ISSN 1342−3177
IAE−AR−2018

Institute of Advanced Energy
Kyoto University

ANNUAL REPORT
2017

京都大学エネルギー理工学研究所
Institute of Advanced Energy, Kyoto University

ANNUAL REPORT

2017

Institute of Advanced Energy
Kyoto University

Gokasho, Uji, Kyoto 611-0011
Japan

CONTENTS

Foreword ·········· 1

1. Staff List ·········· 2
2. Organization Chart ·········· 9
3. Research Activities ·········· 11

3-1. Research Activities in 2017 ·········· 13

Advanced Energy Generation Division

Quantum Radiation Energy Research Section ·········· 15

Advanced Atomic Energy Research Section ·········· 23

Advanced Particle Beam Energy Research Section ·········· 29

Advanced Plasma Energy Research Section ·········· 35

Advanced Energy Research Section ·········· 43

Advanced Energy Conversion Division

Advanced Energy Materials Research Section ·········· 47

Advanced Laser Science Research Section ·········· 53

Advanced Energy Structural Materials Research Section ·········· 57

Complex Plasma Systems Research Section ·········· 65

Clean Energy Conversion Research Section ·········· 71

Advanced Energy Utilization Division

Chemical Reaction Complex Processes Research Section ·········· 75

Molecular Nanotechnology Research Section ·········· 81

Biofunctional Chemistry Research Section ·········· 85

Structural Energy Bioscience Research Section ·········· 91

Advanced Energy Utilization Division ·········· 99

Laboratory for Complex Energy Processes ··········101

Complex Energy Processes Research Section ··········101

3-2. Award ··········107

4. Joint Usage/Research Program ··········115
5. Collaboration Works in the Laboratory for Complex Energy Processes ··········123
6. Projects with Other Universities and Organizations ··········131
7. How to get to IAE ··········135

FOREWORD

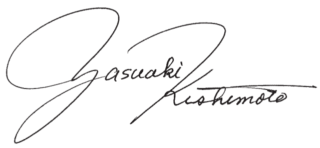
Institute of Advanced Energy (IAE) was established in 1996 for pursuing research aimed at the development of energy science and the creation of advanced technology that drives it. This work, which is outstanding both in terms of environmental harmony and social acceptance, is conducted by 3 divisions and 14 research sections (including two with guest researchers) that engage in research on energy generation, conversion, and advancement, as well as the Laboratory for Complex Energy Processes, which specializes in highly project-oriented cross-disciplinary R&D. IAE has leveraged its track record and strengths as a research institute to focus on "plasma and quantum energy" and "soft energy" as fields of vital importance. It is devoted to R&D on nuclear fusion and advanced atomic energy, for which these disciplines serve as a scientific foundation, on distributed energy sources, typified by sunlight and biological systems, and on the advanced materials and effective energy utilization systems that support these technologies. IAE also has emphasized international collaborative research on advanced energy to lead the field of energy science and technology as an international pioneer.

Since AY2011, IAE has emphasized operating as a "Joint Usage / Research Center (JURC)" under the title of "Zero-Emission Energy (ZE) System", applying the energy ideals of the institute to the challenge of "zero emissions". Under this initiative, the institute employs its broad variety of resources to promote collaboration/cooperation and the formation of communities across multiple academic disciplines. Encouraged by this assessment, we have continued our efforts in the areas of zero-emission energy research and community formation.

In AY2013, IAE was also approved for the development of "innovative strategy for highly efficient utilization of solar energy" (by the Ministry of Education, Culture, Sports, Science and Technology: 2013-2018) with the expectation of advancing energy research based on new bio, optical, and nano-technologies. The project has been aggressiviely advanced and produced several key results. The bidirectional collaborative research program with the National Institute for Fusion Science and also the promotion program of cooperation between industries and universities/national institutes by using advanced facilities have been progressed in pursuing research on boosting the performance of nuclear fusion plasma and on technology for the recovery and utilization of various advanced energy.

This annual report summarizes the IAE's research findings for FY2017 (April 2017-March 2018). Due to the space limitation, only key results including publication and presentaion performed in the year in each division and research section, and also in Laboratory for Complex Energy Processes are edited. Please contact to each researchere for more detail information.

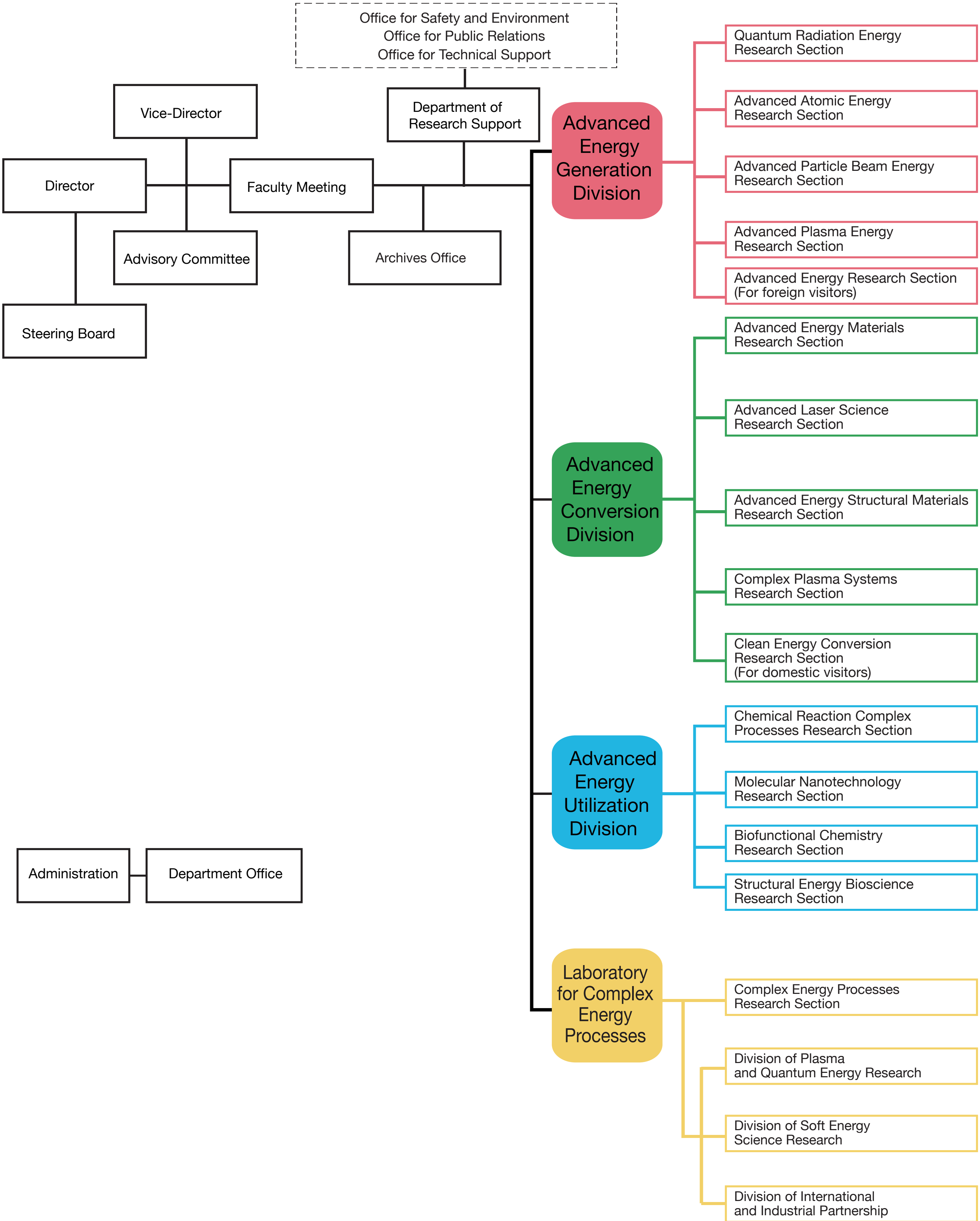
We would appreciate it if we could have your continuous support and encuragement for our instititute.



