC was inferred from an anisotropic SC phase diagram [1]. On the other hand, the details of SC in the pristine $ZrTe_3$ has not been evaluated due to low T_c ~ 2 K, although coexistence of anisotropic CDW and anisotropic SC is possibly realized. Here, we revealed the SC properties of the pristine $ZrTe_3$ below 2 K using high quality crystals and a homemade adiabatic demagnetization refrigerator (ADR).
In all the previous reports, $ZrTe_3$ crystals were grown by the chemical vapor transport (CVT) technique. In this work, we employed modified flux method to grow ZrTe3 crystals. As a result, the residual resistivity ratio (*RRR*), which is an indicator of the crystal quality, in the flux-grown crystals was found to be 82 (I//b), which was 4 times larger than that of the CVT-grown ones (*RRR* ~ 20) [2]. To determine the SC parameters, the resistivity under various magnetic fields parallel to all the three axes was measured using the ADR, which was able to go down to 0.2 K. The determined coherence lengths indicate that the spatial extension of the Cooper pairs in $ZrTe_3$ is a tri-axial ellipsoid with $c < b < a$.
[1] Xiangde Zhu *et al.* Sci. Rep. **6**, 26974 (2016)
[2] Xiyu Zhu *et al.* Phys. Rev. B **87**, 024508 (2013)

keywords : ZrTe3, single crystals, CDW, anisotropy

PCP2-6 16:00–18:00

Scanning Tunneling Microscopy Measurements in $ZrTe_{3-x}Se_x$

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Department of physics, Tokyo University of Science

We report results of scanning tunneling microscopy and spectroscopy (STM/STS) measurements in $ZrTe_{3-x}Se_x$. $ZrTe_3$ is one of transition metal trichalcogenide compounds, having the structure composed of the triangular prismatic chain. This material undergoes the Charge Density Wave (CDW) transition at 63K along the a-axis with 14 times of the lattice constant and shows the filamentary superconductivity below 2K.
Recently, it was found that CDW order in $ZrTe_3$ is suppressed by partial Se substitution for Te of 4% and shows bulk superconductivity at around 4K [1]. This result indicates that superconductivity and CDW order appeared in this material is quite sensitive for the Se substitution. To understand the appearance of superconductivity by the small amount of Se substitution, both the structural and the electronic measurements are needed. In this study, we prepared $ZrTe_{3-x}Se_x$ single crystals and performed STM/STS measurements. We discuss the changes in the surface structure and the electronic structure in $ZrTe_3$ by Se doping.
Reference
[1] Xiangde Zhu et al., arXiv:1606.02284v1 [cond-mat.supr-con] 7 Jun 2016

keywords : Trichalcogenide compounds, Charge density wave, Scanning tunneling microscopy

PCP2-7 16:00–18:00

Enhancement of superconductivity induced by Se doping in *2H*-TaS_2

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Layered tantalum dichalcogenides TaX_2 (X = S, Se, Te) show polytypism and they present different physical properties and electronic ordered states depending on their stacking. Recently, it was reported that *1T*-$TaS_{2-x}Se_x$ ($1.0 \leq x \leq 1.5$) and *4H*$_b$-$TaS_{2-x}Se_x$ show superconductivity at higher superconducting transition temperature (T_c) than that of the host-materials, TaS_2 and $TaSe_2$. Therefore, it is expected that other polytypes such as *2H* also show the superconductivity at higher T_c than that of the host-materials by Se doping.
To clarify this, we systematically synthesized single crystals of *2H*-$TaS_{2-x}Se_x$ ($0 \leq x \leq 2$) and examined T_c. By measuring the temperature dependence of the resistivity, we found that CDW transitions at $x = 0$ and $x = 2$ were suppressed and the superconductivity emerged in the huge x range of $0.3 \leq x \leq 1.5$. More importantly, the maximum T_c in this series is higher than that of the host-materials and highest among other polytypes including *1T* and *4H*$_b$. The surface observation by scanning tunneling microscopy revealed local CDW modulation in the samples that show the superconductivity.
We will report the details of the results and discuss relation to the superconductivity in other polytypes.
[1] J. A. Wilson *et. al.* Phys. Rev. Lett. **32**, 882 (1974)
[2] Y. Liu *et. al.* Appl. Phys. Lett. **102**, 192602 (2013)
[3] Y. Liu *et. al.* J. Appl. Phys. **115**, 043915 (2014)

keywords : Tantalum dichalcogenide, Polytype, CDW, Superconductivity

PCP2-8 16:00–18:00

Effect of Fe-doping on the CDW state in 1*T*-TaS_2 investigated by STM/STS

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Transition metal dichalcogenide provides an ideal platform for investigating various electronic states, such as charge density wave (CDW) and superconductivity. Among them, 1*T*-TaS_2 has attracted great interest because of the variation in the CDW formation depending on temperature [1]. Especially, it forms commensurate CDW (CCDW) state with a Mott insulating gap below 180 K [2]. Recently, it is reported that Fe substitution to Ta suppresses the CCDW and Mott transition immediately, and induces superconductivity at maximum critical temperature of 2.1 K, implying the competition between two electronic states [3]. In order to understand the doping evolution of the CDW state in terms of the CDW structure and the electronic state, we performed scanning tunneling microscopy and spectroscopy on $Ta_{1-x}Fe_xS_2$ ($0 \leqq x \leqq 0.05$) at 4.2 K. We revealed that the correlation length of the CDW structure decreases as increasing Fe concentration. Tunneling spectra of Fe-doped samples show finite conductance at Fermi energy. Furthermore, we also observed two types of the spectra. One has symmetric spectrum with respect to the Fermi energy, and another has asymmetric one. In this conference, we will discuss its origin.
References
[1] B. Sipos *et al.*, Nat. Mat. 7, 960 (2008).
[2] J. J. Kim *et al.*, Phys. Rev. Lett. 73, 2103 (1994).
[3] L. J. Li *et al.*, Euro. Phys. Lett. 97, 67005 (2012).

keywords : transition metal dichalcogenide, charge density wave, superconductivity

PCP2-9 16:00–18:00

A Study on the Vibrational and Superconducting Properties in Granular Boron Doped Diamond Film

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Diamond is an ultimate material of choice for various applications. Heavily boron doped diamond shows superconductivity. We report on a detailed study of the vibrational modes resulting due to an inelastic scattering process in the granular superconducting boron doped diamond film. As a result of enhanced boron incorporation in the σ–bonded carbon network, an insulating system is driven to a superconducting state. This transition is due to the broadening of the impurity band that ultimately merges with the completely filled delocalized band beyond a critical impurity concentration for the metal to insulator transition (MIT). In doing so, discrete vibrational mode originating from the Γ - point of the reciprocal lattice interfere with the background energy continuum resulting into a Fano-type asymmetric resonance phenomenon. The asymmetry parameter of the peak is found to be q = - 3.2 and the resonance lifetime of ~ 10-13 s is estimated. Our estimate of the upper critical field shows that H_c2 (0)~5.22 T and the coherence length ξ~7.9 nm.

keywords : Boron doped diamond, Raman spectroscopy, Superconductivity

PCP2-10 16:00–18:00

Exploration of Topological Superconductors in Au-Pb-Bi Compounds

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Topological superconductors have been theoretically proposed to be available for fault tolerant quantum computation. Doping carriers into topological “insulators" has been broadly adopted as a strategy to find a topological superconductor. As an alternate approach, searching topological “semimetals" showing superconductivity is effective. Following the later, we have investigated Au-Pb-Bi compounds by first-principles calculations and single crystal growth.
Although properties especially in single crystals have been poorly explored, four Au-Pb-Bi intermetallic superconductors are known: $AuPb_3$ (T_c ~ 4.4 K), Au_2Pb (1.2 K), $AuPb_2$ (3.1 K), and Au_2Bi (1.8 K). First, we performed first-principles calculations with and without spin-orbit coupling and found that relativistic effects were significant in all the compounds. Noncentrosymmetric $AuPb_3$ turned out to be a gapless metal with giant spin band splitting at the Fermi level. This material may be a Weyl semimetal and a topological superconductor. Even if not, it may host a parity mixing superconducting state. Centrosymmetric Au_2Pb (orthorhombic) was found to be a topological semimetal by theoretical calculations using the Wilson loop method. Next, we have tried to grow single crystals. By a modified horizontal Bridgman method, we successfully grew single crystals of stoichiometric $AuPb_3$, Au_2Pb, and Au_2Bi. Furthermore, we also succeeded in growing single crystals of $Au_2Pb_{1-x}Bi_x$, in which T_c increased with x from 1.2 K (x = 0.00) to 2.0 K (x = 0.11). Magnetic phase diagram and superconducting parameters will be discussed in details to clarify the nature of the superconducting states.

keywords : Topological superconductor, Single crystal, Substitution effect, Spin-orbit coupling

PCP2-11 16:00–18:00

Superconductivity of the Sr-intercalated Bi_2Se_3

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The three-dimensional (3D) topological insulator (TI) is attracting a lot of interest as a new state of matter. Superconductivity of $Cu_xBi_2Se_3$ is very interesting. When Cu is introduced to this compound with the nominal formula $Cu_xBi_2Se_3$, superconductivity with a maximum transition temperature T_c of 3.8 K is observed for the doping range $0.10 < x < 0.30$, even though the bulk carrier density n is only ~ 10^{20} cm^{-3} [1]. Furthermore, nematic superconducting state is discovered in $Cu_xBi_2Se_3$ [2].

Superconductivity is observed in Sr-intercalated Bi_2Se_3 [3]. The compound is stable in air/moisture unlike $Cu_xBi_2Se_3$. The feature is very effective to reveal the superconducting state. We investigate that the difference in the Sr intercalated value of x affects the occurrence of superconductivity.

Synthesized the single crystals of Sr-intercalated Bi_2Se_3 were confirmed by powder X-ray diffraction. Electrical resistivity $\rho(T)$ measurements were performed by using dc four-terminal method. Specific heat measurements were performed by a relaxation method.

Superconductivity is confirmed by $\rho(T)$ measurements. Around 3 K,$\rho(T)$ of $Sr_{0.1}Bi_2Se_3$ clearly shows the drop, but does not reach zero resistivity. The result indicates that superconductivity is not bulk nature. We consider that nominal composition is not corresponding to the actual composition of x. With increasing the intercalated value of x increase, superconducting transition is clearly observed at around 3 K. Specific heat measurements were performed to confirm bulk nature of superconductivity and to reveal superconducting state. We will introduce the temperature (T) and field (H) dependence of the specific heat and discuss the superconducting state.

[1] Y. S. Hor *et al.*, Phys. Rev. Lett., **104**, 057001 (2010)
[2] S. Yonezawa *et al.*, arXiv:1602.08941v1
[3] Shruti *et al.*, Phys. Rev. B **92**, 020506(R) (2015)

keywords : Superconductivity, Bi2Se3

PCP2-12 16:00–18:00

Superconducting gap symmetry of the single crystal of β-$PdBi_2$

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The recent discovery of the topologically protected surface states in the β-$PdBi_2$ has reignited the research interest in this class of superconductors [1]. Furthermore, β-$PdBi_2$ is reported to be a superconductor with superconducting transition temperature (T_c) = 5.4 K and multi-gap superconductivity [2]. On the other hand, μSR measurement suggests that superconductivity is full-gap symmetry with a single gap [3]. In the present situation, superconducting gap of β-$PdBi_2$ is controversial. To reveal superconducting gap symmetry of β-$PdBi_2$, specific heat measurement was performed down to 0.28 K. In this presentation, we discuss the superconducting gap symmetry of β-$PdBi_2$.

Single crystals of β-$PdBi_2$ were grown by a melt growth method. Electrical resistivity $\rho(T)$ was observed by a standard dc-four-prove method. Specific heat $C(T, H)$ was measured by a relaxation method with a ^{3}He cryostat.

The $\rho(T)$ shows superconductivity at T_c = 4.8 K. Residual resistivity ratio (RRR) is estimated to be 4 obtained from ρ(300 K)/ρ(5.0 K). This value is smaller than that of the previous report [1]. From specific heat measurement, clear jump was observed at T_c = 4.8 K. T^3-dependence of the specific heat $C(T)$ suggests that full-gap symmetry with a single gap and strong coupling with $\Delta C_e/k_BT_c$ = 1.8. Field dependence of the specific heat $C(H)$ clearly shows linear dependence. This result also suggests full-gap symmetry with a single gap.

We have tried to measure thermal conductivity $\kappa(T, H)$ at low temperatures to obtain more information about superconducting gap symmetry. Detailed analysis of $\kappa(T, H)$ will be presented, and we discuss the superconducting gap symmetry of β-$PdBi_2$.

keywords : beta-PdBi2, Superconductivity, Superconducting gap symmetry

PCP2-13 16:00–18:00

Large Upper-Critical Field of the Se-doped BiS_2-based Superconductor

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Superconductivity of the Bi*Ch*-based layered compound La(O,F)BiS_2 has much attention[1]. The crystal structure consists of the LaO layer and Bi*Ch* layer, which is very similar to the FeAs-based superconductors. The Bi*Ch*-based superconductor is known to have the large upper-critical field $\mu_0 H_{c2}(0)$ = 24 T applying magnetic field along *ab*-plane. We focus on the Se-doped compound, which is known to induce bulk superconductivity at $T_c \sim 4$ K with $x < 0.3$[2]. We investigate the superconducting properties of the Se-doped compound, especially upper critical field $\mu_0 H_{c2}(0)$.

We succeeded to synthesize the single crystals with x = 0, 0.1, 0.2, 0.3, 0.4, 0.5, 1. Electrical resistivity ρ(T) was measured by a standard dc-four-prove method in zero and magnetic field up to 11 T.

We confirm superconducting transition from ρ(T) measurements in several magnetic fields. With increasing x, T_c increases up to 4.1 K (x = 0.5). The $\mu_0 H_{c2}(0)$ is determined from ρ(T) measurements in several magnetic fields. The H_{c2}(T) behaves as convex curve in all compounds. Maximum value of the $\mu_0 H_{c2}(0)$ is estimated to be 0.7 T at x = 0.3 with applying magnetic field along *c*-plane. On the other hand, the $H_{c2}(0)$ with applying magnetic field along *ab*-plane decreases at x = 0.2, although compound with x = 0.3 shows maximum value of $\mu_0 H_{c2}(0)$. Interestingly, we discover that compound with x = 0.3 shows the extraordinary upper-critical field along *ab*-plane. In magnetic field range below 12 T, although it is very difficult to determine the upper critical field, we roughly estimated the value with the fitting function of $H_{c2}(T) = H_{c2}(0)(1 - (T/T_c)^{3/2})^{2/3}$, and the value is more than 80 T. From the results, superconducting anisotropy (γ_s) can be estimated to be about 110 in compound with x = 0.3.

[1] Y. Mizuguchi *et al.*, J. Phys. Soc. Jpn. **81**, 114725 (2012).
[2] H. Takafumi *et al,*. J. Phys. Soc. Jpn. **84**, 024723 (2015).

keywords : BiCh2-based superconductor, Superconductivity, Upper-critical field

PCP2-14 16:00–18:00

Growth and characteristics of BiS_2-based superconducting single crystals

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R(O,F)BiS_2 (R: rare earth element) are called BiS_2-based superconducting materials. R(O,F)BiS_2 is composed of stacked $R_2(O,F)_2$ layers and Bi_2S_4 layers. We have grown the R(O,F)BiS_2 single crystals using CsCl-based flux (CsCl/KCl or only CsCl). All the obtained single crystals had a plate-like shape with a well-developed ab-plane of around 1-2 mm in size. The grown single crystals of La(O,F)BiS_2 and Ce(O,F)BiS_2 showed superconducting at about 3 K while the T_cs of Pr(O,F)BiS_2 and Nd(O,F)BiS_2 exhibited approximately 4-5 K. We investigated some interesting properties of R(O,F)BiS_2 single crystals, such as c-axis transport property, magnetic ordering of Ce(O,F)BiS_2 and possibility of mono-layered applications.

keywords : BiS2-based superconductors, Layered mixed-anion compound, Flux growth

PCP2-15 16:00–18:00

Effect of Lead and Antimony Substitution on $LaO_{0.5}F_{0.5}BiS_2$

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We examined the effect of Lead and Antimony substitution on the superconducting transition temperature (T_C) in La(O,F)BiS_2. T_C in La(O,F)BiS_2 increases by the substitution of the element with the smaller ionic radius in the block layer [1]. This result indicates that T_C in La(O,F)BiS_2 is sensitive to the structural stress.

In this study, we examined the effect of the element substitution in the superconducting layer, namely the BiS_2 layer in $LaO_{0.5}F_{0.5}BiS_2$. Antimony ions, which has smaller ionic radius than bismuth ions, was substituted for bismuth ions in the BiS_2 layer. It is noted that Antimony ions is isovalent to bismuth. Lead ions, which has bigger ionic radius than bismuth ions, was also substituted for bismuth ions in the BiS_2 layer. Lead is not isovalent to bismuth.

$LaO_{0.5}F_{0.5}Bi_{1-x}Sb_xS_2$($x$=0-0.08) single crystals and $LaO_{0.5}F_{0.5}Bi_{1-x}Pb_xS_2$($x$=0-0.12) single crystals were grown by flux method with CsCl/KCl flux. Obtained crystals were examined by X-ray diffraction, magnetic susceptibility, and electrical resistivity measurements. By comparing these results obtained, we discuss the substitution effect on the crystal structure and TC in $LaO_{0.5}F_{0.5}Bi_{1-x}A_xS_2$ (A=Pb,Sb).

[1] Y. Fang *et al.*, Phys. Rev. B **91** 064510 (2015).

keywords : BiS2 superconductor, Chemical pressure

PCP2-16 16:00–18:00

Evaluation of Bi Defects in BiS_2-based superconductors by Scanning Tunneling Microscopy and Spectroscopy

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Layered BiS_2-based superconductors LnOBiCh_2 (Ln = La, Pr, Ce, Nd, Yb, Bi Ch = S, Se) exhibit superconductivity near 3 K when the electron carriers are doped by a substitution of F for O [1]. In Nd(O,F)BiS_2, the F concentration estimated by an ARPES measurement is not consistent with the nominal or analytical value of F concentration [2]. It is suggested that this inconsistence is due to existence of Bi defects. On the other hand, novel electronic structures related to Bi defects are observed by Scanning Tunnelling Microscopy and Spectroscopy (STM/STS) in $NdO_{1-x}F_xBiS_2$ and $CeO_{1-x}F_xBiS_2$ [3, 4]. Thus, Bi defects are important to understand these electronic properties in BiS_2-based superconductors.

In this study, an observation of Bi defects and the electronic structure was performed in some Ln(O,F)BiCh_2 materials (Ln = La, Ce, and Nd, Ch = S, Se) using STM/STS. We report the density of Bi defects in these BiS_2-based compounds and the effect of the defects on the electronic structure.

[1] S. Demura et al., Nov. Supercond. Mater. **2**, 1 (2016).
[2] Z. R. Ye et al., Phys. Rev. B **90**, 045116 (2014)..
[3] T. Machida et al., J. Phys. Soc. Japan **83**, 113701 (2014).
[4] S. Demura I., Physics Procedia **81**, 49 (2016).

keywords : BiS2-based superconductivity, Single crystal, STM

PCP2-17 16:00–18:00

Anomalous Temperature Dependence of Resistivity in $LaO_{1-x}F_xBiSe_2$ Single Crystals

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Tokyo Univ.ersity of Science

Newly discovered BiS_2 based superconductors, such as $LnO_{1-x}F_xBiS_2$ (Ln = lanthanoid), change their transport properties and superconducting transition temperature (T_c) by changing lanthanoid or the amount of F. Whereas most of them show monotonous metallic or semiconducting temperature dependence of resistivity, $EuFBiS_2$ exhibits a broad hump below 280 K in resistivity. As a reason for this hump, Fermi surface reconstruction due to CDW transition is implied [1].
Recently, $LnO_{1-x}F_xBiSe_2$, which was fully substituted to Se for S in $LnO_{1-x}F_xBiSe_2$, was also found to be superconductor at about 4 K [2]. We prepared $LaO_{1-x}F_xBiSe_2$ single crystals with several F concentrations, and found these samples exhibit a broad hump in resistivity around 100 K, which has not been reported before. These temperatures at which the hump appears were almost independent of the amount of F. Scanning tunneling microscopy measurements were also performed on these samples. Together with these results, we will discuss the origin of this hump structure.
[1]H. Zhai *et al.*, *Phys. Rev. B* **90**, 064518 (2014)
[2]J. Shao *et al.*, *Euro. Phys. Lett* **107**, 37006 (2014)

keywords : BiS2, BiSe2

PCP2-18 16:00–18:00

Evolution of superconductivity and metallic conductivity by chemical pressure effect in $REO_{0.5}F_{0.5}BiCh_2$ superconductors

*Kohei Nagasaka, Osuke Miura, Yoshikazu Mizuguchi

Tokyo Metropolitan University

Recently, several kinds of BiS_2-based superconductors with BiS_2 superconducting layers have been discovered such as $Bi_4O_4S_3$ and $REO_{1-x}F_xBiS_2$ (RE = rare earth) . However, the mechanisms of BiS_2-based superconductivity has not been clarified. Recent studies on physical properties and crystal structure have revealed that in-plane chemical pressure in the BiS plane is an essential factor essential for the emergence of superconductivity . To obtain further information on the origin of BiS_2-based superconductivity, investigation on the superconductivity from several points of view.
In this study, we have focused on the relationship between in-plane chemical pressure, superconductivity, and normal state metallicity. We prepared polycrystalline samples of $Ce_{1-x}Nd_xO_{0.5}F_{0.5}BiS_2$, $LaO_{0.5}F_{0.5}Bi(S_{1-x}Se_x)_2$, $LaO_{1-x}F_xBiS_2$, and $LaO_{1-x}F_xBiSSe$. The purity and crystal structure of the obtained samples were characterized by X-ray diffraction. From the magnetization, electrical resistivity, and Hall resistivity measurements, superconducting and normal state properties were systematically investigated. As one of the results, we found that the enhancement of in-plane chemical pressure in the BiS plane is related to the emergence of metallic conductivity in both $Ce_{1-x}Nd_xO_{0.5}F_{0.5}BiS_2$ and $LaO_{0.5}F_{0.5}Bi(S_{1-x}Se_x)_2$. We address this phenomena from viewpoints of carrier concentration and/or carrier mobility.

keywords : chemical pressure, BiS2-based superconductors

PCP3-1 16:00–18:00

Novel Diamond Anvil Cell with B-doped Diamond Electrodes

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The great discovery of 200 K superconductivity in hydrogen sulfide under 150 GPa has recently reported by resistivity measurements using a diamond anvil cell (DAC) [1]. It is interesting that if we can measure the resistivity under extremely higher pressure above 300 GPa, superconductivity at room temperature in hydrogen could be observed [2]. However, resistivity measurement is difficult because of the necessity for small sample sizes (< 100 μm) and the deformation of electrodes by compression. The development of an innovative technique is required for the measurements under high pressure. In this study, we have developed a DAC specialized for the resistivity measurements under high pressure [3]. The key component is a heavily boron-doped metallic diamond as an electrode [4]. The resistivity measurements can be easily performed by the DAC using the microscale boron-doped diamond electrodes fabricated on the diamond substrate.

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[2] N. W. Ashcroft, Phys. Rev. Lett. 21, 1748 (1968).
[3] R. Matsumoto, Y. Sasama, M. Fujioka, T. Irifune, M. Tanaka, T. Yamaguchi, H. Takeya and Y. Takano, Rev. Sci. Instrum., 87, 076103 (2016).
[4] Y. Takano, M. Nagao, I. Sakaguchi, M. Tachiki, T. Hatano, K. Kobayashi, H. Umezawa and H. Kawarada, Appl. Phys. Lett. 85, 2851 (2004).

keywords : High Pressure, Diamond Anvil Cell

PCP3-2 16:00–18:00

Examination of the Position Estimation Method for The Magnetic Metal Contaminant Detection

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In the production site, it is demanded that the magnetic contaminant (e.g. iron material, stainless steel) of Φ50μm or lager, which is mixed in the product is removed completely. However, in the case of particle size is smaller than Φ50μm, the attraction removal of contaminant using the conventional method which uses the magnet, becomes difficult. Therefore, it is very useful to detect the contaminant and simultaneously to find its location. In this study, we examined the contaminant inspection technique which used SQUID as high sensitive magnetic sensor that could detect the magnetic contaminant and estimate its position. In this technique, the magnetic field from the magnetic contaminant is generated by magnetizing the contaminant using the excitation coil. The contaminant is moving in a certain direction. Then, the contaminant is detected by measuring the magnetic field. The waveform of the detection signal differs depending on the distance between the location of the contaminant passes and the SQUID. Utilizing this difference, the waveform comparison between the envelope of the reference pattern and the envelope of the detected pattern is performed. As a result, it is possible to obtain the Euclidean distance what is the index representing the similarity. Then, using the Euclidean distance, estimate the passing position (the position perpendicular to the moving direction) of the magnetic contaminant. Because the detected patterns are uncorrelated with the particle size, this technique can estimate the position of the contaminant, regardless of the particle size. This position estimating method was evaluated using the actual detection signal from the magnetic particle.

keywords : SQUID, Position estimation, Magnetic contaminant, Contaminant inspection

PCP3-3 16:00–18:00

Evolution of the CDW gap in Valence Skipper $RbTlX_3$ (X=F,Cl,Br): A First-principle study

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$BaBiO_3$, which is the parent compound of the high-Tc superconductor $(Ba,K)BiO_3$, is a so-called valence skipper. Since the formal valence of Bi in $BaBiO_3$ is the unstable 4+ state, Bi atoms spontaneously disproportionate to Bi^{3+} and Bi^{5+}, accompanied with the displacement of anions. Crystal symmetry is also lowered and the charge-density wave (CDW) emerges. The hole doping restores the high crystal symmetry, collapses the CDW gap, and induces superconductivity.

The electronic structure of recently found $RbTlCl_3$ is known to be very similar to that of $BaBiO_3$. In this paper we investigated the evolution of the CDW gap in $RbTlX_3$ (X=F,Cl,Br) by a first-principles study. When we fix the position of anion and apply hydrostatic pressure, the CDW gap collapses very slowly. On the other hand, when we apply hydrostatic pressure and let the anion position free, the anions shift toward the center of the two Tl atoms, and eventually the CDW gap collapses quite rapidly. We found that $RbTlBr_3$ has the smallest gap among these three compounds as expected, and a moderate hydrostatic pressure (~few GPa) can collapse the CDW gap and make the system metallic. As for this metallic state, we can expect a large charge fluctuation and possibly a superconducting state.

keywords : valence skip, CDW, superconductivity, electronic calculation

PCP3-4 16:00–18:00

Partial-Initiated Surface Flashover Characteristics of Ribbed Surface Insulator in Cryogenic Environment

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Conductive particles are unavoidable due to many reasons such as installation, transportation, operation, etc. These conductive particles are the main cause of electrical insulation failure and superconducting power equipment cannot be exception. In this paper, installing ribs at the surface of insulator has been considered as a solution for improving the tolerance towards conductive particles. In previous research, Tokio Yamagiwa et al. had proved that surface flashover characteristics had been improved by installing ribs at the surface of cylindrical post insulator in SF6 environment. Four different type of specimen made of Teflon was fabricated in order to establish the effectiveness of rib at the surface of insulator in terms of surface flashover characteristics at cryogenic environment. Firstly, tangential electric field analysis along the creepage distance was carried out because electric field parallel to the surface played an important role in surface flashover. Then experimental work was carried out for clean surface and conductive particles attached surface. From the experimental results, it was found that both surface flashover characteristic and the tolerance towards conductive particles could be improved by installing ribs at the surface of insulator.

keywords : Conductive particle, Cryogenic, Particle initiated, Ribbed insulator

PCP3-5 16:00–18:00

Interplay between staggered flux and *d*-wave superconducting states in Hubbard model

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Interplay between staggered flux (SF) and *d*-wave superconducting (dSC) orders is studied for the Hubbard model with a diagonal transfer t' (t-t'-U model) on a square lattice, because the SF state is considered one of the strong candidates that cause the pseudogap phenomena in underdoped high-T_c cuprates [1-3] and coexistence or exclusivity of the pseudogap and dSC gap is in debate in experiments. In this study, a variational Monte Carlo method is used to cope with strong correlations. In the Jastrow-type trial wave function $\Psi = P\Phi$, we allow for the coexistence of SF and dSC orders in the one-body part Φ, and a configuration-dependent phase factor, which is vital to treat a current-carrying state like the SF state for a large-U/t region, is introduced into P besides ordinary correlation factors. Systematically varying the values of U/t, t'/t, and doping rate, we confirm in what area of these parameters the SF and dSC orders coexist or exclude each other, and clarify the features the optimized state possesses in each area.

[1] H. Yokoyama, S. Tamura, and M. Ogata, JPS Conf. Proc. **3** 012029 (2014).
[2] H. Yokoyama, S. Tamura, T. Watanabe, K. Kobayashi, and M. Ogata, Physics Procedia **58** 14 (2014).
[3] Y. Toga and H. Yokoyama, Physics Procedia **81** 13 (2016).

keywords : Superconductivity, pseudogap, cuprate, Hubbard model

PCP3-6 16:00–18:00

Effects of Impurity Potential on Antiferromagnetic and *d*-wave Superconducting States in Hubbard Model

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3. Department of Physics, University of Tokyo, Bunkyo, Tokyo, Japan

Recent numerical studies on the two-dimensional Hubbard (t-t'-U) model [1,2] argued that antiferromagnetic (AF) states or phase-separated states become widely predominant in the underdoped regime for $U \gtrsim W$ (W: band width) and homogeneous *d*-wave superconductivity (*d*-SC) does not arise. This feature is not consistent with the behavior of cuprates, but can be naturally interpreted through analysis of variational Monte Carlo (VMC) calculations [2]. Because the predominance of AF states is also confirmed in the t-J [3] and d-p [4] models, a mechanism of destabilizing the AF order in cuprates possibly comes from the inhomogeneous impurity potentials inherent in cuprate superconductors. In this presentation, we would like to discuss this possibility using a VMC method. As a first step, we introduce into the Hubbard Hamiltonian modulated one-body potentials according to the positions of dopant atoms in the block layers in cuprates. In the trial states ($\Psi=P\Phi$), in addition to various factors used for homogeneous systems, we consider the effects of potential modulation in three patterns: The effects are introduced to (i) one-body (Hartree-Fock) part Φ, (ii) correlation factors P, and (iii) both parts. We will discuss how this potential modulation affects the AF and *d*-SC states.

[1] T. Misawa, M. Imada, Phys. Rev. B **90** (2014) 115137; J. Otsuki *et al.*, Phys. Rev. B **90**, 235132 (2014); B.-X. Zheng, G. K.-L. Chan, Phys. Rev B **93**, 035126 (2016).
[2] R. Sato, H. Yokoyama, J. Phys. Soc. Jpn. **85**, 074701 (2016).
[3] R. Sato, H. Yokoyama, presented in this symposium.
[4] S. Tamura, Ph. D Thesis, Tohoku University (2016).

keywords : Hubbard model, Impurity potential, antiferromagnetism, d-wave superconductivity

PCP3-7 16:00–18:00

Theory of high-temperature superconductivity in strongly correlated fermions system

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Despite much intensive study about high-temperature superconducting cuprates and iron pnictides etc, its mechanism still remains an unsolved problem. Recently, the author proposed the composite fermions theories of these superconductors [1]. The theories are based on the extended d-p model emphasizing that the electronic state of superconductors can be described by the composed fermions constructed with newly defined operators. The peculiarity in these theories is that the Hamiltonian is so modified by the unitary transformation using these fermion operators as to apply the mean field approximation. However, it is another problem to unite these theories into a unified theory to explain generally the properties of these superconductors. Here in order to find the unified theory, the high-temperature superconductivity is more generally investigated in strongly correlated fermions system. It is found that the results can provide a universal explanation about the various superconducting and normal properties of high-temperature superconductors.

[1] K. Nishi, Phys. Proc. 27 (2012) 80; Phys. Proc. 58 (2014) 18;
Phys. Proc. 81 (2016) 17.

keywords : High Tc superconductivity

PCP4-1 16:00–18:00

Impurity Effects on T_c and Electronic Transport Properties in the Undoped Superconductor T'-$La_{1.8}Eu_{0.2}CuO_4$

*Koki Ohashi[1], Takayuki Kawamata[1], Tomohisa Takamatsu[1], Tadashi Adachi[2], Masatsune Kato[1], Shuma Naito[1], Kei Hayashi[1], Yuzuru Miyazaki[1], Yoji Koike[1]

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Recently, it has attracted interest that superconductivity appears in a wide range of x and even in the undoped mother compound ($x = 0$) of adequately reduced thin films of T'- $Nd_{2-x}Ce_xCuO_4$ with the Nd_2CuO_4-type (so-called T'-type) structure. We have investigated impurity effects on the superconducting transition temperature T_c and electronic transport properties, using polycrystalline bulk samples of the undoped mother compound T'-$La_{1.8}Eu_{0.2}CuO_4$ (T'-LECO).

First, effects of magnetic Ni and nonmagnetic Zn impurities on T_c in undopued T'-LECO have been investigated to clarify the pairing symmetry [1]. It has been found that the suppression rates of T_c by Ni and Zn impurities are nearly the same and very similar to those in the optimally doped and overdoped regimes of hole-doped T-$La_{2-x}Sr_xCuO_4$ with the K_2NiF_4-type (so-called T-type) structure where the pairing symmetry is d-wave. These results strongly suggest that the superconductivity in undoped T'-LECO has d-wave symmetry and is mediated by the spin fluctuation.

Second, we have measured the electrical resistivity and the thermoelectric power, using polycrystalline bulk samples of undoped T'-LECO sintered by the spark plasma sintering method. As a result, a resistivity drop due to the superconducting transition has been observed at ~ 20 K for the first time, and very small values of the thermoelectric power have been observed, suggesting that undoped T'-LECO is semimetallic with both electron and hole carriers as inferred from the band structure without charge-transfer gap [2].

[1] K. Ohashi *et al*, J. Phys. Soc. Jpn. **85**, 093703 (2016).
[2] T. Adachi *et al.*, J. Phys. Soc. Jpn. **82**, 063713 (2013).

keywords : undoped superconductor, pairing symmetry, electronic transport properties, impurity effect

PCP4-2 16:00–18:00

An effective Hamiltonian and its phase diagram for T'-structure cuprates

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It has long been considered that the phase diagram of hole- and electron-doped cuprates were well-established; there exists antiferromagnetism (AF) around the half-filling of their phase diagram, and then d-wave superconductivity (dSC) emerges with carrier doping. Tsukada et al. claimed that, however, thin films of the so-called T'-structure cuprates exhibit superconductivity without chemical doping of electrons, only when excess oxygen in as-grown samples are properly removed [1]. This observation has been followed by several experimental studies based on T'-NCCO thin films [2], polycrystalline samples [3], and even on single crystals [4]. Theoretically, however, it is rather inconceivable that dSC appears around the half-filling of the phase diagrams of the t-J or Hubbard model on a square lattice.

Thus in this contribution, we propose a two-band model for T'-structure electron-doped cuprates. The present two-band models is derived from the d-p model essentially along with the idea of Zhang and Rice [5], but explicitly consists of Cu d-orbitals and symmetrically hybridized O 2p orbitals. We also study the phase diagram of this two-band model using fluctuation exchange approximation. We find that the d-wave superconductivity appears even at the half-filling when the charge transfer gap $\Delta = Ud - \Delta p$ is small enough, that is, less than about 1eV, where Ud is the on-site Coulomb repulsion on Cu site and Δp is the energy difference between the O 2p and Cu 3d levels. We show the phase diagrams of this two-band model for several model parameters.