March 2018

Yasuaki KISHIMOTO
Director
Institute of Advanced Energy
Kyoto University

2. ORGANIZATION CHART



3. RESEARCH ACTIVITIES

3-1. RESEARCH ACTIVITIES IN 2017

Quantum Radiation Energy Research Section

H. Ohgaki, Professor
T. Kii, Associate Professor
H. Zen, Assistant Professor
H. Farzaneh, Program-Specific Senior Lecturer
A. J. J. Botelho, Foreign Visiting Professor
K. Sakaue, Part-time Lecturer
(K. Miura, Specially Appointed Professor)
(J. Wannapeera, Researcher)
(J. Yan, Researcher)

1. Introduction

Coherent-radiation energy with wide wavelength tunability, high power and high efficiency is quite promising in the 21st century that is sometimes called the "era of light". The research in this section aims at developing the technology to generate new quantum-radiation energy and apply the radiation in various fields; atomic energy including plasma heating, energy transportation in the universe, material science, material synthesis, electronic device, medical and biological science, etc. Free-electron laser (FEL) is one of the powerful candidates for the new quantum radiation, and it is sometimes called the light source of next generation.

2. Free-electron Laser

FEL is regarded as a light source of the next generation because of its wide wavelength tunability where the conventional lasers cannot reach, potential high efficiency, and high power. However, the system is usually much larger and the cost is higher than conventional lasers. We are going to overcome these difficulties by exploiting an RF (radio-frequency) gun, an undulator, etc.

2.1 KU-FEL

The target wavelength of KU-FEL is MIR (Mid infra-red) regime, from 5 to 20 μm. The high power tunable IR laser will be used for basic researches on energy materials and systems. Figure 1 shows a schematic drawing of the KU-FEL system. The KU-FEL consists of a 4.5-cell thermionic RF gun, a 3-m travelling wave accelerator tube, a beam transport system, and a 1.8-m undulator and a 5-m optical resonator. The FEL device now can cover the wavelength range from 3.5 to 23 μm. The maximum macro-pulse energy which can provide is around 30 mJ in a 2-μs macro-pulse at the wavelength of 9 μm. The FEL is routinely operated and opened for internal and external users.

Another topic of KU-FEL development is introduction of photo-cathode RF gun, which enables us to generate higher peak power and wider tunable range MIR-FEL. Development of a UV-laser system for illuminating photo-cathode has been completed under collaboration with Dr. R. Kuroda, Researcher of AIST. In FY2014, we have achieved FEL lasing with photo-electron beam generated from LaB_6 cathode. Further study is undergoing to use this operation mode for user experiments.

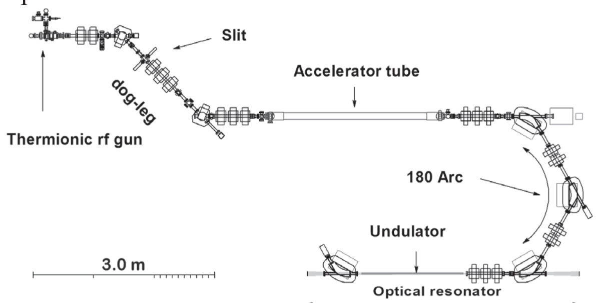


Fig. 1 Schematic drawing of the KU-FEL

2.2 MIR-FEL Application in the Energy Science

Mode-selective phonon excitation (MSPE) is important issue for the bulk solid material to develop the energy saving devices. An MIR-FEL pump, visible pico-second laser probe system has been constructed for measuring the dynamics of phonon vibration which is induced by MIR-FEL irradiation.

High-resolution photoacoustic spectroscopy (PAS) system for solid samples using an MIR-FEL has been also developed and demonstrated.

2.3 THz Coherent Undulator Radiation Source

A new compact terahertz coherent undulator radiation source has been constructed. It consists of a 1.6-cell RF-gun, a solenoid magnet, a magnetic chicane bunch compressor, a triplet quadrupole magnet, a planar undulator, and a laser system for photocathode. Schematic view of the proposed system is shown in Fig 2. In this device, short electron bunches are generated by the photocathode RF gun and the bunch compressor. The electron bunches are injected to the undulator and intense coherent undulator radiation can be generated.

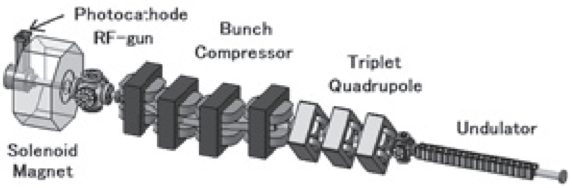


Fig. 2 3D image of THz coherent undulator radiation source.

In order to know the basic performance of the device, detailed experiments have been conducted. As the results, it was confirmed that the device can provide quasi-monochromatic THz radiation from 160 to 650 GHz. Intensity saturation due to space charge effect has been observed. This saturation should be avoided to generate THz radiation with higher peak power.

3. Bulk HTSC Staggered Array Undulator

An undulator with strong magnetic field will play an important role in future synchrotron light sources and free electron lasers. We have developing a new udulator which consists of stacked bulk high critical temperature superconductors array and a solenoid magnet. New scheme to control field distribution at the entrance of the undulator was developed.

4. Isotope Imaging for Nuclear Security

A Nuclear Resonance Fluorescence (NRF) method is a powerful tool for investigation not only of the nuclear physics, but also of isotope imaging inside the nuclear waste canisters. We have been developing an isotope imaging technique by using NRF. The absorption can be measured by sample material and "witness target".

A demonstration experiment of the NRF-CT imaging by using LCS gamma-ray beam has been carried out at the LCS gamma-ray beamline, BL-1U, at UVSOR-III where 5.4 MeV LCS gamma-rays with a flux of 1×10^7 photons/s can be available.

By using NRF absorption method a NRF-CT image has been taken for a sample target consists of aluminium, stainless steel, and lead rods of 8 mm in diameter which form a 5 × 5 rod array. X-axis of 1-cm interval and θ-axis of 36 degree interval have been scanned. The NRF signals from the witness target (natural lead) were measured by a Ge detector. At the same time, transmission gamma-rays have been measured by a $LaBr_3(Ce)$ detector which gives a density distribution of the sample target. The segmented CT reconstruction method has been developed and we obtained clear ^{208}Pb distribution than last year's one.

5. Assessing the benefits and impacts of clean energy development in Asian mega cities

This research focuses on demonstrating how clean energy policies and programs can help achieve multiple energy, environmental, public health and economic benefits in a cost-effective way in Asian mega cities. To this aim, a robust integrated modeling framework is developed which tends to be characterized by extensive underlying data and relatively complex formulation that represents the fundamental engineering and economic decision making of the society at a city level. The four mega-cities which will be evaluated in detail in this research are Tokyo, Seoul, Delhi and Shanghai. We have evaluated the existing clean energy policy developments, countermeasures and challenges in selected cities. And we are designing strategic plans that achieve greater or border benefits in selected cities.

6. Japan-Thailand Project for Effective Use of Biomass Wastes as well as Low-rank Coals

Our section has organized a Japan-Thailand joint research project entitled "*Development of clean and efficient utilization of low rank coals and biomass by solvent treatment*" as one of the projects that are supported by the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA) through the program called Science and Technology Research Partnership for Sustainable Development (SATREPS). More than 15 Japanese researchers from Kyoto University, Akita University, Central Research Institute for Electric Power Industry (CRIEPI), and Kobe Steel Co. Ltd and 12 Thai researchers from the Joint Graduate School of Energy and Environment at King Mongkut's University of Technology Thonburi and PTT Public Company Limited are involved in the project.

Through 6 years of cooperation starting from 2013 we are to develop several technologies to convert biomass wastes as well as low rank coals into valuable products such as carbon fiber, biofuel, high quality solid fuel, etc. based on a novel degradative solvent extraction technology developed at Kyoto University.

Acknowledgment

These works were partially supported by the Grant-in-Aid for Scientific Research and challenging Exploratory Research, by the Ministry of Education, Culture, Sports, Science and Technology of Japan, Unit of Academic Knowledge Integration Studies of Kyoto University, and The Collaboration Program of the Laboratory for Complex Energy Processes, Institute of Advanced Energy, Kyoto University.

Collaboration Works

NSTDA（タイ），JASTIP、WP2，大垣英明

中国科学技術大学（中国），極短パルス電子ビームによる CSR および自由電子レーザーに関する研究，大垣英明

University of Malaya（マレーシア），Study on Energy Usage and Quality of Life for Rural Community Through Rural Electrification using Renewable Energy，大垣英明

University of Yangon（ミャンマー），PV installation program in University of Yangon， 大垣英明

Institute of Technology of Cambodia（カンボジア），A study on economic and technical impacts of mass integration of solar home system on power distribution system， 大垣英明

China University of Petroleum（中国），Assessing the multiple benefits of clean energy in Asian mega-cities, Hooman Farzaneh

Tongji University（中国）、Indian Society for Applied Research & Development（インド）、 University of Technology Sydney（オーストラリア）、University of Malaya（マレーシア）、United Nations University-International Institute for Global Health（マレーシア），Multiple Benefits Assessment of the Low Emission Development Strategies in Asia Pacific Cities， Hooman Farzaneh

エネルギー･環境連合大学院/キングモンクット大学トンブリ校（タイ）、タイ石油公社 Research & Technology Institute（タイ），低品位炭とバイオマスのタイ国におけるクリーンで効率的な利用法を目指した溶剤改質法の開発，三浦孝一

Financial Support

1. Grant-in-Aid for Scientific Research

紀井俊輝，基盤研究(A)，新材料 MgB2 と超伝導電流流体解析による新型アンジュレータ精密磁場制御法の確立

紀井俊輝，挑戦的萌芽研究，ベクトルポテンシャルと電子ボルテックスビームとの相互作用の探索

Hooman Farzaneh， 基盤研究 (C)， Assessingthemultiplebenefitsofcleanenergypoliciesi-nAsianmega-cities

全炳俊，若手研究(A)，超短バンチ電子ビームを用いた新奇 THz 自由電子レーザ発生手法の研究

2. Others

大垣英明，科学技術振興機構，日 ASEAN 科学技術イノベーション共同研究拠点－持続可能開発研究の推進－

大垣英明，科学技術振興機構，平成 29 年度「日本・アジア青少年サイエンス交流事業（さくらサイエンスプラン）」

大垣英明，日本学術振興会，極短パルス電子ビームによる CSR 及び自由電子レーザーに関する研究

大垣英明（代表・総合生存学館・川井秀一），研究拠点形成費等補助金（博士課程教育リーディングプログラム），京都大学大学院思修館

Hooman Farzaneh，Asia-Pacific Network for Global Change Research (APN)，Multiple Benefits Assessment of the Low Emission Development Strategies in Asia Pacific Cities

Hooman Farzaneh，日本学術振興会，平成 29 年度若手研究者ワークショップ（ブラジル），持続発展可能な都市エネルギーシステムの構築-アジアとラテンアメリカの経験―

三浦孝一，科学技術振興機構，低品位炭とバイオマスのタイ国におけるクリーンで効率的な利用法を目指した溶剤改質法の開発

三浦孝一，国際協力機構，地球規模課題対応国際科学技術プログラム（SATREPS）低品位炭とバイオマスのタイ国におけるクリーンで効率的な利用法を目指した溶剤改質法の開発

三浦孝一，国際協力機構，地球規模課題対応国際科学技術プログラム（SATREPS）低品位炭とバイオマスのタイ国におけるクリーンで効率的な利用法を目指した溶剤改質法の開発

Publications

H. Ohgaki, I. Daito, H. Zen, T. Kii, K. Masuda, T. Misawa, R. Hajima, T. Hayakawa, T. Shizuma, M. Kando, S. Fujimoto，Nondestructive Inspection System for Special Nuclear Material Using Inertial Electrostatic Confinement Fusion Neutrons and Laser Compton Scattering Gamma-rays，IEEE Transactions on Nuclear Science，64，7，1635-1640，2017

T. Muangthong-on, J. Wannapeera, H. Ohgaki, K. Miura, TG-DSC Study to Measure Heat of Desorption of Water during the Thermal Drying of Coal and to Examine Role of Adsorption of Water Vapor for Examining Spontaneous Heating of Coal over 100 ° C, Energy Fuels, 31, 10691-10698, 2017

T. Muangthong-on, J. Wannapeera, H. Ohgaki, K. Miura, Examination of interactions of solvent treated coal with oxygen and water vapor at over 100 ° C using TG-DSC for examining propensity to spontaneous heating of the solvent treated coal, Energy Fuels, 31, 11723-11730, 2017

T. Muangthong-on, J. Wannapeera, H. Ohgaki, K. Miura, Effect of Solvent on the Degradative Solvent Extraction of Low Rank Coal, Energy Fuels, 31, 11954-11962, 2017

H. Ohgaki, H. Farzaneh, N.A. Rahim, H.S. Che, M.A.M. Radzi, W.S-H. Wong, L.C. Hung, Study on Quality of Life Change for Rural Community through Rural Electrification by Renewable Energy: Preliminary Result, ASEAN Journal of Management & Innovation, 4, 2, 1-8, 2017

M. Kitaura, H. Zen, K. Kamada, S. Kurosawa, S. Watanabe, A. Ohnishi, K. Hara, Visualizing Hidden Electron Trap Levels in Gd3Al2Ga3O12:Ce Crystals Using a Mid-Infrared Free Electron Laser, Applied Physics Letters, 112, 31112, 2017

S. Suphakul, H. Zen, T. Kii, H. Ohgaki, Measurement of Coherent Undulator Radiation of Compact Terahertz Radiation Source at Kyoto University, International Journal of Magnetics and Electromagnetism, 3, 1, 008, 2017

K. Watcharakorn, M. Trairat, W. Janewit, H. Zen, T. Kii, K. Miura, H. Ohgaki, Proposal of Liquid Membrane-FTIR Spectroscopy to Quantify the Oxygen Content in Soluble Fraction of Degradative Solvent-Extraction, International Journal of Experimental Spectroscopic Techniques, 2, 010, 2017

N. Sei, K. Hayakawa, Y. Hayakawa, K. Nogami, H. Ogawa, H. Ohgaki, T. Sakai, T. Tanaka, H. Zen, Measurement of Electron-Bunch Length using Coherent Radiation in Infrared Free-Electron Laser Facilities, Proceedings of IPAC'17, 288-291, 2017

H. Yamashita, T. Kii, K. Masuda, K. Nagasaki, T. Nogi, H. Ohgaki, K. Torgasin, H. Zen, The Influence of Initial Current Density Distribution on the Emittance Reduction, Proceedings of IPAC'17, 3744-3746, 2017

H. Farzaneh, Multiple benefits assessment of the clean energy development in Asian Cities, Energy Procedia, 136, 8-13, 2017

H. Farzaneh, Development of a Bottom-up Technology Assessment Model for Assessing the Low Carbon Energy Scenarios in the Urban System, Energy Procedia, 107, 321-326, 2017

K. Miura, H. Ohgaki, N. Sato, M. Matsumoto, Formulation of the Heat Generation Rate of Low-Temperature Oxidation of Coal by Measuring Heat Flow and Weight Change at Constant Temperatures Using Thermogravimetry−Differential Scanning Calorimetry , Energy Fuels, 31, 11669-11680, 2017