[1] A. Tsukada et al., Solid State Commun. **133**, 427 (2005).; [2] O. Matsumoto et al., Physica C **469**, 924 (2009).; [3] S. Asai et al., Physica C **471**, 682 (2011).; [4] T. Adachi et al., J. Phys. Soc. Jpn. **82**, 063713 (2013).; [5] F. C. Zhang and T. M. Rice, Phys. Rev. B **37**, 3759 (1988).

keywords : Electron doped cuprates, T'-structure, d-p model, An effective Hamiltonian

PCP4-3 16:00–18:00

OPTICAL STUDY OF ELECTRON-DOPED CUPRATE $Pr_{1.3-x}La_{0.7}Ce_xCuO_{4+\delta}$ IN UNDER-DOPED REGION

*Ryota Ohnishi[1], Masamichi Nakajima[1], Sigeki Miyasaka[1], Setsuko Tajima[1], Tadashi Adachi[2], Taro Ohgi[3], Akira Takahashi[3], Yoji Koike[3]

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It is known that there remain a lot of excess oxygen between CuO_2 layer and a fluorite layer in T'-214 cuprates such as $(Pr, Ce)_2CuO_4$, which degrades superconductivity. Although we can observe superconductivity if we properly reduce the as-grown crystals, we do not know whether excess oxygen are completely removed by reducing treatment or not.

Recently, a new reduction method has been developed, which enables us to make electron-doped cuprates superconducting even for the low Ce contents where antiferromagnetism was observed in the conventional samples [1]. That motivated us to re-examine the phase diagram of electron-doped cuprates and to investigate the difference between the new and the old reduction methods in terms of optical spectrum.

Single crystals of $Pr_{1.3-x}La_{0.7}Ce_xCuO_{4+\delta}$ (PLCCO) with $x = 0.05$ were grown by a traveling-solvent floating-zone method [2]. The sample reduced by the new method showed a superconductivity transition at 24.8 K.

The reflectivity of PLCCO was much higher than that of $Nd_{2-x}Ce_xCuO_{4+\delta}$ (NCCO) with $x = 0.05$ that was reduced by a conventional method. The reflectivity value is comparable to that of conventionally reduced NCCO with $x = 0.125$ [3]. We found that the pseudogap was formed around 3000 cm^{-1} in the reduced PLCCO when the temperature decreases. This result suggests that the pseudogap depends only on the Ce content but not on the oxygen content.

[1]T. Adachi *et al.,* J. Phys. Soc. Jpn. **82**, 063713 (2013).; [2]M. Horio *et al.*, Nat Commun. **7**, 10567 (2016). [3]Y. Onose *et al.*, Phys. Rev. B **69**, 024054 (2004).

keywords : High-Tc superconductor,Electron-Doped cuprates, Reduction annealing, Optical spectra

PCP4-4 16:00–18:00

Magnetron sputtering growth of strain-controlled infinite-layer $Sr_{1-x}La_xCuO_2$ thin films with high T_c

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As the crystal structure of electron-doped infinite-layer (IL) $Sr_{1-x}La_xCuO_2$ (SLCO) is the simplest among all cuprate superconductors, they are of significant importance for understanding of the high-T_c cuprates. It is known that key factors are strain tuning and reduction annealing to obtain superconducting IL thin films. However, the preparation of superconducting IL thin films remains difficult because the strain and annealing effects have not been well understood.

The SLCO thin films were deposited on $Ba_ySr_{1-y}TiO_3$ (BSTO; y = 0.2 – 0.7) buffered substrates by DC sputtering at a growth rate of 0.2 nm/min and 1.0 nm/min. After SLCO thin film growth, in situ reduction annealing was performed in vacuum (~10^{-3} Pa) at 525°C for 1 – 45 min to induce superconductivity. The SLCO thin films on the BSTO (y = 0.6) buffer layers [SLCO/BSTO(0.6)] shows the best electrical properties (low resistivity and high residual resistivity ratio) among our thin films. For the growth rate of 1.0 nm/min, T_c of SLCO/BSTO(0.6) was maximum (18 K) at annealing time (t_A) of 4 min. On the other hand, for the growth rate of 0.2 nm/min, SLCO/BSTO(0.6) exhibited the best T_c (36 K) at t_A = 25 min. This results indicates that the growth rate may have an enormous impact on superconducting properties. The implications of these results are discussed in terms of the oxygen sublattice in the IL compound.

keywords : Electron-dope, Lattice strain, Infinite-layer

PCP4-5 16:00–18:00

Theoretical Calculations of Superconductive Transition in Ladder Cuprate $SrCu_2O_3$

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The restriction of dimensions in ladder cuprate is expected to provide strongly correlated electron systems. Previous calculations have predicted that electron-doped ladder cuprate should have a high superconductive transition temperature (T_c). In this study, we investigated optimal doping of ladder cuprate using the fluctuation exchange (FLEX) method on the basis of *ab initio* downfolding. $SrCu_2O_3$ was used as the model substance for superconductivity. First, we calculated the band structure of undoped $SrCu_2O_3$ using PHASE/0 based on density functional theory. The four bands near the Fermi level (E_F) have a Cu_{dx2-y2} character. Next, we carried out FLEX calculations using hopping integrals between sites derived using the Wannier90 program. Here, with the temperature (T) fixed at 0.02 eV, we examined the dependence of the eigenvalue (λ) of the Eliashberg equation on the electron occupation of a Cu site (n). The λ value with heavy electron-doping (0.35 electrons/Cu site) was found to be singularly close to unity. This is likely due to the divergent density of states (DOS) on the top of the pseudo-one-dimensional bands. We also confirmed that the sign of the gap function changes in the transitions of the interband. Our calculations show that heavily electron-doped ladder cuprate, even when far from half filled, can have a high Tc owing to its distinctive bands.

keywords : Ladder cuprate, ab initio downfolding, FLEX calculation

PCP5-1 14:00–16:00

Superconducting properties of polycrystalline $FeSr_2ErCu_2O_{6+y}$

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$FeSr_2ErCu_2O_{6+y}$ (ErFe1212) shows superconductivity only after proper annealing in N_2 flow and subsequent annealing in O_2 flow and under high O_2 pressure. Superconductivity of ErFe1212 was sensitively affected by the annealing temperature in N_2 flow.

To study the superconducting property and magnetic property of polycrystalline ErFe1212, the annealing temperature in N_2 flow was optimized. ErFe1212 samples were annealed at various temperatures in N_2 flow and annealed subsequently at 300 ℃ in O_2 flow and under high O_2 pressure. The optimum temperature determined by resistivity measurement was 780 ℃. The resistivity of the sample annealed under the optimum condition began to decrease at 61.2 K and was vanished below 43.6 K under zero magnetic field and below 12 K under 16 T. A two-step transition was observed in ρ - T curves due to the superconductivity in individual grains and across inter-grain boundaries. The critical current density in individual gains, J_c^{intra}, at 10 K under 100 mT was estimated at 2.80×10^9 A/m^2 from the Bean model. On the other hand, the critical current density in inter-grain boundaries, J_c^{inter}, at 10 K was estimated at 1.6×10^4 A/m^2 from the ac magnetization curve below 0.1 mT. Though J_c^{intra} of ErFe1212 was roughly as similar value as J_c^{intra} of $YBa_2Cu_3O_{7-\delta}$, J_c^{inter} of ErFe1212 was much smaller than that of $YBa_2Cu_3O_{7-\delta}$.

keywords : Cuprate superconductor, Fe1212

PCP5-2 14:00–16:00

Cu substitution for Nb in $NbSr_2GdCu_2O_z$ ($z \approx 8$)

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Nb-based "1-2-1-2" compounds, $NbBa_2LaCu_2O_z$ and $NbBa_2PrCu_2O_z$ ($z \approx 8$), have been synthesized for the first time in 1991by Ichinose *et al.* and Kato *et al.* have recently reported that Sn doping into their related compounds, $NbSr_2RECu_2O_z$ (RE: Sm, Eu or Gd), makes them superconducting by generating carriers due to Sn^{4+} substitution for Nb^{5+}. In our subsequent study, however, nominal compositions of $NbSr_2RECu_2O_z$ give no single "1-2-1-2" phase, *i.e.*, existence of a quite small amount of secondary phase is detected by X-ray diffractometry in all of the samples. In this study, we report the results of trial experiments of several types of element-substitution. Samples are prepared by a solid-state reaction method using Nb_2O_5, $SrCO_3$, Gd_2O_3 and CuO. Nominal compositions of $(Nb,Cu)Sr_2GdCu_2O_z$, $NbSr_2Gd(Cu,Nb)_2O_z$, $Nb(Sr,Gd)_2GdCu_2O_z$ and $NbSr_2(Gd,Sr)Cu_2O_z$ are used. It is concluded that a small amount of Cu substitutes Nb and that a composition of $(Nb0.96Cu0.04)Sr_2GdCu_2O_z$ gives a single "1-2-1-2" compounds. Detailed experimental conditions and results of the cases of other rare-earth elements are discussed.

keywords : NbSr2GdCu2O8

PCP5-3 14:00–16:00

Substitution effect of some lanthanoid elements in $Y(Sr,Ba)_2(Cu,Mo)_3O_z$

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Since the discovery of $YBa_2Cu_3O_z$ (z~7; "1-2-3" compound), which is well-known as the first superconductor having a superconductivity transition temperature (T_c) higher than 77 K (liquid-nitrogen temperature), substitution effect of Sr for Ba in this material has been widely investigated. Its solubility has proved to be 50-60 at.% and T_c decreases as the Sr content increases. While fully substituted compound, $YSr_2Cu_3O_z$, has not been synthesized at an ambient pressure, it has been reported that ~10 at.% substitution of Mo or W for Cu stabilizes the Sr-substituted compound (Den and Kobayashi, 1992). For this system, we have investigated a single-phase formation in a wide compositional range of nominal compositions, $Y(Sr_{1-y}Ba_y)2(Cu_{3-x}Mo_x)O_z$, and given a relationship between x and y giving single-phase compounds. In this study, substitution effect of some lanthanoid elements for Y in the $Y(Sr_{1-y}Ba_y)2(Cu_{3-x}Mo_x)O_z$ system is investigated. Samples with nominal compositions of $RE(Sr_{1-y}Ba_y)2(Cu_{3-x}Mo_x)O_z$ ($0 \le x \le 0.4$, $0 \le y \le 1$; RE: Nd, Sm, Gd, Dy, Ho and Er) were prepared by a solid reaction of commercial powders of RE_2O_3, $SrCO_3$, $BaCO_3$, CuO, and MoO_3. Initial mixture of those powders are calcined at 850˚C for 10 h in air and finally sintered at 960~1000˚C for 10 h in air. They are characterized mainly by means of powder X-ray diffractometry (XRD; θ-2θ). It is found that, for the cases of RE=Dy and RE=Ho, appropriate combinations of x and y give single "1-2-3" compounds while for the cases of RE=Nd, RE=Sm and RE=Er, no single "1-2-3" are obtained. These results are discussed mainly on the standpoint of ionic radius of the lanthanoid elements.

keywords : Y(Sr,Ba)2(Cu,Mo)3Oz, substitution effect, lanthanoid

PCP5-4 14:00–16:00

Effect of Tb substitution on properties of $FeSr_2YCu_2O_{6+\delta}$ magnetic superconductor

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$FeSr_2YCu_2O_{6+\delta}$ has tetragonal $Ba_2YCu_3O_{6+\delta}$-type structure and exhibits superconductivity at 60 K and antiferromagnetic order of Fe at 20 K [1]. Most of the lanthanoid atoms can be substituted for Y in $FeSr_2YCu_2O_{6+\delta}$ similarly to $Ba_2YCu_3O_{6+\delta}$, and additionally Tb can be substituted for Y in $FeSr_2YCu_2O_{6+\delta}$ while $Ba_2TbCu_3O_{6+\delta}$ is not formed. T_c of $FeSr_2TbCu_2O_{6+\delta}$ (T_c = 30 K) is much lower than that of $FeSr_2YCu_2O_{6+\delta}$ although the oxygen content, 6+δ, of $FeSr_2TbCu_2O_{6+\delta}$ is comparable with that of $FeSr_2YCu_2O_{6+\delta}$. $FeSr_2TbCu_2O_{6+\delta}$ also exhibits antiferromagnetic order of Tb at 7 K and does not exhibit antiferromagnetic order of Fe. The antiferromagnetic ordering temperature of Tb is higher than that of lanthanoid ions in other $Ba_2YCu_3O_{6+\delta}$-type compounds.

[1] T. Mochiku et al., J. Phys. Soc. Jpn. 71 (2002) 790.

keywords : high-Tc superconductor, magnetic superconductor, FeSr2YCu2O6+d, Tb substitution

PCP5-5 14:00–16:00

Oxidation and reduction effects of successive superconducting transitions in ultra-fine $YBa_2Cu_4O_8$ ceramics

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Stoichiometric $YBa_2Cu_4O_8$ ceramics with the perovskite structure are composed of the superconducting CuO_2 planes and the edge-sharing CuO zigzag chains. They are recognized to be stable and be free from microscopic randomness due to the oxygen vacancy. In this study, we performed linear and non-linear resistivity measurements in ultra-fine $YBa_2Cu_4O_8$ ceramics synthesized by the citrate pyrolysis method, which are composed of homogeneous grains of submicron size. A successive superconducting transition was observed in the ultra-fine ceramics, while the onset of the superconducting transition temperature T_C^{onset} was equal to that in the normal samples with 10 μm order of grains. Interestingly, by the reduction treatment, the successive transition became pronounced and the temperature of the zero resistivity T_C^{zero} was suppressed, although T_C^{onset} and mass of the specimen exhibited no change. This change was reversible and T_C^{zero} recovered to the initial temperature by the oxidation treatment. We performed the same measurements on the samples with different sintered-time. SEM images of this series show a weak sintered structure with submicron grains. The sintering process fuses and joins the adjacent grains and reduces the total grain surface area, and the variation in T_C^{zero} by the reduction and oxidation treatments decreased with increasing the sintered-time, which indicates that the grain surface is related to the successive superconducting transition. The full width at half maximum (FWHM) of the non-linear resistivity reflects the growth of the intergrain superconducting area. The FWHM tends to narrow with increasing sintered-time and be spread by the reduction treatment. As a result, the successive superconducting transition is attributed to the intergrain superconductivity and the grain surface seems to be deoxidized.

keywords : Oxidation and reduction effects, Ultra-fine $YBa_2Cu_4O_8$ ceramics, Grain surface, Linear and non-linear resistivity

PCP5-6 14:00–16:00

Field-Temperature Phase Diagram of Intergrain Ordering in Superconductive Ceramic YBCO

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Ceramic $YBa_2Cu_4O_8$ superconductors composed of sub-micron size grains are considered as random Josephson-coupled networks containing so-called π junctions and they show successive phase transitions.[1] With decreasing temperature, the intragrain superconducting transition occurs at first inside each grain at T_{c1} =81K. The second glass transition occurs among the grains at T_{c2} ($< T_{c1}$) at which a sharp peak of nonlinear susceptibility is observed. This critical phenomenon suggests onset of the chiral-glass phase, where the chirality is frozen, i.e., the circulation of superconducting current loops are frozen.[2] The third transition at T_{c3} is the intergrain superconducting one, where the phase of superconducting order parameter corresponding to the pseudo XY spin of spin-glass systems is frozen, and the resistivity of the ceramics diminished. We measured the temperature and field dependences of the nonlinear susceptibility and the resistivity to determine the transition temperatures T_{c2} and T_{c3} in magnetic field. In zero-field, the transition temperatures of T_{c2} = 61 K coincides that of T_{c3}. T_{c3} decreases monotonously with increasing field. However, T_{c2} increases up to 62 K at 30 Oe, then T_{c2} decreases with increasing field. The transition line for T_{c2} behaves very different from that for T_{c3} in applied magnetic field. The results suggest the spin-chirality decoupling scenario predicted by Kawamura.[2]
[1] H.Deguchi et al. , Physics Procedia 45 (2013)129-132.
[2] H.Kawamura, J.Phys. Soc. Jpn. 79 (2010) 011007.

keywords : superconductive ceramics, YBCO, chiral glass transition, random Josephson-coupled network

PCP5-7 14:00–16:00

Double pair breaking peak in triple layer cuprate Bi2223

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In the family of bismuth strontium calcium copper oxide superconductors ($Bi_2Sr_2Ca_{n-1}Cu_nO_{2n+4}$) the triple Cu-O plane component ($n=3$) $Bi_2Sr_2Ca_2Cu_3O_{10}$ (Bi2223) stands out for its complexity and interesting physics. Like in other multiple layer cuprates, the two outer Cu-O planes (OP) are inequivalent to the inner Cu-O plane (IP).
A doping imbalance was observed in Bi2223 by NMR as in other multilayer cuprates [1], with the two OP being overdoped and the IP underdoped. Recent ARPES experiments indicated that the two band showed two superconducting gaps with two different values. However, there has been no other experimental report indicating two different electronic states in IP and OP.
In the present work Bi2223 samples have been examined by Electronic Raman Scattering ERS, which is a valuable technique being momentum resolved, relatively surface insensitive and sensible also to unoccupied states.
Optimally doped Bi2223 single crystals have been grown by a travelling solvent floating-zone method (TSFZ) and subsequently measured by ERS. The result shows that, in the B_{1g} configuration at 10K, not one but, two pair breaking peaks appear at different energies. This is a direct fingerprint of the double superconducting gap in Bi2223, supporting the previous ARPES results, and is the first Raman observation of the inequivalent electronic states corresponding to the IP and OP in the multilayer cuprates.
[1] H. Mukuda et al, JPS Conf. Proc. , 012105 (2014)
[2] S. Ideta et al, Phys. Rev. Lett. 104, 227001 (2010)

keywords : d electron system, Cuprates, Raman Scattering Spectroscopy, Superconductivity

PCP5-8 14:00–16:00

STS measurement of Ni impurity effect in Bi2212

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We report STS measurements about the temperature dependence of density-of-state for optimally-doped and overdoped Ni-Bi2212. We found that there were two types of a pseudogap; larger one, which had a typical pseudogap size and decreased with increasing a temperature, and smaller one, which seemed almost temperature independent in our measured temperature range. The larger gap seemed to switch to the smaller gap with some overlap region with increasing a temperature. Similar behavior was found in the optimally doped samples with an enhanced gap size and the temperature range. We may identify the large gap as a conventional pseudogap and the small one as new pseudogap, which is associated with Ni impurity. This shows a peculiarity of Ni impurity, and suggests an unusual interaction between an impurity and the Cu-O electronic system.

keywords : High-Tc, Bi2212, STM/STS, impurity effect

PCP5-9 14:00–16:00

Spin injection effect in thin Bi2212 single crystal

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Utsunomiya University

The transport properties using a hybrid structure of superconductor and ferromagnetic metal have been investigated intensively. The spin injection is one of the key techniques for introducing nonequilibrium state into superconductors, at which the superconducting order parameter is suppressed. Here, we present a study of the influence of the spin injection on the in-plane transport properties of $Bi_2Sr_2CaCu_2O_y$ (Bi2212) in which thin superconducting sheets (CuO_2) alternate with insulating layers (SrO, BiO). The sample was fabricated by patterning a flake cleaved from a bulk Bi2212 single crystal into a 50 μm wide bridge structure. The in-plane transport was measured at 77 K by four terminal method as a function of external magnetic field while spin polarized current (SPC) was injected into the Bi2212 bridge from two contacts of Co(20nm)/Au(10nm) bilayer, which were formed onto the bridge. By injecting SPC, unusual non-zero voltage region was observed below I_c in I-V characteristic. We believe that this is due to redistribution of the current flowing in the bridge because the critical current in the vicinity of the surface is suppressed by the spin injection into the top layer of the bridge. Indeed, we observed that $I_c^{(Inj)}$ corresponding to the onset current of non-zero voltage was varied depending on SPC. Furthermore, we observed hysteretic field dependence of the magnetoresistance. This also suggests the suppression in superconductivity due to injection of SPC.

keywords : Spin injection, BSCCO

PCP5-10 14:00–16:00

And-renormalization effects on antiferromagnetism and d-wave superconductivity in two-dimensional t-J model

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In recent numerical studies [1] including ours [2], it has been argued that antiferromagnetic (AF) states or phase-separated states widely prevail in the underdoped regime of two-dimensional Hubbard (t-t'-U) model for U≳W (W: band width) and homogeneous d-wave superconductivity (d-SC) does not appear. We showed using a variational Monte Carlo (VMC) method that these features are naturally understood by taking account of band-renormalization effects (BRE) in the AF state [2]. Hence, it is important to check whether or not a t-J-type model, which is another plausible model of cuprate superconductors (SC's), shares such features, which are not consistent with the properties of cuprates.
In this work, we discuss the t-t'-J model using a Jastrow-type trial wave function, Ψ=PΦ. In the many-body factor P, we introduce intersite factors that depends on the charge and spin configurations of nearest-neighbor sites besides the onsite projection. As the one-body part Φ, we adopt AF and d-SC states in which effective bands are optimized in the same manner as in [2]. As a first step, here we consider properties of the two ordered states, independently. It is found that in contrast to the previous results without BRE, the AF state becomes widely predominant over the d-SC state also in the t-t'-J model. A Lifshitz transition is found in the AF state as in the Hubbard model [2], but the transition point tends to shift to t'=0 at half filling. As compared to the Hubbard model, the d-SC state is somewhat more stabilized for t^'/t~0; this stability is originated in the gain in exchange energy rather than the energy gain in the hopping term.
[1] T. Misawa and M. Imada, Phys. Rev. B 90, 115137 (2014); J.Otsuki et al., Phys. Rev. B 235132 (2014); B.-X. Zheng, G. K.-L. Chan, Phys. Rev B 93, 035126 (2016). [2] R. Sato, H. Yokoyama, J. Phys. Soc. Jpn. 85, 074701 (2016).

keywords : cuprate, d-wave superconductivity, antiferromagnetism, t-J model

PCP6-1 14:00–16:00

Detecting Vortex Motion with Scanning Tunneling Microscopy

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Because of the fundamental and practical importance, we have studied dynamics of vortices driven by current by means of transport measurements, where the characteristic vortex velocity is of order of mm/s-m/s. The transport measurements probe the average velocity of moving vortices in the entire sample, while it is also important to observe the individual vortex motion and configuration. For this purpose, we attempt to observe the vortex motion using a scanning tunneling microscopy/spectroscopy (STM/STS) simultaneously with the transport measurements. Due to the scanning nature, an observable vortex velocity in STS is limited to be nm/s. Information on faster vortex motion could be available by measuring vortices passing under the fixed tip. Another key factor of STM/STS is that a tunneling current for observing vortex motion is as small as pA. Because of the limit of the current amplifier, an observable vortex velocity is limited to μm/s, which is by three-order magnitude lower than that required in our study. To increase the measurement current, we use STS in the point contact region. We study a thin amorphous Mo_xGe_{1-x} film, in which sufficient transport data are accumulated.
In zero magnetic field, we observe a small conductance peak, which spans the range of a few mV about a zero bias voltage, indicating an Andreev reflection. Then, we apply a magnetic field and inject a transport current I to drive the vortices. As long as I is smaller than the depinning current, the conductance peak stays almost unchanged. However, when I exceeds the depinning threshold, the peak height shows a decrease, which is attributed to the vortices passing under the tip. Although we have not yet obtained reliable data showing real-time vortex motion, the presence of vortex motion is clearly detected by the point contact measurement.

keywords : STM, vortex motion, point contanct, Andreev reflection

PCP6-2 14:00–16:00

Non-equilibrium depinning transition driven by dc current and vortex density

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The presence of a non-equilibrium depinning transition has been predicted by numerical simulation [1], while there is no experimental proof for the prediction. We have recently provided evidence of the non-equilibrium depinning transition in a vortex system of amorphous Mo_xGe_{1-x} films with random point pinning [2]. We have measured the time evolution of voltage $V(t)$ generated by the vortex motion at the fixed magnetic field B, i.e., fixed vortex density, just after the dc driving current I with a sharp rise was suddenly applied to the vortex system with an ordered initial configuration. We observe a decay of $V(t)$ toward a steady-state value indicative of dynamic disordering and a power-law divergence of the relaxation time $\tau(I)$ near the depinning current I_d determined from the I-V characteristics. We also study the critical behavior of the depinning transition when the vortex density B is increased at fixed I and find again a power-law divergence of $\tau(B)$ near the depinning field B_d. The critical exponents of the transition are almost identical to each other independent of whether I or B is varied. We will present the critical behavior found near the particular point in the peak-effect regime, specifically, around the peak field where $I_d(B)$ takes a peak and discuss the implication.
[1] C. Reichhardt and C. J. Olson Reichhardt, Phys. Rev. Lett. 103, 168301 (2009).
[2] S. Okuma, Y. Tsugawa, and A. Motohashi, Phys. Rev. B 83, 012503 (2011): S. Okuma and A. Motohashi, New J. Phys. 14, 123021 (2012).

keywords : plastic depinning transition, non-equilibrium phase transition, peak effect

PCP6-3 14:00–16:00

Random organization of vortices under anisotropic conditions

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Colliding particles under periodic drive self-organize to avoid future collisions, which has been known as “random organization (RO)"[1]. With increasing the amplitude of ac-drive, a relaxation time of RO diverges at a threshold, suggesting that the particle system in the steady state shows a dynamic transition from reversible flow to irreversible flow. The reversible-irreversible transition (RIT) has been studied in periodically driven colloidal suspensions [1] and superconducting vortices [2] in a Corbino-disk where a global shear is applied [3]. Recently, we revealed that RIT and RO also occur in a strip-shaped superconducting film of amorphous Mo_xGe_{1-x} where a local shear due to pinning is applied [4].

In this work we study how RO changes in the vortex system under tilted field. When field is tilted, e.g., θ=36°, from perpendicular direction to the sample plane, hexagonal lattice of vortices is expanded by a factor of $1/\cos\theta$ along the tilt direction. For amorphous Mo_xGe_{1-x} films a side of the expanded lattice prefers to be parallel to the tilt direction, which works as an anisotropic condition. We find that relaxation times of RO for the ac-drive parallel to the tilt direction are an order of magnitude shorter than those under untilted field. Furthermore, ac-drive perpendicular to the tilt direction leads to a further reduction of relaxation times. These results indicate that the anisotropy given by tilt filed significantly limits possible configurations of vortices in the transient RO process.

[1] L. Corte et al., Nat. Phys. 4, 420 (2008): D. J. Pine et al., Nature 438, 997 (2005).
[2] N. Mangan et al., Phys. Rev. Lett. 100, 187002 (2008).
[3] S. Okuma et al., Phys. Rev. B 83, 012503 (2011).
[4] R. Nitta et al., Phys. Procedia, 65, 105 (2015).

keywords : non-equilibrium phenomena, self-organization, anisotropic effect

PCP6-4 14:00–16:00

Spin-polarized Local Density of States around Vortex in Helical p-wave Superconductors

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The ruthenate superconductor Sr_2RuO_4 has been much attention as a topological superconductor, since exotic quantum states such as Majorana Fermion are expected. A lot of experimental and theoretical studies support that Sr_2RuO_4 is a spin-triplet chiral *p*-wave superconductor. However, another possible pairing is a helical *p*-wave, because the difference of condensation energy between chiral and helical states is very small [1]. Therefore, to confirm the pairing states of Sr_2RuO_4 and other candidate materials, it is important that we study the unique behaviors of physical quantity as a chiral or helical *p*-wave superconductor.

In our previous study for chiral *p*-wave superconductor [2], it is found that the NMR relaxation rate T_1^{-1} around the vortex depends on whether the chirality of Cooper pair is parallel or anti-parallel to the vorticity. On the other hand, in the vortex state of helical *p*-wave superconductor, we expect that spin-polarized low-energy excitations around the vortex are induced, reflecting the interaction between vorticity and chirality of each spin-component of Cooper pair. Additionally, these low-energy excitations relate to the Majorana Fermion.

In this work, we calculate the spin-polarized local density of states (LDOS) in the vortex lattice state of helical *p*-wave superconductors by self-consistent Eilenberger theory. In particular, we investigate the site and magnetic field dependences of spin-polarized LDOS in order to clarify the unique behavior of low-energy excitations around the vortex. These theoretical estimates of spin-polarized LDOS may be confirmed by the spin-resolved scanning tunneling microscopy and spectroscopy measurements.

[1] M. Tsuchiizu *et al.*, Phys. Rev. B **91**, 155103 (2015)
[2] K. K. Tanaka *et al.*, Phys. Rev. B **93**, 094507 (2016)

keywords : Helical p-wave superconductor, vortex state, quasi-classical theory

PCP6-5 14:00–16:00

Spin-current induced around half-quantum vortices in chiral p-wave superconducting states

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2. Eidgenössisch Technische Hochschule

Chiral p-wave superconducting state exhibits several distinct features, such as topological excitations and half-quantum vortices in each of which a Majorana zero-mode is bounded. A half-quantum vortex (HQV) formed by a π-rotation of the superconducting phase and a π-rotation of d-vector around the vortex core[1]. Thus the magnetic flux through HQV is one-half of the flux quantum Φ_0. HQVs are topologically possible objects, however, the energetic stability is a subtler question. Indeed, HQVs have not been seen in Sr_2RuO_4 for years. Unscreened spin current induced around HQVs can make them unstable[2-4]. Thus it has been pointed out that a possible way to stabilize HQVs is to limit the size of a sample.

In this contribution, to clarify the size effects microscopically, we study the spin-current distribution around HQVs in a chiral p-wave superconducting state based on a square lattice tight-binding model with an anisotropic attractive interaction between electrons on nearest-neighbor sites, a spin-orbit interaction, and the effects of magnetic field within the Peierls description and Zeeman coupling[5]. The superconducting vortex lattice states are described within the Bogoliubov-de Gennes theory. We also investigate the phase diagram for the stability of HQV with respect to the anisotropy of the interaction and the strength of the spin-orbit coupling.

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keywords : p-wave superconductors, half-quantum vortices, spin current

PCP6-6 14:00–16:00

Temperature Distribution and Critical Current of Long HTS Cables Cooled with Subcooled Liquid Nitrogen

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The cooling of the long superconducting HTS transmission lines performs by pumping of subcooled liquid nitrogen (LN2) along the cable. The temperature of LN2 along the cable increases because the heat losses of the cryostat and heat generation in the HTS cable. The experiment at test cable line in Ishikari shows that rate 35 L/min rate LN2 flow provides increasing of LN2 temperature by 1 K per 1 km of length. The technology when the back flow of LN2 cools the radiation shield surrounding the cable pipe is also applied in Ishikari project. In this case the ambient heat flow is 50 times less than without radiation shield. All heat from environment removes by LN2 back flow. When transport current is close to critical value the Joule heat of HTS cable is significant. This heat increases the temperature of LN2 flowing along the HTS cable. Near the outlet the temperature of HTS cable is maximal and critical current is minimal. From safety point of view the critical current of whole cable should be determined equal to critical current near outlet. However, there is no technical possibility to detect the critical current of the last segment of the cable. The critical current detects only by the total voltage over the cable. The average critical voltage drop of the cable happens when the warm end of the cable is under overcritical current. It can lead the damage of the cable. The situation with overheating of the cable enhances because HTS tapes is under PPLP insulation with low heat transport properties. The present work contains analysis of temperature distribution along the cable and the way for obtaining the critical current of long HTS cable cooled by subcooled LN2. The influence of PPLP insulation is also taken into account. We also performed extrapolation of obtained results for longer cable lines up to 10 km length.

keywords : HTS cable

PCP6-7 14:00–16:00

Manipulation of Magnetic Flux States in Superconducting Squares with Artificial Pinning Sites

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We report the direct observation of magnetic flux states in mesoscopic superconducting squares with artificial pinning sites. Employing a scanning SQUID microscope, we magnetically image the configuration of magnetic flux penetrating in five holes in square dots. The observed magnetic images clearly reveal how the magnetic flux are distributed and trapped in the holes. We show that the flux states can be manipulated by the arrangement of holes.

keywords : Mesoscopic superconductors, Flux States, Scanning SQUID microscope

PCP6-8 14:00–16:00

Magnetic field dependence of most stable vortex states in the chiral helimagnet / superconductor bilayer system

*Saoto Fukui, Masaru Kato, Yoshihiko Togawa

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The vortex state is affected by a magnet, in particular, a ferromagnet [1]. For example, in a ferromagnet / superconductor bilayer system, vortices spontaneously appear in the superconductor because of the magnetic field from the ferromagnet.

Recently, the chiral helimagnet attracts much attention. This magnetic structure of the chiral helimagnet shows helical rotation, and it forms a soliton lattice under a magnetic field [2]. We consider a chiral helimagnet / superconductor bilayer system. We expect the helical magnetic structure leads to singular vortex configurations in the superconductor.

Therefore, we study effects of the chiral helimagnet on vortex states in the superconductor [3-5]. We investigate a chiral helimagnet / superconductor bilayer system. To obtain vortex states, we solve the Ginzburg-Landau (GL) equations in the superconductor. We incorporate the effect of the chiral helimagnet on the superconductor as an external field magnetic field. For this external magnetic field, we use the exact solution that can be obtained from the Hamiltonian in the chiral helimagnet.

For solving the GL equations, we use the finite element method. From various initial state, we solve the GL equations iteratively. Then, we obtain various vortex configurations under same magnetic field distribution. In order to find the most stable vortex state, we compare the Ginzburg-Landau free energies of these states.

In this presentation, we show magnetic field dependence of most stable vortex states in the chiral helimagnet / superconductor bilayer system.

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keywords : Superconductor, Chiral helimagnet, Vortex states, Finite element method

PCP6-9 14:00–16:00

Simulations of vortices in a star-shaped plate with an artificial pin

*Hiroki Miyoshi[1], Atsuki Ito[1], Vu The Dang[1,2], Ho Thanh Huy[1,2], Masahiko Hayashi[2], Masaru Kato[1,3,4], Takekazu Ishida[1,4]

1. Department of Physics and Electronics, Osaka Prefecture University
2. University of Sciences, Vietnam National University HCMC, Ho Chi Minh, Viet Nam
3. Department of Mathematical Science, Osaka Prefecture University
4. Institute for Nanofabrication Research, Osaka Prefecture University

Although a triangular vortex lattice is stable in bulk type-II superconductor, exotic vortex configurations are expected to appear in a small superconducting plate [1]. Theoretical calculations on vortex structures in star-shaped superconducting has been given in our preceding work [2]. In this work, we extended our theoretical studies to the case of having an artificial pin. We performed the Ginzburg-Landau (GL) calculations systematically to compare with the pin-free case [2] by using the finite element method [3]. We found that a vortex tends to accomodated in an aritificial pin in the star-shaped plate. We found a systematic evolution of vortex structure with increaseing magnetic field. We compare our theoretical calculations with vortices in a star-shaped $Mo_{80}Ge_{20}$ plate with an artificial pin and without an artificial pin obtained by a scanning SQUID microscope [4]. We reconstructed the vortex image on the sample surface by the inverse Fourier transformation method [5].

keywords : Ginzburg-Landau calculations, vortex distribution, scanning SQUID microscope

PCP6-10 14:00–16:00

Molecular Dynamics Simulation on Vortex Lattice Melting in Meso-scopic Superconductors

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After the discovery of cuprate High-Tc superconductors, vortex states in the H-T phase diagram were explored in detail. Interestingly, there are melting line of vortex lattice. This melting behavior comes from weak pinning, large thermal and quantum fluctuations in the cuprate High-Tc superconductors.

Recently, Ooi et al. showed the melting temperature in meso-scopic cuprate superconducting square plate oscillates with increasing magnetic field. They explained this oscillation comes from the stability of configuration of n^2 vortices (n=1,2,3,4,5,…).

In order to confirm this phenomenon, we study the vortex lattice melting in mesocopic superconductors using the molecular dynamics method [2,3] for vortices. Temperature dependence of vortex dynamics comes from the fluctuation force and penetration dependence in the vortex-vortex interaction. Using the standard deviation of the positions of vortices, we can determine the melting temperature. Changing the vortex numbers, we find the melting temperature oscillates with increasing the vortex number.

In the presentation we will discuss the size dependence and shape dependence of the vortex-melting curves.

This work was supported by JSPS KAKENHI Grant Number JP26400367.