J. Wannapeera, R. Ashida, H. Ohgaki, K. Miura, Production of carbon fiber and activated carbon fiber from the extract produced from the degradative solvent extraction of biomass, Proceedings of 2017 ICCS&T, 2017

J. Yan, R. Ashida, H. Ohgaki, K. Ichikawa, K. Miura, Gasification of Carbon formed in Nano-Space of Iron Ore, Proceedings of 2017 ICCS&T, 2017

K. Miura, H. Ohgaki, N. Sato, M. Matsumoto, Kinetic Analysis of Air Oxidation of Low Rank Coal at 50 to 150 ° C using Heat Generation Rate measured by TG-DSC, Proceedings of 2017 ICCS&T, 2017

Presentations

大垣英明，中赤外自由電子レーザーでできること，第 61 回知の拠点セミナー，京都大学東京オフィス，2017.4.21

全炳俊，エネルギーの光を照らす強力な光：自由電子レーザー，エネルギー理工学研究所第 22 回公開講演会，京都大学宇治キャンパスおうばくプラザ，2017.5.13

H. Ohgaki, Introduction of Japan-ASEAN International Collaboration Platform on Renewable Energy and Environment, JASTIP-WP2, AUN/SEED-Net Regional Conference on Mechanical and Manufacturing 2017, MƯỜNG THANH LUXURY VIENTIANE HOTEL, Vientine, Laos, 2017.6.29

H. Farzaneh, Clean Energy Development in Asian Cities, Challenges and Opportunities, The 4th International Conference on Energy and Environment Research, ISEP, Polytechnic of Porto, Portugal, 2017.7.17-20

H. Ohgaki, Study on Energy Usage and Quality of Life Change for Rural Community through Rural Electrification by Renewable Energy: Preliminary Result, 6th International Symposium on the Fusion of Science and Technologies, Hanwha Resort Jeju, Jeju, Korea, 2017.7.18

H. Ohgaki, Introduction to JASTIP and JASTIP-Net activities Electrification in Sarawak, Malaysia, JASTIP Workshop Community Renewable Energy in Vietnam, Thailand and Japan 2017, Can Tho University, 2017.7.28

全炳俊，奥村純平，田伏俊介，Krainara Siriwan，Torgasin Konstantin，紀井俊輝，増田開，大垣英明，京都大学自由電子レーザ施設の現状，第 14 回 日本加速器学会年会，北海道大学，2017.8.1-2

S. Krainara, S. Supakul, H. Zen, T. Kii, H. Ohgaki，THz coherent undulator radiation generated from compact accelerator based on photocathode RF gun，第 14 回日本加速器学会年会，北海道大学，2017.8.1-2

紀井俊輝，バルク MgB_2 超伝導体によるバルク超伝導体スタガードアレイアンジュレータ高精度化の検討，第 14 回日本加速器学会年会，北海道大学，2017.8.1

J. Wannapeera, H. Ohgaki, K. Miura，Preparation of Carbon Fiber and Activated Carbon Fiber from Clean Low Molecular Weight Fraction obtained from the Degradative Solvent Extraction of Biomass，第 26 回日本エネルギー学会大会，名古屋，ウィンクあいち，2017.8.1-2

三浦孝一，大垣英明，佐藤延介，松本雄二，低品位炭の低温度域での空気酸化の速度解析，第 26 回日本エネルギー学会大会，名古屋，ウィンクあいち，2017.8.1-2

宮松順也，小野央也，坂上和之，鷲尾方一，飯島北斗，全炳俊，RF 電子銃用高耐久フォトカソードの開発，第 14 回 日本加速器学会年会，北海道大学，2017.8.2

S. Krainara, T. Kii, H. Ohgaki, H. Zen, S. Suphakul，Development of Compact THz Coherent Undulator Radiation Source at Kyoto University，FEL2017，Santa Fe, NM, USA，2017.8.21

H. Zen, T. Kii, S. Krainara, K. Masuda, H. Ohgaki, J. Okumura, S. Suphakul, S. Tagiri, K. Torgasin，Present Status of Infrared FEL Facility at Kyoto University，FEL2017，Santa Fe, NM, USA，2017.8.21

J. Okumura, T. Kii, H. Ohgaki, H. Zen，Development of Mid-Infrared Photoacoustic Spectroscopy System for Solid Samples at Kyoto University Free Electron Laser Facility，FEL2017，Santa Fe, NM, USA，2017.8.22

S. Tagiri, T. Kii, H. Ohgaki, H. Zen，Study on Second Harmonic Generation in SiC Using Infrared FEL，FEL2017，Santa Fe, NM, USA，2017.8.22

H. Zen, T. Kii, K. Masuda, T. Nakajima, H. Ohgaki, Pulse Duration Measurement of Pico-second DUV Photocathode Driving Laser by Autocorrelation Technique Using Two-Photon Absorption in Bulk Material，FEL2017，Santa Fe, NM, USA，2017.8.23

H. Ohgaki，Study on Life Style Change in Rural Community by Renewable Energy Electrification: preliminary result in Sarawak, Malaysia，6th World Conference on Applied Sciences, Engineering and Technology，Universitas Muhammadiyah Ponorogo, Indonesia，2017.8.26

全炳俊，Development of Pump-probe Station at Kyoto University Mid-Infrared Free Electron Laser Facility (KU-FEL)，Workshop on Generation and Application of High Brightness Quantum Beam，京都大学宇治キャンパス，2017.9.4

全炳俊，紀井俊輝，大垣英明，京都大学中赤外自由電子レーザの発振波長限界と共振器損失の波長依存性，日本原子力学会「2017 年秋の大会」，北海道大学，2017.9.14

S. Krainara, H. Ohgaki, H. Zen, T. Kii, S. Suphakul, Observation of THz radiation from THz Coherent Undulator Radiation Source，日本原子力学会「2017 年秋の大会」，北海道大学，2017.9.14

H. Zen，Status of Accelerator based Infrared Light Sources at Kyoto University，2nd International workshop on CSR and free electron lasers from ultra short bunch electron beam，東北大学電子光理学研究センター，2017.9.19

S. Krainara，Investigation of the performance of THz-CUR source at Kyoto University，2nd International workshop on CSR and free electron lasers from ultra short bunch electron beam，東北大学電子光理学研究センター，2017.9.20

S. Jadsadajerm, N. Worasuwannarak, J. Wannapeera, H. Ohgaki, K. Miura，Degradative solvent extraction of biomass waste by petroleum based solvents at 350 °C，第 54 回石炭科学会，秋田ビューホテル，2017.10.18-19

J. Wannapeera, R. Ashida, H. Ohgaki, K. Miura，R. Fugtuan, N. Worasuwannarak，Preparation of Hollow Carbon Fiber from a Biomass derived Extract，第 54 回石炭科学会，秋田ビューホテル，2017.10.18-19

N. Worasuwannarak, N. Setkit, K. Miura，Effect of Mechanical Pressure on the Char Yield during Carbonization of Biomass，第 54 回石炭科学会，秋田ビューホテル，2017.10.18-19

T. Muangthong-on，J. Wannapeera，大垣英明，三浦孝一, TG-DSC による褐炭の乾燥時の水の脱着過程，ならびに乾燥褐炭への水蒸気の吸着過程のエンタルピーの測定，第 54 回石炭科学会，秋田ビューホテル，2017.10.18-19

T. Muangthong-on，J. Wannapeera，大垣英明，三浦孝一，TG-DSC による溶剤改質炭の自然発火性の評価，第 54 回石炭科学会，秋田ビューホテル，2017.10.18-19

三浦孝一，J. Wannapeera，大垣英明，DAEM 法と等温ガス化法による石炭酸化反応の全温度域での速度解析，第 54 回石炭科学会，秋田ビューホテル，2017.10.18-19