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keywords : Vortex lattice melting, Molecular dynamics, Vortex dynamics, Mesoscopic superconductor

PCP6-11 14:00–16:00

A variety of vortex state solutions of Ginzburg-Landau equation on superconducting mesoscopic plates

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It has been confirmed experimentally and theoretically that vortex configurations in mesoscopic superconductors are strongly affected by shapes and symmetries of the samples. However, in the plate with antidots, vortex states with disturbed vortex configuration were also observed. Such states are considered metastable states. In this presentation, we report vortex state solutions of the Ginzburg-Landau equation for the superconducting mesoscopic plate obtained by the finite element method (FEM). Generally, there is more than one solution at a certain field. In the plate with antidots case, we obtained the vortex states in meta stable solutions that have the vortex configuration to avoid the antidots because of the interaction between the vortices. We will also discuss the symmetry breaking and the emergence of a new symmetry of the vortex configuration caused by the gradient field.

keywords : vortex, mesoscopic, Ginzburg-Landau equation

PCP6-12 14:00–16:00

Numerical restoration of surface vortices in Nb films measured by a scanning SQUID microscope

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While the penetration depth λ is one of the material parameters in a bulk type-II superconductor, a penetration depth λ is prolonged an effective penetration depth Λ_{eff}, which depends on a thickness d and a temperature T [1]. We studied a vortex distribution in concave decagon, star, and Packman shape superconducting plate by scanning SQUID microscope by using amorphous $Mo_{80}Ge_{20}$ films [2,3,4], the penetration depth in $Mo_{80}Ge_{20}$ film is rather extended compared to a sample size. In the present work, we measured vortex profiles on a pure Nb film (10 mm x 10 mm) by using a scanning SQUID microscope. We also apply the numerical method to improve the spatial resolution of the scanning SQUID microscope in terms of the inverse Biot-Savart law [5]. We found the temperature dependence of the effective penetration depth Λ_{eff} in Nb film after correcting the effect of broadening of the vortex profile when the observation point is deviated from the surface. We consider that our method is a direct method to determine the penetration depth in the superconducting film.

Acknowledgment
This work is supported by Grant-in-Aid for Young Scientists (B) (No.26800192), Grant-in-Aid for Scientific Research (S) (No. 23226019), Grant-in-Aid for Scientific Research (A) (No.16H02450) from JSPS.

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keywords : scanning SQUID microscope

PCP6-13 14:00–16:00

Magnetism, Fluctuations and Superconductivity in Cuprate High-Temperature Superconductors

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2. Hakodate National College of Technology

We investigate the ground state of a strongly correlated electron system on the basis of the variational Monte Carlo method by adopting improved wave functions that take account of inter-site electron correlation. The improved wave function gives results that are qualitatively different from those obtained by a simple Gutzwiller wave function. The spin and charge fluctuations induce an effective pairing interaction between electrons in the strongly correlated region. This may be able to bring about high-temperature superconductivity.

The electronic state crucially depends on the material parameters such as the strength of the Coulomb interaction U, transfer integrals t, t', and the energy levels of p and d electrons. We clarify the material parameter-dependence of the electronic state, especially the stability of the superconducting state in the correlated region.

keywords : high-temperature superconductivity, strong correlation, improved wave function, variational Monte Carlo method

PCP6-14 14:00–16:00

Equilibrium and dynamic vortex phase diagrams near absolute zero in a thick amorphous film

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2. Dept. of Engineering Science, The University of Electro-Communications

We have developed a measurement of a mode-locking resonance with pulsed currents that generate much less heat [1] than the previous one with continuous currents [2]. We have successfully determined the dynamic melting field $B_{c,dyn}(T)$ for a driven vortex lattice of a thick amorphous Mo_xGe_{1-x} film in the limit of zero temperature (T=0) and construct a dynamic as well as a static vortex phase diagram over the entire temperature range [1]. At T = 0, the vortex state without pinning is composed of vortex-lattice and quantum-vortex-liquid (QVL) phases, and the melting field separating the two phases is identified as $B_{c,dyn}(0)$. By comparing the dynamic and static phase diagrams, we find that when the weak pinning is introduced into the pin-free vortex system, a disordered glassy phase appears just above the vortex-lattice phase. A threshold field separating the two phases is slightly lowered from $B_{c,dyn}(0)$, indicative of defect-induced disordering of the lattice. In contrast, the melting field into the QVL is remarkably enhanced from $B_{c,dyn}(0)$ up to near the upper critical field, indicating the significant suppression of the QVL phase, whose origin is attributed to stronger effective pinning at lower T. From an experimental point of view, the pulsed ML technique developed in this study will be widely used to probe the dynamics of the fast driven vortex matter and, more generally, elastic object interacting with random substrates, which may generate large heat.

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keywords : Vortex phase diagram, Quantum fluctuations, Quantum phase transition, Amorphous films

PCP6-15 14:00–16:00

Dynamic Melting of Anisotropic Vortex Lattices

*Inoue Toshiki[1], Aguri Ochi[1], Yasuki Kawamura[1], Mihaly Dobroka[1], Koichiro Ienaga[1], Shin-ichi Kaneko[1], Nobihito Kokubo[2], Satoshi Okuma[1]

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We have performed comparative study on dynamic melting of driven vortex lattices in magnetic field tilted by 36°from normal to the film plane and that of a driven isotropic lattice in untilted field. Based on mode-locking (ML) measurements, we have found that the vortex lattices in tilted field are expanded in the tilt direction and that the shape and orientation of the driven lattices change with increasing the dc velocity at ML. Associated with this structural change, the dynamic melting field at which the driven lattice melts also changes. Irrespective of the lattice shape and orientation, the dynamic melting seems to occur as the shorter side of the distorted lattices approaches the side length at which the isotropic lattice melts dynamically [1]. In the meantime, we also acquire data suggesting the presence of the two-stage melting in the high velocity region. We construct the phase diagram showing the vortex configuration in the field and dc velocity plane, which highlights the shape and orientation of the lattices prior to dynamic melting at different velocities.
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keywords : Anisotropic lattice, Dynamic melting, Mode-locking resonance

PCP6-16 14:00–16:00

Simulation of Critical Current Density of Bulk High Tc Superconducting Materials with a Thermally Activated Flux Motion

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In the upcoming generation, bulk high Tc superconductivity plays a crucial and promising role in numerous industrial applications ranging from MagLev trains to magnetic resonance imaging (MRI). Especially, the bulk high-Tc superconductors (HTS) as permanent magnets is based on the fact that they can trap magnetic fields by several orders of magnitude higher than the best hard ferro-magnets. The high Tc material could obtain very powerful compact superconducting super-magnets, which can be operated by the cheaper liquid nitrogen temperature or below. As a result, the new advanced technology can use be utilized in a more attractive manner in a variety of medical applications which has the capacity to revolutionize the medical field. Whereas magnetic field dependence of critical current density is very important to understand these materials. For this, a variety of bulk MgB2, RE-123 (RE: Y, Gd, etc.,), and thick film Er-123 were modeled with accord to a thermally activated flux motion. In essence, bulk MgB2 follows a certain criterion where an exponential decaying model is applied. On the other hand, RE-123 and Er-123 requires a unique simulated model where one is increasing and other is decreasing in a circumstance. The modeling of the various superconducting materials could be understood in terms of the pinning mechanisms.

keywords : Bulk Superconducting Materials, critical current density, modeling, melt structured

PCP6-17 14:00–16:00

Microscopic calculation of the flux-flow Hall effect in a superconductor with an isolated vortex

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We study the flux-flow Hall effect in a superconductor with an isolated vortex based on the augmented quasiclassical equations of the superconductivity with the Lorentz force.

Recently, we derived augmented quasiclassical equations of superconductivity with the Lorentz force in the Matsubara formalism so that the charge redistribution due to supercurrent can be calculated quantitatively [1]. The standard Eilenberger equations and Ginzburg–Landau equa- tions cannot describe the vortex-core charging and flux-flow Hall effect because of the missing Lorentz force, which has been incorporated successfully in a gauge-invariant manner within the real-time Keldysh formalism [2]. The augmented quasiclassical equations in the Keldysh for- malism have been used to study charging in the Meissner state with Fermi surface and gap anisotropies [3], and also to calculate flux-flow Hall conductivity numerically for the s-wave pairing on an isotropic Fermi surface [4]. On the other hand, it is still desirable when studying the charging to transform the equations into the Matsubara formalism, in which equilibrium properties and linear responses can be calculated much more easily.

We calculate the ohmic (longitudinal) and Hall resistivities induced by a motion of an isolated vortex by transforming the energy variable of the augmented quasiclassical equations in Keldysh formalism into the Matsubara energy on the imaginary axis. It is shown that linear responses can be calculated much more easily compared to the aproach based on the augmented quasiclassical equations in the Keldysh formalism.

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keywords : Superconductivity, Vortex, Quasiclassical theory, Flux flow resistivity

PCP6-18 14:00–16:00

Charging due to the Lorentz force, Kopnin force and slope in the density of states in superconductors

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Studies on charging in inhomogeneous superconductors have been carried out theoretically and experimentally[1-5]. Despite these efforts, a microscopic understanding of the charging is still missing. This is partly because the standard quasiclassical equations and the Ginzburg--Landau equations cannot describe the charging in superconductors.

We derive a new augmented quasiclassical equations of superconductivity that incorporates a missing factor besides the Lorentz force [6] and Kopnin force [7], i.e., a finite slope in the density of states (DOS), so that charging in superconductors can be calculated microscopically and quantitatively. Their validity is exemplified by calculating the density of states of a three-dimensional *s*-wave superconductor in comparison with the result based on the Bogoliubov-de Gennes equations.Using them, we study charging in an isolated vortex of an *s*-wave superconductor to see which of the Lorentz force, Kopnin force, and slope in DOS contribute dominantly to the charging around the vortex core.

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keywords : Superconductors, Vortex charge, Quasiclassical equations, Lorentz force

PCP6-19 14:00–16:00

Hall effect in the Abrikosov lattice of type-II superconductors

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The Lorentz force on electric currents flowing in magnetic fields generally induces charge redistribution before recovering a steady state to yield the Hall voltage that brings a force balance along the transverse direction. However, we still have quite a poor understanding of this phenomena in superconductors since the force on supercurrent itself may easily be overlooked in the presence of the predominant diamagnetic effect by supercurrent. Hence, physics of the Lorentz force in superconductors remains mostly unexplored theoretically. The main purpose of our study is to clarify the fundamental nature of the Hall effect in superconductors.

Hall effect in superconductors may be divided into two categories: one in equilibrium with persistent currents and the other in nonequilibrium situations with the motion of vortices and dissipation. The first one is inherent to superconductors and easier to handle but nevertheless has not been paid much attention in the literature. Here, we focus on this first category and study vortex charging in type-II superconductors as a function of the magnetic field based on the augmented quasiclassical equations of superconductivity [1,2]. We study the charge density and electric field due to the Lorentz force in the vortex lattice of clean type-II superconductors focusing on the two types of models below: (i) s-wave pairing with isotropic Fermi surface in two dimension [3] and (ii) $d_{x^2-y^2}$-wave pairing with anisotropic Fermi surface obtained from the tight-binding approximation for two-dimensional square lattice model. Results and considerations are shown in detail in our presentation.

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keywords : Vortex, Hall effect, Magnetic field dependence

PCP7-1 14:00–16:00

Fabrication of Low Temperature LPE-$NdBa_2Cu_3O_y$ Films without Nd/Ba Substitution via Phase Decomposition Process

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Shimane University

Recently, we fabricated biaxial-oriented $REBa_2Cu_4O_8$ (RE124) epitaxial films on $NdGaO_3$ (001) single crystalline substrate by using KOH flux at ~650°C [1]. In a previous work, we succeeded in fabrication of $NdBa_2Cu_3O_y$ (Nd123) films directly above 425°C by the KOH flux method under ambient pressure. However, the T_c of Nd123 films fabricated at 425 ~ 525°C were drastically lower than that of well-known single-crystalline Nd123 phase. It is considered that the T_c degradation of low temperature fabricated Nd123 films was caused by Nd/Ba substitution [2]. On the other, RE124 has a rigorous stability of oxygen stoichiometry and no structural phase transition (such as RE/Ba substitution) as opposed to RE123 phase. Moreover, RE124 keeps stable at far lower temperature than RE123 in the ambient atmosphere [3]. In this investigation, to increase the T_c for Nd123 film by a simple and low temperature method, we fabricated the Nd124 films without Nd/Ba substitution by KOH flux method, and then heat-treated for phase decomposition from Nd124 into Nd123 as no Nd/Ba substitution.

From XRD 2θ–θ pattern and SEM-EDS analysis, as-grown film fabricated at 600°C showed single-phase Nd124 without Nd/Ba substitution. Moreover, obtained film was decomposed the crystal phase from Nd124 into Nd123 + CuO by heat-treatment in reduction atmosphere. The c-axis length of Nd123 phase decomposed from Nd124 was longer than that of Nd123 phase prepared directly. We can suggest that the Nd124 film become to Nd123 phase as no Nd/Ba substitution.

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keywords : Liquid phase epitaxy, RE124, RE123, Dedomposition

PCP7-2 14:00–16:00

Preparation of $EuBa_2Cu_3O_{7-\delta}$ Films Decomposed From $EuBa_2Cu_4O_8$ Films Deposited by Molten Hydroxide Method

*Yugo Miyachi, Shuhei Funaki, Keisuke Soeda, Yasuji Yamada

Shimane University

Y123 powder decomposed from Y124 shows T_c =90 K and high inter-grain J_c with segregation of Cu oxides [1]. To apply RE124-to-RE123 decomposition materials to coated conductors, highly-oriented RE124 films is required. Recently, we have reported the preparation of Eu124 films by using low-temperature liquid NaOH-KOH [2], and Eu124 films showed high orientation coefficient and T_c which is comparable to bulk Eu124. In this paper, we report Eu123 films decomposed from Eu124 films deposited with NaOH-KOH, and discuss relationships between decomposition conditions, T_c and distribution of Cu.

The Eu124 films were deposited on $SrTiO_3$ (001) substrates at 475°C by the NaOH-KOH flux method [2]. To decompose Eu124 phase, the films were annealed at 550-650°C under $P(O_2)$ = 10^{-4} atm. The decomposed films were oxygenation-annealed at 450°C under $P(O_2)$ = 1 atm. Phase identification, distribution of Cu and T_c were evaluated by XRD, SEM-EDS and four probe electrical measurements, respectively.

From XRD patterns, Eu124 phase decomposed to Eu247 phase at 600°C under $P(O_2)$ = 10^{-4} atm, and Eu123 phase appeared at 625°C and 650°C. From SEM-EDS observation, Cu oxide particles precipitated on/into the matrix with diameter of a micron order. From R-T measurements, the as-deposited Eu124 films showed T_c^{zero}=69 K, the Eu247 films decomposed at 600°C showed T_c^{zero}=85 K and the Eu123 films decomposed at 625, 650°C showed T_c^{zero}=93 K.

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keywords : REBCO, Molten hydroxide method, Critical temperature, Phase transformation

PCP7-3 14:00–16:00

Measurements of Shielding Current Decay in YBCO Tapes Formed into One Turn Coil

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2. Kyushu univercity

The superconducting coils can excite magnetic fields with low losses. Thus the magnets have been applied to MRI. Recently, applications of HTS tapes to MRI have been studied for improvements of cooling efficiency and increase in magnetic fields. Especially, developments of MRI using REBCO tapes are expected, because REBCO tapes have higher critical current densities in external magnetic fields than that of BSCCO tapes. In order to realize the MRI using REBCO tapes, it is important to clarify properties of shielding currents in the tapes under external magnetic fields and transport currents, because the shielding currents deteriorate the field quality. In addition, magnetic fields change corresponding to the shielding currents decay. Therefore, in particular, it is important to clarify the properties of shielding current decay. In this paper, we measured the shielding current decay in a sample coil wound with YBCO wires. A diameter of the sample coil is 190 mm. Critical current of the sample is 114 A. And an effect of DC current flowing through the sample on the properties of shielding current decay was studied experimentally.

keywords : REBCO, Shielding current decay, MRI

PCP7-4 14:00–16:00

Enhancement of J_c in-field for $YBa_2Cu_3O_y$ Coated Conductors Using Vapor-Liquid-Solid Growth Method by Introducing Y_2BaCuO_5

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A Vapor-Liquid-Solid (VLS) growth method enables REBCO films to grow rapidly compared with the conventional PLD method [1, 2]. However, RE_2O_3 precipitates or defects are usually introduced into the REBCO films via liquid phases as natural pinning centers, because it is difficult to introduce artificial pinning centers (APCs) using this method. Thus, our objective is enhancement of J_c in-field by introducing APCs into VLS-REBCO. In this presentation, we introduced Y_2BaCuO_5 (Y211) phase into VLS-$YBa_2Cu_3O_y$ (YBCO) matrix.
We fabricated Y211-doped YBCO films with PLD method on CeO_2 buffered IBAD-MgO substrates. Ba-Cu-O liquid layer and YBCO vapor phase were supplied using surface modified targets with Y211 on YBCO seed layers. We changed proportion of Y211 on the targets.
The crystallinities of YBCO grown via liquid phase were great. T_c and J_c in self-field at 77 K of VLS-YBCO with Y211 were 91.4 K and 2.9 MA/cm^2. The J_c-B property at 77 K was enhanced by adding Y211, for example, J_c at 1 T was about four times larger than pure VLS-YBCO. Additionally, the J_c-B-θ property at 77 K, 1 T showed isotropic. These results suggest that Y211 phase can be grown in a VLS-YBCO matrix and acts as the APCs. We will discuss superconducting properties of Y211-doped VLS-YBCO at various temperatures.
This work was partly supported by JSPS (Nos. 23226014, 15H04252, 15K14301, 15K1430), JST-ALCA, and NU-AIST alliance project. The metal substrates were provided from SRL, ISTEC.
[1] Y. Yoshida *et al.*: Appl. Phys. Lett. **69** (1996) 845
[2] I. Hirabayashi *et al.*: IEEE Trans. Appl. Supercond. **9** No. 2 (1999) 1979

keywords : Vapor-Liquid-Solid growth, thin film, REBCO coated conductor, flux pinning

PCP7-5 14:00–16:00

Carrier Density Dependence of the Critical Temperature in $BaHfO_3$ doped $SmBa_2Cu_3O_y$ Films

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$BaMO_3$ (BMO, M= Zr, Sn, Hf) doped $REBa_2Cu_3O_y$ (REBCO, RE= Rare Earth) films show large critical current densities (J_c) in magnetic fields. BMO forms nanorods in the REBCO matrix. A high content of BMO increases matching fields due to the more nanorods, however, it suppresses critical temperatures (T_c) possibly due to the interface strain. In this study, we investigate the origin of the T_c degradation in the REBCO films with the high content of the BMO nanorods.
We fabricated SmBCO films on $LaAlO_3$(100) substrates by the PLD method using a Nd:YAG pulsed Laser. An alternating targets technique was used to introduce various contents of $BaHfO_3$ (BHO) of 0 ~ 15.2 vol.% into the SmBCO films. As well as the earlier reports, T_c was suppressed with increasing the BHO content. The c-axis length of the SmBCO matrix expanded with the higher BHO content by a strain due to a lattice misfit between BHO and SmBCO. n decreases with increasing the BHO content. Those results indicate that the c-axis expansion for the higher BHO content causes a lack of oxygen in the SmBCO matrix, which results in the less T_c because oxygen in the CuO chains supply carriers to CuO_2 planes in SmBCO. From these findings, a high oxygen doping into a SmBCO matrix might improve T_c even in BHO heavy doped SmBCO films. We will optimize annealing conditions for the higher oxygen doping to improve T_c in the BHO heavy doped SmBCO films.
This work was partly supported by a Grant-in-Aid for Scientific Research (15H04252, 15K14301, 15K14302 and 16H04512), JST - ALCA and NU - AIST.

keywords : REBCO, thin film, nanorods, carrier density

PCP7-6 14:00–16:00

Improvement of In-Field J_c of $YBa_2Cu_3O_y$ + $BaHfO_3$ Thin Films by Modified Crystallization Process in TFA-MOD Method

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In-field critical current densities (J_c) of $YBa_2Cu_3O_y$(YBCO) thin films have been enhanced by introduction of flux pinning centers, such as $BaZrO_3$ nanoparticles[1]. There have been several papers reporting the effect of heating processes in metal organic deposition (MOD) on the sizes of flux pinning centers in the YBCO films using trifluoroacetates (TFA). Currently, there are two representative heating processes available for MOD, one is the conventional heating processs (1-step) and another one is the two-step heating process (2-step) [2, 3]. The advantages of 2-step is its capability of fabricating YBCO films with finer flux pinning centers at higher number density, resulting higher critical current density J_c than the film by 1-step. Similar behaviors were also reported from $BaHfO_3$ (BHO) in YBCO films by 2-step [4].
In this study, additional heating and cooling processes were introduced in prior to the conventional heating process as the first step of 2-step, and cooling process was modified to examine the effect of cooling methods on the YBCO films with BHO. Two different cooling methods were applied as the first heating process, one at furnace cooling and another one at air cooling. In-field J_c of air cooling was found higher than that of furnace cooling, which suggests that the air cooling would probably introduce finer and denser BHO nanoparticles within the YBCO film.
[1] T. Puig et al, Supercond. Sci. Technol. 21 (2008) 034008
[2] K. Kimura et al, IEEE Trans. Appl. Supercond. 23 (2013) 6601704.
[3] K. Konya et al, Physica C. 494 (2013) 144-147.
[4] H. Horita et al, Supercond. Sci. Technol. submitted (2016)

keywords : TFA-MOD, Flux pinning center, YBCO

PCP7-7 14:00–16:00

Study of the superconducting coil effect on current density distribution in BSCCO tape after an over-current pulse

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The development of power transmission lines based on long-length HTS tapes requires the high quality production of these tapes. A serious damage can happen to the HTS power cable due to overcurrent conditions or because of technical errors. To avoid the cable damage in any urgent case, Superconducting coils technology is used to limit the over-current. Comprehensive understanding of the current density characteristics of the HTS tape after such condition and after using SFCL is required to restart the operation of the power transmission line. At the same time, current distribution along and across the HTS tape provides us with the sufficient information about the quality of the tape performance in different current feeding regimes.
Hence, we examine BSCCO tape under different current feeding regimes after pulse and by using the superconducting coil. Firstly an over-current pulse current is applied and followed by a DC 100A. Afterwards the power-feeding scenario is applied with the use of the coil. We scanned both; direct and permanent magnetic field above the BSCCO tape via a Hall probe sensor. Using an inverse problem technique we calculated the corresponded current density distributions.
We show a picked current density distribution after the over-current pulse as an effect of an opposite electric field at the tape edges. However, the current distribution profiles after using a SFCL show a similitude with normal current feeding condition, and an absence of the opposite electric field at the edges. The current distribution is uniform after using the over-current limiter.

keywords : BSCCO tape, Over-current pulse, Superconductor coil, Hall probe

PCP7-8 14:00–16:00

High-Speed Shielding Current Analysis in Cracked HTS Film: Implementation of H-Matrix Method and Variable Reduction Method

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Since physical properties of HTS films are remarkably degraded by cracks, nondestructive crack detection is crucial in a production process of large-sized HTS films. Recently, the scanning permanent-magnet method (SPM) was developed for measuring the critical current density of an HTS film and its applicability to crack detection in an HTS film was also suggested. However, the performance of the SPM as a crack detector has not yet been investigated enough.

On the other hand, evaluation of the shielding current density is indispensable for numerical simulations of crack detection. After discretized with time, an initial-boundary-value problem of the shielding current density reduces to a problem in which a nonlinear boundary-value problem is solved at each time step. However, the solution of the nonlinear problem by the Newton method is extremely time-consuming mainly because a linear system with a dense matrix has to be solved at each iteration cycle of the Newton method. Recently, the authors showed that, if the linear system is solved with GMRES, remarkable speedup of the shielding current analysis can be realized.

In the present study, two methods are proposed for further accelerating the shielding current analysis: fast matrix-vector multiplication by the $\mathcal{H}$-matrix method and variable reduction by the QR factorization. The performance of both methods is evaluated numerically and, as an application of the methods, detectability of multiple cracks in an HTS film is investigated numerically.

keywords : critical current density, nondestructive detection, numerical simulation, surface crack

PCP7-9 14:00–16:00

Study on Oxygen In-diffusion in Joint Configuration

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The application of 2G HTS coated conductors (CCs) in systems operated in persistent current mode with high temporal stability, requires superconducting joint with high current transportation capacity and practical processing time. During the high-temperature sintering stage for joining two CCs, oxygen out-diffusion seems inevitable. Thus post oxygen annealing is necessary to restore superconductivity of the joining area. However, the oxygen in-diffusion process is slow because of the closed architecture of the joining area and low diffusivity of oxygen at annealing temperature. In this work, two types of structure for high efficiency oxygen in-diffusion has been studied, including micro hole matrix along c-axis and latticed pathway parallel to a-b plane. Finite element method was applied to simulate the oxygen in-diffusion behavior for both types. And in-situ resistance relaxation measurement was performed to verify the effect of designed structure.

keywords : superconductor, joint, oxygen diffusion, latticed pathway

PCP7-10 14:00–16:00

Epitaxial growth of superconducting MgB_2 thin films with a Mg buffer layer at 110°C

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MgB_2 is a BCS superconductor with remarkably high superconducting transition temperature T_c = 39 K [1]. It has significant potential for fabricating highly efficient superconducting devices because of not only high superconducting transition temperature but also small penetration depth and extremely short electron–phonon scattering time. Fabrication of superconducting devices based on MgB_2 thin films requires the development of tractable nanofabrication processes and methods for growing high-quality MgB_2 thin films.
We grew crystalline MgB_2 thin films with an epitaxial Mg buffer layer on *c*-plane 4H-SiC or sapphire substrate at a low substrate temperature of 110°C using molecular beam epitaxy [2]. In spite of unpreceded low growth temperature, superior crystallinity and surface flatness were confirmed by in situ reflection high-energy electron diffraction and X-ray diffraction measurements. Moreover, we successfully confirmed the occurrence of sharp superconducting transition at 27 K.
To the best of our knowledge, the present growth temperature is the lowest compared to any preceding reports on superconducting MgB_2 thin films, and is lower enough to apply a lift-off technique using conventional organic-based lift-off resist. New MgB_2 thin film growth process is, thus, promising for the development of a convenient nanofabrication technique for MgB_2 thin films based on a standard lift-off process with a commercial organic resist instead of widely-used dry etching method.
[1] J. Nagamatsu, *et al.*, Nature **410**, 63 (2001).
[2] H. Shishido, *et al.*, Appl. Phys. Express **8**, 113101 (2015).

keywords : Epitaxial thin film, MgB2, MBE

PCP7-11 14:00–16:00

Upper critical fields and critical current densities of Nb_3Sn doped with (Ti,Ta) of (Ti,Ga)

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It is well known that the small amount of Ti addition to the bronze significantly increases the growth rate of the Nb_3Sn layer and the critical current density J_c characteristic in the high magnetic field [1]. Hence, in order to get the Nb_3Sn having further excellent critical current properties, the addition of Ta or Ga in the bronze with Cu-15Sn-0.3Ti was carried out. The effect on the upper critical field B_{c2} and J_c by adding (Ti,Ta) or (Ti,Ga) is discussed.

The samples prepared by the bronze process. The addition of Ta (+0.08mass%) or Ga (+0.5mass%) in the bronze with Cu-15Sn-0.3Ti was carried out. The standard sample which added only Ti was also prepared. Heat treatment of 100 hours or 200 hours at 700℃ for the diffusion of elements was performed. SQUID magnetometer was used to obtain B_{c2} and J_c from hysteresis curve of magnetic moment. It was confirmed by EDX observation that (Ti,Ta) or (Ti,Ga) elements was homogeneously distributed in the Nb_3Sn layer.

B_{c2} at 0 K was estimated from the temperature dependence of B_{c2} by WHH theory [2]. It is found that B_{c2} of the standard sample is the highest for heat treatment of 200 hours. On the other hand, B_{c2} for the 100 hours is higher in sequence as (Ti,Ga) additions > (Ti,Ta) additions > standard. J_c of the standard sample is the highest for heat treatment of 200 hours. It is observed that the magnetic field dependence of J_c under the high magnetic field is improved by (Ti,Ta) or (Ti,Ga) additions for heat treatment of 100 hours.

In conclusion, the standard sample for 200 hours is the best in the present study. Although a positive effect of (Ti,Ta) and (Ti,Ga) additions is confirmed, the improvement in B_{c2} and J_c is limited. It is necessary to find the optimum condition to obtain better performance in addition of fourth elements than the standard one.
[1] K. Tachikawa *et al.*: J.Appl.Phys. **53** (1982) 5354; [2] N. R. Werthamer *et al.*: Phys. Rev. **147** (1966) 295

keywords : Nb3Sn, elemental addition, bronze process, critical current density

PCP7-12 14:00–16:00

Fabrication and Properties of Nb_3Al Superconductor sintered after hot-pressing

Wen Jia Lin[1], Ping Yuan Li[2], Li Yuan Xu[1], Zhou Yu[1], Yong Liang Chen[1], Xi Feng Pan[2], Guo Yan[2], Yong Zhao[1,3], *Yong Zhang[1]

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2. Western Superconducting Technoligies Co., Ltd.
3. School of Physical and Science Technology, Southwest Jiaotong University

High-energy ball milling is an effective approach to prepare Nb-Al supersaturated solid-solutions, and high performance Nb_3Al superconductor is prepared after heat treatment under 1000°C. During hot pressing and sintering process, the use of pressure can provide energies for reaction and accelerate the reaction between elements, resulting in shorter sintering time and lower sintering temperature. A series of Nb_3Al superconductor bulks have been fabricated by the hot pressing and sintering process, and the effects of milling time and annealing temperature are determined on Nb_3Al phase formation and superconducting properties. After optimizing the milling and annealing process, Nb3Al superconductor bulks are obtained after ball milling for 2 h, hot pressing under 3.4×10^7 Pa and sintering at 950° C for 3h. The critical temperature (T_c) reaches 15.6 K and the critical current density (J_c) is 10^6 A/cm^2 at 4.2 K without outer field.

keywords : Nb3Al superconductor, High-energy ball milling, hot pressing process, Superconductivity

WBP1-1 16:00–18:00

Fabrication of (Y,Gd)$Ba_2Cu_3O_{6+y}$ Coated Conductor Containing Refined $BaZrO_3$ Particles by TFA-MOD Method Using Reel-to-Reel System

*Koichi Nakaoka, Akira Ibi, Takato Machi, Yukie Usui, Keisuke Wada, Teruo Izumi

National Institute of Advanced Industrial Science and Technology

The TFA-MOD method possesses an essential advantage of low-cost production for REBCO Coated Conductors (CCs), since it does not require either a high-vacuum system or a high energy source such as laser. On the other hand, the J_c value of MOD-REBCO CCs in magnetic fields is noticeably lower than those of CCs fabricated by vapor-phase method such as PLD and MOCVD. Recently, we have found out that single coating film thickness in multi-coating technique could act as another new process controlling factor for the size of BZO particles as APCs. As the single coating film thickness decreases from 150 to 30 nm, the average BZO particle size also decreases from 16 to 13 nm. An increase in J_c value in magnetic fields was confirmed by thickness of single coating film, and J_c value of 1.6 MA/cm^2 at 66 K, 3 T was obtained at the single-coating film thickness of 30 nm. However, this new process with a thin film coating requires a significantly large number of repetitions of the coating/calcination process to obtain a thick film, which result in a low production rate and a higher technical cost. For this problem, the new starting solution, which realized high travelling rate with maintaining film quality, was developed.

In this work, we have investigated to achieve high rate coating/calcination process and demonstrate that the fabrication of REBCO CCs by reel-to-reel system with cost efficiency.