全炳俊，吉田恭平，紀井俊輝，大垣英明，京都大学中赤外自由電子レーザにおけるポンププローブ実験系の構築，第 27 回日本赤外線学会研究発表会，大阪市立大学杉本キャンパス，2017.10.26

大垣英明，ASEAN 地域の非電化地区における再生可能エネルギー導入による住民生活への影響，研究・イノベーション学会，京大国際イノベーション棟，2017.10.28

全炳俊, 紀井俊輝, 大垣英明, 早川岳人, 静間俊行, 平義隆, 豊川弘之, 大東出, 山崎潤一郎, 加藤政博, LCS ガンマ線を用いた 2 次元同位体分布測定 2, UVSOR シンポジウム，岡崎コンファレンスセンター，2017.10.28

北浦守，全炳俊，鎌田圭，黒澤俊介，渡邉真太，大西彰正，原和彦，GAGG:Ce 結晶に潜む浅い電子捕獲準位を赤外光で見る，UVSOR シンポジウム，岡崎コンファレンスセンター，2017.10.28

H. Ohgaki，JASTIP Approach to to Exit Strategy，Feasibility Study on Social Implementation of Bioenergy in East Asia，Convention Center Room CC405, NSTDA, Thailand，2017.10.31

H. Ohgaki，Impact of Solar Home System on Change of Quality of Life in Rural Community in Sarawak, Malaysia，The 10th Regional Conference on Energy Engineering (RCEneE2017)“Energy Sufficiency and Efficiency through Regional Collaboration”，Yangon Technological University, Yangon, Myanmar，2017.11.9

全炳俊, 紀井俊輝, 大垣英明, 早川岳人, 静間俊行, 平義隆, 豊川弘之, 大東出, 山崎潤一郎, 加藤政博, 単色ガンマ線の核共鳴蛍光吸収測定による同位体 CT イメージングの実証，ビーム物理研究会 2017, 岡崎コンファレンスセンター，2017.11.17

石原篤, 恩地太紀, 赤坂友幸, 福本祐介, 紀井俊輝, 関野正樹，大崎博之，岸尾光二，富田優，半円状 MgB2 超電導バルク磁石の磁場特性評価, 2017 年度秋季（第 95 回）低温工学・超電導学会，高知市文化プラザかるぽーと，2017.11.22

赤坂友幸, 恩地太紀, 石原篤, 福本祐介, 関野正樹, 大崎博之，岸尾光二，紀井俊輝，富田優，MO センサーによる高温超電導バルク磁石の捕捉磁場分布評価（２），2017 年度秋季（第 95 回）低温工学・超電導学会，高知市文化プラザかるぽーと，2017.11.22

H. Ohgaki，NRF based Nondestructive Inspection System for SNM using Laser-Compton Gamma-rays，The 2nd Workshop on Radiation Security Inspection Technology，KAERI, Dejeong, Korea，2017.12.1

H. Ohgaki，Study on Energy Usage and Quality of Life for Rural Community Through Rural Electrification using Renewable Energy，The 3rd ASEAN Smart Grid Congress and the 5th Inernational Conference on Sustainable Energy，Ho Chi Minh City University of Technology, Ho Chi Minh, Vietnam，2017.12.4

T. Kii，Effect to periodic magnetic field quality of non-uniformity of Jc in each piece of bulk supercon-ductor array，The 10th International Workshop on Processing and Applications of Superconducting (RE)BCO Large Grain Materials (PASREG 2017)，Shibaura Institute of Technology, Tokyo，2017.12.11

清紀弘，小川博嗣，全炳俊，大垣英明，田中俊成，早川恭史, 境武志, 住友洋介, 高橋由美子, 早川建, 野上杏子, 赤外自由電子レーザー施設におけるコヒーレント放射を用いた電子ミクロパルス譴バンチ長譴観測，第 31 回日本放射光学会年会放射光科学合同シンポジウム，つくば国際会議場，2018.1.9

川崎平康, 佐藤碧美, 藤岡隼, 小山貴裕, 築山光一, 全炳俊，皮膚メラニンに対する中赤外自由電子レーザー譴照射効果に関する研究，第 31 回日本放射光学会年会放射光科学合同シンポジウム，つくば国際会議場，2018.1.9

全炳俊，紀井俊輝，大垣英明，広波長帯域高速焦電検出器を用いた京都大学中赤外自由電子レーザの光共振器損失測定, 第 31 回日本放射光学会年会 放射光科学合同シンポジウム，つくば国際会議場，2018.1.9

H. Ohgaki，Study on QOL Change in Rural Community by Renewable Energy Electrification in Sarawak, Malaysia，1st International Conference on New Frontiers in Engineering, Science and Technology，Delhi Technological University, New Delhi, India，2018.1.9

奥村純平，京都大学自由電子レーザにおける中赤外レーザ光励起・光音響分光システムの構築，第 24 回 FEL と High Power Radiation 研究会，おうばくプラザ，2018.2.15

田伐俊介，中赤外自由電子レーザを用いた SiC における二次高調波発生に関する研究，第 24 回 FEL と High Power Radiation 研究会，おうばくプラザ，2018.2.15

S. Krainara，Study on space charge effect in a compact THz Coherent Undulator Radiation (THz-CUR) source at Kyoto Univ.，第 24 回 FEL と High Power Radiation 研究会，おうばくプラザ，2018.2.16

T. Kii，Ultra-short period high field undulators for compact light sources，The 60th ICFA Advanced Beam Dynamics Workshop FLS2018，Hotel Equatorial Shanghai，2018.3.8

H. Zen，Measurement of Extraction Efficiency of Mid-Infrared Free Electron Laser, KU-FEL，Workshop on CSR and FELs from ultra-short bunch electron beams，National Synchrotron Radiation Laboratory, Hefei, China，2018.3.13

T. Kii，Bulk High-Tc Superconductor Staggered Array Undulator -- Principle of Operation --，Workshop on CSR and FELs from ultra-short bunch electron beams，National Synchrotron Radiation Laboratory, Hefei, China，2018.3.13

S. Krainara，Effect of space charge in short electron bunch on THz Coherent Undulator Radiation at Kyoto University，Workshop on CSR and FELs from ultra-short bunch electron beams，National Synchrotron Radiation Laboratory, Hefei, China，2018.3.14

清紀弘，小川博嗣，田中俊成，早川恭史，境武志，住友洋介，高橋由美子，早川建，野上杏子，全炳俊，大垣英明，電子バンチ長計測のためのコヒーレントエッジ放射の研究，日本物理学会第 73 回年次大会，東京理科大学（野田キャンパス），2018.3.22

柏木茂，二宮慎吾，全炳俊，鹿又健，齊藤寛峻，齊藤悠樹，高橋健，長澤育郎，南部健一，西森信行，日出富士雄，三浦禎雄，武藤俊哉，濱広幸，マイケルソン干渉計を用いたコヒーレント遷移放射スペクトル計測による極短電子ビームのパルス長評価，日本物理学会第 73 回年次大会，東京理科大学（野田キャンパス），2018.3.22

全炳俊，紀井俊輝，大垣英明，4.5 空洞熱陰極高周波電子銃における逆流電子起因陰極温度上昇の観測，日本物理学会第 73 回年次大会，東京理科大学（野田キャンパス），2018.3.25

宮松順也，小野央也，坂上和之，鷲尾方一，飯島北斗，全炳俊，高周波電子銃用 Cs-Te フォトカソードの高耐久化に関する研究，日本物理学会第 73 回年次大会，東京理科大学（野田キャンパス），2018.3.25

全炳俊，紀井俊輝，大垣英明，京都大学小型中赤外自由電子レーザの引き出し効率測定，日本原子力学会 2018 年春の年会，大阪大学吹田キャンパス，2018.3.26

S. Krainara, H. Ohgaki, T. Kii, H. Zen, S. Chatani，Study on space charge effect in a compact THz coherent undulator radiation (THz-CUR) source at Kyoto University，日本原子力学会 2018 年春の年会，大阪大学吹田キャンパス，2018.3.26

Advanced Atomic Energy Research Section

S. Konishi, Professor
K. Ryuta, Associate Professor
K. Mukai, Assistant Professor

1. Introduction

Stable energy supply and recycling of waste within the environmental capacity are the key issues for future life of the humankind. Main purpose of our research section is to pursue advanced energy systems for the sustainable development under global environmental constraints. We propose a Zero-emission energy scenario based on fusion energy with biomass-based recycling system where biomass waste is converted into liquid fuel or stored after a carbonization process. Our research section focuses on development of hydrogen isotope recovery system, fusion material R&D, feasibility study for fusion–biomass hybrid power system, conversion of biomass waste, and fusion neutron generation/measurement. Followings are main research achievements in the fiscal year of 2017.