This study was supported by the Ministry of Economy, Trade and Industry (METI), the Japan Agency for Medical Research and Development (AMED), and the New Energy and Industrial Technology Development Organization (NEDO).

keywords : coated conductor

WBP1-2 16:00–18:00

The influence of the grain-boundary angle on flux pinning properties in TFA-MOD (Y,Gd)BCO CCs

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TFA-MOD derived REBCO coated conductors (CCs) are expected for magnet applications because of low-cost and high critical current density (J_c). For the applications, its in-field J_c needs to be further improved. For the enhancement of in-field J_c, one is the improvement of intra(granular)-J_c and the other is the improvement of inter(granular)-J_c. For the enhancement of intra-J_c, controlling the carrier density and adding pinning centers are effective. On the other hand, the intra-J_c is strongly dependent on the grain-boundary (GB) angle. Generally, the GBs of buffer layer strongly influences the GBs in REBCO CC. However, the influence of the GBs on in-filed J_c in TFA-MOD REBCO CCs is not clear. In this work, we fabricated (Y,Gd)BCO CC with the various angle of GB ($\Delta\varphi$) of CeO_2 buffer layer. The CC with $\Delta\varphi$=2° shows high self-field J_c of 5.1 MA/cm^2, which is 1.5 times higher than that with $\Delta\varphi$=4°. Although the CCs with different $\Delta\varphi$ are similar irreversibility field, in-field J_c at 77 K and $B \| c$ for the CC with $\Delta\varphi$=2° higher than that with $\Delta\varphi$=4°. The enhancement of in-field J_c comes from the improvement of self-field J_c. We would suggest that the flux pinning properties of the CCs are insensitive to the $\Delta\varphi$ of the CeO_2 buffer layer at given temperature and magnetic field. We will discuss the influence of $\Delta\varphi$ of the CeO_2 buffer layer on in-field J_c and flux pinning properties in TFA-MOD CCs at various temperature and magnetic field. A part of this work was supported by JSPS (26709076).

keywords : TFA-MOD, (Y,Gd)BCO, grain-boundary, coated conductor

WBP1-3 16:00–18:00

The effect of intermediate heating treatment on in-field J_c in TFA-MOD BZO doped (Y,Gd)BCO wires

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The TFA-MOD $REBa_2Cu_3O_y$ wire is one of candidate wire for the magnet application because of low-cost and high critical current density(J_c). However, the application required high in-field J_c property. So far, we have succeeded in obtaining high in-field J_c by addition of $BaZrO_3$ nanoparticles (NPs) into $(Y_{0.77},Gd_{0.33})Ba_2Cu_3O_y$ ((Y,Gd)BCO+BZO) films. For further enhancement of J_c, controlled size of BZO NPs is one of key factors. Recently, AIST successfully controlled size of BZO NPs by the introduction of the intermediate heat treatment (IHT) process. However, the effect of IHT on in-field J_c and microstructure for high vol% of (Y,Gd)BCO+BZO wires is not clear.
In this work, in order to investigate the effect of IHT on superconducting properties, we fabricated high vol% of BZO doped (Y,Gd)BCO wires. The (Y,Gd)BCO+BZO wires with IHT show high critical temperature (T_c) and self-field J_c ($J_c^{s.f.}$), which are almost same with that of (Y,Gd)BCO+BZO wire without IHT. At in-field, the (Y,Gd)BCO+BZO wire with IHT shows higher in-field J_c and nearly isotropic angular dependence of J_c compared to that of wire without IHT. From the microstructure study, the (Y,Gd)BCO+BZO wire with IHT has smaller size and uniformly dispersed BZO NPs compared to that of wire without IHT. These results suggest that the introduction of IHT is important role for improving in-field properties.
This work was supported by JSPS (26709076).

keywords : nanoparticles

WBP1-4 16:00–18:00

Effect of $BaZrO_3$ nanoparticle on critical current density in the longitudinal magnetic field for $REBa_2Cu_3O_y$ wires by TFA-MOD

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The Lorenz-force-free DC cable proposed by Prof. T. Matsushita can carry high current-carrying capacity compared with a conventional superconducting DC cable. The trifluoroacetate metal organic deposition (TFA-MOD) process derived $REBa_2Cu_3O_y$ (REBCO) wires are one of the valuable candidates for the Lorenz-force-free DC cable because of low-cost and high superconducting performance. However, the Lorenz-force-free cable requires further high critical current density (J_c) in the longitudinal magnetic field ($H||I$) for TFA-MOD REBCO wires. So far, we have succeeded in obtaining high J_c for the $(Y_{0.77}Gd_{0.23})$ $Ba_2Cu_3O_y$ wires with $BaZrO_3$ nanoparticles (NPs) ((Y,Gd)BCO+BZO) in the transverse magnetic field ($H\perp I$). However, the effect of BZO NPs on superconducting properties in the longitudinal magnetic field for (Y,Gd)BCO wires is not clear.
In this work, we fabricated (Y,Gd)BCO+BZO wires to investigate the superconducting properties in the longitudinal magnetic field. The critical temperature of (Y,Gd)BCO+BZO wires is almost same with that of standard (Y,Gd)BCO wires, indicating that even with the introduction of BZO NPs, the crystallinity and the composition of the matrix hardly change. In the longitudinal magnetic field ($H||I$), the J_c of (Y,Gd)BCO+BZO wire shows 3.7 MA/cm^2 at 77 K and 1.0 T, which is higher compared with standard (Y,Gd)BCO wire. Our results indicate that introduction of BZO NPs by TFA-MOD is an important role in enhancement of the J_c in the longitudinal magnetic field for (Y,Gd)BCO wires.
A part of this work was supported by JSPS (26709076).

keywords : longitudinal magnetic field

WBP1-5 16:00–18:00

The effect of oxygen annealing temperature on in-field J_c of TFA-MOD (Y,Gd)BCO CCs

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$REBa_2Cu_3O_y$ (REBCO) coated conductors (CCs) derived by TFA-MOD process are promising candidate for magnet applications, because those are low cost and high superconducting performance. However, the practical applications require further enhancement of in-field critical current density (J_c). So far, we have obtained high self-field J_c ($J_c^{s.f.}$) values and critical temperature (T_c) for $(Y_{0.77}Gd_{0.23})Ba_2Cu_3O_y$ ((Y,Gd)BCO) CCs by partial substitution of Gd into Y site. The control of carrier concentration in (Y,Gd)BCO layer by oxygen annealing condition is one of key to further enhancement of superconducting properties.
In this work, we prepared the (Y,Gd)BCO CCs with various oxygen annealing temperature (T_A) in order to investigate the effect of annealing temperature on superconducting properties. We demonstrate that the (Y,Gd)BCO CC with T_A=450 ℃ shows T_c=92 K and $J_c^{s.f.}$=4 MA/cm^2. On the other hand, although T_c of (Y,Gd)BCO CC with 350 ℃ is lower than that of CC with 450 ℃, (Y,Gd)BCO CC with 350 ℃ shows high $J_c^{s.f.}$ (=5 MA/cm^2). At high magnetic field, the (Y,Gd)BCO CC with 450 ℃ shows higher J_c values than that with other T_A. We will discuss the influence of oxygen annealing temperature on carrier concentration, irreversibility fields and in-field J_c for TFA-MOD (Y,Gd)BCO CCs.
A part of this work was supported by JSPS (26709076).

keywords : Oxygen annealing, (Y,Gd)BCO

WBP1-6 16:00–18:00

Effects of La addition on the fabrication of fluorine-free MOD-REBCO films

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It is essential to develop REBCO coated conductors of a low cost and excellent mass productivity with high J_c-B performances for the application of the REBCO superconducting films to high current-carrying superconducting wires. In order to realize the object, we have been studying the fabrication of REBCO films by a fluorine-free metal organic deposition (FF-MOD) method. In our previous study, we studied the effect of Ho addition on the fabrication of fluorine-free MOD-GdBCO films, and found that the J_c-B performance of the films are improved by Ho oxides formed in the film. In this study, we have investigated the effects of La addition on the growth and superconducting properties of REBCO (RE = Gd, Sm, Nd) superconducting thin films using the fluorine-free MOD method. Coating solutions for REBCO thin films were prepared by using Gd, Ba, Cu 2-ethylhexanates solved in toluene. La was added to the REBCO films by La 2-ethylhexanate solutions in range of 1 to 10 mol%. REBCO thin films are prepared on $LaAlO_3$ (LAO) single-crystal substrates by coating the starting solutions, calcining process, firing process and the introduction of superconducting carriers by oxygen annealing. GdBCO films with 3 mol% addition showed a highly c-axis orientation. The growth of the GdBCO superconducting phase was suppressed by the La addition over 3 mol%. The amount of holes on the film surface was decreased by the La addition up to 3 mol%. The GdBCO films with 1 and 3 mol% La addition showed the J_c at the self-field over 2MA/cm^2 and improved J_c-B properties. The results indicate that the La addition is effective for the enhancement of the J_c-B performance. The effects of the La addition on the other REBCO films will be discussed later.

keywords : Thin film, MOD, La, Fluorine-free

WBP1-7 16:00–18:00

Flux pinning properties of hafnium doped Gd123 films fabricated by fluorine-free MOD method

*Natsuki Kobayashi[1], Ryusuke Kita[2], Osuke Miura[3]

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In order to improve the flux pinning properties Hf and Zr doping are the very valid way of introducing the perovskite nano-structure such as $BaZrO_3$, and $BaHfO_3$ into RE123 superconductors. However, the studies for Hf doped Gd123 thin films fabricated by the fluorine-free metal organic deposition (FF-MOD) which is the easiest production process have not been done yet. In this study, we have successfully fabricated Hf doped FF-MOD Gd123 thin films on $LaAlO_3$ substrates and investigated their flux pinning properties. T_c of Hf doped films slightly decreases about 1 K compared with 92.5K for non-doped one. However, as Hf doped amount increased, J_c gradually increased in high magnetic fields. The maximum J_c of 2.72 MA/cm^2 at 0T, and 0.27 MA/cm^2 at 1T were achieved for Hf 10 mol% doped film, which are three times larger than ones for non-doped film. Furthermore, as Hf doping amount increased, the flux pinning force increased, and the peak sifted to high magnetic field side. Thus the non-saturation phenomenon of F_p is clearly observed. The elementally pinning force and effective pinning density also increased. We believe that effective APCs are introduced into Gd123 thin films by Hf doping.

keywords : fluorine-free metal organic deposition, artificial pinning centers, Hf doping, GdBCO

WBP2-1 16:00–18:00

Influence of chemical etching and partial melting heat treatment on the structure and superconducting properties of YGdBCO coated conductors

*Ming Jiang Wang[1], Wen Tao Wang[1], Lian Liu[1], Bao Lei Huo[1], Bing Cai Wu[1], Zhi Bin Liu[1], Yong Zhang[1], Cui Hua Cheng[3], Yong Zhao[1,2]

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3. School of Materials Science and Engineering, University of New South Wales, Sydney, Australia.

This study examined the structure and superconducting properties of YGdBCO CCs before and after a chemical etching and partial melting heat treatment. It is pretty critical to optimize these treating parameters for the development of a superconducting joint between YGdBCO CCs. The chemical etching at lower temperatures about 5-20℃ was used to remove Cu and Ag stabilizer layers. The Ic value of sample etched at 5℃ with NH3:H2O2 of 1:1 was 85A, near to that of virgin sample about 87A. The samples with different partial melting temperatures and oxygen partial pressures during melting stage displayed various structures and superconducting properties. Few secondary phases such as BaCuO, (YGd)211 and CuO were generated in the samples with melting temperature above 790℃and P(O2) about 0.01-0.4 Torr. The superconducting properties of YGdBCO have been almost restored by oxygenation annealing process. Based on the optimal parameters obtained in this study, future work on the superconducting joint of the YGdBCO CCs will be carried out.

keywords : YGdBCO CC, chemical etching, partial melting, oxygen partial pressure

WBP2-2 16:00–18:00

Stability diagram of $GdBa_2Cu_3O_{7-\delta}$ for an off-set composition in low oxygen pressures with oxide refinement process

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We have studied the phase stability of $GdBa_2Cu_3O_{7-\delta}$ (GdBCO) compound for the specimens with the nominal composition of Gd : Ba : Cu = 1 : 1 : 2.5 in low oxygen pressures (PO_2) regime ranging from 1 to 150 mTorr. Due to the GdBCO coated conductors fabrication via the reactive co-evaporation deposition and reaction (RCE-DR) process with this composition, an accurate determination of the phase stability boundary of GdBCO for this off-set composition from GdBCO is prerequisite for the RCE-DR process optimization since the growth conditions of GdBCO film can be fully understood. For this study, Gd-Ba-Cu-O amorphous precursor films were deposited on $LaAlO_3$ (001) substrates at 200° C by pulsed laser deposition (PLD). By reel-to-reel tube furnace, as-deposited amorphous films were annealed at various high temperatures in low oxygen pressures (PO_2). Experimental results reveal that GdBCO is formed by reaction of $Gd_2O_3 + L_1 \rightarrow Gd_2CuO_4 + L_2 \rightarrow GdBa_2Cu_3O_{7-\delta} + Gd_2CuO_4 + Cu_2O$. Also, stability boundaries of GdBCO for the off-set composition are remarkably shifted to the lower temperature regions compared with those of the on-set composition of Gd : Ba : Cu = 1 : 2 : 3. In addition, to enhance the pinning properties, size-refined Gd_2O_3 or Gd_2CuO_4 is trapped in matrix via the process condition of maximized nucleation rate and minimized growth rate. Details will be presented for a discussion.

keywords : phase stability, GdBCO, low oxygen pressure, off-set composition

WBP2-3 16:00–18:00

The thermal and mechanical Stresses during Al alloy coating on 2nd generation superconducting coated conductor

*Ho-Sup Kim, Byung-Geol Kim, Jeong-Hyeon Jo, Chang-Hwan Lee

Korea Electrotechnology Research Institute

The thermal and mechanical stresses induced during Al alloy coating on 2nd generation superconducting coated conductor are investigated. The Al alloy coating by hot-dip method on the Cu stabilized GdBCO coated conductor was performed for the purpose of the following process of anodizing the Al alloy, which provides a better heat emission property and mechanical reinforcement of coated conductor. Al alloy coating was carried out by reel-to-reel hot-dip method. During the process, the coated conductor tape was exposed to high temperature of molten Al alloy and tensile stress induced by the tension between take-up reel and pay-off reel. We investigated the effect of the temperature of molten Al alloy and tensile stress on the superconducting properties measured by the non-contact Hall Probe measurement system and PPMS, and microstructure by SEM. We found out the optimal conditions of good Al alloy coating without the superconducting characteristic breakdown and delamination of the coated conductor.

keywords : superconducting coated conductor, GdBCO, aluminum, anodizing

WBP2-4 16:00–18:00

The post-annealing effect of GdBa2Cu3O7-δ coated conductors by RCE-DR process

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We report the improved superconducting properties of GdBa2Cu3O7- δ (GdBCO) coated conductors (CCs) by a post-annealing process. On the basis of the stability phase diagram of GdBCO, the GdBCO CCs fabricated by a reactive co-evaporation deposition & reaction (RCE-DR) process were post-annealed at the temperatures of 760 ℃ in low oxygen pressures below 300 mTorr. The pinning properties of annealed GdBCO samples were sensitive to the annealing conditions, including oxygen pressure, temperature, and time. In comparison with as-prepared sample, post-annealed GdBCO CCs could be improved in the magnetic direction parallel to c-axis. It was found that the microstructure and superconducting properties of GdBCO CCs strongly depend on the post-annealing condition. In this presentation, details of the relationship among the post-annealing conditions, microstructure, and superconducting properties of GdBCO CCs are discussed.
This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) and the Ministry of Trade, Industry & Energy(MOTIE) of the Republic of Korea (No. 20131010501800).

keywords : GdBCO, Post-annealing, flux pinning

WBP2-5 16:00–18:00

Particles in $GdBa_2Cu_3O_{7-\delta}$ Film Prepared by Pulsed Laser Deposition

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$GdBa_2Cu_3O_{7-\delta}$ (GdBCO) is one of the REBCO type high temperature superconductors whose critical temperature and critical current density are higher than those of $YBa_2Cu_3O_{7-\delta}$ (YBCO). Particles with submicron diameters are commonly observed on the surface of REBCO films prepared by pulsed laser deposition (PLD) [1] [2]. These particles cause the decrease of the current paths which deteriorate superconducting properties of the films. It has not been clarified yet but the number density of these particles in GdBCO was found higher than that in YBCO.
In this study, we investigated cause of the differences of the number density of particles in GdBCO and that in YBCO, by comparing the microstructures of targets.
GdBCO and YBCO targets were sintered at the same temperature of 960 □C, their surfaces were polished, and examined by scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDS). The results of observation by SEM and EDS, although the surface features of the targets were almost the same at low magnification, segregation of Cu were commonly observed in the case of YBCO than GdBCO.
[1]R.Nagaishi et.al. The Review of Laser Engineering. 1992, vol. 20 no. 5, p.43-50
[2]N.Uemura. Kyushu University Bachelor Thesis. 2014

keywords : Pulsed Laser Deposition, GdBCO, YBCO, particles

WBP2-6 16:00–18:00

Grain growth and surface modification of epitaxial CeGdZrO film on NiW substrate

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Northwest Institute for Nonferrous Metal Research

The CeO_2 films with the mixed of gadolinium and zirconium doping films were deposited on NiW substrates by chemical solution deposition. The influence of mixed doping cations on the microstructure and texture of films were systematically investigated. And the morphological evolution of films with different dwell times was also discussed. The phase formation, texture and surface morphology of $(Ce_{0.8}Gd_{0.2})_1$-xZr_2O_2-δ films were characterized by X-ray diffraction and atomic force microscopy. The Zr^{4+} doping cation had stronger effect on the crystal structure of CeO_2 than Gd^{3+} doping cation. The increased Zr^{4+} doping in CGZ thin film could relax the compression strain and cause a decreased lattice mismatch between substrate and layer, and might promote the epitaxial growth of CGZ film. The self limited grain growth could be clearly observed in CGZ films and the mixed doping cations were beneficial for the minimization of the surface degradation of CeO_2 film. The results indicate that the $(Ce_{0.8}Gd_{0.2})_1$-xZr_xO_2-δ film can be a candidate buffer layer of coated conductors.

keywords : Coated conductor, Buffer layer, CeO2, Chemical solution deposition

WBP2-7 16:00–18:00

Phase stability and superconducting property of Cu excess SmBCO coated conductors

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Various methods to make coated conductors have been tried to increase the critical current property for commercialization. Recently, RCE-DR(Reactive Co-Evaporation by Deposition and Reaction) is the most promising process for real commercialization of coated conductors, because RCE-DR is the fastest and high thru-put process to make high critical current coated conductor. km long GdBCO(GdBa2Cu3O7-y) coated conductor with high critical current over 600A/cmw. was already commercialized by SuNAM Co. using RCE-DR process. GdBCO coated conductor was fabricated by using Cu excessed precursor in RCE-DR process. In this study, we fabricated SmBCO coated conductor using Cu excess precursor. Optimum Cu excessed precursor was examined to achieve high critical current of SmBCO coated conductor. In this process, optimum composition ratio of precursor is 1:1:4(Sm:Ba:Cu). On the other hands, phase stability of SmBCO superconducting phase converted from Cu excessed precursor was investigated to confirm the the heat treatment schedule in RCE-DR process. In order to examine the superconducting property of SmBCO coated conductor, critical current was measured by 4-probe method.
This work was supported by the Power Generation & Electricity Delivery Core Technology Program of the Korea Institute of Energy Technology Evaluation and Planning(KETEP) granted financial resource from the Ministry of Trade, Industry & Energy, Republic of Korea

keywords : RCE-DR, SmBCO, coated conductor, phase stability

WBP2-8 16:00–18:00

Electro-mechanical properties of GdBCO coated conductor laminated with Al alloy tape

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2. SuNAM Co. Ltd.
3. Andong National University

In this study, we fabricated aluminum alloy laminated GdBCO conductors for superconducting power cable and evaluated their electro-mechanical properties. Aluminum 3104 alloy tape that was 4 mm wide and 0.1 mm thick was laminated with with GdBCO tape using continuous ultrasonic soldering method. Sound bonding with uniform Sn – 3 wt% Ag - 0.4 wt% Cu, SAC solder layer was observed between GdBCO and Al tape. Typical thickness of bonded SAC solder layer was 7 to 10 micron. Bonding strength was evaluated with T-peel test. Higher bonding strength was observed when the ultrasonic vibration amplitude increased. The degradation of critical current, Ic due to pre-tensile loading under bending mode at room temperature was investigated. According to this evaluation, Ic degradation was observed to be remarkably increased in bent region of Al alloy laminated CC tape. Detailed experimental results will be presented in the conference.
This work was supported by the Power Generation & Electricity Delivery Core Technology Program of the Korea Institute of Energy Technology Evaluation and Planning(KETEP) granted financial resource from the Ministry of Trade, Industry & Energy, Republic of Korea

keywords : electro-mechanical property, REBCO, coated conductor, lamination

WBP2-9 16:00–18:00

Fabrication of $YBa_2Cu_3O_{7-x}$ Thin Films with $BaHfO_3$ by Inkjet Printer

*Sei Katagi, Ryo Teranishi, Yukio Sato, Kenji Kaneko

Kyushu University

There are several methods available to fabricate $REBa_2Cu_3O_{7-x}$ (RE : rare earth, REBCO) high temperature superconductors, such as metal organic deposition (MOD), pulse laser deposition (PLD) and chemical vapor deposition (CVD). Spin-coating and dip-coating techniques have commonly been applied to coat substrates with the solution for the case of MOD. Recently, Feys reported the possibility of applying inkjet printing technique to coat the substrates with YBCO solution to fabricate YBCO film by MOD [1]. In addition, designing and printing patterns with solutions can be accomplished by inkjet printers, correspondingly.
Two types of YBCO solutions were prepared, one with Hf to introduce $BaHfO_3$ APC and another one without Hf. The solution with Hf was used for inkjet printer to coat a pattern on an ion beam assisted deposition (IBAD) substrate with the line width of around 100 μm and the lines intervals of 150 μm, followed by the calcination at 823 K for 120 min. The one without Hf was then coated over this sample by spin-coating, calcined at 823 K for 120 min. The sample was crystallized at 1043 K for 120 min and YBCO film was finally fabricated.
In this paper, inkjet printer technique was applied to fabricate YBCO with artificial pinning centers and microstructures of them were investigated by X-ray diffraction analysis.
[1] J. Feys, et al J. Mater. Chem. 22 (2012) 3717-3726

keywords : superconductor, inkjet printer, artificial pinning centers

WBP3-1 16:00–18:00

Development of long BMO doped REBCO coated conductors with high in-field properties by PLD method

*Akira Ibi, Koichi Nakaoka, Takato Machi, Teruo Izumi

National Institute of Advanced Industrial Science and Technology (AIST)

$REBa_2Cu_3O_X$ (REBCO, RE: rare earth element) with $BaMO_3$ (BMO, M: metal) coated conductors have been expected for the industrial and commercial applications at high temperatures in magnetic fields, such as magnetic resonance imaging (MRI), heavy ion medical accelerator and magnetic levitation (Maglev). For example, we fabricated coated conductors (CCs) of $EuBa_2Cu_3O_X$ (EuBCO) with $BaHfO_3$ (BHO) by the IBAD and PLD methods. They exhibited the high in-field minimum I_c value, (I_c(min)), of 141.2 (77 K in 3 T) and 411.3 (65 K in 3 T) A/cm-w for a short sample, and 133.9 (77 K in 3 T) A/cm-w for 93 m CC with 3.6 μm in thick for EuBCO with BHO layer, respectively. However, to realize REBCO with APCs coated conductors for industrial and commercial applications, the much higher in-field performance is required.

We have tried to develop the long BMO doped REBCO coated conductors with improvement of I_c anisotropies and high I_c values at high magnetic fields by the PLD method. For objectives of this work, we have attempted to increase the concentration of doping material such as BMO by changing the deposition mechanism from the vapor-solid (V-S) mode to the vapor-liquid-solid (VLS) one for several RE materials or investigating (Eu, RE)BCO coated conductors. From these results, we are trying clear of effective factors to improve of high in-field properties of REBCO with APCs coated conductors by the PLD method. The details of in-field performance of the the long BMO doped REBCO coated conductors fabricated by the PLD method will be discussed and presented.

keywords : REBCO with BMO coated conductors, PLD method

WBP3-2 16:00–18:00

TENSILE STRAIN CHARACTERISTICS OF BMO DOPED REBCO COATED CONDUCTORS

*Shinji Fujita, Shogo Muto, Tomo Yoshida, Hiroki Sato, Mitsunori Igarashi, Kazuomi Kakimoto, Yasuhiro Iijima, Kunihiro Naoe

Fujikura Ltd.

REBCO coated conductors (CCs) are expected to show high performance for superconducting applications due to their high tensile strength and high critical current density under magnetic fields. Fujikura has developed REBCO CCs with high performance by ion beam assisted deposition (IBAD) and pulsed laser deposition (PLD) method. It is generally known that the critical current (I_c) of a common superconducting wires varies with the applied longitudinal tensile strain, but that of Fujikura's commercial CCs little varies due to the peculiarities of the REBCO crystal orientation. Recently, we have developed $BaMO_3$ (BMO, M : Zr or Hf) doped REBCO CCs in order to enhance their in-field critical current density. In this study, we investigated the strain dependence of the BMO doped REBCO CCs. As a result, it was confirmed that the I_c varies with applied strain like other superconducting wires, even though the crystal orientation did not change.

This work includes the results supported by the New Energy and Industrial Technology Development Organization (NEDO).

keywords : artificial pinning, mechanical properties

WBP3-3 16:00–18:00

Critical Current Density of YBCO Films with Different Configurations of Columnar Defects in Longitudinal Magnetic Field

*Tetsuro Sueyoshi, Yasuya Iwanaga, Takafumi Kai, Takanori Fujiyoshi

Kumamoto University

We investigated the critical current density (J_c) properties of $YBa_2Cu_3O_y$ thin films with columnar defects (CDs) in longitudinal magnetic field, where different configurations of CDs were systematically installed into the films by using heavy-ion irradiation: a parallel configurations of CDs aligned along the c-axis with different densities of CDs, and two bimodal splay configurations composed of CDs crossing at $\pm\theta_i$ relative to the c-axis, where the splay plane defined by the two irradiation angles is perpendicular or parallel to the transport current direction. For the unirradiated sample under the longitudinal magnetic field, a peak was observed in the magnetic field dependence of J_c, which was located around 0.1 T and the peak value was 1.1 times higher than the self-field J_c. In the case of the parallel configurations, the J_c value increases with increasing the density of CDs under the transverse magnetic field (the maximum Lorentz force configuration), which is higher than that of the unirradiated sample. Under the longitudinal magnetic field, by contrast, there is no peak in the magnetic field dependence of J_c for the parallel CD configurations, where the J_c decreases with increasing the density of CDs and is lower than that of the unirradiated sample. Such degradation effect by CDs under longitudinal magnetic field was observed even for the splay CD configurations. These results suggest that linear and continuous CDs cannot work as effective PCs under the force-free condition for any configuration of CDs.

keywords : Critical current density, Longitudinal magnetic field, Columnar defects, High-Tc superconductors

WBP3-4 16:00–18:00

Introduction of pinning centers into SmBCO Coated Conductor by Reactive Co-evaporation Method

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2. Functional Nano-materials Research Department, Korea Institute of Materials Science, Changwon, Korea

SmBCO coated conductors were fabricated with pinning centers by reactive co-evaporation method in the EDDC (Evaporation using Drum in Dual Chambers) deposition chamber. The deposition system was composed of dual chambers: reaction chamber and evaporation chamber. Superconducting materials of Sm, Ba, and Cu were evaporated in the evaporation chamber and deposited on the substrate which was mounted on the drum while the deposited elements reacted with oxygen and turned into SmBCO superconducting phase in the reaction chamber. The tape type samples with the length of 30 cm, the width of 4 mm and the thickness of 0.1 mm were prepared with the structure of Ag/SmBCO/LMO/MgO/Y2O3/Al2O3/Hastelloy, where the continuous composition spread SmBCO film was formed along the length. Critical current was measured using non-contact Hall Probe method, and angular dependence of critical current under high magnetic field and the field dependence of critical current were measured. We found out that superconducting properties of those samples under magnetic field were highly influenced by the composition ratio of SmBCO film. Compared with the samples with no pinning centers, critical current under magnetic field of those samples with optimal composition ratio was improved drastically. The elemental mapping of the high-Jc SmBCO coated conductor was measured by TEM-EDX. We confirmed secondary phases and Sm/Ba anti-site phase which take the role of pinning centers.

keywords : SmBCO, superconducting coated conductor, reactive co-evaporation, pinning centers

WBP3-5 16:00–18:00

Deployment of a high-temperature superconductivity application research project of Leading Initiative for Excellent Young Researchers (LEADER) in Muroran Institute of Technology

*Xinzhe Jin[1,2]

1. Muroran Institute of Technology; 2. RIKEN Center for Life Science Technologies

The research project of “Leading Initiative for Excellent Young Researchers (LEADER)" has been started this year in Japan, which 150 researchers will be employed with research funding benefit period of 5 years in tenure track or permanent positions. In superconductivity field, a high-temperature superconducting wire application with ID number 16810210 was adopted, that has two subjects: superconducting joint and multi-core filamentation for $REBa_2Cu_3O_{7-\delta}$ (RE123, RE: Rare Earth such) coated conductor. In ISS2016, the latter will be presented and discussed.
We have started to develop a multi-core type RE123 split wire [1], which only the ceramics layers (RE123 and buffer layers) in the coated conductor is electrically separated by a phase stress utilizing the difference in toughness between ceramics and metal, such as V-bending by a stress along longitudinal direction of the coated conductor using commercially available single-core RE123 coated conductor. In last year, we have reported that was demonstrated for samples (width: 4 mm) having core numbers of 2, 3, 4, and 5. The results show high performances that has a high critical current above 95% of that for single-core wire, and a high tensile stress tolerance above 650 MPa. In this study, experiments for a 6-core split wire and coils were carried out; for an example, current test for 6-core wire was carried out at 4.2 K in magnetic field of 15 T. Furthermore, a short (length: 0.3 m) 9-core split wire with average core distance of 444 μm was fabricated, recently. With these results, developments of the split wire for ultra-high field use such as NMR and MRI will be discussed in upcoming ISS2016.
[1] Jin et al., 2016, Development of a $REBa_2Cu_3O_{7-\delta}$ multi-core superconductor with “inner split" technology, Supercond. Sci. Technol. **29** 045006[8pp] (2016)

keywords : high temperature superconductor, superconducting wire, superconducting joint, multi-core

WBP3-6 16:00–18:00

Joint of $REBa_2Cu_3O_y$ Coated Conductors Using Metal Organic Deposition Method

*kazuya hiramatsu, Ryo Teranishi, Yukio Sato, Kenji Kaneko

Kyushu University

Joint techniques for $REBa_2Cu_3O_y$(REBCO) coated conductors (CCs) are required to fabricate long length CCs, and there are several joint techniques available, such as a diffusion joint[1], a solder joint[2], a superconducting joint by melting diffusion of REBCO layer[3], and a superconducting joint using metal organic deposition (MOD)[4]. Among these processes, it has been reported that the superconducting joints by melting diffusion of REBCO layer offered zero resistance but with complicated process inevitably, such as annealing in high vacuum[3]. Nevertheless, the MOD process is the best candidate to simplify the direct superconducting joint process due to its inexpensiveness and facileness, at ambient pressure. In this study, joint temperatures were varied to attain the optimum heating condition for this MOD-joint process.
Two pieces of YBCO precursor film were coated on GdBCO CCs, and jointed together with face-to-face manner at 770, 800, 825, 850 °C, then microstructures of joints were examined. X-ray diffraction (XRD) analysis was carried out to investigate the orientation of YBCO layers coated on CeO_2 substrates, instead due to the closeness of the lattice parameters between YBCO and GdBCO. From XRD analysis, the peaks of YBCO 00ℓ were present at 770, 800, 825°C, but absent at 850 °C due to its decomposition. The highest yield of YBCO was achieved from the sample fabricated at 800 °C, according to the rocking curve analysis of YBCO 005 peak. In addition, peaks of $BaCeO_3$ started appearing when the temperature was raised beyond 800 °C. From these results, optimum temperature for MOD-joint was found at 800°C.
[1] T. Watanabe et.al, Physics Procedia 45 (2013) 165-168.
[2] Jun Lu et. al, IEEE Trans. Appl. Supercond. 21 (2011) 3009-3012.
[3] Y. J. Park et. al, Supercond. Sci. Technol. 27 (2014) 085008.
[4] K. Hiramatsu et. al, Physycs Procedia 81 (2016) 109-112

keywords : joint, coated conductor

WBP3-7 16:00–18:00

Nanostructural Characterization of Low Resistance Joints Using Ag Pastes for $GdBa_2Cu_3O_y$ Coated Conductor

Tomohiro Kato[1], Takato Machi[2], Daisaku Yokoe[1], Ryuji Yoshida[1], *Takeharu Kato[1], Teruo Izumi[2], Tsukasa Hirayama[1], Yuh Shiohara[3]

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$GdBa_2Cu_3O_y$ (GdBCO) coated conductors were fabricated by PLD on Hastelloy™ substrate tapes with buffered-CeO_2/$LaMnO_3$/IBAD-MgO/Y_2O_3/Gd-Zr-O layers. Ag stabilizing layers were deposited by sputtering on the GdBCO layers. The surfaces of the Ag stabilizing layers were mechanically polished. These coated conductors were splice jointed by a face-to-face manner using a paste containing nano-sized Ag particles under a pressure of about 50 MPa at 150 ℃ for 1 hr. The low electrical resistance of 6 nΩ at the joint was attained. The jointed coated conductors were sectioned by an Ar-ion beam at the accelerating voltage of 6 kV and then the cross-sections were further etched using an Ar-ion beam of 4 kV in a Hitachi IM4000 ion milling system. The cross-section of the jointed coated conductors was observed by a Hitachi SU8000 scanning electron microscope (SEM) at the accelerating voltage of 1 kV. Furthermore, the jointed regions were thinned in a Hitachi NB5000 focused ion microscopy-SEM system for preparation of a transmission electron microscopy (TEM) specimen. The specimen was examined in a TOPCON EM-002B TEM with twin energy dispersive spectroscopy (EDS) detectors at the accelerating voltage of 200 kV. The size of the Ag particles in the starting pastes were confirmed to be a few tens of nanometers in diameter. Cross-sectional SEM images of the jointed coated conductors indicated both the surfaces of the stabilizing Ag layers were partially bonded by the Ag particles. EDS analysis did not detect oxygen or other elements in the region of the bonding parts. The larger the splice jointed area, the lower the electrical joint resistance.
This research is supported by the Development of Medical Devices and Systems for Advanced Medical Services from the Japan Agency for Medical Research and development, AMED.

keywords : Low Resistance Joints, Ag pastes, SEM, TEM

WBP3-8 16:00–18:00

A study on Electromechanical Properties of a Novel Twisted Soldered-Stacked-Square (3S) HTS Wire with 1 mm Width

*Zeng Lin Xie, Min Hu, Zhu Yong Li, Yong Kang Zhou, Dao Yu Hu, Li Lin Sun, Zhi Jian Jin, Zhi Yong Hong

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In high temperature superconducting (HTS) applications, the external magnetic field affects their performances of critical current and ac loss significantly. Thus it takes some difficulty to design the HTS devices to optimal structures in aspect of their performance. To improve their performance, a novel soldered-stacked-square (3S) HTS wire is developed through narrowing, stacking and soldering processes using 2G narrow tapes with 1mm width. The electrical and mechanical properties of the 3S wire have been tested. In this study, various structures of novel 3S wire samples will be fabricated and tested. Then the 3S wires will be directly twisted each other as tight as possible. Moreover, we evaluate the fundamental electrical and mechanical characteristics of the twisted 3S wires including critical current, AC loss, and tension and so on. More detailed fabrication process and evaluation results will be described and presented in this paper.

keywords : 2G narrow tape with 1 mm width, Twisted Soldered-Stacked-Square (3S) HTS Wire, electrical characteristics, mechanical characteristics

WBP3-9 16:00–18:00

The Property of Hot-Dip Aluminizing for HTS Coated Conductor

*ByungGeol Kim, JeongHyeon Cho, HoSup Kim, ChangHwan Lee

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Quench protection and mechanical reinforcement of HTS coated conductors has emerged as one of the major unresolved obstacles in their implementation. Especially, large-scale superconducting electric devices for power industry depend critically on stable coated conductors.
A new technique of hot-dip aluminizing of Cu stabilized HTS coated conductor will be introduced in this study in order to fabricate anodized coated conductor, which provides a better heat emission property and mechanical reinforcement thanks to Al2O3 layer. The present work is focusing on the reaction between molten alloys and Cu stabilizing layer during hot dip treatment. The measurement of Ic by non-contact hall probe and observation of morphology and microstructure of inter-metallic layers on the surfaces of coated conductor by hot dip treatment were carried out and the results will be discussed in detail.

keywords : Hot-Dip Aluminizing, GdBCo Coated Conductor, Quench Protection, Mechanical Reinforcement

WBP3-10 16:00–18:00

Numerical Investigation on Detection of Internal Crack in HTS Film by Using Contactless Method for Measuring j_C

*Teruou Takayama, Ayumu Saitoh, Atsushi Kamitani

Yamagata University

As is well known, a critical current density j_C is one of the most important parameters for engineering applications of high-temperature superconductors (HTSs). For the purpose of contactlessly measuring j_C in an HTS film, the contactless methods such as the inductive method, the hall probe method, and permanent magnet method have been developed. These methods are applied to the measurement of j_C-distributions for the case with large-area samples such as an HTS wire or tape. On the other hand, they are also used to the defect detection of the HTS bulk or film.

In the previous study, a numerical code has been developed for analyzing the time evolution of a shielding current density in an HTS film with a crack. By using the code, the inductive method was reproduced numerically. The results of the computations show that when the coil approaches any cracks, the estimated value of the threshold current always decreases. Furthermore, even when the outer diameter of the coil is in contact with the edges, the accuracy of the inductive method is slightly degraded. However, an internal crack cannot be considered in this code since we calculated the shielding current density in the film as a single-layer HTS film.

The purpose of the present study is to develop a FEM code for analyzing the time evolution of the shielding current density in a multiple-layered HTS film containing a crack. By using the code, we numerically investigate the applicability of the inductive method to the detection of an internal crack in the film.

keywords : Internal cracks, Surface cracks, Layer division multiplexing, Thin films

WBP4-1 16:00–18:00

Determining Pinning Parameters in Flux Creep-Flow Model for *E-J* characteristics of High Temperature Superconductors by using Differential Evolution

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It is well known that current density dependence of electric field (*E-J* characteristics) of high temperature superconductors (HTSs) can be explained by the flux-creep flow model. It is necessary to determine five pinning parameters to fit the theoretical result and experimental result. In our previous studies, genetic algorithm, mesh method and steepest descent method were used to determine the five pinning parameters. It was found that these methods were effective to find the pinning parameters in short period. In this study, differential evolution is used for determination of the pinning parameters.

Differential evolution (DE) is one of the methods in evolutionary computation to find an optimization of a problem. DE uses agents and agents evolve according to algorithm. It is known that DE is generally simpler and faster than genetic algorithm. In the present works, we first confirmed that DE can be used to find the pinning parameters using model data in which the pinning parameters are given. Then, it is found that the pinning parameters determined by DE are better than these by mesh method. In mesh method, all set of pinning parameters with same interval are calculated and find the best parameter set.

keywords : E-J characteristics, Differential Evolution, pinning parameters, Flux Creep-Flow model

WBP4-2 16:00–18:00

Evaluation of self-magnetic field of oxide superconducting tapes with ferromagnetic shielding

*Kei Kashiwagi[1], Vladimir Vyatlin[2], Edmund Soji Otabe[1], Yuta Hiramatsu[1], Masaru Kiuchi[1], Satarou Yamaguchi[2]

1. Kyushu Institute of Technology
2. Chubu University

High Temperature Superconducting (HTS) is expected to be engineering application such as a power transmission cable, because critical temperature of HTS is higher than the boiling point of nitrogen. The shape of the conventional cable is the co-axial layered type using HTS tapes. On the other hand, stack of HTS tapes is considered to obtain compact size of cable. The problem of this stacked type cable is that the c-axis component of magnetic field at edge of tapes is significant, and the critical current drastically reduces. For example, if Bi-2223 tape was subjected to 0.025 T to c-axis direction, the critical current density is three times less than that of zero magnetic field. Therefore, ferromagnetic shielding around the stacked type cable is considered to be effective to reduce the c-axis component of magnetic field. In this study, the magnetic field distribution is calculated in stacked type cable with ferromagnetic shielding by using Finite Element Method (FEM).

We used JMAG [1] by JSOL and FEMM [2] for FEM calculation. In the calculation, we assumed that the width and the thickness of tape are 4 mm and 0.2 mm, respectively, and the transport current on tape is 200 A, and the tape is covered with the ferromagnetic shielding of M50. It was confirmed that the smallest magnetic field of edge of tape with ferromagnetic shielding after optimization of the shape of shielding was 0.01 T, which is four times less than that of tape without ferromagnetic shielding. The effect of twist of the stacked type cable is also investigated, and it is found that the twist effect is not significant.

[1] http://www.jmag-international.com/
[2] http://www.femm.info/

keywords : Finite Element Method, ferromagnetic shielding, superconducting tape

WBP4-3 16:00–18:00

Numerical Reproduction of Screening-Current-Induced Fields in HTS Tape Windings Using Finite Element Method

*Yuma OKABE, Tomokazu Honda, Kazuhiro Kajikawa

Kyushu University

Superconducting magnets for magnetic resonance imaging and nuclear magnetic resonance require a highly uniform magnetic field in their central part, so that these magnets have been usually wound with multifilamentary wires composed of low temperature superconductors. On the other hand, high temperature superconductor (HTS) wires have also been developed and become commercially available, and these wires are in the form of a flat tape with very large cross-sectional aspect ratio. Therefore, if this type of wire is used as a winding for superconducting magnet and a transport current is applied to it, the central magnetic field has very low uniformity because of a screening current induced in the HTS tape. In order to eliminate the screening-current-induced fields (SCFs), the methods based on abnormal transverse-field effect have been proposed and validated experimentally. In this study, the SCFs in one of the HTS coils fabricated previously with coated conductors are evaluated numerically by using a one-dimensional finite element method, in which only the perpendicular components of current vector potentials are considered due to a very thin superconductor layer in the coated conductor. It is assumed that the voltage-current characteristics in the superconducting layer can be represented by the critical state or n-value model, in which the field-dependent critical current density is also taken into account. The numerically calculated results of the SCFs are compared with the experimental results observed in the previous work.

keywords : High temperature superconductor, Abnormal transverse-field effect, Screening current, Finite element method

WBP4-4 16:00–18:00

Reduction of Screening-Current-Induced Fields Using New Structure of HTS Coil

*Tomokazu HONDA, Yuma Okabe, Kazuhiro Kajikawa

Kyushu University

Superconducting magnets for magnetic resonance imaging and nuclear magnetic resonance require a highly uniform magnetic field in their central part, so that these magnets are usually wound with multifilamentary wires composed of low temperature superconductors. On the other hand, if high temperature superconductor (HTS) wires with tape shape are used for windings of superconducting magnets, the magnetic fields produced by in-plane screening currents induced in the tapes degrade the uniformity of a main magnetic field generated by a transport current. Therefore, a useful method to reduce the screening-current-induced fields (SCFs) in the HTS windings on the basis of the abnormal transverse-field effect has been proposed, and furthermore validated for an HTS coil sandwiched between a pair of coaxial copper shaking coils to apply axial AC magnetic fields to it. In this study, we propose a new structure of HTS coil without any additional shaking coils. This proposed structure enables us to use an inner bore of the HTS coil effectively, whereas it cannot eliminate the SCFs completely because the innermost and outermost parts of the HTS winding are always exposed to magnetic fields less than the full penetration fields. We also report a series of experimental results for confirmation of the effectiveness of reducing the SCFs in an HTS coil fabricated with a coated conductor.

keywords : High temperature superconductor, Screening current, Abnormal transverse-field effect, AC magnetic field

WBP4-5 16:00–18:00

Ac and dc characterizations of striated and copper-plated coated conductors

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Striated coated conductors have been attracted interests from the viewpoint of the reduction of shielding-current-induced fields as well as the reduction of ac losses. We have been characterizing striated and copper-plated coated conductors, in which their plated copper layers allow current sharing between filaments.
We measured the frequency dependences of the magnetization losses in the stacks of these conductors in order to determine the coupling time constants. The coupling time constants could be determined by comparing the measured losses with the calculated ones. In this report, we focus on the number of stacks (up to 16) and the separation between conductors (down to 0.025 mm). These parameters are closely related to the simulation of coils by stacks of conductors.
We also carried out the dc transport measurements of the conductors in order to study the dc current sharing properties. We attached current leads to the plated copper layer of a sample and dc current was supplied to the entire conductor. It should be noted that the critical currents of filaments are not always same. If the current in a filament reaches its critical current, the current might transfer to the other filaments through the transverse filaments between filaments. We attached many voltage taps over the sample to measure the local voltages and tried to look at the current transfer phenomena.

keywords : coated conductor, shielding-current-induced field, striation, ac loss

WBP4-6 16:00–18:00

Magnetic Microscopy for the Characterization of Magnetic Relaxation in Multi-filamentary Bi-2223 Tape with DC Transport Current and External Magnetic Field

*Kohei Hisajima, Kohei Higashikawa, Takumi Suzuki, Kazutaka Imamura, Masayoshi Inoue, Takanobu Kiss

Kyushu University

We have developed magnetic microscopy system which can apply transport current as well as external magnetic, and investigated the magnetic relaxation characteristics in multi-filamentary Bi-2223 tape. Understanding of magnetization properties in high-temperature superconducting (HTS) tapes has been recognized as a significant issue for HTS magnet applications such as MRI and NMR because they affect the spatial homogeneity and temporal stability of the magnetic field. In our previous study, we investigated the magnetic relaxation characteristics in multi-filamentary Bi-2223 tape, and found that all the filaments were always coupled and the relaxation could be simply governed by its *E-J* properties. On the other hand, the characterization was done only with external magnetic field without transport current; transport current should be applied in case of a practical coil. In this study, we updated the scanning Hall-probe microscopy (SHPM) system to be able to apply also transport current to the sample. As a result, it was found that the magnetic relaxation characteristics of the multi-filamentary Bi-2223 was influenced by the magnitude of the transport current. However, it was also found that local properties just obeyed the *E-J* properties. This suggests that it is possible to predict the magnetization characteristics of the tape only by its *E-J* properties. This would be a very important finding for HTS magnet applications.

keywords : Scanning Hall-probe Microscopy (SHPM), magnetic relaxation, Bi-2223, E-J properties

WBP4-7 16:00–18:00

Electomagnetic properties of YBCO ceramic oxides system for magnetic force

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YBCO superconductor with sliver oxide was prepared by thermal pyrolysis method to develop a superconductor device. The YBCO superconductor with 2.0 wt% silver oxide showed the greatest suspension. The maximum induced voltage of the YBCO superconductor with 2.0 wt. % of silver oxide formed by thermal pyrolysis method was about 3.95 mV at $2.0x10^{-3}$ T. A lever-type magnetic force measurement unit quantitatively well determined the distance between the superconductor and toroidal maget in which an attractive and a repulsive force due to suspension effect acted under a complicated magnetic field. It can be sued for optimum designing a superconductor device. This research was supported by the Korean Electric Power Corperation [Grant number : R16XA01]

keywords : Ceramic superconductors, YBCO, Superconductor device

WBP4-8 16:00–18:00

Analytical and Experimental Evaluation of DC Insulation Characteristics of PPLP/LN_2 Composite Insulation System according to The Variation of Overlapping Rate

*Jin-Yong Na, Ryul Hwang, Ik-Soo Kwon, Bang-Wook Lee

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As an insulating material for the DC superconducting cable, Polypropylene Laminated Paper (PPLP) is most commonly used which winds the high-voltage conductor of DC superconducting cable. During the winding process of PPLP, a number of butt gaps are inevitably introduced in each layer. For insulation design of dc superconducting cable, the butt gaps should be inevitably considered because the electric field is significantly influenced by the butt gaps filled with liquid nitrogen (LN_2). Also, a variation of overlapping rate is determined by the distance between butt gaps of each layer which has an effect on the electric field. Therefore, in this paper, the DC breakdown test was performed in order to investigate the DC insulation characteristics according to the variation of overlapping rate in PPLP/LN_2 composite insulation system. For the breakdown test, specimens were composed of three layered PPLP and butt gaps were fabricated at upper and middle layers. Also, the DC electric field analysis was carried out in order to verify not only the DC electric field distribution and transition according to overlapping rate but the correlation between analytical and experimental results. From the analytical and experimental results, it was found that the decrement of overlapping rate diminished the DC dielectric performance.

keywords : Overlapping Rate, Polypropylene Laminated Paper (PPLP), Liquid nitrogen (LN2), Composite Insulation

WBP4-9 16:00–18:00

Improved Delamination Properties of Coated Conductors

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Coated conductors (CCs) are prospective for electric power applications due to not only better cost performance but also high Jc-B properties compared with BSCCO tapes. However, CCs is composed of multi-layered thin films and metal substrate, and post-treatments are essential to put CCs to practical use, which are slit and/or multi-filament. For this reason, CCs delaminate between multi-layers. This delamination prevents CCs from functioning as superconducting wire, therefore there is a need of improving delamination strength of CCs. In this study, we try to improve delamination properties of CCs.

keywords :

WBP5-1 14:00–16:00

Development of MgB_2 wire and coil for the next generation of MRI magnet

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Magnesium diboride (MgB_2), a superconducting material, consists of light elements which are abundant on the earth, and the critical transition temperature is much higher than those of conventional niobium-based materials. Such excellent characteristics offer an exciting opportunity for the development of the next generation of superconducting wires and magnets, especially for lightweight, space-saving, and low-cost magnetic resonance imaging (MRI) scanners operated at a higher temperature than for the conventional system. The practical realization with reliable performance including a persistent-mode operation, however, still requires further improvement of the transport critical current property and the development of MgB_2-based superconducting technology. Here, we report on our recent progress of superconducting performances of MgB_2 wires, joints, and coils for MRI magnets. Some of the wires were fabricated with carbon doping, which improves the in-field critical current density, and the superconducting joints between the two carbon-doped mono-core wires achieved current carrying retention in the joint of up to approximately 70% compared to wire without a joint. MgB_2 coils were also fabricated via the wind and react method, and the persistent-mode operating states in solid nitrogen were evaluated.
This study was supported by JSPS KAKENHI grant number 26709021, the Australian Research Council (FT110100170, DE130101247), University of Wollongong and Australian Institute for Innovative material internal grant, and a Korea Basic Science Institute grant C36222.

keywords : MgB2, MgB2 wire, superconducting joint, MgB2 coil

WBP5-2 14:00–16:00

Spatially Resolved Measurement of Local Critical Current Density Distribution and Compositional Variation in MgB_2 Thick Film

*Kazutaka Harada[1], Kohei Higashikawa[1], Masayoshi Inoue[1], Takanobu Kiss[1], Hideaki Tanaka[2]

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MgB_2 superconductors have the highest critical temperature, 39 K, in metal-based superconductors and can have good grain connectivity since it has long coherence length, therefore, there is no such problem as weak coupling well-known in oxide superconductors. Currently, the MgB_2 wire made by Powder-In-Tube (PIT) method has been vigorously developed. However, a problem in the PIT method is that the filling factor of MgB_2 doesn't increase enough. On the other hand, highly dense films composed of fine crystal grains can be obtained by deposition process such as Electron-Beam evaporation method. Accordingly, MgB_2 films have superior J_c characteristics to that of PIT wire. A thick film coating of MgB_2 layer on a metal substrate has a good potential as high performance superconducting tape.
It is essential to develop a technology for achieving spatially uniform J_c with good reproducibility. Nevertheless, in the conventional J_c evaluation methods, it is difficult to obtain the local characteristic, therefore, understanding of the J_c limiting mechanism is insufficient [1].
In this study, we have investigated local J_c distribution and its limiting factor in the MgB_2 thick film by hybrid microscopy: Scanning Hall-probe Microscopy (SHPM), SEM and EDX. Correlation between the J_c distribution and compositional variation has been shown.
First, the result of measurements of J_c distribution obtained from SHPM. Then, a correlated study with site-specified compositional analysis has been carried out. It has been found that Mg and B are segregated in the low J_c region. This suggests that the local J_c is limited by the unreacted B because of the compositional deviation during the deposition.
[1] K. Higashikawa etc.: “Characterization of Local J_c Distribution in Superconducting Wires and Tapes Based on Scanning Hall-probe Microscopy," TEION KOGAKU **49** (9) (2014) 485-493

keywords : MgB2, thick film, critical current density, Scanning Hall-probe Microscopy

WBP5-3 14:00–16:00

Numerical Simulations of Operations of Parallel-Type Superconducting Level Sensors for Liquid Hydrogen Using Experimental Results of Electrical Resistivity

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2. Tokai University
3. Jecc Torisha Co., Ltd.

A parallel-type superconducting level sensor for liquid hydrogen has been proposed to improve the accuracy of output [1]. A stainless-steel sheathed MgB_2 wire and its non-heat-treated wire have been used as superconductive and non-superconductive wires, respectively, in the previous research. However, it has been assumed that both the stainless-steel sheaths of the wires have an identical temperature property of resistivity. In this study, the temperature dependence of electrical resistivity is experimentally evaluated in four sample wires to clarify the effects of drawing process and heat treatment on the resistivity of stainless-steel. Two of them have been used for the previous parallel-type level sensor. The other two samples are a purchased non-composite solid wire of the stainless-steel and its heat-treated wire. The temperature dependence of the resistivity is measured by the four terminal method. It is found from the experiment that the resistivity of the work-hardened stainless-steel is reduced by the heat treatment. By using the obtained experimental results of resistivity, the numerical simulations of operations of parallel-type level sensors are carried out. A one-dimensional finite difference method is used because the diameters of wires are very small and it can be enough to consider only the temperature profiles along the wires. The output errors in the parallel-type level sensors for changes in the gas states are numerically estimated. It is found that the output error of the level sensor can be reduced by using the non-composite stainless-steel wire with heat treatment as the non-superconductive wire.
[1] K. Kajikawa, et al., Physics Procedia 36, 1396 (2012)

keywords : Electrical resistivity, Liquid hydrogen, Numerical simulation, Superconducting level sensor

WBP5-4 14:00–16:00

Numerical Analysis of In-Field Magnetization in Mono-core MgB2 Wire with Magnetic Sheath

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2. NIMS

For further performance improvement of superconducting wire, it is necessary to investigate the relationship between local I_c distribution and its microstructure. In our previous study, we proposed a characterization method of critical current distribution in superconducting wires based on scanning Hall-probe microscopy (SHPM). However, in case of MgB_2 wires, it was difficult to detect signals from MgB_2 filament because of the magnetic sheath, e.g., iron and Monel. As a first step, we simply polish the wire to expose MgB_2 filaments under investigation. Then, we've succeeded in nondestructive characterization by using in-field SHPM at where we applied high enough magnetic field in comparison to the saturation field of the magnetic sheath. For example, we obtained magnetic image at an external magnetic field of 3 T which was sufficiently higher than the saturation magnetic field of the iron sheath around ~2 T. This allows us to detect an irreversible signal from the MgB_2 filament, therefore, we succeeded in detecting I_c degradation in nondestructive manner. However, to obtain quantitative value of the I_c, it is inevitable to carry out numerical analysis taking into account nonlinear magnetization in the magnetic sheath because we cannot simply apply inversion problem of the Biot-Savart law from the magnetic field profile. In this study, we performed a numerical analysis by use of finite element method. The relationship among external magnetic field, internal field, and remanent field profile has been investigated. By comparing with experimental results, we finally obtained local I_c value in the MgB2 wire from the in-field SHPM. This scheme is very effective and useful as a non-destructive non-contact diagnostics for MgB_2 wires.

This work is supported by Japan Science and Technology Agency (JST) as Advanced Low Carbon Technology Research and Development Program (ALCA)

WBP6-1 14:00–16:00

Preparation and transport properties of superconducting $Sr_2VFeAsO_{3-\delta}$ wires fabricated by *ex-situ* powder-in-tube process

*Suguru IWASAKI, Yoichi KAMIHARA, Masanori MATOBA

Keio University

Since the discovery of superconductivity in $LaFeAsO_{1-x}F_x$ [1] with high superconducting critical temperature (T_c), there has been a large progress in the field on iron-based superconductors and revealed that the iron-based superconductors have very high upper critical magnetic field (H_{c2}) [2]. The iron-based superconductors have a potential for applications under high magnetic field. One of the applications is superconducting wires. To date, $Ae$$Fe_2As_2$ (122 phase) [3], LnFeAsO (1111 phase) [4] and FeCh (11 phase) [5] (Ae = K, Ba, Sr, Ln = La, Sm, Ch = Se, Te) are mainly used for fabricating a wire by powder-in-tube (PIT) process. On the other hand, the fabrication of superconducting wire using a perovskite-related iron-based superconductor, $Sr_2VFeAsO_{3-\delta}$, has not been reported before 2016. We successfully observed zero resistivity for the wires of $Sr_2VFeAsO_{3-\delta}$ fabricated by PIT process, though their critical properties are still low.

In this symposium, we will report the detail of fabrication of wires and their superconducting properties.

Citation
[1] Kamihara Y *et al.*, J. Am. Chem. Soc. **130**, 3296 (2008).
[2] Hosono H and Kuroki K, Physica C. **514**, 399, (2015)
[3] Matsumoto A *et al.*, Supercond. Sci. Technol. **25**, 125010 (2012).
[4] Fujioka M, Ph. D. thesis "Study on Iron-based Mixed-anion Superconducting Wire by Reactive Solid State Binder Method", Keio Univ. Japan (2012). In Japanese
[5] Mizuguchi Y *et al.*, Supercond.Sci. Techol. **24** 125003 (2011).

keywords : Fe based superconductors, Powder-in-tube process

WBP6-2 14:00–16:00

The angular dependence of irreversibility line in $BaZrO_3$ nanoparticles doped $BaFe_2(As_{0.66}P_{0.33})_2$ films

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2. SUSTERA

The iron-based superconductor such as carrier-doped $BaFe_2As_2$ is one of the candidate materials for magnet application due to high upper critical filed (H_{c2}), small anisotropy (γ_H), and high critical temperature. From our previous study, $BaZrO_3$ nanoparticles (BZO NPs) doped $BaFe_2(As_{0.66}P_{0.33})_2$ (Ba122:P) films exhibited an increase in critical current density (J_c) (M. Miura *et al., Nat. Commun.* 2013). Recently, we reported that Ba122:P film with BZO NPs shows higher irreversibility lines (H_{irr}) compared to that of film without BZO NPs. However, the influence of pinning landscapes in Ba122:P films on angular dependent H_{irr} an open issue.

In order to investigate the influence of densities of BZO NPs on H_{c2} and H_{irr}, we fabricated Ba122:P films with various density of BZO NPs. The films with BZO NPs show gradually higher H_{c2} with the increasing density of BZO NPs. Moreover, high density of BZO NPs doped film shows higher H_{irr} at all magnetic field orientations, indicating that BZO NPs are always the dominant pinning center. We will discuss the influence of microstructure (size, shape and density of defects) on angular dependence of H_{c2} and H_{irr} in Ba122:P films with various density of BZO NPs.

This work is supported by JSPS (26709076). A part of this work was supported by the JSPS, Japan, through the 'Funding Program for World-Leading Innovative R&D on Science and Technology Program'.

keywords : Pnictides, Ba122, nanoparticle

WBP6-3 14:00–16:00

Development of Fe-based superconducting wires for liquid hydrogen level sensors

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Liquid hydrogen (LH) is considered to be one of the future clean energy carriers. To ensure the safety of transportation and storage, it is necessary to accurately monitor the amount of LH in a tank. A superconducting wire can be used for the LH level sensor because the output voltage changes in response to the LH level. The T_c of the material must be higher than the boiling point of LH (~20 K), thereby LH level sensors have been developed using MgB_2 superconducting wires with T_c = 30-35 K [1]. However, those MgB_2 wires need heating system to improve accuracy because the T_c of MgB_2 wires are rather high compared with 20 K and they become superconducting in the gaseous hydrogen. Accordingly, a superconductor with T_c close to 20 K is a good candidate material for LH level sensors. Here, we focus on a Fe-based superconductor, $Ba(Fe,Co)_2As_2$, as a candidate material for LH level sensors. $Ba(Fe,Co)_2As_2$ possesses the maximum T_c of 25 K and its T_c is tunable by varying Co concentrations [2]. In order to examine the feasibility, we fabricated $Ba(Fe,Co)_2As_2$ superconducting wires with different Co concentrations by powder-in-tube method. We successfully controlled the T_c of the wires in the range of 20-25 K. In addition, the superconducting transitions in resistance curves were very sharp with width of 0.5-1 K. Using the wires, we also developed prototype LH level sensors. We performed the proving tests using LH and found a good correspondence between the output voltage and the actual LH level, demonstrating that $Ba(Fe,Co)_2As_2$ superconducting wires can be used for LH level sensors [3].

[1] C. Haberstroh, *et al.* Proc. ICEC21-ICMC2006, 357 (2007); K. Kajikawa, *et al.* Proc. ICEC22-ICMC2008, 425 (2009); M. Takeda, *et al.* IEEE Trans. Appl. Supercond. 19, 764 (2009).
[2] A. S. Sefat, *et al.* Phys. Rev. Lett. 101, 117004 (2008).
[3] S. Ishida, *et al.* JP-A-2016-081394.

keywords : Fe-based superconductors, superconducting wires, liquid hydrogen level sensor

WBP6-4 14:00–16:00

Large and field-insensitive critical current densities in (Sr,Na)Fe_2As_2 superconducting tapes

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'122 types' iron-based superconductors are extensively studied for both basic science and applications. In particular, (AE,K)Fe_2As_2 (AE = Ba,Sr), superconducting wires and tapes have been widely studied for its very large critical current densities (J_c) even at high fields [1]. Recently, a new material joined this kind of research, namely (Sr,Na)Fe_2As_2 [2]. The reported transport J_c at 20 K up to 2.5 T is comparable to that in (AE,K)Fe_2As_2 tapes in the same condition. Following this study, we have fabricated (Sr,Na)Fe_2As_2 tapes by optimizing the sintering temperature and time, and characterized their transport J_c at 4.2 K up to 14 T. The transport J_c for the (Sr,Na)Fe_2As_2 tape sintered at 870℃ reaches 4.9×10^4 A/cm^2 under self-field, and it is suppressed only down to 1.9×10^4 A/cm^2 even at 14 T. We will also report compositional distributions and magneto-optical images of current distribution in tapes processed under different conditions.

[1] Y. Ma, Supercond. Sci. Technol. **25**, 113001 (2012).
[2] A. Iyo, N. Shinohara, K. Tokiwa, S. Ishida, Y. Tsuchiya, A. Ishii, T. Asou, T. Nishio, K. Matsuzaki, N. Takeshita, H. Eisaki, and Y. Toshida, Supercond. Sci. Technol. **28**, 105007 (2015).

keywords : Superconducting tapes, (Sr,Na)Fe2As2, Critical current density, Powder-in-tube (PIT)

WBP7-1 14:00–16:00

Magnetic flux invasion in REBCO bulk magnets with varying pre-magnetized flux distributions in multiple-PFM processes

Tetsuo Oka[1], Kensuke Hara[1], Akira Takeda[1], Jun Ogawa[1], Satoshi Fukui[1], Takao Sato[1], *Kazuya Yokoyama[2], Akira Murakami[3]

1. Niigata University
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3. Ichinoseki National College of Technology

The motion of magnetic flux invading into the HTS bulk magnets were experimentally studied in their pulsed field magnetization processes. The authors paid attention to the effects of the shapes of the pre-magnetized trapped flux distributions before the successive field applications by means of varying the M-shaped distribution. Since the magnetic flux invasion into the sample is affected by the microscopic Jc distribution, we estimated the differences of the magnetic flux motions between the Dy123 and Gd123 systems, which has relatively low and high Jc, respectively. As for the Dy123 system, the increase of remaining flux in the periphery region of the M-shaped distribution resulted in the decrease of flux-trapping according to the promotion of flux invasion. On the other hand, trapped flux density has been raised to 3.4 T owing to the effective suppression of flux invasion for the Gd123 bulk magnet. The experiments showed that the peak heights and the positions of the formerly trapped M-shaped fluxes precisely affect the heat generation and the trapped field performance.

keywords : bulk superconductor, pulsed field magnetization, magnetic flux density, flux invasion

WBP7-2 14:00–16:00

Influence of Artificial Defects on Trapped Field Performance in a Superconducting Bulk Magnet

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We study to improve the trapped magnetic field of the $REBa_2Cu_3O_x$ bulk magnet activated by pulsed field magnetization (PFM). However, it is difficult to trap a high magnetic field by PFM due to the strong magnetic shield caused by an increase of critical current density with the recent progress in material technology. Then, we proposed to supply the magnetic flux in the bulk by processing small holes in part of the sample for the purpose of supplying the magnetic flux through the bulk without generating heat by decreasing superconductivity artificially in the holed portion. In our previous study, a hole was opened in a growth sector region (GSR) in accordance with the idea that the performance of a growth sector boundary (GSB) was not decreased because a critical current density of GSB was higher than that of GSR. In the next study, a small hole was processed on a GSB in order to decrease the magnetic shield toward the magnetic flux that entered through a GSB, and the trapped field performance was investigated. The experimental results suggested that placing a hole at a GSB was advantageous in trapped field performance as compared with placing a hole at a GSR. In this paper, more three holes were processed in bulk with a single hole at a GSB, and trapped field performance was investigated using the sample with four holes. Although the maximum trapped field was the almost same as that of the bulk with a single hole, it could be trapped by lower applied field in the low temperature.

keywords : REBCO bulk magnet, pulsed field magnetization, growth sector region/boundary, trapped field

WBP7-3 14:00–16:00

Effect of resin impregnation on Y-Ba-Cu-O bulk superconductors

*Atsuhiro Ono, Kazuo Inoue, Muralidhar Miryala, Masato Murakami

Shibaura Institute of Technology

Y-Ba-Cu-O bulk superconductors have significant potential for high field magnets. However, the mechanical strength is insufficient for high field applications. Bulk samples contain many structural defects and cracks which act as the fracture origin when the electromagnetic forces are imposed. The trapped magnetic field gradually decreases due to the internal crack growth when a bulk superconductor is magnetized repeatedly. The mechanical properties are known to be improved through resin impregnation. We have focused on the silicone resin which has excellent adhesiveness with ceramics and low-temperature resistance, and performed the durability test which applies the magnetic field for resin impregnated bulks repeatedly. It was found that the silicone resin impregnation suppresses a decline in the trapped magnetic field. This suggests that the silicone resin impregnation is effective in improving the mechanical stress.

keywords : Bulk superconductor, Silicone resin, Impregnation, trapped magnetic field

WBP7-4 14:00–16:00

Effects of Carbon Nanotube Addition on Superconductivity in Y-Ba-Cu-O Bulk Superconductors

*Kazuo Inoue, Yuya Miyake, Muralidhar Miryala, Masato Murakami

Shibaura Institute of Technology

Y-Ba-Cu-O bulk superconductors have significant potential for engineering applications due to high critical current density and high trapped magnetic fields, which is attributed to the presence of pinning centers such as the interfaces of $YBa_2Cu_3O_x$ (Y123) matrix and micro-sized Y_2BaCuO_5. The introduction of nano-sized secondary phase is known to be more effective as the pinning center than that of micro-sized one. The diameter of carbon nanotube (CNT) is close to the coherence length of the high-temperature superconductors, which may influence the flux pinning behavior. We have investigated the effects of CNT addition on superconductivity and microstructure in Y123 bulk superconductors. SEM observation showed needle-like particles, which have around 100 nm in length, in the Y123 matrix for the CNT added samples. The critical current density exhibited the highest value for the 0.25 wt% CNT added sample. This suggests that nano-sized needle shape particles are active as the pinning center.

keywords : Y-Ba-Cu-O bulk superconductors, Carbon nanotube, Critical current density

WBP7-5 14:00–16:00

Effect of growth temperature on superconducting properties of bulk GdBa2Cu3Oy bulk superconductors grown by IG process

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Recently, the flux pinning performance of Y-123 material was dramatically improved by optimizing the processing conditions during the infiltration-growth (IG) process. In this presentation, we adapted the IG technique and produced several bulk $GdBa_2Cu_3O_y$ samples at the growth temperatures of 983, 985, 987, 990, and 992 °C with the same holding time of 25 h. Our results indicate that 986 °C is the optimum temperature to produce large Gd-123 growth without spontaneous nucleation. Magnetization measurements showed a sharp superconducting transition with Tc (onset) around 91.2 K. The critical current density at 77 K and self-field was 15,000 A/cm^2. The critical current density values are correlated with the microstructural changes in the bulk Gd-123 material.

keywords : infiltration-growth, Gd-123 bulk

WBP7-6 14:00–16:00

Superconducting Performance, Microstructure and SEM by EDX Analysis of IG Processed $YBa_2Cu_3O_y$ Bulk Superconductors by Top and Interior Seeding Methods

*Naoki Ide[1], Miryala Muralidhar[1], Monika Radusovska[2], Diko Pavel[2], Jirsa Milos[3], Masato Murakami[1]

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2. Institute of Experimental Physics, Slovak Academy of Sciences, Material Physics Laboratory
3. Institute of Physics ASCR

The top-seeded and interior seeded methods, together with infiltration growth (IG) technique were used to produce $YBa_2Cu_3O_y$ (Y-123) samples with Y_2BaCuO_5 (Y-211) secondary phase particles. The superconducting performance was studied by SQUID magnetometer and microstructure by optical and scanning electron microscopy. Optical micrographs showed a complete growth of Y-123 bulk single grain starting at the lower part of the bulk, when we used the interior seeding process. The Y-211 particles dispersion was quite uniform in lower and upper parts of the samples, both in the *a*- and *c*-axis growth sectors, both in the beginning and the end. However, Y-211 particles density was rather low in the lower part of the *c*-axis growth sector, close to the seed crystal. Volume fraction of Y-211 particles estimated from optical micrographs was constant 2 mm below the interior seed position. The trapped field experiments showed single cones, indicating that a single grain Y-123 material can be produced by utilizing the interior seeded method with IG process. The (T_c, J_c) performance and microstructure of IG processed samples produced by top-seeded and interior-seeded methods will be compared in this presentation.

The work was supported by Grant-in-Aid FD research budget code: 112261, SIT (Shibaura Institute of Technology) and by APVV No. 0330-12, VEGA 2/0121/16.

keywords : IG process, interior seeded methods, Y-123, Y-211

WBP7-7 14:00–16:00

Property of the GdBCO-Ag Bulk Superconductors Fabricated by Cooling-Rate-Controlled-Melt-Growth

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Light rare-earth (LRE, e.g., Nd, Sm, and Gd) bulk superconductors having superior performance for trapped magnetic flux are attractive for industrial power applications. Because LREBCO bulks could retain high T_c performance, they can sustain high trapped magnetic flux density. However, cation off-stoichiometry caused by the substitution of LRE element on Ba sites might lead to lower T_c and degrade the performance of bulks, which is common in the conventional melt growth procedure. Recently, it was reported that Cooling-Rate-Control-Melt-Growth (CRCMG) method could effectively control the cation stoichiometry for SmBCO bulks. SmBCO bulks with high T_c performance was obtained by the crystal growth using this method [1].
In this study, we fabricated GdBCO-Ag bulk samples using the CRCMG method. Each precursor for the bulks was prepared with a diameter of 20 mm. In the beginning of crystal growth, these bulk samples were cooled at a rate of 0.3 ℃/h from 1011 ℃ to 1008 ℃; then the bulks were cooled at different cooling rates (0.1, 0.3, 0.5, 0.8 and 1.0 ℃/h, respectively) until crystal growth was completed. We measured the trapped magnetic field in these bulk samples through field cooled magnetization at 1 T external magnetic field and liquid N_2 temperature. We will present the relationship between trapped field and cooling rate of our samples and show the range of the cooling rate necessary to ensure GdBCO-Ag bulks with higher performance.
[1] X.X. Cui, *et al.*, J. ALLOY. COMPD, Vol. 663 (2016) p.10

keywords : GdBCO-Ag bulk, Cooling-Rate-Control-Melt-Growth, Cation stoichiometry, Air-processed

WBP7-8 14:00–16:00

Stress-strain behavior of Gd123 superconducting bulk material under repeated loading

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2. National Institute for Fusion Science

Stress-strain behavior of a Gd123 single-grain bulk material was investigated through bending tests with repeated loading at room temperature. The loading level was increased with the repeat. Usual bending tests with static loading were also carried out. The fracture strength evaluated by the bending tests with repeated loading was slightly lower than that with static loading. While the Weibull plot data for the fracture strength evaluated by the bending tests with static loading distribute around the line drawn by linear fitting of the data, the Weibull plot data with repeated loading do not distribute around the line. Effects of the repeated loading on the mechanical properties are investigated through the observations on the microstructures and fracture surfaces of the specimens.

keywords : Gd123 bulk, Bending test, Mechanical properties, Stress-strain behavior

WBP7-9 14:00–16:00

Mechanical properties of EuBaCuO superconducting bulk material at liquid nitrogen temperature

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In order to evaluate the mechanical properties of EuBaCuO superconducting bulk material, bending tests were carried out at liquid nitrogen temperature (77 K) for specimens cut from a EuBaCuO single-grain bulk sample. The average value of the bending strength at 77 K was higher than that at room temperature (RT). One of the reasons for it is decrease of the interatomic distance by cooling. The Young's modulus was also evaluated through the bending tests. Due to the decrease of the interatomic distance, the Young's modulus at 77 K was also higher than that at RT. These mechanical property data of the EuBaCuO bulk sample were comparable to those of other REBaCuO bulk materials (RE: rare-earth elements). Relationship between the mechanical properties and microstructures in the EuBaCuO bulk sample is discussed.

keywords : EuBaCuO, Bulk material, Mechanical Properties, Strength

WBP8-1 14:00–16:00

Bending properties of spark plasma sintered MgB_2 superconducting bulk materials

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Since superconducting bulk materials are subjected to electromagnetic force and thermal stress in the superconducting devices, improvements of the mechanical properties are required for the development of high performance devices. It is known that packing ratio of conventional MgB_2 bulk material is around 50%. Due to the low packing ratio, mechanical properties of conventional MgB_2 bulk materials are inferior to those of REBaCuO (RE: rare-earth elements) bulk materials. On the other hand, mechanical properties of high packing ratio MgB_2 bulk materials fabricated by using spark plasma sintering (SPS) are excellent. However, effects of the SPS conditions on the mechanical properties of MgB_2 bulk materials have not been understood extensively. In this study, effects of the SPS conditions on the mechanical properties of the MgB_2 bulk materials are investigated through bending tests of specimens cut from the bulk materials. Relationship between the mechanical properties and microstructure of these bulk materials are discussed.

keywords : MgB2 bulk, Spark plasma sintering, Bending test, Mechanical properties

WBP8-2 14:00–16:00

Effects of Ag content on bending strength of MgB_2 superconducting bulk material

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1. National Institute of Technology, Ichinoseki College
2. Shibaura Institute of Technology
3. National Institute for Fusion Science

Ag addition is commonly carried out for REBaCuO (RE: rare-earth elements) superconducting bulk materials because Ag addition is effective in improving the mechanical properties without degradation of the superconducting properties. In this study, effects of Ag addition on the mechanical properties of MgB_2 superconducting bulk material are investigated. Five MgB_2 bulk samples with different Ag content were prepared. Ag contents of the MgB_2 bulk samples were 2, 4, 6, 8 and 10 wt%, respectively. In order to evaluated the mechanical properties of the Ag added MgB_2 bulk samples, 3-point bending tests were carried out for specimens cut from the MgB_2 bulk samples. Bending stress-strain behaviors of the MgB_2 bulk samples were almost linear until the fracture. No significant difference was observed for the Young's modulus of the MgB_2 bulk samples. On the other hand, the fracture strength was improved by the Ag addition, which is similar to the effects of Ag addition on the fracture strength of REBaCuO superconducting bulk materials.

keywords : MgB2 bulk, Ag addition, Bending test, Mechanical properties

WBP8-3 14:00–16:00

Improved Critical Current Densities in Bulk MgB_2 Fabricated using Nano Amorphous Boron Combined with Optimal Processing Conditions

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2. Experimental Physics, Saarland University

We prepared bulk MgB_2 superconductor samples from commercial powders of Mg metal (99.9% purity) and nanometer-sized amorphous B (98.5% purity) powders using a single-step solid state reaction at varying temperatures between 794 °C to 806 °C in steps of 3 °C in pure argon atmosphere to further optimize the sintering temperature of bulk MgB2 material to obtain high critical current densities. X-ray diffraction (XRD) analysis showed that all the samples were single phase MgB_2. The magnetization measurements confirmed a sharp superconducting transition with Tc,onset at around 38.5 K. The critical current density (Jc) values for the MgB_2 samples produced at 803 °C showed the highest currents of all processed materials., i.e., the highest critical current density reached 350 kA/cm^2 and 210 kA/cm^2 (20 K, self-field and 1 T). This is the best critical current performance of the bulk MgB_2 material at 20 K, produced without any external dopants. Our results clearly demonstrate that the optimization of the sintering conditions combined with nanometer-sized amorphous B powders will play an essential role to improve the bulk MgB_2 performance.

keywords : MgB2, Nano Amorphous Boron, XRD, SEM

WBP8-4 14:00–16:00

Production and Characterization of Bulk MgB_2 Material made by the Combination of Crystalline and Carbon Coated Amorphous Boron Powders

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The object of this investigation is to reduce the cost of bulk production and in the same time to increase the critical current performance of bulk MgB_2 material. High-purity commercial powders of Mg metal (99.9% purity) and two types of crystalline (99% purity) and 16.5% carbon-coated, nanometer-sized amorphous boron powders (98.5% purity) were mixed in a nominal composition of MgB_2 to reduce the boron cost and to see the effect on the superconducting and magnetic properties. Several samples were produced mixing the crystalline boron and carbon-coated, nanometer-sized amorphous boron powders in varying ratios (50:50, 60:40, 70:30, 80:20, 90:10) and synthesized using a single-step process using the solid state reaction around 800 °C for 3 h in pure argon atmosphere. All samples are characterized by x-ray diffraction, scanning electron microscopy (SEM), and superconducting performance, T_c and J_c at 20 K were recorded by SQUID magnetometer. All results analyzed and explained improved critical current performance on the basis of the carbon content in the final product.

keywords : MgB2, Carbon Coated Boron, Metallic superconductor, critical current density

WBP8-5 14:00–16:00

Microstructure and critical current densities in bulk MgB_2 using carbon-coated amorphous boron

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The MgB_2 bulk was prepared from commercial powder of Mg metal and 4.5% of carbon-encapsulated boron using a single-step solid state reaction at 805°C for 3 h in pure argon atmosphere. To see the effect of carbon content in the final product and the distribution uniformity, 20 mm in diameter bulk MgB_2 sample was cut into several pieces from bottom to top and the microstructure, superconducting performance, and chemical analysis by SEM-EDX were studied. DC magnetization measurements showed in all samples selected from various positions a sharp superconducting transition with onset T_c at around 35.5 K. SEM analysis indicated a dispersion of grains between 200 and 300 nm in size, as the main pinning medium in this MgB_2 superconductors. SEM by EDX analysis confirmed that the carbon content at various locations of the pellet was uniform. The critical current density (J_c) at 20 K for all measured positions was quite uniform, around 330 kA/cm² and 200 kA/cm² at zero field and 1 T, respectively. The results indicate that the *carbon-encapsulated* boron is crucial for the production of high quality bulk MgB_2 materials for various industrial applications.