- Modeling of fuel system and operation scenario analysis in a DEMO fusion reactor.
- Development of liquid lithium lead (LiPb) droplet system for efficient hydrogen isotope recovery.
- Conversion of waste biomass by endothermic reaction into liquid fuel or solid carbon.
- Generation of fusion neutron by the cylindrical discharge fusion device and a two-dimensional neutron measurement by imaging plate.
- Chemical interaction between fusion blanket steel and ceramic breeder at elevated temperatures.

2. Quantitative feasibility analysis of tritium recovery from PbLi droplets

For an efficient tritium recovery system, quantitative feasibility analysis of the tritium recovery efficiency from multiple columns of liquid PbLi droplets with a case study based on the HCLL specification was performed. As a safe side assumption, the tritium once released and reabsorbed on another droplet was considered to be not re-emitted while falling. By the analogy with the thermal radiation theory, the view factor which expresses the intersection ratio of radiation on another surface was applied for the estimation. The dependences on nozzle design parameters, such as nozzle pitch, number of nozzles, chamber wall clearance, and exhaust port design, were investigated. Case study results suggest that, by choosing well-suited parameters approximately 40% to 60% of the single column recovery efficiency was secured for multiple columns even on the conservative condition. The release chamber exhaust port design had a major influence.

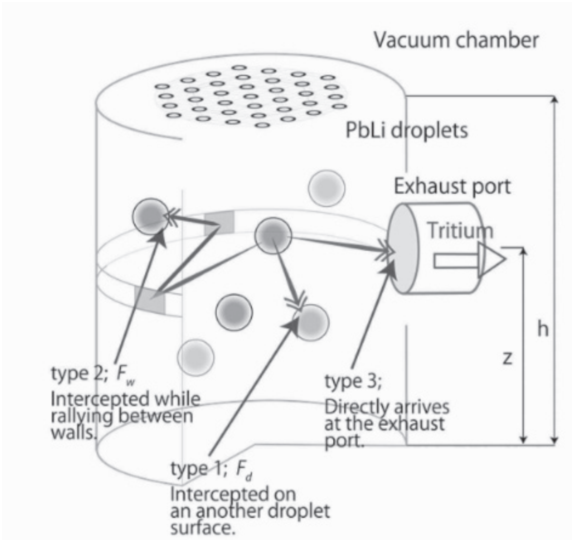


Fig. 1 Behavior of released tritium in an array of PbLi droplets in vacuum. Two released tritium atoms recombine to form T_2 molecule and emitted.

[F. Okino, L. Frances, D. Demange, R. Kasada, S. Konishi, *FUSION SCIENCE AND TECHNOLOGY* 71 (2017) 575–583.]

3. Scenario Analysis of fusion power plant.

Any fusion power reactors such as DEMO that achieves tritium self-sufficiency with breeding blankets can produce tritium by DD reaction followed by exponential breeding in the blanket within reasonable total operation period. The present study further suggests that realistic Power Ascension Tests (PAT) of DEMO can produce its tritium to be needed in the series of tests by its own program until reaching steady state full power operation, with no external supply or additional operation costs. Closed tritium fuel plant was described by a system dynamics model, and analyzed considering realistic PATs of DEMO, that will be mainly pulsed DD and low concentration DT. Typical PATs require years of operation from zero power criticality to full power, with pulsed power output and long dwell time between them. Output power is gradually increased in PATs to check the functions of reactor systems and components. In the case of fusion DEMO, zero power criticality corresponds to DD operation. While plasma may be fired in pulses, tritium plant is continuously operated to recover all the tritium produced by the DD and low DT burn. Depending on the different time constant of tritium retention in components, tritium is transferred by deuterium purge, and high concentration tritium is finally collected in the storage, to be available for the next tests at virtually no additional cost. Realistic "initial loading tritium" will be 100 g for commissioning of tritium plant far prior to the plasma operation.

To obtain fundamental knowledge on the plasma control requirements for the future commercial fusion power plants, a dynamic simulation model of a nuclear fusion power plant was constructed. The fusion power plant model was designed with a 1500 MW thermal output tokamak reactor with He-cooled Li_2TiO_3 solid breeder blanket (coolant outlet conditions: 8 MPa and 515.8 °C). A superheated Rankine cycle was designed to achieve the electrical output of 485.38 MW with the operating pressure of 20.5 MPa. Two plasma output patterns, a step decrease of power and a single pulse decrease of power, were simulated to assess the response of the power plant. A sudden step decrease in fusion neutron led to an immediate decrease in the blanket temperature and the first coolant temperature. In order to avoid the sharp temperature drop, a need for a turbine bypass mechanism or a He coolant boiler bypass mechanism was indicated. On the other hand, because of the delay in the plant responses, the deviation of the electrical output from steady state could be minimized by recovering the plasma output in few tens of seconds. Based on the findings, a new diagram was presented that illustrates important plasma control requirements for future commercial fusion power plants.

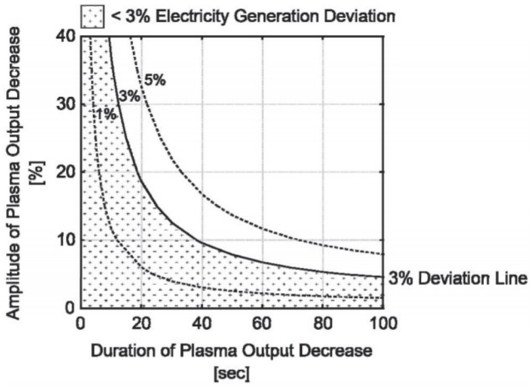


Fig. 2 Plasma control requirements for the future commercial fusion power plants.

[S. Konishi, R. Kasada, F. Okino, *Fusion Engineering and Design*, 121 (2017) 111–116.]
[S. Takeda, S. Sakurai, R. Kasada, S. Konishi, *IEEE Transactions on Plasma Science*, 99 (2017) 1–6.]

4. Characterization of corrosion layer on reduced-activation steel by Li ceramics under moist atmosphere

By production of tritium from Li-containing ceramic breeder, helium sweep gas contains certain amount of moisture that may have influence on corrosion behavior of blanket structural steel. Thus, this study focuses on effect of moisture in sweep gas on chemical compatibility between ceramic breeder (Li_4SiO_4 with 20 mol% of Li_2TiO_3) and reduced-activation structural steel (EUROFER97). These materials were contacted and heated at 623, 823, and 1073 K for up to 12 weeks where the H2O concentrations of the outlet gas were 0.13–0.24 vol.%. In the two-phase breeder specimen, Li_4SiO_4 was preferably decomposed into Li_2SiO_3 with a possible formation of Li_2O or LiOH depending on environmental condition. Formation of corrosion layers on the EUROFER specimen was enhanced in the wet condition, especially at the elevated temperatures of 823 and 1073 K. Though these results showed parabolic growth rates, an extrapolation from data of the elevated temperatures to 623 K was not feasible in the wet atmosphere, which could derive from the difference of the chemical form in the breeder specimen. Effective diffusion coefficient of oxygen into EUROFER at 623 K was given to be 4.5×10^{-14} cm^2/s and a possible thickness of the corrosion layer after a 2-year use was predicted.