This work was supported by Grant-in-Aid FD research budget code: 112261, SIT (Shibaura Institute of Technology) and by APVV No. 0330-12, VEGA 2/0121/16.

keywords : MgB2, Critical current density

WBP8-6 14:00–16:00

Influences of Co substitution on FeSe Superconductors with High-Energy Ball milling Aided Sintering Process

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Northwest Institute of Nonferrous Metal Research

$FeCo_xSe$ bulks with different content of Co in excess substitution (x=0.02, 0.05, and 0.10) were prepared with high-energy ball milling (HEBM) aided sintering process. The influences of Co in excess substitution on the lattice parameters, phase composition, microstructures, as well as the superconducting properties and magnetic properties were systematically studied. The monotonous change of lattice parameters with Co substitution content suggested that the Co ions had entered into the Fe interstitial position in tetragonal β-FeSe matrix instead of hexagonal δ-FeSe phase. And Co substitution also effected the content of hexagonal phase due to the influences of thermodynamic properties. Meanwhile, the microstructures also underwent an decrease of grain size with the increasing Co content. Due to the change of electronic structures and magnetic order with Co substitution, the superconducting properties of FeSe disappeared.

keywords : Superconductors, FeSe, substitution, powder metallurgy

WBP8-7 14:00–16:00

Growth of $FeTe_{0.6}Se_{0.4}$ bulk single crystals and critical current properties under high magnetic field

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Tokyo Metropolitan University

Fe-based superconductor is one of the candidate materials for superconductivity applications, because of its high upper critical field (H_{C2}). Among them, Fe-chalcogenide family has some advantages, such as lower toxicity than FeAs-based superconductors, very low anisotropy of superconductivity, and low costs for the raw materials. In addition, the composition (pseudo binary) and crystal structure are the simplest among the Fe-based superconductors. Recently, a high critical current density (J_C) of 1.4 MA/cm^2 at 5 K and 0 T was observed in the $FeTe_{0.5}Se_{0.5}$ thin film. Therefore, further improvement of superconducting properties of Fe-chalcogenide superconductors is well expected. In this study, we have fabricated $FeTe_{0.6}Se_{0.4}$ large-size bulk single crystals with high J_C under high magnetic field. $FeTe_{0.6}Se_{0.4}$ single crystals were prepared by the melting method. We investigated J_C properties using the residual magnetization method. From this analysis, we confirmed that the obtained bulk crystals are intrinsically single crystals from a critical current viewpoint. The J_C-B properties were analyzed from magnetization measurements by using Bean critical state model. The estimated J_C is more than 0.1 MA/cm^2 at 4.2 K and 7 T. Therefore, we expect that J_C properties of $FeTe_{0.6}Se_{0.4}$ bulk single crystals can be more enhanced by optimizing sample preparation procedure and introduction of effective pinning centers.

keywords : FeTe0.6Se0.4, under high magnetic field, single crystal, bulk

EDP1-1 14:00–16:00

Defect detection of pipes using ultrasonic guided wave and HTS-SQUID

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Kindai University

We have developed a remote non-contact inspection method for pipes using ultrasonic guided waves and high temperature superconducting (HTS) SQUID. In the previous study, we showed that the ultrasonic guided waves generated by magnetostrictive transmitter on metallic pipes could be detected by a HTS-SQUID gradiometer, and clarified influence of measurement parameters, such as liftoff and current intensity fed to the transmitter, on magnetic signals measured by the gradiometer. In this study, we conducted experiments to measure magnetic signals due to reflected waves at defects on pipes. We prepared two aluminum pipes as samples, with thickness of 6 mm, diameter of 60 mm, and length of 2000 mm. Three magnetized nickel thin plates were glued on each sample pipe. One of them was used as the magnetostrictive transmitter by winding a coil. We placed the HTS-SQUID gradiometer at lift-off 2mm above the other nickel plate. A slit parallel to the pipe axis was introduced in one of the sample, while a slit parallel to the circumference of the pipe was introduced in the other. The guided waves at 30 kHz were generated in the respective pipe, and they were converted into magnetic signals by the Villari effect of nickel. The magnetic signals due to the wave were measured by the HTS-SQUID gradiometer. On the both samples, it was possible to detect the magnetic signals due to the reflected guide waves at the defects by the gradiometer.

keywords : HTS-SQUID, pipe, Magnetostrictive effects, NDE

EDP1-2 14:00–16:00

Vector Scanning SQUID system for High Spatial Resolution

*THE DANG VU[1,2], Thanh Huy Ho[1,2], Shigeyuki Miyajima[1], Hiroaki Shishido[1,3], Masaaki Maezawa[4], Mutsuo Hidaka[4], Masahiko Hayashi[5], Takekazu Ishida[1,3]

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Superconducting quantum interference devices (SQUIDs) are used a wide fields of application such as magnetics, electronics, biology, spintronic, security analysis, agriculture, information technology and physics [1,2]. The conventional scanning SQUID microscopes can observe the distribution of local magnetic fields by scanning a single coil which senses magnetic fields in X and Y direction.
We proposed a novel system of a 3-dimensional (3D) scanning SQUID microscope with high sensitivity for magnetic fields and high spatial resolution [3]. We present a vector scanning SQUID sensor which center of x, y and z coil were arranged in a line and the distance between them and sample are same. A program contains an inverse transformation and two filters which base on features of scanning SQUID sensor to solve all of these problems such as angle of sensor, particles and contacting surface [4]. The cryostat system has the cables required in our scanning system, an XYZ piezo-driven scanner, and a safety structure to prevent the sensor from crashing with sample.
This work was supported by Grant-in-Aid from JSPS and MEXT (No. 25600018, No. 26820130, No. 26800192, No. 23226019, No. 15K13979) from Japan Society for the Promotion of Science (JSPS). The SQUID sensors in this work were fabricated in CRAVITY facilities at AIST.
[1] J. R. Kirtley et al., Appl. Phys. Lett., 66, 1138 (1995).
[2] H. T. Huy et al., Supercond. Sci. Technol., 26, 065001 (2013).
[3] S. Miyajima et al., IEEE Trans on Supercond., 25, 1600704 (2015).
[4] M. Hayashi et al., Appl. Phys. Lett. 100, 182601 (2012).

keywords : SQUID sensor, Josephson Junctions, Pick-up coils, Scanning SQUID microscope

EDP1-3 14:00–16:00

Ultra-low Field SQUID-NMR using LN_2 Cooled Cu Polarizing Field coil

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Toyohashi University of Technology

We are developing an Ultra-Low Field (ULF) Magnetic Resonance Imaging (MRI) system using a High-Temperature Superconductor rf-superconducting quantum interference device (SQUID) for food inspection. The advantage of the ULF- Nuclear Magnetic Resonance (NMR) / MRI as compared with a conventional high field MRI, is compact and low cost. In previous system, we have measured the NMR signal with a permanent magnet to polarize a sample; in the case, a sample transportation mechanism was required. It is difficult to measure the NMR signal of the sample with short relaxation time such as fat, because of the long transportation time.
In this study, we developed ULF-NMR/MRI system using a polarizing coil as a substitute for the magnet in order to measure the fats. The handmade polarizing coil was cooled at 77K by liquid nitrogen so that much current can be flown. The measured decay time of the polarizing magnetic field was 40 ms (80 mT / 42 A) at the sample position. Other components of the measurement system were a SQUID, a Cu wound flux transformer, a Helmholtz coil for a measurement field of 56.3 μT and an AC coil for a 90°pulse field. The protocol was as follows: Firstly, a sample was pre-polarized for 5 s by the polarizing coil. In this period the flux transformer circuit was electrically opened so that the SQUID was not exposured by the strong polarizing field. Subsequently, a 90°pulse was applied to rotate the magnetization of the sample. After closing the flux transformer circuit, the NMR signal was then detected by the SQUID via the flux transformer. As a result, NMR spectrum of the water sample was obtained at 2.4 kHz corresponding to the measurement field strength of 56.3 μT. The signal intensity and the signal to noise ratio (SNR) of the spectrum were 28.7 pT and 9.3, respectively. The results suggested that the ULF-NMR/MRI system has the potential for the food inspection.

keywords : SQUID, ultra-low field NMR/MRI, food inspection

EDP1-4 14:00–16:00

2D-MPI System using HTS-SQUID

*Kazuya Kobayashi, Yusaku Sanada, Seiichiro Ariyoshi, Saburo Tanaka

Toyohashi University of Technology

Magnetic Particle Imaging (MPI) is an imaging technique, with high sensitivity and high speed imaging, utilizing non-linear magnetization response for detection of super-paramagnetic iron oxide nanoparticles (MNP) [1]. MPI measures the magnetization change in the MNP under the AC magnetic field. Since the signal of the magnetization change is much smaller than signal generated by the AC magnetic field, the signal response at the fundamental frequency cannot be used. Therefore generally a third harmonic of the response is measured. However this method has disadvantages that power of the AC magnetic field is large and the system becomes large. In this study, we investigated the 2D imaging using a second harmonic, which can be obtained with a greater signal than the case of the third harmonic theoretically [2]. Moreover, an HTS SQUID (Superconducting Quantum Interference Device) magnetometer was employed in the study to enhance the signal to noise ratio.
A 2D-MPI system, which enables an imaging by scanning a DC magnetic field under a gradient magnetic field was constructed. When applying an AC magnetic field to the MNP sample, the magnetization response from the sample was detected by a differential detection coil. The DC and the AC magnetic field coils were prepared for each direction x and z, so that the system can measure the signals in two directions. A detection coils was also prepared for each direction. The signals from the detection coils were sent to HTS-SQUID via a flux transformer and then amplified by a lock-in amplifier. As a result, the detected position of the signal corresponded to the position of the sample.
References
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[2] Y. Zhang, H. Murata, Y. Hatsukade, and S. Tanaka, Rev. Sci. Instrum., vol. 84, p. 094702, 2013.

keywords : MPI, MNP, SQUID, second harmonic

EDP1-5 14:00–16:00

Investigation of readout coil for performance improvement of high-T_c rf-SQUID

*Yuji Miyato

Osaka University

Superconducting quantum interference devices (SQUIDs) are well known as high-sensitive magnetic sensor for various applications. We have developed high T_c rf-SQUIDs for the application of SQUID microscopy [1]. The SQUID performance depends on the designs of not only the rf-SQUID itself, especially the slit inside it [2,3], but also the readout coil combined for fluxed locked loop control. In this study, we focused on the readout coil to improve the SQUID performance. The readout coil can serve as the excitation coil applying rf-magnetic field to excite the rf-SQUID at the resonant frequency, the detection coil for the resonance change caused by the external quasi-static magnetic field, and the feedback coil for flux locked loop (FLL) to measure the intensity of the external magnetic field quantitatively. For the excitation and detection of the rf-SQUID, the readout coil should be coupled to the rf-SQUID in the proper matching condition. In contrast, for the FLL feedback, the week coupling should be better for the sensor sensitivity as long as the noise does not increase. Thus, the SQUID performance can be affected by the coil design and the coupling position. The rf-SQUID performances were investigated by combining several types of our developed rf-SQUIDs with various readout coils having different designs. We will discuss about the relation between the SQUID performance and the readout coil design.
[1] T. Hayashi, et al., Supercond. Sci. Technol., 20 (2007) S374.
[2] A. Sakai, et al., Phys. Proc., 65 (2015) 181.
[3] T. Ashizuka, et al., Phys. Proc., 65 (2015) 185.

keywords : rf-SQUID, HTS-SQUID, readout coil

EDP2-1 14:00–16:00

Experimental and simulation results of a symmetrical pad to reduce a stray ground current in superconducting integrated circuits

*Hideo Suzuki, Tomohiro Ono, Nobuyuki Yoshikawa

Yokohama National University

Extracting bias current is widely used to avoid harmful effect by spreading the bias return current on a ground plane in SFQ circuits, which causes malfunction and decreasing the operating margin by the stray magnetic field. Although the extracting bias current is useful, we found that normal pad structure using a bias pad and a current extracting pad produces stray ground current (magnetic field) for its asymmetric structure. We proposed a symmetrical pad structure, which can reduce the stray ground current in superconducting circuits. The bias current is extracted from a nearby ground pad of a bias pad in usual method. In contrast, the symmetrical pad consists of a bias current pad and two current extracting pads arranging both sides of the bias pad. In the new structure, the bias current is extracted on halves from the two pads symmetrically to the bias pad, reducing the stray ground current. We have designed and experimentally tested a test chip with SQUIDs as sensors to compare the symmetric pad to the asymmetric pad structures. The chip was fabricated with the AIST advanced process 2 (ADP2). We have confirmed the symmetric pad structure is superior to the asymmetric one and the pads placing off the ground plane is better than that on the ground plane. The experimental results were also compared to the simulated results using the FastHenry program.
This work was supported by a Grant-in-Aid for Scientific Research (S) (No. 26220904) from the Japan Society for the Promotion of Science (JSPS). The devices were fabricated in the clean room for analog-digital superconductivity (CRAVITY) in National Institute of Advanced Industrial Science and Technology (AIST).

keywords : superconducting integrated circuit, SFQ, FastHenry

EDP2-2 14:00–16:00

Simulation and Measurement of Influence of Flux Quantum Trapped in Moat on Superconducting Circuit

*Hibiki Imai, Yuki Yamanashi, Nobuyuki Yoshikawa

Yokohama National University

Various applications of superconducting integrated circuits, which utilized the low-power and high-speed characteristics, have been investigated. Because the superconducting circuits are sensitive to the external magnetic field, adequate placement of moats [1] is important for the stable operation. However, the magnetic flux quantum trapped in the moat might affect circuit operation, where the distance between the moat and the signal line is small. To evaluate the influences of the trapped flux in the moat, we calculated how much the trapped flux in the moat couples to the signal line using an inductance extraction tool, InductEx [2].
We devised a simulation model that enables us to calculate the coupling strength between the magnetic flux quantum trapped in the moat and the signal line. The results show a reasonable dependence of coupling strength on the distance between the moat and the signal line. According to the result, 4.4 x 10-2 of the quantum flux couples to the signal line when one flux quantum is trapped in the moat and the distance from the signal line (its size is 10.2 x 1.2 μm) and the moat (its size is 5 x 1 μm) is 3 μm. This simulation is assumed the use of the AIST 2.5 kA/cm2 Nb standard 2 process [3]. We experimentally measured flux linkage between the signal line and the flux quantum trapped in the moat by measuring modulation of the threshold current of the dc-SQUID. The measured flux linkage was 8.1 x 10-2 of the flux quantum when one flux quantum is trapped in the moat and the distance from the signal line to moat is 3 μm.
[1] M. Jeffery et al., Appl. Phys. Lett., vol. 67, p. 1769, 1995.
[2] C. J. Fourier et al., Supercond. Sci. Technol., vol 24, pp. 12015, 2011.
[3] M. Hidaka et al., Supercond. Sci. Technol., vol. 19, pp. 138-142, 2006.

keywords : Superconducting circuit, moat, flux trapping

EDP2-3 14:00–16:00

Design and Evaluation of Adiabatic-Quantum-Flux-Parametron Autocorrelators for Submillimeter-Wave Spectrometry

*Saki Kobako, Yuki Yamanashi, Nobuyuki Yoshikawa

Yokohana National University

Submillimeter-wave spectrometry is required in the radio astronomy. Superconductor receivers like SIS mixers are promising devices for the submillimeter-wave spectrometry because of their high-sensitivity and wide-band operation. However, the performance of spectrometry systems is usually limited by signal processing circuits located at room temperature. Moreover, signal processing circuits, which calculate spectrum of the detected wave, consume huge amount of power [1]. To overcome this problem, superconducting signal processing circuits, which operate at low temperature with extremely low-power consumption, are effective.
An autocorrelation-type spectrometer is suitable for the superconducting signal processing circuit because the circuit can be implemented by placing simple calculation units composed of two buffers and an EXOR gate. However, if we build a large-scale autocorrelator that contains several thousands of channels, the power consumption becomes a crucial problem. Recently, an adiabatic quantum-flux-parametron (AQFP) [2] has been studied as an ultra-low-power superconductor logic circuit. In this study, we designed an autocorrelator using AQFP circuit. We designed 1-bit 4-ch autocorrelators using AQFP and rapid single-lux-quantum (RSFQ) circuits [3] and compared their performances. The experimental results will be reported.
This work was supported by JSPS KAKENHI Grant Number 26220904. The devices were fabricated in the clean room for analog-digital superconductivity (CRAVITY) in National Institute of Advanced Industrial Science and Technology (AIST).
[1] I. Vernik et al., *IEEE Trans. Appl. Supercond.*, vol. 15, pp. 419-422, 2005.
[2] N. Takeuchi et al., *Supercond. Sci. Technol.*, vol.26, pp. 035010, 2013.
[3] K. K. Likharev et al., *IEEE Tran. Appl. Supercond.*, vol. 1, pp. 3-28, 1991.

keywords : AQFP circuit, Spectrometry, Autocorrelator

EDP2-4 14:00–16:00

High-Speed Superconductive Decimation Filter for Sigma-Delta Analog to Digital Converter

*Tomu Wakamatsu, Yuki Yamanashi, Nobuyuki Yoshikawa

Yokohama National University

A sigma-delta analog to digital converter (ADC) composed of a single-flux-quantum (SFQ) circuit is superior to semiconductor ADCs in terms of accuracy, the sampling frequency, and power consumption. In order to build the ADC system, a decimation filter that converts ultra-high-speed output data from the ADC to the lower frequency digital data is required. The performance of the ADC system is generally limited by not the maximum sampling frequency of the ADC but by the maximum operation frequency of the decimation filter.
In this study, we investigate a decimation filter by hybridize a shift-register-based [1] and a counter-based [2] decimation filters. In the investigated decimation filter, the shift-register-based decimation filter is used for the first stage to process the ultra-high-speed data from the sigma-delta ADC and the counter-based decimation filter is used for the following stage to implement the filter with the small circuit area. We designed and simulated the investigated decimation filter. We obtained that the maximum operation frequency is 39.8 GHz assuming the AIST 2.5 kA/cm^2 Nb standard 2 process [3]. More than 30 GHz output data can be processed by the investigated decimation filter. We experimentally obtained the low-speed operation of the designed decimation filter.
[1] H. Hasegawa et al., IEEE Trans. Appl. Supercond., vol. 11, pp. 517-520, 2001.
[2] T. V. Filippov et al., IEEE Trans. Appl. Supercond., vol.11, pp. 545-549, 2001.
[3] M. Hidaka et al., Supercond. Sci. Technol., vol. 19, pp. S138-S142, 2006.

keywords : A/D converter, decimation filter, sigma-delta ADC, SFQ circuit

EDP2-5 14:00–16:00

Evaluation of Bit Error Probabilities for an Integrated Quantum Voltage Noise Source for Johnson Noise Thermometry

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National Institute of Advanced Industrial Science and Technology

We experimentally and numerically evaluated bit error probabilities (BEPs) of an integrated quantum voltage noise source (IQVNS) for Johnson noise thermometry (JNT). Previously, we developed the IQVNS based on a rapid single flux quantum (RSFQ) technology and confirmed basic performances toward the redefinition of the Boltzmann constant [1-3]. The BEP evaluation for the IQVNS, which comprises mostly RSFQ digital circuitry, is of great importance because the accuracy of the JNT measurements is guaranteed with the assumption of its stable, error-free operation. In this paper, we prove the IQVNS stability by evaluating the BEPs. We measured dependence of BEPs on bias currents supplied to the digital circuit components of the IQVNS at a 50-kHz clock frequency. We obtained a sufficiently wide bias margin ranging from 89% to 112% of the designed value at a BEP of 10^{-12} by fitting experimental data to a complementary error function. We also numerically confirmed a sufficiently low BEP of less than 10^{-12} at a target clock frequency of 8.2 GHz. These results indicate that the IQVNS operates highly stably and is applicable to the JNT measurements with metrological accuracy.
This work was supported by JSPS KAKENHI Grant Numbers 22246013 and 25289126.
[1] M. Maezawa, T. Yamada, and C. Urano, J. Phys.: Conf. Ser., vol. 507, p. 042023, 2014.
[2] T. Yamada, C. Urano, and M. Maezawa, Appl. Phys. Lett., vol. 108, p. 042605, Jan. 2016.
[3] C. Urano et al., IEEE Trans. Appl. Supercond., vol. 26, no. 3, p. 1800305, April 2016.

keywords : Johnson noise thermometry, integrated quantum voltage noise source, rapid single flux quantum, bit error probability

EDP2-6 14:00–16:00

Implementation of a Double-Active-Layered AQFP Cell Library Using Double Gate Process

*Takumi Ando[1], Naoki Tsuji[1], Fumihiro China[1], Naoki Takeuchi[2,3], Shuichi Nagasawa[4], Mutsuo Hidaka[4], Yuki Yamanashi[1,2], Nobuyuki Yoshikawa[1,2]

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We have been doing research on the adiabatic quantum-flux-parametron (AQFP), which is an ultra-low-power superconductor logic [1]. In the previous study [2], we built an AQFP cell library using AIST standard process (STP2), and an 8-bit AQFP carry look-ahead adder designed using the cell library, which includes approximately 1,000 Josephson junctions, was demonstrated. In order to realize even larger circuits, we herein designed the double-active-layered AQFP cell library using the AIST double gate process (DGP), which is a seven-Nb-layer fabrication process. The most remarkable feature of the DGP is that it owns two active layers separated by a single ground plane, which enables to design AQFP circuits through the upper four layers and/or through the lower four layers, independently. Therefore, the double-active-layered cell library can achieve a high circuit density via stacking and overlapping AQFP circuits. We fabricated test circuits for double-active-layered AQFP cells. In measurement, we confirmed wide operation margins for both the AQFP cells designed through the upper four layers and designed through lower four layers. We also demonstrated a correct data propagation between upper and lower cells. Our measurement results reveal a high circuit density and a high design flexibility of the double-active-layered AQFP circuits.

[1] N. Takeuchi, D. Ozawa, Y. Yamanashi, and N. Yoshikawa, *Supercond. Sci. Tech.*, vol. 26, no. 3, p. 035010, 2013.
[2] N. Takeuchi, Y. Yamanashi, and N. Yoshikawa, *J. Appl. Phys.*, vol. 117, p. 173912, 2015.

keywords : QFP, Adiabatic logic, Superconducting integrated circuit

EDP2-7 14:00–16:00

Implementation of a Look-Up Table Based on Phase Shift Elements and Dual-Rail SFQ Circuits

*Soya Taniguchi[1,2], Hiroshi Ito[1], Takuya Kurihara[1], Masamitsu Tanaka[1], Hiroyuki Akaike[1], Akira Fujimaki[1]

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2. JSPS Research Fellow

We propose to build a field programmable gate array (FPGA) based on single-flux-quantum (SFQ) circuits. This FPGA has a high potential to operate over 10 GHz because of high-throughput characteristics of SFQ circuits, which would expand the field of reconfigurable circuits. In previous study [1], the component circuits of FPGA based on SFQ circuits occupy large areas.
We designed a compact look-up table (LUT) based on phase shift elements (PSEs) and dual-rail SFQ circuits. The LUT is a component circuit of an FPGA. The designed 2-input, 4-bit LUT was composed of a decoder and memories. The decoder was constructed by a 2×2-Join, a primitive in dual-rail circuits. The 2×2-Join enabled us to reduce the circuit area and the number of Josephson junctions. As a result, the circuit area of the decoder was reduced to one-tenth of the synchronous circuit. We used a 1:2 demultiplexer (DEMUX) based on PSEs to efficiently implement 1-bit memory. The DEMUXes are a core function and used in large numbers in an LUT because it determines the binary output. The PSEs are made of ferromagnets. An SFQ is output from one of the output ports depending on the direction of magnetization. The area of 1-bit memory was reduced to one-fifth of the memory based on conventional SFQ circuits. The outputs of the DEMUX are merged into two outputs of the LUT by confluence buffers (CBs). We successfully confirmed correct operation of these component circuits with wide bias margins over ±20%.

[1] C. J. Fourie and H. V. Heerden, IEEE Trans. Appl. Supercond., vol. 17, no. 2, pp. 538-541, Jun. 2007.

keywords : single-flux-quantum, reconfigurable circuits, phase shift element, ferromagnetic patterns

EDP2-8 14:00–16:00

A random access memory cell using quantum flux parametron

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Adiabatic quantum-flux-parametron (AQFP) logic has a potential to become a basic technology to realize an ultra-low-power computing system because of its extremely low bit-energy with three orders of magnitudes lower than that of rapid single-flux-quantum logic [1]. To date, an 8-bit carry look-ahead adder using the AQFP logic circuits have been demonstrated [2]. Large-scale memories, which are compatible with the AQFP circuits, are highly demanded for realizing high-performance computing systems. In this study, we have proposed, designed and measured a random access memory cell based on AQFP circuits. The memory cell is composed of a storage QFP gate and a read AQFP gate. The storage QFP gate is formed by biasing an AQFP gate with DC current to obtain two stable logic states, so that is can store 1 bit of information. The storage QFP gate has three current inputs, I_{d}, I_{wx} and I_{wy} for writing a datum, where I_{d} corresponds to the input datum, and I_{wx} and I_{wy} are the row and column selection current for writing. The read AQFP gate is magnetically coupled with the storage QFP gate in order to read the logical state of the storage QFP gate. The read AQFP gate has two current inputs I_{rx} and I_{ry} for reading a datum, where I_{rx} and I_{ry} are the row and column selection current for reading. The amplitude of each input current for the memory cell has to be the same level as the output current of AQFP gates to maintain the compatibility with AQFP logic. We implemented the memory cell using the AIST standard process and confirmed its correct operation. It is shown that the memory cell can operate by small enough input currents of the same level as the output current of AQFP gates.
[1] N. Takeuchi, et al., *IEEE Trans. Appl. Supercond.*, vol. 23, no. 3, p. 1700304, Jun. 2013.
[2] N. Takeuchi, et al., *J. Appl. Phys.*, vol. 117, no. 17, p. 173912, May 2015.

keywords : QFP, AQFP, memory, Josephson integrated circuits

EDP3-1 14:00–16:00

THz detection using Substrate Absorption Type STJ with Position Resolution

*Masahiko Sone[1], Naoki Igarashi[1], Masato Naruse[1], Hiroaki Myoren[1], Yoshiaki Sasaki[2], Chiko Otani[2], Tohru Taino[1]

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2. RIKEN

Terahertz (THz) waves are categorized between millimeter radio wave and infrared radiation. For its unique characteristics such as a good transmittance for soft materials, the THz waves have a great potential as non-destructive imaging tool. We have developed a substrate absorption type superconducting tunnel junction (STJ) for the THz detector [1]. The STJ detects phonons generated in the substrate when THz waves are illuminated from the substrate side. These phonons are isotropically diffused in the substrate. Therefore, the position resolution of its detector is low.

In this research, we have proposed and fabricated a new substrate absorption type STJ for the THz imaging. Since trenches in x- and y-direction are on the opposite side of the STJs, absorption parts for THz waves like islands exist under STJs. The purpose of trenches is to restrict diffusion of phonons in the substrate. The size of island and trenches pitch is variable and it decides the position resolution. In addition, Al layer that reflects the THz waves is deposited in trenches. The fabrication method and the evaluation results will be presented.
[1] C. Otani et al., IEEE Trans. Appl. Supercond., Vol. 15, No. 2, pp. 591- 5941 (2005).

keywords : THz, STJ

EDP3-2 14:00–16:00

Development of large-scale array of superconducting detectors for the CMB polarization measurement

*Ryo Koyano[1], Munehisa Semoto[1], Satoru Mima[2], Kenji Kiuchi[2], Masato Naruse[1], Hiroaki Myoren[1], Chiko Otani[2,3], Osamu Tajima[4], Shugo Oguri[4], Tohru Taino[1]

1. Saitama University; 2. RIKEN; 3. Tohoku University; 4. KEK

The Big Bang cosmology is the prevailing cosmological model to explain the beginning of the universe. On the other hand, it has still several issues that can not be explained. The inflation theory resolves several outstanding issues in cosmology, including the flatness, horizon and monopole problems [1]. Recently, primordial gravitational waves caused by inflation was noted that create a characteristic polarization pattern in CMB [2].

GroundBIRD experiment is a project for the purpose of ground-based observations of the CMB polarization pattern. As a strategy, we plan to observe at 220 GHz (112 pixels) to understand dust emissions, as well as at 145 GHz (55 × 6 pixels) for CMB measurements.

We have been developing Microwave Kinetic Inductance Detectors (MKIDs) for GroundBIRD as a large-scale array detector [3]. The detector was composed of probe antenna, millimeter-wave circuit, and MKIDs. Antenna was designed to be center frequency 145 GHz, the bandwidth more than 30%, and linear polarization crosstalk -40dB below.

We have been fabricated a prototype detector for optimizing the millimeter-wave circuit. In order to reduce the yield of the problem in the manufacturing process, the prototype detector size was 20mm square to be approximately 1/4 of actual size. We got a resonance characteristic at 100 mK of prototype detector. The detail results will be presented.

[1] A. R. Liddle et al., “Cosmological Inflation and Large-Scale Structure", (2000).; [2]C. L. Bennett et al., "Nine-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations", submitted to ApJS, (2013).; [3] S. Oguri et al., “GroundBIRD: observation of CMB polarization with fast scan modulation and MKIDs" SPIE, (2016).

keywords : CMB, MKIDs, GroundBIRD

EDP3-3 14:00–16:00

Development of STJ for neutron detector on Si-LBO hybrid substrate by surface-activated room-temperature bonding

*So Endo[1], Go Fujii[2], Masahiro Ukibe[2], Hideki Takagi[2], Masataka Ohkubo[2], Masato Naruse[1], Hiroaki Myoren[1], Chiko Otani[3], Tohru Taino[1]

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2. AIST
3. RIKEN

Neutron with a permeability to metal and sensitivity to light elements, such as hydrogen and lithium has been expected as new non-destructive imaging tool. Superconducting tunnel junctions (STJs) on a single crystal Li2B4O7 (LBO) substrate have proposed as a next generation neutron detector because of high detection efficiency. On the other hand, its spatial resolution is low because the detector utilizes the whole substrate as an absorber for neutrons. As a solution, we have proposed a STJ detector on a Si-LBO hybrid substrate that is bonded Si and LBO substrate by epoxy glue and is pixelated by dicing saw. However, it is thought that propagating phonons in the substrate are attenuated by epoxy glue of between Si substrate and LBO substrate.