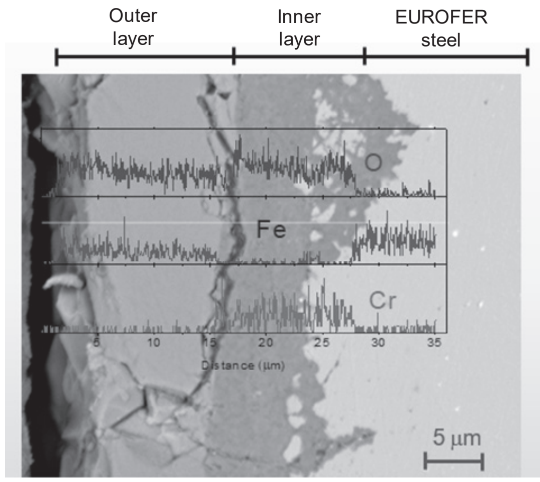


Fig. 3 Double corrosion layer on EUROFER reduced-activation ferritic martensitic steel by two-phase Li ceramics (Li_4SiO_4 and Li_2TiO_3) formed by heating at 800 °C after 72 h.

[K. Mukai, M. Gonzalez, R. Knitter, *Fusion Engineering and Design*, 125 (2017) 154–159.]

Financial Support

1. Grant-in-Aid for Scientific Research
武田秀太郎，特別研究員奨励費，モデル規範形適応制御の過度応答性改善に関する研究とその核融合炉制御への応用

2. Others
小西哲之，SCK CEN (Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie Nucléaire, Belgium, the Coordinator)，Innovative cladding materials for advanced accident-tolerant energy systems- IL TROVATORE

小西哲之，向井啓祐，量子科学技術研究開発機構，原型炉の初期装荷トリチウム調達シナリオの検討

小西哲之，東レエンジニアリング（株），エネルギー理工学研究所に対する研究助成

小西哲之，東レエンジニアリング（株），小型中性子ビーム減の開発

小西哲之，量子科学技術研究開発機構，ブランケットシステムのトリチウム透過量評価

笠田竜太，科学研究費補助金（基盤(A)分担者），ダイバータ用耐照射性銅合金の創成（研究代表者核融合科学研究所室賀健夫）

笠田竜太，核融合科学研究所・LHD 計画共同研究，ヘリカル炉ダイバータ用耐照射性ナノ粒子分散銅合金の開発法を目指した溶剤改質法の開発

Publications

E. Hasenhuetl, R. Kasada, Z. Zhang, K. Yabuuchi, Y-J. Huang, A. Kimura，Evaluation of Ion-Irradiation Hardening of Tungsten Single Crystals by Nanoindentation Technique Considering Material Pile-Up Effect, Materials Transactions，58，5，749-756，2017

F. Okino, L. Frances, D. Demange, R. Kasada, S. Konishi, Tritium Recovery Efficiency from an Array of PbLi Droplets in Vacuum，Fusion Science and Technology, 71，Issue 4, Part 2，575-583，2017

S. Konishi, R. Kasada, F. Okino，Myth of initial loading tritium for DEMO-Modelling of fuel system and operation scenario，Fusion Engineering and Design，121, 111-116，2017

S. Konishi, M. Enoeda, M. Nakamichi, T. Hoshino, A. Ying, S. Sharafat, S. Smolentsev, a, Functional materials for breeding blankets-status and developments，Nuclear Fusion，57，9，92014，2017

K. Mukai, M. Gonzalez, R. Knitter，Effect of moisture in sweep gas on chemical compatibility between ceramic breeder and EUROFER97，Fusion Engineering and Design，125，154-159，2017

S. Takeda, S. Sakurai, R. Kasada, S. Konishi，Plasma Control Requirements for Commercial Fusion Power Plants: A Quantitative Scenario Analysis with a Dynamic Fusion Power Plant Model，IEEE Transactions on Plasma Science，PP，99，1-6，2017

武田秀太郎，第 33 回プラズマ・核融合学会年会核融合若手インフォーマルミーティング会議報告，プラズマ・核融合学会誌，93，3，157，2016

S. Takeda, S. Sakurai, R. Kasada, S. Konishi，Environmental Life Cycle Assessment of High Temperature Nuclear Fission and Fusion Biomass Gasification Plants, Proceedings of ICAPP 2017, 17582-17582, 2017

H. Nam, R. Kasada, S. Konishi，Feasibility of Waste to Bio-Diesel Production via Nuclear-Biomass Hybrid Model; System Dynamics Analysis，Proceedings of ICAPP 2017，17674-17674，2017

小西哲之，福島原発のトリチウム汚染水海洋放出の是非を問う，エネルギーフォーラム，753，83-84，2017

Presentations

S. Takeda, S. Sakurai, R. Kasada, S. Konishi，Environmental Life Cycle Assessment of High Temperature Nuclear Fission and Fusion Biomass Gasifi cation Plants，ICAPP2014，Hotel Fujita Fukui & The Westin Miyako Kyoto，2017.4.24-28

H. Nam , R. Kasada , S. Konishi，Feasibility of Waste to Bio-Diesel Production via Nuclear-Biomass Hybrid Model; System Dynamics Analysis，ICAPP2014, Hotel Fujita Fukui & The Westin Miyako Kyoto, 2017.4.24-28

S. Takeda, S. Sakurai, R. Kasada, S. Konishi，Plasma Control Requirements for Commercial Fusion Power Plants: A Quantitative Scenario Analysis with a Dynamic Fusion Power Plant Model，SOFE2017，Shanghai Marriott Hotel City Centre （中国・上海），2017.6.4-8

F. Okino, R. Kasada, S. Konishi，Liquid PbLi atomization in vacuum for tritium and heat recovery, SOFE2017, Shanghai Marriott Hotel City Centre （中国・上海），2017.6.4-8

S. Konishi，Validation of Tritium Self-Sufficiency of DEMO，SOFE2017，Shanghai Marriott Hotel City Centre （中国・上海)，2017.6.4-8

笠田竜太，小西哲之，金宰煥，中道勝，EPMA-SXES によるベリライドの化学状態分析，日本金属学会 2017 年秋期（第 161 回）講演大会，北海道大学，2017.9.6-9

笠田竜太，八尾栄彰，秋吉優史，小西哲之，Xe フラッシュ法による核融合炉第一壁材料の熱伝導特性評価，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

八尾栄彰，笠田竜太，小西哲之，大野直子，鵜飼重治，能登裕之，菱沼良光，室賀健夫，高エネルギー水冷ボールミルを用いた ODS-Cu の開発，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

興野文人，笠田竜太，小西哲之，液体 PbLi からのトリチウムと熱エネルギーの非接触抽出，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

志村力，笠田竜太，小西哲之，安堂正巳，谷川博康，マイクロピラー圧縮試験よるイオン照射した Fe 単結晶の強度特性評価，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

小西哲之，燃料製造のためのバイオマスハイブリッド核融合炉概念の検討，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

向井啓祐，M. Gonzalez，R. Knitter，Chemical compatibility between EUROFER and ceramic breeder under dry and moist atmospheres，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

小西哲之，笠田竜太，医療用低線量率核融合中性子源の電極上核融合反応，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

K. Mukai，Comparison of the chemical compatibility between EUROFER97 and ceramic breeder under dry and moist atmospheres，19th International Workshop on CERAMIC BREEDER BLANKET INTERACTIONS（CBBI-19），Kyoto University, Uji Campus，2017.9.21-23

K. Mukai, M. Gonzalez, R. Knitter，Effect of moisture in sweep gas on chemical compatibility between ceramic breeder and EUROFER97，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