In this presentation, we propose a new Si-LBO hybrid substrate formed by surface-activated room-temperature bonding. In this bonding method, the contact surfaces are sputter-etched by high energy Ar atom/ion beam and bonded in vacuum without materials such as epoxy glue in order to solve the signal attenuation in Si/LBO bonding interface. The fabrication process and the measured results will be presented.

keywords : Neutron, STJ

EDP3-4 14:00–16:00

Fabrication method of superconducting TSV for STJ detector using 3D integration technique

*Kohei Morita[1], Soki Hatakeyama[1], Masahiro Aoyagi[2], Masato Naruse[1], Hiroaki Myoren[1], Tohru Taino[1]

1. Saitama University
2. AIST

We have developed superconducting tunnel junctions (STJs) as a next generation photon detector. Although STJ detector has great potential, it is difficult to increase the number of the STJ array without the increasing of the insensitive area.
To solve this problem, we have proposed and demonstrated an embedded STJ (e-STJ) using 3D integration technique for the photon detector with large detection area. This detector has three features; the detector is embedded in the substrate, its wiring utilizes Through Si Via (TSV) , the detector chip and wiring chip are connected using a flip chip bonding.
In this presentation, we fabricated and demonstrated the superconducting TSV. The TSV was formed by a deep reactive ion etching. The fabrication process and experimental result of the TSV will be presented.

keywords : STJ, e-STJ, TSV, 3D

EDP3-5 14:00–16:00

Development of LEKID detectors for Light Dark Matter Searches using Liquid Helium

*Yosuke Kida[1], Hirokazu Ishino[1], Atsuko Kibayashi[1], Yosuke Yamada[1], Kunimoto Komatsu[1], Naoto Hidehira[1], Masashi Hazumi[2], Nobuaki Sato[2], Satoshi Kohjiro[3], Hirotake Yamamori[3], Fuminori Hirayama[3]

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We have developed the superconducting detector LEKID (Lumped Element Kinetic Inductance Detectors) for a dark matter search using liquid helium. It is supposed that the dark matter consists of weakly interacting massive particles (WIMPs). Direct searches for the WIMPs have been conducted using Xe, Ge, Si and NaI as targets. Those experiments have sensitivities for WIMP mass down to about 10 GeV/c^2. In 2013, W. Guo and D. N. McKinsey have proposed to use liquid helium as a target to obtain a sensitivity beyond 10 GeV/c^2 in WIMP mass. Helium may have sensitivity to the light WIMP mass less than 10 GeV/c^2, as it is a light element. Recoiled helium atoms produce scintillation light photons with the wavelength of 80 nm (16 eV in energy). Those photons are detected with the superconducting detector LEKID. The LEKIDs offer us a frequency domain multiplexing readout that reduces the number of readout cables, decreasing the heat load from the outside.
The superconducting detectors are fabricated with photolithographic techniques in clean rooms, CRAVITY at AIST and one at KEK. We use Nb or NbN for superconducting materials. The LEKIDs have cross-talks among the resonators. It is necessary to reduce the cross-talks to less than 1%, while having an acceptance as large as possible. We have been researching for an optimized LEKID design that has the cross-talks with the required level. We report on the current status of the development of LEKIDs that satisfy our requirements.

keywords : Kinetic Inductance Detectors, Dark Matter

EDP3-6 14:00–16:00

Combined operation of two TESs for low-energy photon applications

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The University of Tokyo

Conventionally, TES is used as an independent device although TES arrays are employed for some applications. In the past, we demonstrated a parallel bias scheme with some weak link between neighboring TESs. This principle ensures a coupling of two TESs could make it possible to coordinate two TESs operation as an active circuit. We have used a simulation code based on a two-fluid model for the investigation of such a combined operation of two TES electrically coupled each other. Of course, in some condition the TESs become unstable. However, we could find a operating condition and the electrical circuit that enables a stable operation. Based on such an idea, we are trying to investigate a TES circuit mostly for low-energy photon applications.

keywords : Transition Edge Sensor

EDP3-7 14:00–16:00

Stress Control of Reactively Sputtered Thick NbN Film on Si Wafer Changing the Location of the Substrate Si Wafer Against the Nb Target on a Magnetron Cathode

*Yasuhiro Suzuki[1], Nobuhiro Iguchi[1], Kazuhiro Adachi[1], Tatsumi Hioki[1], Akihisa Ichiki[1], Tomoyoshi Motohiro[1], Che-Wei Hsu[2], Shinya Kumagai[2], Minoru Sasaki[2]

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2. Graduate School of Engineering, Toyota Technological Institute

We have been developing a superconducting NbN thin film coil in a spiral trench on a Si-wafer using MEMS technology. Connecting the coils on the different wafers using wafer-bonding process, a cylindrical wafer stack is to be formed as a compact SMES unit [1]. The critical current density of our NbN film was measured to be around 1100A/mm^2. Therefore, the critical current I_c in the spiral coil increases with the film thickness. Up to now, we measured I_c of 430 mA for a NbN spiral coil of 3.5 micrometer in thickness while 47 mA for 0.5 micrometer in thickness although the geometrical design of the spiral trench was also changed. However, if we make the NbN film thicker, the film is apt to have higher tensile or compressive stress which can cause peeling of the film from the Si substrate. It is well known that the stress of the sputtered thin films can be controlled from tensile to compressive ones by controlling the bombardment of high energy argon atoms reflected from the target surface. Based on this knowledge, a specially designed sputter-deposition apparatus was fabricated in which the substrate can be located not only at the different target-to-substrate distances but also at several different lateral distances from the target center normal. Using this apparatus, various stress conditions could be realized which contributed to fabrication of thick NbN film spiral coil in the trench.
[1]N. Sugimoto, N. Iguchi, Y. Kusano, T. Fukano, T. Hioki, A. Ichiki, T. Bessho, T. Motohiro , “Compact SMES with a Superconducting Film in a Spiral Groove on a Si-Wafer Formed by MEMS Technol. with Possible Energy Storage Volume-Density Surpassing That of Li-Ion Batteries(I)" FD-13, *28th Int'l Symp. on Superconductivity*, Nov. 16-18,2015 Tower Hall Funabori, Funabori, Tokyo
[2]J. A. Thornton, J. Tabock and D. W. Hoffman:, *Thin Solid Films* **64**, 111(1979).

keywords : sputter-deposition, NbN, SMES, MEMS

EDP3-8 14:00–16:00

Capacitance Measurements of Niobium SIS Junctions at Microwave Frequencies

*Konomi Sato[1], Takafumi Kojima[2], Matthias Kroug[2], Takeshi Sakai[1] and Yoshinori Uzawa[2]

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3. National Institute of Information and Communications Technology

We describe our experimental set-up and an evaluation method for estimating the capacitance of superconductor-insulator-superconductor (SIS) junctions. Devices under test are mounted on a 4-K probe station and S-parameter measurements can be performed by contacting distinct circuits with a movable probe arm. This allows to collect data for tens of junctions per cooling cycle.
The SIS junctions are based on Nb/AlOx/Nb or Nb/AlNx/Nb tri-layers and vary in size ranging from about 1 μm² to 20 μm². They are integrated with a coplanar type pattern designed such that a reliable contact with the three finger probe is possible but only add a minimum of parasitic inductance. A permanent magnet was used to suppress the Josephson current. In order to effectively see the junction capacitance, S-parameters were measured at the bias voltage of about 1 mV (sub-gap resistance region) in the frequency range of DC to 30 GHz. The junction capacitance was then estimated by fitting S-parameters based on an equivalent circuit model. We have characterized several sets of junctions with different current densities j_c = 10 – 40 kA/cm². The results show that the junction`s time constant, which is the product of normal state resistance Rn and capacitance C, decreases towards higher jc and is uniform within +/-5% across the wafer.
Acknowledgment This work was supported in part by JSPS KAKENHI under Grant JP26420330, JP15K18057, JP16K13789.

keywords : radio astronomy, superconductor-insulator-superconductor mixer, cryogenic probe station, junction capacitance.

EDP4-1 14:00–16:00

Simulations of chaos generation from Josephson junctions with various junction parameters

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Ibaraki University

In general, it is well known that voltage waveforms between the electrodes of Josephson junction under irradiation of a microwave behave chaos characteristics under appropriate conditions. In order to apply the chaos to a random number generator, we have been studying the Josephson chaos by simulations, in which the Josephson junction is assumed to fabricate with YBCO materials. We used RCSJ model in order to present the equivalent circuit of the Josephson junction, and derived a derivative equation. The Lyapunov exponents, which determined if the state of the Josephson junction was chaotic or not, were calculated from the time evolutions of the voltages obtained from the equation. In the simulation, the junction parameters were assigned the feasible values for the actual YBCO Josephson junctions. Since the products of critical current (I_c) and normal resistance (R_n) for the YBCO Josephson junctions has typically been reported about 2 mV, I_c and R_n were set, as the first assumption, to 1 mA and 2 Ω, respectively. As the second assumption, capacitance (C) was set to 82.3 fF, which corresponded to McCumber parameter $ß_c$ of 1. No bias current was applied to simplify the device operation. The regions, in which the chaos was generated, were investigated by changing the value of R_n and C. As a result, we found that a decrease of R_n and an increase of C made decrease the required value of the frequency, at which the chaos was obtained. We also found that there was a lower limit in the value of R_n, with which chaos occurred.

keywords : YBCO, Josephson junction, chaos

EDP4-2 14:00–16:00

Evaluation of detectable angle of mid-infrared slot antennas

*Ryosuke Obara[1], Junsei Horikawa[2], Hisashi Shimakage[1], Akira Kawakami[3]

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3. NICT

In general, mid-infrared (MIR) detectors are based on the particle nature of light. Such detectors usually suffer from a tradeoff between sensitivity and speed because the sensitivity depends on the detection area, and their electrostatic capacitance tends to increase with the area. Thus, it is difficult to realize the mid-infrared detectors with both of fast and high-sensitive characteristics. In order to realize fast detectors without sacrificing detection area, we proposed to use antennas for detecting MIR waves. In our previous works, we fabricated MIR detectors with nano-antenna, and measured its antenna properties using FTIR. Furthermore, we evaluated its response speed of 0.3 ns. In this presentation, we report on the evaluation of detectable angle of MIR slot antennas.
The MIR detector consists of twin slot antennas and bolometer. The slot antennas were designed 2.6×0.2 μm^2 as to resonate at 61 THz. These are located parallel and separated 1.6 μm each other. The bolometer was fabricated by a 7.0-nm thick NbN thin film, and it was located center of the twin antennas. We have confirmed the critical current decreased when the detector absorbed MIR energy through twin slot antennas. For evaluating the angle dependence of its sensitivities, we set up directionality evaluation system. Two polarizers in front of quantum cascade laser were used for keeping laser power constant, even if the laser polarization changes. The detector was mounted in a rotatable refrigerator. The MIR light was introduced through CaF_2 window, and the detectors were cooled to 4.0 K. We measured angle dependences of the detector sensitivity, by rotating the detector. The results showed clearly the twin slot antenna behave as the MIR antenna in an appropriate manner, and indicated our MIR detectors with twin slot antenna would have both of high sensitivity and high speed characteristics.

keywords : mid-infrared, detector, antenna

EDP4-3 14:00–16:00

Calculations of superconducting parametric amplifiers performances

*Takashi Goto[1], Hisashi Shimakage[1], Shingo Saito[2], Masanori Takeda[3]

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3. Shizuoka University

Superconducting parametric amplifiers have high-quality characteristics, such as a broad bandwidth, an extremely low-noise property, and a high dynamic range. Thus, they would be promising devises for the use of a radio astronomy field. Their amplification principle is same as that of nonlinear optical fiber parametric amplifier, and based on a degenerate four-wave mixing. The superconducting parametric amplifiers consist of a superconducting transmission line, which is made by a superconducting thin film. In general, each of superconducting materials has a unique inductance component, which is called a kinetic inductance. As it has nonlinear characteristics with respect to a current bias, its nonlinearity can be utilized for the superconducting parametric amplifiers. In this presentation, we report on the estimations of superconducting parametric amplifier performances. Single-crystal NbTiN, poly-crystal NbTiN, and YBCO thin films are considered as the superconducting materials. On the basis of measured parameters, theoretical calculations were implemented for evaluations of kinetic inductance nonlinearities and parametric gains. We found that strong nonlinearities were obtained in the single-crystal NbTiN and YBCO thin films. As a result, a large parametric gains were expected for such materials, even if their configurations were with shorter line lengths and smaller pump powers.

keywords : Kinetic inductance, NbTiN, YBCO, Nonlinearity

EDP4-4 14:00–16:00

Optical Design of Linearity Measurement System for Superconducting SIS Mixer on Millimeter Band Atmospheric Spectrometer

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1. Institute for Space-Earth Environmental Research (ISEE), Nagoya University
2. Advanced Technology Center, National Astronomical Observatory of Japan

Minor atmospheric molecules radiate millimeter and/or sub-millimeter wave spectral lines by rotational transitions. The atmospheric research group of ISEE, Nagoya University is operating the millimeter wave atmospheric spectrometers in Hokkaido, Argentina, and Syowa Station, and monitoring long-term variation and altitudinal distribution of minor atmospheric molecules such as O_3 and ozone depleting substances NO and ClO.
The superconducting SIS mixer is mounted on the millimeter-band atmospheric spectrometer, and the mixer performance greatly affects the measurement accuracy. But it is pointed out that the linear response between the input and output of the mixer may be distorted for large input power. The molecular spectral intensity is calibrated by the radiation from 77K and 300K black-bodies as reference sources, on the assumption that the linearity of the SIS mixer is assured within this range. Thus, it is important to experimentally establish how much the mixer linearity is assured and to make correction if necessary.
Conventional method to evaluate the linearity of SIS mixer was based on 4-points measurements or two-pairs of measurements to derive the input-output slopes for the low power inputs (two points around 77K) and high power inputs (two points around 300K). But this method brings some uncertainties due to the limited discrete measurement points. Therefore, we have developed a new linearity measurement system which can continuously change the mixer input-power between ~77K and ~300K .
In this presentation, we describe the design of the new linearity measurement system and report the results of test measurements.

keywords : middle atmosphere, minor molecules, millimeter wave, superconducting mixer

EDP4-5 14:00–16:00

Design of compact high pole HTS tri-band bandpass filters

*Takahiro Unno, Naoto Sekiya

University of Yamanashi

We have designed a compact high pole high-temperature superconducting (HTS) tri-band bandpass filter (TBPF) with a new feeding structure. The TBPF is realized by combining an eight-pole dual-band bandpass filter (DBPF) which uses stub-loaded meander line resonators with an additional microstrip line, and an eight-pole single band bandpass filter (SBPF) which uses meander line resonators. The DBPF enables independent control of the center frequencies of the first and second bands. A newly feeding structure extended feedline of the TBPF is adjusted the external quality factor by changing the feedline width, feedline length, and position of SBPF. This feeding method enable to control external quality factor of each frequency. The TBPF was designed and analyzed using an electromagnetic simulator based on moment method. The center frequencies of the three-pass-bands are 1.5, 2.0, 2.5 GHz; three bands have a 2% bandwidth. The TBPF was fabricated using double-sided $YBa_2Cu_3O_7$ thin film on a 33.1×29×0.5 mm Al_2O_3 substrate. As a result, the overall filter circuit size is only 0.375 λ_g × 0.287 λ_g , which is the guided wavelength of the 50 Ω line on the substrate at the 1.5 GHz. We will show the detail simulation result and simulated ones at the conference.

keywords : high-temperature superconductor, tri-band bandpass filter, meander-line resonator, stab-loaded resonator

EDP4-6 14:00–16:00

Design of high quality factor spiral coil using double-side REBCO wire for RF applications

*Yuki Monjugawa, Naoto Sekiya

University of Yamanashi

We have designed a high quality factor RF coil using double-side REBCO wire for MRI, NMR, NQR and wireless power transfer. We proposed the double-side REBCO wire which was constructed with two conventional REBCO wires without copper stabilizer. The proposed wire can effectively suppress conductor loss of hastelloy and thereby the RF coil used it can be obtained much higher quality factor than one used copper wire. A three-dimensional electromagnetic field simulator was used to design the RF coil with the proposed REBCO wire. We designed the RF coil embedded in styrene foam to keep its structure. We investigated the wire width and thickness dependence of quality factor of the RF coil and influence of styrene foam on quality factor. We will show the detail simulation method and result at the conference.

keywords : REBCO wire, high-temperature superconductors, RF coil, quality factor

EDP4-7 14:00–16:00

Development of High-T_c Superconducting Terahertz Emitter

*Takanari Kashiwagi[1,2], Hiroyuki Kubo[1], Kazuki Sakamoto[1], Takumi Yuasa[1], Yuki Tanabe[1], Chiharu Watanabe[1], Takuya Katsuragawa[1], Taiga Tanaka[1], Yuki Komori[1], Ryusei Ota[1], Genki Kuwano[1], Kento Nakamura[1], Manabu Tsujimoto[1,2], Takashi Yamamoto[3], Ryozo Yoshizaki[1,2], Hidetoshi Minami[1,2], Kazuo Kadowaki[1,2]

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Recently, the generation and detection of electromagnetic waves in the terahertz(THz)-frequency range have been fascinating areas of research and have attracted much attention because these frequencies are thought to be useful for practical applications. In 2007, continuous monochromatic coherent THz waves generated from a mesa structure made from high-T_c superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) single crystal were first reported[1]. The coherent synchronization of the emission from the many intrinsic Josephson junctions (IJJs) existing in a single Bi2212 crystal[2] is the operation principle of this emitter.

According to the recent studies on this emitter, the inhomogeneous temperature distribution of the mesa structure has been observed and these results clearly indicate that the Joule heating strongly affects the radiation characteristics and conditions of this device[3]. Recently. we developed a stand-alone mesa structure which does not have a superconducting substrate under the mesa structure. In addition, the stand-alone mesa structure was sandwiched between two sapphire substrates in order to efficiently remove Joule heat generated by a bias current. To date, we obtained a few tens of micro-watt in output power and emission frequency tunability ranging from approximately 0.3 to 2.4 THz by using different shapes of the stand-alone mesa structures[4]. We will show the details of the radiation characteristics of such device structures in the conference.

[1] L. Ozyuzer *et al.*, Science **318**, 1291 (2007).
[2] R. Kleiner and P. Müller, PRB **49**, 1327 (1994).
[3] For example; H. B. Wang, *et al.*, PRL **102**, 017006 (2009)., H. Minami *et al.*, PRB **89**, 054503 (2014).
[4] T. Kashiwagi *et al.*, PRApplied **4**, 054018 (2015), APL. **106** 092601 (2015).

keywords : Intrinsic Josephson junctions, Bi2212 single crystal, THz waves

EDP4-8 14:00–16:00

I-V characteristics and THz radiation properties of Bi2212 mesas

*Akinobu Irie, Yoshihiko Yajima, Takashi Watanabe, Kazuhiro Yamaki

Utsunomiya University

Intrinsic Josephson-junction (IJJ) stacks in $Bi_2Sr_2CaCu_2O_y$ (Bi2212) are a promising source to emit the intense, continuous, and monochromatic terahertz waves. It is considered that the emission power is characterized by the number N of synchronizing IJJs in the stack and hence straight way to increase the power is to make mesa consisting of a larger number of IJJs. On the other hand, the increase in N is known to cause the significant heating problem which results in reduction of voltage across the stack and a variety of I-V curves have been observed from sample to sample. In this study, we fabricated the IJJ mesas with different configuration and investigated their emission properties. The IJJ mesa emitters were fabricated using photolithography and Ar ion miring or hydrochloric acid modification process. We observed that the I-V curves of the mesas were strongly influenced by the current lead geometry even for the same N because of different thermal distribution. Furthermore, we observed THz radiation from IJJs biased at inner branches of multiple I-V structures. The radiation in each branch was observed at a relatively broader range around the voltage corresponding to the cavity resonance condition. We estimated the number of active IJJs from the voltage ratio of outermost and inner branches and found that the lowest number corresponded to 36% IJJs in the mesa.

keywords : Inririnsic Josephson junctions, THz radiation

APP1-1 16:00–18:00

Detection Method of Normal transitions in a High Temperature Superconducting Coil wound with a plurality of YBCO superconductors by the Active Power Method and H-coils

*Ryo Kadowaki, Nozomu Nanato

Okayama University

The presenters have developed a small power source with a single-phase high temperature superconducting (HTS) transformer for supplying large AC current [1]. Small current is supplied to its primary coil and then large current is outputted from its secondary coil. For safety operation of this power source, a protection system for normal transitions in the HTS transformer is essential to protect its windings from excessive heating at the normal area. The secondary coil consists of a plurality of insulated HTS tape conductors for supplying large AC current. When the normal transitions occur in some conductors and not in the other ones, detection of resistive voltage at the normal area is very difficult because the voltage is very small. In this presentation, the presenters propose a method to detect the normal transitions in the bundle conductor by using the active power method which has been proposed by the presenters and H-coils. An H-coil is installed on every strand HTS tape conductor and its voltage is used to calculate the active power. As experimental results for a YBCO HTS coil, it was found that the proposed method was useful for detecting the normal transitions in the superconducting coil wound with the YBCO bundle conductor.
[1] N. Nanato, Y. Kobayashi, Quench Detection and Protection for High Temperature Superconducting Transformers by Using the Active Power Method, Physics Procedia, Vol. 58, pp. 264-267 (2014)

keywords : Normal transition, Protection, Bundle, H coil

APP1-2 16:00–18:00

Locating of Normal Transitions in A Bi2223 High Temperature Superconducting Coil by Using Capacitor Type Voltage Terminals and the Active Power Method

*Kohei Okura, Nozomu Nanato, Yasunobu Kumagai, Hiroki Aoyama

Okayama University

It is important to locate positions of normal transitions in a high temperature superconducting (HTS) coil for identifying its design and fabrication weakness. The authors have presented capacitor type voltage terminals as a method to measure voltages of the coil windings through insulators of the coil [1]. It was shown that this method enabled to detect the normal transitions without direct contact to the superconducting windings and could be useful for locating the positions of the normal transitions [2]. In locating the positions, temperature in the normal areas has to be kept under allowable temperature of the windings to avoid their deterioration due to excessive heating. In this presentation, the authors propose a safe location method which consists of the above contactless method and the active power method which has been proposed by the authors [3]. As experimental results for a Bi2223 HTS coil, it was found that the proposed method enabled to locate the positions of the normal transitions without exceeding the allowable temperature and also more precisely than the conventional contactless method.

[1]N. Nanato, K. Nishiyama: Non-destructive Detection of Normal Transitions in High Temperature Superconducting Coil, Physics Procedia, Vol. 58, pp. 260-263 (2014)
[2]N. Nanato, K. Nishiyama: Locating of normal transitions in a Bi2223 high temperature superconducting coil by non-contact voltage measurement method, Cryogenics, Vol. 72, pp. 53-56 (2015)
[3]N. Nanato, Y. Kobayashi: Quench Detection and Protection for High Temperature Superconducting Transformers by Using the Active Power Method, Physics Procedia, Vol. 58, pp. 264-267 (2014)

keywords : Normal transition, Location, Capacitor type voltage terminal, Active power method

APP1-3 16:00–18:00

Detection of Normal Transitions in a Hybrid Single-phase Bi2223 High Temperature Superconducting Transformer by using the Active Power Method and a Magnetic Flux Detection Coil

*Shingo Nakamura, Nozomu Nanato, Shinichi Tanaka

Okayama University

The authors have been developing a small and light AC power source with a hybrid single-phase Bi2223 high temperature superconducting (HTS) transformer for supplying a large current. The transformer consists of a primary copper coil and a secondary Bi2223 superconducting coil. It is important to detect normal transitions in the secondary coil to protect from excessive heating in the normal area. The authors have presented the active power method as a detection method of the normal transitions in a superconducting coil [1]. In the method, the normal transitions are detected by measuring active power dissipated in the superconducting coil. The hybrid transformer has a primary copper coil and an iron core and therefore no load loss is always consumed in the transformer. Then the conventional active power method cannot detect accurately the normal transitions due to the no load loss. In this presentation, the authors propose a new detection method by using the active power method and a magnetic flux detection coil attached on the inside of the secondary coil. Induced voltage in the magnetic flux detection coil by a primary and leakage flux of the secondary coil enables to calculate the active power dissipated in only the secondary coil. As experimental results for a hybrid single-phase Bi2223 HTS transformer, it was found that the proposed method enabled to detect the normal transitions in its secondary coil and the detection system became simpler than the conventional one.
[1] N. Nanato, Y. Kobayashi, Quench Detection and Protection for High Temperature Superconducting Transformers by Using the Active Power Method, Physics Procedia, Vol. 58, pp. 264-267 (2014)

keywords : Normal transition, Transformer, Active power method, Magnetic flux detection coil

APP1-4 16:00–18:00

Protection System for Normal Transitions in a Single-phase 1 kA Class Bi2223 High Temperature Superconducting Transformer by Using the Active Power Method

*Noriyuki Koide, Nozomu Nanato, Takaaki Ono, Takahumi Adachi

Okayama University

The authors have developed a small power source with a single-phase Bi2223 high temperature superconducting (HTS) transformer for supplying large AC current [1]. A protection system is needed for normal transitions in the transformer for its safety operation. The system detects immediately the normal transitions and protects the transformer from excessive heating in the normal area. The authors have proposed the active power method as a detection method of the normal transitions and studied its effectiveness for the transformer [1]. However, the conventional active power method could not avoid insufficient recognition of the normal transitions by no load loss (iron loss) signals. Therefore, the authors improved the active power method to detect the normal transitions regardless of the no load loss signals and configured a protection system based on the improved method. As experimental results for a 1 kA class Bi2223 HTS transformer, it was confirmed that the system could protect the transformer correctly. In this presentation, the authors show the experimental results and current carrying property of the small power source with the 1 kA class transformer.

keywords : Normal transitions, Protection, Active power method, HTS Transformer

APP1-5 16:00–18:00

Quench Behaviors and Characteristics of the Metal-Insulated 2G HTS Coil with Parallel Resistors

*Beomyong Eom, Myung-Hwan Sohn, Kideok Sim, Haejong Kim Kim, Kichul Seong

Korea Electrotechnology Research Institute

In order to increase the electrical, thermal, mechanical stabilities of the 2G High Temperature Superconducting (HTS) coils, we used non-insulation(NI) Coil. In this case, we obtained the stability of 2G HTS having NI coil without insulation layer. However, charge-discharge speed was very slow because of low contact resistor between the turn and turn. This characteristic is one of key issues in applications requiring fast charge-discharge speed. In such case, as one of alternatives, metal-insulation coil or partial insulation coil was adopted in order to enhance the stability of the 2G HTS coil and the charge-discharge speed.

In this study, we prepared a metal-insulated (MI) 2G HTS double pancake coil with parallel resistors. Also, we used the superconducting wire having 4 mm in width and 0.14 mm in thickness. Stainless steel tape as a metal-insulation was used with 4 mm in width and 0.08 mm in thickness. The diameter of metal-insulated 2G HTS coil was 80 mm and each single pancake coil wound 100 turns. The parallel resistor in a novel design of 2G HTS coil was adopted using Indium sheet, for decreasing contact resistance.

This paper describes quench behaviors of MI 2G HTS coil by using heater located on 15th turn coil part, under the temperature of liquid nitrogen. Also, we discuss the quench behaviors and stability in the case of the different contact resistance induced by changing the number of parallel resistors.

This work was supported by Korea Electrotechnology Research Institute (KERI) Primary Research Program through the National Research Council of Science & Technology (NST) funded by the Ministry of Science, ICT and Future Planning (MSIP) under Grant 16-12-N0101-25

keywords : Metal-insulation, no-insulation, contact resistance, parallel resistor

APP1-6 16:00–18:00

Conduction Cooling System based Design and the Experimental analysis of A Metal Insulated HTS Magnet

*Jongho Choi, Chan-Kyeong Lee, Sung-Kyu Kim, Minwon Park, In-Keun Yu

Changowon National University

In the fabrication and operation of an HTS magnet, ensuring thermal stability against uneven quench is the most important factor. The no insulation (NI) winding method allows the HTS magnet to maintain the best thermal stability by distributing the quench energy evenly. The NI HTS magnet has the characteristic resistance connected to the inductance of the magnet in parallel. The charging and discharging time are depended on the characteristic resistance.

In our previous research, the characteristic resistance was measured at about 100 μΩ, and it required 2,300 s to charge the current of the NI HTS magnet of 230 mH with the maximum magnetic flux density. Thus, we employed the winding method of metal insulation (MI) using stainless steel to reduce the long charging and discharging time. A sample HTS magnet was designed and fabricated with the MI method and its fundamental characteristic analysis was conducted.

On the basis of the electromagnetic analysis results, the thermal design and detailed experimental analysis of the MI HTS magnet under the conduction cooling condition were performed in this paper. The conduction cooling condition was achieved using the 1st stage GM cryo-cooler. The characteristic resistances and the charging and discharging times of the magnet were measured according to the various coil temperatures such as 30 K, 40 K, 50 K, and 60 K. And then, the long-term current flowing test was conducted by monitoring the coil temperatures. In addition, the thermal stability of the HTS magnet was analyzed when the over current flew into the magnet.

The thermal and electromagnetic characteristics analysis results of the sample magnet will be applicable for the commercial application of the HTS DC induction furnace and their optimal designs.

keywords : Conduction cooling, Metal insulation, Induction heating, HTS magnet

APP1-7 16:00–18:00

Study on the Control of Current Bypassing and the Thermal Behavior in the Non-Insulated HTS Coil

*Kentaro Tami, Daiseki Kanenoto, SeokBeom Kim, Hiroshi Ueda

Okyayama University

In the case of motors and generators, the benefits of using high temperature superconducting (HTS) coils can be represented by the reduction of 50% in both losses and sizes compared to conventional machines. However, it is hard to establish quench detection and protection devices for the HTS coils applied to the rotors of motors and generators. So, the stability of the coils is lower than for the quiescent coils applied to NMR, MRI and so on. Therefore, it is important to improve the self-protection ability of HTS coils. We have studied the methods to improve the self-protection ability of HTS coils by removing the turn-to-turn insulation and inserting metal tape instead of the electrical insulation. The operating current in the non-insulated HTS coil was bypassed into the transverse direction by the generated normal region because of their electrical contact among the winding. It is necessary to create a normal region by the heater in the HTS coil in order to bypass the current optionally into the transverse direction and understand the thermal conductive behavior when the thermal disturbance is generated in the non-insulated HTS coil, so the design issues about the location of heaters are very important. In this study, we examined the method to control the current bypassing to the turn-to-turn direction for controlling the effective number of turns of the non-insulated HTS coil. The measured the current bypassing properties including temperature and voltage profiles, and estimated the thermal conduction properties coil will be presented.

keywords : HTS Coil, 2G Wire, Superconducting Moter

APP2-1 16:00–18:00

Study on the Permanent Current Switch in HTS Coils Wound with 2G Wire for Compact NMR Magnets

*Keito Sugo, SeokBeom Kim, Hiroshi Ueda, Ryo Saito

Okayama University

High temperature superconducting (HTS) magnets wound with REBCO wires are used in many applications, and the superconducting magnet which is operated in persistent current mode has many advantages. Therefore , we have been developing compact NMR relaxometry devices using HTS coils operated at liquid nitrogen temperature. The required strength and homogeneity of magnetic field of proposed NMR relaxometry devices are 1.5 T and 150 ppm/cm3 respectively. The proposed HTS magnet for NMR relaxometry device consists with stacked HTS double pancake coils wound with REBCO wires and operated by persistent current mode (PCM) using superconducting joint between REBCO wires. So, the joint techniques between REBCO wires are very important issue and many studies have been carried out, and the K-JOINS, Inc. has developed successfully the high performance superconducting joint by partial melting diffusion and oxygenation annealing process. In PCM operation, the ability of persistent current switch (PCS) is very important, so, in this study, the thermal properties of 2G wire against the various thermal inputs by heater were investigated experimentally to design the PCS for HTS magnets. The termal behaviors of the GdBCO wires with / without stabilizer were measured as functions of amount of heat input and various epoxy resins. The current bypassing properties by developed PCS on the test coil wound with GdBCO wire will be presented.

keywords : permanent current switch, NMR, HTS, coil

APP2-2 16:00–18:00

Study on the magnetic field homogeneity and shimming method of Halbach arrayed permanent magnets for compact NMR relaxometry

*Ryota Nomura, Katuya Hojo, Susumu Fukada, Shinya Ohara, SeokBeom Kim,, Hiroshi Ueda

Okayama University

The nuclear magnetic resonance (NMR) device has been paid attention in food, medicine and drag industries as a useful tool for analyzing organic compound. The resolution of NMR signal is improved by increasing the strength of magnetic field, and 1 GHz-class (23.5 T) NMR magnet wound with low temperature superconducting conductors such as NbTi and Nb3Sn has been already developed. In general, the conventional NMR devices are needed the large space and high operating cost. Therefore, we have been developing the compact magnet for NMR relaxometry device using stacked HTS bulks and HTS coils. The strength and homogeneity of magnetic field required NMR relaxometry are 1.5 T and 150 ppm/cm3 respectively. However these magnets have to operate at low temperature and needed to the coolants (L, N2 L, He) and cryocooler. On the other hand, Halbach arrayed permanent magnets (PMs) are possible to generate thee high field strength and high field homogeneity So Halbach arrayed PMs are very suitable for compact NMR relaxometry device. In this paper, the shape design of Halbach arrayed PMs were studied by 3-D FEM and 8-PMs with size of 10×10×30 mm3 are used. In our analytical result, the field homogeneity of 7689 ppm/±5mm along the x axis was obtained and we need to improve the field homogeneity to develop the compact NMR relaxometry device. Thus, shimming magnets inserted in the Halbach arrayed PM magnets were studied analytically in order to improve to field homogeneity and improved field homogeneity of 2683 ppm/±5mm along the x axis was obtained. The prototype NMR relaxometry consisted of 8-PMs, ID 30 mm and OD 50 mm was designed and tested experimentally to compare the analytical result. The detail analytical and experimental results will be discussed.

keywords : NMR, Halbach, Biot-Savart law, PM

APP2-3 16:00–18:00

Numerical study to obtain the improved field homogeneity of HTS bulk magnet with enlarged inner diameter for compact NMR relaxometry

*Susumu Fukada, SeokBeom Kim, Hiroshi Ueda, Katsuya Hojo

Okayama University

We have been studying the compact magnet for NMR device that consists of a stacked high temperature superconducting (HTS) GdBCO bulk annuli trapped by a field cooling (FC) method. It was difficult to trap the uniform magnetic field above 4.7 T (200 MHz-class NMR magnet) and field homogeneity under 0.01 ppm/cm3 at liquid nitrogen temperature (77.4 K) because of the low Jc-B characteristics of present HTS bulks. On the other hand, the strength and homogeneity of the magnetic field required for NMR relaxometry device are 1.5 T and 150 ppm/cm3 respectively. Therefore, we have been investigating the development of the compact HTS bulk magnets for NMR relaxometry device. In our previous works, we could generate the trapped magnetic field over 1.5 T at 77.4 K using the stacked ring-shaped HTS bulks with 80 mm height, and 150 ppm/cm3 field homogeneity was obtained using the fabricated field compensation methods on HTS bulks magnet with 20 mm inner diameter. It is easy to improve the magnetic field homogeneity and magnetic field strength by enlarging the outer diameter, but it causes increased the size of the device and the price of bulk magnets. We studied the various shape HTS bulk magnets using 3-D FEM based analysis to develop the compact NMR magnets. The enlarged inner diameter HTS bulk magnet was designed by bulge type analytical model, and detailed analytical and experimental results will be presented.

keywords : NMR, Bulk, ppm, magnetic field

APP3-1 16:00–18:00

Side-suspended High-T_c Superconducting Maglev Prototype Vehicle Running at a High Speed in an Evacuated Circular Test Track

Dajin Zhou[1], Chenyu Cui[1], Lifeng Zhao[1], Yong Zhang[1], Xiqing Wang[1], *Yong Zhao[1,2]

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2. School of Physical and Science Technology, Southwest Jiaotong University

Research on High-T_c Superconducting (HTS) maglev train is carried out mostly in China, Japan, Germany and Brazil and mainly through static or vibration test. Only a few of reports are available for the direct and effective assessment on the dynamic performance of the HTS maglev train by running on a straight or circular test tracks. For example, Brazil group has carried out running test of full-size maglev train at 7 km/h in a 200 m straight line track, and Japanese group has reached a speed of 42km/h in a circular test track of 12 m in diameter. In order to increase the running speed in a circular track with a high speed, a side-suspended HTS permanent magnetic guideway (PMG) maglev system was proposed and constructed. In this paper, we report that a YBCO HTS maglev prototype vehicle side-suspended beside a PMG was constructed and tested. The stability of side-suspended HTS-PMG system was studied theoretically and experimentally. It is found that there are two types of guiding force existing in the HTS-PMG system, which can be effectively adjusted and controlled by arranging YBCO bulks around the central axis of PMG and the levitation gap. Based on a triangle arrangement of YBCO bulks, the side-suspended HTS maglev prototype vehicle was successfully running stably at a high speed of 102 km/h in a circular test track with 6.5 m in diameter, and in an evacuated tube environment.

keywords：side-suspended, High-Tc Superconducting maglev, permanent magnetic guideway, evacuated circular test track

APP3-2 16:00–18:00

Study of Running Stability in Side-Suspended HTS-PMG Maglev Circular Line System

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Compared to traditional HTS maglev system with up-down configuration, the side-suspended HTS-PMG (permanent magnetic guideway) maglev circular track system can provided larger centripetal force and effectively prevent the maglev vehicle running off the track along the tangent direction during high-speed operation. A research is made on stability of the side-suspended HTS-PMG maglev system through simulation experiment. The results show that the maglev vehicle will gradually get close to the track surface during acceleration under the action of centrifugal force, leading to decay of guidance force and occurrence of vertical eccentric motion. In case of linear array of YBa2Cu3O7 (YBCO) bulks, static and dynamic side-suspension stability of the prototype vehicle can be improved by reducing its field cooling height (FCH) and weight. Besides, in order to ensure stable operation of the prototype vehicle at high speed, it is necessary to increase FCH for a larger centripetal force. In case of linear array of YBCO bulks, however, smaller suspension gap at high FCH will lead to greater decay of guidance force and generation of greater vertical eccentric displacement during acceleration of the prototype vehicle. Fortunately, triangle array of YBCO bulks can effectively keep constant the guidance force and realize stable acceleration of the prototype vehicle at high FCH till high-speed operation. Based on the research on stability of side-suspended maglev vehicle, a side-suspended PMG circular test track with diameter of 6.5m and circumference of 20.4m is successfully designed and established, enabling the prototype vehicle to run stably at up to 102km/h.

keywords：HTS maglev vehicle, the guidance force, side suspension, dynamic stability

APP3-3 16:00–18:00

Nonlinear Vibration Behavior of High-Tc Superconducting Bulks Above a Permanent Magnetic Guideway

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In-depth knowledge of the vibration of high-temperature superconducting (HTS) bulks above a permanent magnetic guideway (PMG) should be regarded as a precondition for its commercial application in rail transit. In previous work, most experiments were conducted based on a linear hypothesis, and cannot be used for interpretation of the complex nonlinear phenomenon; in the area of numerical calculation, some scholars borrowed a model named hypoelasticity relation from solid mechanics, but there were too many undetermined parameters limiting its application. This paper mainly contains three aspects to investigate the actual vibration rule. Firstly, we measured the vibration acceleration signals of YBaCuO bulks levitating above a PM guideway with large displacement excitations. Higher harmonics components were detected in the responses, which indicate an obvious nonlinear vibration phenomenon. Secondly, we proposed a new simplified levitation force model. This model could perform a rather high precision in calculation of eigen frequency by numerical method. Finally, an approximate analytic solution of nonlinear vibration for HTS bulks in the applied magnetic field of PM guideway was obtained by the method of harmonic balance. The vibration of HTS bulks over PM was discussed in detail respectively by experiment, numerical calculation, and approximate analytic solution. By comparing with each other, it is noted that all the three results about eigen frequency agree well. This work is helpful to understand the basic vibration behaviors of HTS maglev.

keywords : HTS maglev, nonlinear vibration behavior, experiments, numerical calculation

APP3-4 16:00–18:00

Curve Negotiation Ability of High Temperature Superconducting Maglev Above Different Permanent Magnet Guideways

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High temperature superconducting (HTS) Maglev has the potential to become a kind of high speed transportations. It is certainly worth studying its transverse stability. Some studies suggest that the guidance force will increase with the HTS bulk away from its balance position. When the distance exceeds a certain limit, the guidance force will decrease with the displacement increasing. Lateral motion will become unstable. In this paper, the guidance force of an HTS bulk levitation unit was firstly measured to study the maximum guidance force and the corresponding lateral position above different kinds of permanent magnet guideways (PMGs). With the experimental data, the dynamic responses of an HTS maglev vehicle were simulated when going through curves or suffering lateral disturbance. The safe speed for curves with different radius was suggested. This work would be helpful to the HTS maglev design especially in guideway construction.
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[2] Z. G. Deng, W. H Zhang, J. Zheng, et al. A high temperature superconducting Maglev ring test line developed in Chengdu, China. IEEE Transactions on Applied Superconductivity, vol. 26, no. 6, Sep. 2016, Art. no. 360507.

keywords : HTS maglev, Simulation calculation, Guidance force, Curve Negotiation

APP3-5 16:00–18:00

Numerical Analysis of Fundamental Characteristics of Superconducting Magnetic Bearings for a Polarization Modulator

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For cosmic microwave background polarization experiments, a polarization modulator has been developed. It requires a continuously rotating optical element, which is called half-wave plate (HWP) and operated below 10 K. A superconducting magnetic bearing (SMB) can be used for achieving a smooth and ultra-low loss rotation of the HWP. 2D and 3D FEM analyses were carried out to examine fundamental characteristics of the superconducting magnetic bearings for a polarization modulator. Several magnetic bearing types were dealt with in the analysis: (a) An axial flux type and a radial flux type, (b) axial and radial magnetization of permanent magnets, (c) with and without steel components for magnetic flux concentration, etc. Magnetic flux line and density distributions, electromagnetic force characteristics, spring constants, rotational losses, etc. were compared among the various superconducting magnetic bearings. From the numerical analysis results, it is discussed what type, configuration and design of superconducting magnetic bearings are more suitable for a polarization modulator.

keywords : Superconducting magnetic bearing, Levitation force, Spring characteristics, Rotational losses

APP3-6 16:00–18:00

Fundamental study on the magnetic field control method　using multiple HTS coils for Magnetic Drug Delivery System

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Okayama University

The magnetic drug delivery system (MDDS) is a key technology to reduce the side effects in the medical applications, and the magnetic force control is a very important issue in MDDS. In this applications, not only the strength of the magnetic field but also the magnetic field gradient is needed in order to enlarge the medicinal effects. In general, the strength of magnetic field and gradient required to MDDS devices are 54 mT and 5.5 T/m. We proposed the new magnetic force control system that consists of the multiple racetrack HTS magnets. We can control the magnetic field gradient along the longitudinal direction by the arrangement of the multiple racetrack HTS magnets and operating current of each magnet. When the racetrack HTS magnets were used, the critical current was reduced by the self-magnetic field. Therefore, the shape design of HTS magnet to reduce penetration of the self-magnet field into the HTS tapes was needed. So, the study on the electromagnetic analysis based on finite element method (FEM) was carried out to design and optimize the shape of multiple racetrack HTS magnet. We were able to suppress the reduction of critical current by placing the magnetic substance at upper and lower side of the HTS magnets. The obtained analytical results including shape optimized HTS magnet will be presented.

keywords : drug delivery system, magnetic tergeting, HTS coil, magnetic field control

APP3-7 16:00–18:00

Power Transfer Characteristics by Different Multi Antennas of Wireless Power Charging System for Superconducting MAGLEV Train

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Recently, the wireless power transfer (WPT) systems have started to be applied to the wireless charging for electrical vehicles and trains because of their advantages compared with the wired counterparts, such as convenience, safety, and fearless transmission of power. However, it has obstacles to commercialize to large power deliver and efficiency in WPT technology. This paper presents the feasibility of technical fusion between wireless power transfer (WPT) system and superconducting magnet technology to enable to charge large power into very low temperature circumstance of superconducting magnet for high speed magnetic levitation (MAGLEV) train without any connector or wire. The superconducting ma gnet in high speed MAGLEV train system maintains keeps stronger magnetic field that plays a role to sustain stable levitation gap. Generally, the superconducting magnet has been supplied by conventional electric power persistently to keep fixed levitation gap and low irregularity tolerance. However, a large thermal loss is indispensably caused by power transfer wires. Fortunately, since superconducting wires have a higher Q-value intrinsically, transfer selectivity and distance between antenna and receiver coils can be improved easily. In this paper, we propose the wireless power charging system via strong resonance coupled method of superconducting Maglev system using various shapes' multi copper antennas at laboratory scale with a purpose built test stand.

keywords : Magnetic levitation train, multi antenna coils, superconducting resonance coil, wireless power transfer

APP4-1 16:00–18:00

Microstructure observations on butt joint for JT-60SA CS coil

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In the JT-60 Super Advanced (JT-60SA) fusion experiment, the magnet system consists of a central solenoid (CS) coil, 18 toroidal field coils, and six plasma equilibrium field (EF) coils. The CS coil is composed of four modules. One module is composed of six octa-pancake coils and four quad-pancake coils. To join these coils, wound with Nb3Sn cable-in-conduit (CIC) conductors, a butt joint technology was adopted in the CS coil. The butt joint is very attractive choice for the CS coil of a Tokamak machine because it allows embedding of the joint into a winding pack that provides maximum flux at a given peak field in the winding. To evaluate the fabrication technology of the butt joint, a joint resistance was measured using a butt joint sample. As a result, the sample fulfilled the design requirement of joint resistance. Compared to a lap joint technology, the butt joint technology is emerging and challenging at present. Hence, not only joint resistance but also microstructural observation is necessary to fully evaluate the butt joint. In this study, a joint interface of the butt joint sample was observed using a field emission scanning electron microscope (FE-SEM) after the joint measurements.

keywords : JT-60SA, Butt joint, Nb3Sn conductor, Cable-in-conduit conductor

APP4-2 16:00–18:00

An effective cryostat design of conduction-cooled HTS magnets for a 300 kW-class HTS DC induction furnace

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A superconducting magnet is operated under cryogenic conditions. To effectively design a cryostat with high temperature superconducting (HTS) magnets, heat invasion loads—including conduction and radiation—should be minimized. These heat loads are closely related to the shape of the cryostat as well as to the HTS magnets, the metal current lead, and the cooling method used. A 300 kW-class HTS DC induction furnace (IF) is being developed, which should lead to the creation of an effective cryostat design. This paper presents two types of cryostat designs of the conduction-cooled HTS magnets including the shape of the cryostat. The supporters for the magnets of the 300 kW-class HTS DC IF were designed using electromagnetic, stress, and heat-transfer analysis. The thermal stability of the HTS magnets was analyzed by considering heat generation and rises in temperature and how these were related to quench phenomena. The most important factor to consider for the optimal design of a cryostat was the minimization of the operating temperature of the magnet. The cooling characteristics that occurred under the 2nd stages cryo-cooler as well as the 1st stage cryo-cooler were analyzed and compared using the finite element method analysis method. To demonstrate the feasibility of the design, a module coil with a half scale was designed and fabricated. It was tested under the conduction cooling condition using the first stage cryo-cooler. The study results discussed in this paper will be applied to the fabrication of the 300 kW-class HTS DC IF.

keywords : Conduction cooling, Cryogenics, HTS magnet, Induction heating

APP4-3 16:00–18:00

Optimal design and fabrication of a high current HTS DC reactor with conduction cooling system

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Changwon National University

A DC reactor connected to high voltage direct current system can reduce the current's ripple or harmonics in power system, however, it experiences a lot of electrical loss due to the resistance of its copper winding. Using high temperature superconducting (HTS) magnets, it is possible to reduce size, weight, and electrical losses compared with general DC reactors. HTS DC reactor magnet needs a cryogenic cooling to achieve and maintain its superconducting state. There are two cooling methods, one is pool boiling HTS magnet in liquid cryogen and the other is conduction cooling by connecting HTS magnet to cryo-cooler directly or indirectly in a vacuum chamber. The conduction cooling system is more effective, smaller and lighter than the pool boiling method. An optimal design of the conduction cooling system is an important factor to operate the reactor stably and effectively.
This paper discussed an optimal design and fabrication of a high current HTS DC reactor with conduction cooling system. The inductance and the operating current of HTS DC reactor were 400 mH and 1500 A, respectively. The conduction cooling system that included HTS magnets, bobbin structures, current leads, support bars and thermal exchangers were designed using 3D CAD program. A Finite Element Method model was built for determining the optimal design parameters and analyzing the thermo-mechanical characteristics. Then, the HTS DC reactor was fabricated using stacked 2G HTS wires and operated under 20 K. The experimental results were compared with the simulation results and described in detail. The study results can be effectively utilized for the design and fabrication of a commercial HTS DC reactor.

keywords : Conduction cooling system, High temperature superconducting magnet, HVDC system, Thermo-mechanical analysis

APP5-1 14:00–16:00

Study on Protection Coordination of Distance Relays for Application of a SFCL in a Power Transmission System

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As the one of the countermeasures for larger fault current in a power transmission system, the research to apply the superconducting fault current limiter (SFCL) into a power transmission system has been progressed together with the development of the SFCL with a power transmission level.
However, the introduction of the SFCL in a power transmission system affects the operation of the existing protective devices such as the distance relay and the current ratio differential relay and causes the malfunction of these protective devices, which has the countermeasures to keep the protective coordination of these protective devices studied.
In this paper, the effect of an SFCL on distance relay in a power transmission system, which has been mainly used for the back-up protective equipment, was studied. Through the short-circuit tests for the simulated power transmission system protected by the simulated distance relays, the effect of the SFCL on the operation of the distance relay was analyzed and the methods to keep the operation zone of the distance relay in a power transmission system with the SFCL were discussed.

Acknowledgements
This research was supported by power generation and electricity delivery R&D program funded by the Ministry of Knowledge Economy and also supported by Korea Electric Power Corporation Research Institute through Korea Electrical Engineering & Science Research Institute (grant number : R13TA02)

keywords : superconducting fault current limiter (SFCL), protective devices, protective coordination, operation zone of the distance relay

APP5-2 14:00–16:00

Fault Current Limiting and Double Quench Characteristics of Transformer Type SFCL with Additionally Coupled Circuit

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In this paper, the transformer type superconducting fault current limiter (SFCL) with additionally coupled circuit was suggested and its peak fault current limiting characteristics due to the fault condition to affect the transient fault current were analyzed through the fault current limiting tests. The suggested transformer type SFCL is basically identical to the previous transformer type SFCL except for the additional coupled circuit. The additional coupled circuit, which consists of the magnetically coupled winding to the primary and the secondary windings together with another superconducting (SC) element and is connected in parallel with the secondary winding of the transformer type SFCL, is contributed to the peak fault current limiting operation for the larger transient fault current directly after the fault occurrence.
To confirm the transient fault current limiting operation of the suggested SFCL, the fault current limiting tests of the suggested SFCL according to the fault angle, which affects the amplitude of the initial transient fault current, were performed and its effective peak fault current limiting characteristics were analyzed through the analysis on the electrical equivalent circuit.

Acknowledgements
This research was supported by power generation and electricity delivery R&D program funded by the Ministry of Knowledge Economy and also supported by Korea Electric Power Corporation Research Institute through Korea Electrical Engineering & Science Research Institute (grant number : R13TA02)

keywords : transformer type superconducting fault current limiter (SFCL), additional coupled circuit, initial transient fault current, peak fault current limiting characteristics

APP5-3 14:00–16:00

Magnetizing Characteristics of Transformer Type SFCL Due to Its Winding Direction of Additional Secondary Winding

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In this paper, the magnetizing characteristics of the transformer type superconducting fault current limiter (SFCL) with the additional non-isolated secondary winding due to its winding direction were analyzed together with its peak fault current limiting operation. To analyze the dependence of its magnetizing characteristics on the winding direction of the additional non-isolated secondary winding, the peak fault current limiting tests of the SFCL were carried out for two winding directions, which were expressed as additive polarity winding and subtractive polarity winding. The flux linkage and the magnetization current, which were related with the saturation of the iron core comprising the transformer type SFCL, were calculated from the measured voltage and the current values. The magnetizing powers during the fault period in case of the subtractive polarity winding were observed to be more increased compared with the additive polarity winding.

keywords : magnetizing characteristics, transformer type superconducting fault current limiter (SFCL), winding direction

APP5-4 14:00–16:00

Transient Fault Current Limiting Characteristics of Transformer type SFCL with Two Non-Isolated Secondary Windings using Double Quench

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In this paper, the transformer type SFCL with two non-isolated secondary windings using double quench was suggested and its transient fault current limiting characteristics were analyzed. The suggested transformer type SFCL largely consists of two high-TC superconducting (HTSC) elements, one primary winding and two non-isolated secondary windings, which are wound on the same iron core. Except for the structure with non-isolated secondary winding, the suggested transformer type SFCL can limit the fault current with two limiting operational currents like previously reported transformer type SFCL with two triggering current levels. However, its peak fault current limiting characteristics are different from the previous transformer type SFCL.
To confirm its peak fault current limiting operation with two limiting operational currents, the fault current limiting tests of the suggested SFCL according to the fault angle, which affects the amplitude of the initial transient fault current, were performed and its peak fault current limiting characteristics were discussed.

keywords : transformer type SFCL, transient fault current limiting characteristics, two limiting operational currents, peak fault current limiting characteristics

APP5-5 14:00–16:00

Application Validity Studies of Various Kinds of Superconducting Fault Current Limiters for HVDC Grids

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Hanyang University

The increasing demand for long-distance power delivery and cost-effective access for renewable energy requires the application of HVDC power systems. And the final goal of HVDC power system is to implement HVDC Grids, which could connect diverse energy resources and multiple load demands. But, the key obstacle for commercialization of HVDC grid is the absence of DC Circuit Breaker (DCCB), which can reliably break the DC fault current and isolate faulty line as soon as possible. Several prototypes of DCCB has been proposed, but the commercialization is not fulfilled yet due to excessive requirements of high-speed operation and protection-coordination in HVDC grids. Actually, stand-alone DCCB application for HVDC grids has little possibility of realization. In this respect, the application of Fault Current Limiter (FCL), which can suppress both transient fault current and energy stress on DCCB, could be an alternative to solve this issue. Among FCL, various kinds of Superconducting FCLs(SFCLs) have been developed for AC grids and their excellent performances were already approved. Therefore, it is our concern to verify applicability of conventional AC SFCL for HVDC grids to cooperate with DCCB. In order to confirm the validity of AC SFCL for HVDC grid, three types of well-known SFCLs including Resistive SFCL (R-SFCL), Inductive Shielded Core SFCL (I-SFCL) and Saturated Iron core SFCL (SI-SFCL), were modelled in Matlab/Simulink, and then their current limiting and recovery characteristics were examined with the connection of DCCB in HVDC grids composed of Half Bridge VSC HVDC systems. From the simulation results, strengths and weaknesses of SFCLs for HVDC grids were analyzed and the optimal working principles of SFCL for HVDC grids are proposed in detail.

keywords : Resistive SFCL (R-SFCL), Inductive Shielded Core SFCL (I-SFCL), Saturated Iron Core SFCL (SI-SFCL)

APP5-6 14:00–16:00

Optimal Location of Superconducting Fault Current Limiters (SFCLs) for Fault Current Reduction in the Korean AC Transmission Grid

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As electrical power systems grow more complicated and electrical loads increase, the fault current exceed a circuit breaker rating for some substations, which is an especially important issues in power systems having a highly meshed configuration. The application of superconducting fault current limiters (SFCLs) in power systems is very attractive because SFCLs offer superior technical performance in comparison to conventional devices to limit fault currents. In this paper, we propose optimal location of Superconducting Fault Current Limiters (SFCLs) for fault current reduction in the Korean AC transmission grid. We shows the performance of deploying the SFLS to 154kV transmission systems in case of a bus exceeding the short circuit capacity. A development project applying Superconducting Fault Current Limiters (SFCLs) to 154kV transmission systems is considered by KEPCO.

keywords : Superconducting Fault Current Limiters, Fault Current Reduction, AC transmission grid, Optimal Location

APP5-7 14:00–16:00

Stability Improvement of VSC HVDC system according to Superconductivity combined DC Circuit Breaker

*HYEWON CHOI, INSUNG JEONG, SANGYONG PARK, NOA PARK, SUNHO WHANG, JUNBEOM KIM, HYOSANG CHOI

CHOSUN University

The HVDC system has a next-generation power transmission concept, which has simple lines and is convenient for long-distance large power transmission. In addition, it facilitates the power grid connection between countries, and is also eco-friendly as it emits non-hazardous electromagnetic waves. Research on the circuit-breaking technology is indispensable to improve the stability and reliability of the HVDC system.
In this study, a superconductor-combined DC circuit breaker was proposed by applying the current-limiting performance of the superconductor to the existing circuit-breaking technology. The superconductor-combined DC circuit breaker system is a module in which the inductor-type superconducting current limiter and the resonance-type DC circuit breaker are integrated. A DC-simulated grid similar to the actual VSC HVDC system was formed using the EMTDC/PSCAD program to analyze the current-limiting and circuit-breaking characteristics of the superconductor-combined DC circuit breaker.
The simulation results showed that the superconductor-combined DC circuit breaker limited the maximum fault current by more than 30%, and that the burden on the DC circuit breaker decreased about octuple. In addition, the breaking speed of the circuit breaker significantly decreased. HVDC System Stability Improvement through the Application of the Superconductor-combined DC Circuit Breaker
This research was supported by Korea Electric Power corporation [grant number: 16106]

keywords : Direct Current, DC Circuit Breaker, SFCL, Superconductivity

APP6-1 14:00–16:00

Study on the Method of ON/OFF Field Switching using the HTS Bulks for Medical Applications

*Takuya Nakagawa, Ryoma Hirano, Yoshikazu Tomisaka, SeokBeom Kim, Hiroshi Ueda

Okayama University

The high magnetic fields are useful in analysis medical equipments and medicine applications such as a culture of man's bone or a cell. The necessary of the high strength magnetic fields are increasing in fields of medical applications and NMR analysis. So, the techniques for magnetic field concentration are very important. The novel electromagnets and trapped the high temperature superconducting (HTS) bulk magnets was fabricated and used in the cell culture and the magnetic targeting system. In these applications, not only the strength of magnetic field but also the magnetic control ability including ON/OFF field switching are needed to enlarge the medicinal effects. In general, although the superconducting magnet can generate the high magnetic fields, but ON/OFF magnetic switching is impossible because of its large inductance. So, the development of system that magnetic field generating and ON/OFF switching can be realized at the same time is a very important issue. Therefore, we have studied the control methods of magnetic field using HTS bulks and shielding current according to its perfect diamagnetism of the superconductors. The magnetic control system which consists of the HTS bulk and magnetic sources were proposed to achieve the ON/OFF field control and field amplification. The shape of HTS bulk to develop the magnetic control system was optimized by FEM based analysis and the abilities of its field switching and amplification were confirmed by experiments. We found that the HTS bulk with slit configuration can control the applied magnetic field, and the amplified magnetic fields were obtained at the slit part of the HTS bulk.

keywords : ON/OFF field switching, Field amplification, HTS bulk, Slit configuration

APP6-2 14:00–16:00

Study on the Rotation Properties and the Design Issue of Non-Contact Rotating System Using HTS Bulks and Permanent Magnets

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Okayama University

Non-contact rotating system using magnetic levitation technology doesn't have mechanical friction. Therefore, there are advantages like, no energy loss and maintenance is rarely needed. It is very useful using in vacuum chamber or clean room where dislike generated dust. For these reasons, a lot of researches about non-contact levitation technology using electrostatic force, pressure, ultrasonic wave, air pressure and magnetic force have been conducted. Among them, the technology using magnetic force has the advantages that can generate relatively large levitation force and easy to handle.
The high temperature superconducting (HTS) bulks which magnetized by field cooling (FC) method, shows the diamagnetic behavior and pinning effect at the same time. From our previous study, it is known that our system using ring-shaped permanent magnets and ring-shaped HTS bulks (ID 20 mm, OD 60 mm and 5 mm height) is very useful to apply to the non-contact rotating system. Therefore, in this study, we have developed a stator with six poles to investigate the rotation properties of the developed levitation system, and the rotating speed of 840 rpm was obtained. However, it was found that there were unstable rotating properties during rotation. Therefore, we have studied about structure optimization of the rotating system in order to improve the moving stability of the rotating shaft. The detailed experimental results about structure optimization and the obtained moving stability of the levitated rotating shaft will be presented.

keywords : HTS Bulks, Non-contact Rotating machine, Magnetic Levitation System, pinning effect

APP6-3 14:00–16:00

Development of the Turning System Using Permanent Magnets for the Direction Change from Floor Traveling to Wall Traveling in 3-D Superconducting Actuator

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The electric device applications of a high temperature superconducting (HTS) bulk having stable levitation and suspension properties due to their strong flux pinning force have been proposed and developed. We have been investigating a three-dimensional (3-D) superconducting actuator using HTS bulk to develop the transportation device with non-contact and moves in free space. It is expected that our proposed 3-D superconducting actuator will be useful as a transporter used in a space full of combustible gas and a clean room which manufactures the silicon wafer where dislikes mechanical contact and dust. Proposed actuator consists of the trapped HTS bulk as a mover and two-dimensionally (2-D) arranged electromagnets (EMs) consisted with iron core and copper coil as a stator. The HTS bulk can be moved the 3-D directions and rotates without upper side EMs. The current and the polarity of each EM are individually controlled by the switching power supply.
As next step, we have been developing 3-D actuator that a mover can be moved on both directions of floor and vertical wall. In this actuator, the development of the new system for changing the moving directions between floor and wall (floor ↔ wall) was needed, and 2-D arranged EMs are installed on the wall and tested experimentally. However, this system cannot realize smooth motion of the mover and the control method was complex. Therefore, the new method to change the direction was proposed and developed. In this study, EMs are replaced with the rail-shaped permanent magnets (PMs) with 20 mm in rail width, 26 mm in rail interval, 6 mm in thickness and 260 mm in radius of curvature. In design of the new turning system, the polarity arrangement and coercive force of each PM were used as parameters. The dynamic behaviors of the mover in the proposed system was experimentally investigated and the obtained results will be presented.

keywords : HTS bulk, flux pinning, magnetic levitation, actuator

APP6-4 14:00–16:00

Correlations between magnetic flux and levitation force of HTS bulks above a permanent magnet guideway

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In order to clarify the correlations between the magnetic flux density and the levitation force of high temperature superconducting (HTS) bulks, the magnetic flux density at the bottom and top surfaces and the levitation force of a bulk superconductor were precisely measured when vertically moving towards a permanent magnet guideway. In this study, the HTS bulk was descended from the cooling position to the working position and when the HTS bulk arrived at the working position, a relaxation measurement of 300 s was performed. During the movement and relaxation processes, the magnetic flux density of the bulk superconductor was recorded by a multipoint magnetic field measurement platform in real time; and the levitation force was collected by a self-developed maglev measurement system. The results reveal that the magnetic flux density and the levitation force of the bulk superconductor are in direct correlation from the point view of the inner supercurrent, and the variation tendency of which is united. In general, this work is instructive for understanding the connection of the magnetic flux density, the inner current density and the levitation behavior of HTS bulks employed in a maglev system. Also, it enriches the experimental evaluation method of the maglev system.
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keywords : bulk superconductor, magnetic characteristics, supercurrent, levitation force

APP7-1 14:00–16:00

Feasibility study on the brushless HTS exciter of a modularized large-scale HTS wind power generator

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Changwon National University

In this paper, the authors performed a feasibility study on the brushless HTS exciter of a modularized large-scale HTS wind power generator and suggested allowable range of the unbalanced field current of each modularized exciter.
The value of the field current of the brushless HTS exciter is determined by some parameters such as inductance and resistance of the brushless HTS exciter. Each module may have slightly different values of parameters due to the fabricating process mismatch. They cause the unbalanced field current. Unbalanced rate of the field current is calculated by the difference between field currents of modules. Based on the calculated unbalanced rate, the electromagnetic characteristics of the unbalanced field condition are analyzed using 2D finite element method.
The results are compared to the results of the conventional HTS exciter. As a result, the magnetic field distributions of the generator considering the conventional and brushless HTS exciters are presented. Compared to the conventional HTS exciter, the output characteristics are almost the same until 3% of the unbalanced rate. However, when the rate is over 3%, the output power decreased and the torque ripple increased exponentially. These problems are likely to suffer serious mechanical problems as a result of the noise, or the stress of the generator. Therefore, the authors will apply a control algorithm in the brushless HTS exciters for maintaining the unbalanced rate under allowable range. The results can effectively be utilized to design a modularized large-scale wind power generator.

keywords : HTS generator, module coil, flux pump, wind turbine

APP7-2 14:00–16:00

Electrical and structured analysis for 15MW REBCO designed wind turbine generators

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2. Fuji Electric
3. ISTEC

We studied the design of 15 MW offshore wind turbine generators with REBCO superconducting tapes. In Japan, the sea becomes deep abruptly with distance from the shore. Therefore offshore wind farms need to be built on floating bodies and then the output power should be over 15 MW per a wind turbine from the viewpoint of economical efficiency. However the conventional generators composed of copper wire and iron cores for low-speed revolution are huge and heavy as compared with generators for commercial frequency. Enhancement of the magnetic flux density at the gap by using a superconducting rotor should lead to the drastic reduction of weight and size of generators. In this paper we studied the design of 15 MW generators with a rotating REBCO superconducting field winding by numerical simulation taking into account of electromagnetic properties of REBCO superconducting tapes. We first investigated the Ic and ac loss properties of REBCO superconducting tapes. Next we designed several kinds of 15 MW generators. Then we numerically calculated the properties of the generators, e.g. torque properties, required REBCO tape length, ac loss, i.e. efficiency, weight. As a result, we found out that superconducting generators can be reduced to 1/4 to 1/3 in weight against conventional ones and B at the gap should be around 2 T from the viewpoint of cost and total weight.

keywords : fully superconducting generators, REBCO, wind turbine generators

APP7-3 14:00–16:00

Design and Performance Analysis of a Novel Stator-HTS Squirrel Cage Induction Motor with High Power to Weight Ratio

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We develop a novel high temperature superconducting(HTS) squirrel cage induction motor with a higher rotating speed, that is aimed to high power to weight ratio and lightweight, which adopts the structure with both HTS windings and copper windings in the stator slots. Due to the limitation of curvature radius of superconducting tapes, pitch of HTS windings can be only set to 1 and copper windings adopt the whole pitch arrangement structure, which such design details of the HTS motor would ensure the superconducting coils can undertake larger current and reduce AC losses. In the armature structure, the HTS winding coefficient can only reach to 0.5 owing to its special arrangement, so copper windings are crucial to eliminate the pulsating torque produced by superconducting windings for stable operation of motor. In order to keep the HTS windings in superconducting state and larger current density, a special fixed cooling system at 66K with the method of gas extraction and decompression, which is made of Aramid Fiber, has been fabricated and the whole structure of the stator is placed in liquid nitrogen. According to the basic principles and electromagnetic field theory, the electrical performances of the novel designed stator-HTS motor are analyzed including the flux density distributions, the torque and the back electromotive force by using the method of finite element. Finally the HTS squirrel cage induction motor can reach a power to weight ratio of 5 by the finite element verification.

keywords : Stator-HTS motor, High power to weight ratio, Aramid Fiber, AC losses

APP7-4 14:00–16:00

Development of A large AC Current Supply with A Single-phase Air-core Bi2223 High Temperature Superconducting Transformer

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Okayama University

It is very important to grasp current conduction characteristics of high temperature superconductors for developing high temperature superconducting (HTS) apparatus such as HTS electric cables, motors and SMES. HTS tapes used in the apparatus have large critical current and therefore large current supply is needed to grasp the current conduction characteristics. However, commercial power supplies especially for large AC current are generally very large and heavy and are difficult to handle in general laboratories. The presenters have been developing a compact power supply with a single-phase Bi2223 HTS transformer [1]. In order to minimize the transformer, the presenters are studying a possibility of an air-core transformer which has no iron core resulting in a small and light supply. The air-core transformer needs large excitation current, however no copper loss is consumed in the transformer unlike general transformers with copper windings. Therefore the transformer has a possibility to make the supply small and light without increasing loss. The presenters will show current carrying properties of an air-core and iron core transformers including iron loss and AC loss.
[1] N. Nanato, Y. Kobayashi, Quench Detection and Protection for High Temperature Superconducting Transformers by Using the Active Power Method, Physics Procedia, Vol. 58, pp. 264-267 (2014)

keywords : Current supply, Air-core transformer, HTS transformer, Current conduction characteristics

APP7-5 14:00–16:00

Providing a Proper Vacuum Level in the Thermal Insulation Layer of the Long HTS Cable Line

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Successful development of superconducting power transmission lines implies an increase in the distance between the intermediate cooling stations. This is particularly true for laying the cable in difficult-to-reach areas like mountainous terrain or seabed. Current report discusses the possibility of providing a proper vacuum level in the cryogenic pipe of up to 10 km length taking into account the key role of the thermal insulation in achieving high performance characteristics of HTS lines.
The experimental data on the time-dependent behavior of the vacuum level obtained during measurements at 1 km HTS DC line in Ishikari (Hokkaido, Japan) were used in analysis. The feature of the line is the additional thermal protection by means of radiation screen being in thermal contact with the liquid nitrogen return pipe. The cryogenic pipe has a sufficiently large inner diameter to provide higher pumping speed and improved conductance. Preliminary purging of the vacuum space with dry carbon dioxide (CO_2) is used. As can be seen, employing these approaches, we can maintain the vacuum in the cryogenic pipe if the pumping ports are spaced up to 10 km apart.
This work was supported in part by the Japanese Ministry of Economy, Trade and Industry (METI).

keywords : HTS power transmission line, Superinsulation, Vacuum pumping

APP7-6 14:00–16:00

A Study on a 10 kVA Single-Phase HTS Transformer with a Cylindrical Central Iron Core

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Shanghai Jiao Tong University

During the past decade, a number of high temperature superconducting (HTS) transformer prototypes have been designed, and the majority of them are full-core transformers and air-core transformers. However, in this study, we proposed a new type of HTS transformer, where the iron core is different in that the limbs and connecting yokes are absent. To investigate the performance of this type of HTS transformer, we design and fabricate a 10 kVA single-phase HTS partial core transformer prototype using the secondary generation (2G) HTS GdBCO wires. The iron core is at room temperature, and the windings are immersed in liquid Nitrogen. The structures of primary and secondary windings are three layers connected in series and nine double pancakes connected in parallel, respectively. Fundamental characteristics are obtained by standard short-circuit, no-load and load tests in liquid Nitrogen temperature of 77 K. In addition, an equivalent circuit of the HTS transformer is proposed to analyze the characteristic of the transformer. The calculated values based on the equivalent circuit are consistent with that of experiment. The detailed results about the design of the HTS partial-core transformer, the experiment, and the equivalent circuit are presented and discussed in this study.

keywords : transformer, partial-core

APP7-7 14:00–16:00

Thermal Properties of HTS Coils with Conduction Cooling by Using Heat Pipes

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3. Chubu Electric Power
4. Graduate University for Advanced Studies

High-Temperature Superconducting (HTS) coils can generate high magnetic fields with low loss so the HTS coils are expected to be applied to various fields. Recently, a liquid hydrogen storage system using an HTS levitation coils has been proposed. This system is high efficiency because low heat invention. In addition, it has robustness against earthquake by controlling HTS levitation coil to suppress the tank motion corresponding to the ground shaking. In order to apply the HTS coil to such applications, conduction cooling coils are required. And, in this case of cooling pass by solid thermal conduction, heat generation in the coil can not be sufficiently removed. Therefore, we have proposed an HTS coils with conduction cooling by using a self-oscillation-type heat pipes (OHP), that have excellent thermal transport properties. In this paper, design of the test coil using OHPs and evaluation of its thermal properties using a numerical analysis are carried out. The effects of contact thermal resistances between the windings and OHPs and inter-turn are studied. As a result, it is shown that our coils have high performances. Next, we fabricated a dummy coil applied OHPs. The coil have FRP plates instead of superconducting winding. We report the results of cooling experiments on the dummy coil and thermal properties of the coils with OHPs.

keywords : HTS coil, Heat pipe, AC loss, Levitation

APP7-8 14:00–16:00

Characteristics of Superconducting WPT by multi-receive coils

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The use of portable electronic devices such as smart phones and tablet PCs is abruptly increasing these days. In addition, free information exchange became possible via mobile communication networks, wireless LAN, etc. With the development of electronic devices, communication systems have been developing as well. Despite such development, the power supply for the electronic devices still relies on wired systems. The wired power supply has many limitations in terms of place and mobility. The limited and degraded battery capacity of mobile devices is also requiring the need for the study on the wireless power supply and chargeable wireless power transmission technology. A superconducting coil was fabricated and applied to the magnetic resonance wireless power transmission. The superconductor has a very low resistance at a very low temperature, and can increase the quality factor (Q-factor).
In this study, it was combined with a copper coil with the same resonant frequency considering the application of superconducting coils to real life. A superconducting coil was applied to the transmitter side to increase the Q-factor, and a copper coil was applied to the receiver side to improve the applicability and mobility of the electronic devices. In this setting, the wireless power transmission and the 1:n wireless power transmission characteristic were considered to derive the performance and characteristic of the magnetic resonance wireless power transmission required in real life.
This research was supported by Korea Electric Power corporation [grant number: 15575]

keywords : WPT, Superconducintg coil, Resononace, Multi coil

Correspondence

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