T. Urakawa, H. Matsuura, Y. Kawamoto, S. Konishi，Influence of modified neutron emission spectrum on tritium production performance in blanket systems with NBI-heated deuterium plasma，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

C-H. Park, T. Nozawa, R. Kasada, H. Tanigawa, S. Konishi，The Effect of Wall Flow Velocity on Compatibility of SiC Materials with Liquid Pb-Li Alloy by，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

S. Takeda, S. Sakurai, R. Kasada, S. Konishi，Heat Storage for Stable Electricity Generation: A Quantitative Scenario Analysis with Dynamic Fusion Power Plant Model，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

F. Okino, R. Kasada, S. Konishi，Liquid PbLi atomization in vacuum，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

O. Leys, A. Pucci, K. Mukai, M. Kolb, R. Knitter，Introduction of Lithium Orthogermanate into Advanced Ceramic Breeders，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

M. Akiyoshi, R. Kasada, Y. Ishibashi, L. Garrison, J. Geringer, W. Porter, Y. Katoh，Validation of Miniature Test Specimens for Post-Irradiation Thermal Diffusivity Measurement，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

R. Kasada, S. Konishi, K. Aoki, R. Ochiai, H. Gwon, Y. Morizono, K. Hokamoto，Thermal conductivity of Tungsten Coating on F82H and copper Formed by Underwater Explosive Welding，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

K. Okano, R. Kasada, Y. Ikebe, Y. Ishii, K. Oba, M. Kashiwagi, R. Sakamoto, N. Sawa, H. Takenaga, A. Nishimura, M. Fukuie, S. Fujioka, Y. Ueda, T. Akiyama, An Action Plan of Japan toward Development of DEMO Reactor，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

S. Konishi, R. Kasada ，Experimental Validation of Fuel Self-Sufficiency of DEMO，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

H. Nam, R. Kasada, S. Konishi，Economic Comparison between bio-diesel and electricity via Fusion-Biomass gasification hybrid model considering Carbon pricing，ISFNT-13，The Westin Miyako Kyoto Hotel，2017.9.25-29

S. Konishi，Update of the studies on the cylindrical discharge fusion neutron source，19th Japan-US workshop Fusion Neutron Source for Nuclear Assay and Alternate Applications， Kansai University Senriyama Campus，2017.10.17-19

R. Kasada，Electronic Structure of the Beryllides，ICFRT-18，Link Station Hall Aomori，2017.11.5-10

K. Mukai，Corrosion Characteristics of Reduced Activation Ferritic-Martensitic Steel EUROFER by Li2TiO3 with Excess Li，ICFRT-18，Link Station Hall Aomori，2017.11.5-10

R. Shimura，Nanoindentation Hardness and Micro-Pillar Compression Tests of Ion-Irradiated Single Crystal Fe (110)， ICFRT-18， Link Station Hall Aomori，2017.11.5-10

H. Yao，Development of ODS-Cu using a Water-Cooled High Energy Ball Mill，ICFRT-18，Link Station Hall Aomori，2017.11.5-10

向井啓祐，小西哲之，放電型中性子源を用いた実験体系中の中性子束分布の評価, 日本原子力学会 2018 年春の年会， 大阪大学　吹田キャンパス，2018.3.26-28

小西哲之，武田秀太郎，Nam Hoseok，バイオマス核融合ハイブリッド Ver2 の未来エネルギーシステム適合性，日本原子力学会 2018 年春の年会，大阪大学 吹田キャンパス，2018.3.26-28

南昊錫，小西哲之，福島事件以降ドイツ原子力政策変化と日本への示唆，日本原子力学会 2018 年春の年会，大阪大学 吹田キャンパス，2018.3.26-28

興野文人，向井啓祐，小西哲之，液体 PbLi からのトリチウムと熱エネルギーの非接触抽出－その 4 液体金属微細粒の粒径式，日本原子力学会 2018 年春の年会，大阪大学 吹田キャンパス，2018.3.26-28

屋敷昌也，笠田竜太，八尾栄彰，秋吉優史，φ3mm 微小試験片を用いた核融合炉ダイバータ候補材の熱拡散率評価手法の開発，日本原子力学会 2018 年春の年会，大阪大学 吹田キャンパス，2018.3.26-28

笠田竜太, 八尾栄彰, 小西哲之, Mohammad Aghamiri, 大野直子，鵜飼重治，能登裕之，菱沼良光，室賀健夫, REDOX 反応制御 MA 法による ODS-Cu 合金の創製，日本原子力学会 2018 年春の年会，大阪大学 吹田キャンパス，2018.3.26-28

Advanced Particle Beam Energy Research Section

K. Nagasaki, Professor
K. Masuda, Associate Professor
S. Ohshima, Assistant Professor
M. Bakr, Senior Researcher

1. Introduction

Advanced and innovative control methods for the collective behavior of charged particles are being developed in this research section to bring about enormous contributions to the human beings. Studies of nonlinear interactions between charged particles and electromagnetic fields are particularly emphasized. We focus on the following subjects; improvement and understanding of confinement and transport in fusion plasmas, development of heating and current drive systems using high power millimeter waves, development of advanced diagnostics in high temperature plasmas, development and application of compact and portable neutron/proton sources driven by fusion reaction, and production/diagnostics of highly brilliant relativistic electron beams for advanced light sources such as free electron laser.

2. Development of an ultra-compact DD-IEC Neutron Generator

First and second prototypes of the ultra-compact Inertial electrostatic confinement (IEC) device have been fabricated, assembled and tested. The 1st prototype IEC chamber was fabricated from SUS316L, with 17 cm anode diameter (IEC17), as shown in Fig. 1. Grid cathode concentrically placed at the chamber center is assembled from 6 rings of Molybdenum with 8 cm diameter. Multistage feedthrough technique was employed in this version, by utilizing 3 stages feedthrough junction sinking in oil inside SUS cylinder (22 cm dimeter) to enable applying 120 kV to the compact configuration <70 cm height. D-D interaction is used in this system for neutrons production with maximum energy 2.45 MeV. The neutron production rate (NPR) from the SUS chamber was ~2.8×10^7 n/sec by applying ~10.5 kW power, ~ 30% of the power supply capacity. The 2nd prototype of the DD-IEC was fabricated with the same anode and cathode diameters, 17 and 8 cm, respectively. The anode material was chosen to be Titanium with expectation of lighter system and higher NPR compared to SUS chamber. The NPR generated from 2nd prototype at 5.6 kW applied power was ~6.8×10^7 n/sec, it is 2.4 times higher NPR compared to SUS chamber with 50% less applied power.

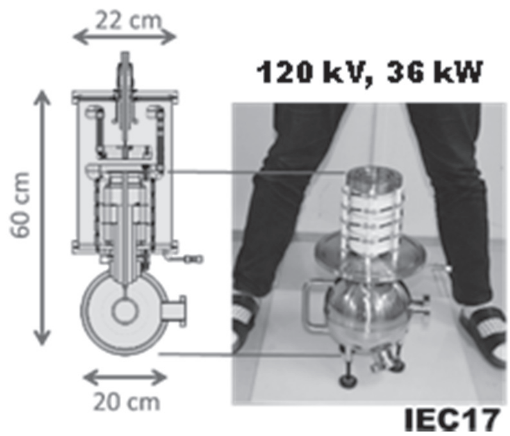


Fig. 1 The first prototype DD-IEC neutron source for special nuclear material(SNM) interrogation svstem.

3. SNMs Interrogation system using DD-IEC neutron source and TMFDs

Our group has been developing the world's first of its kind, portable active interrogation system for detecting special nuclear materials (SNMs), such as U-235 and Pu-239, based on the threshold energy neutron analysis technique (TENA). The system employs a DD neutron generator based on inertial electrostatic confinement (IEC) for interrogating suspicious objects and tensioned metastable fluid detector (TMFD) for detecting secondary neutrons from the fission reactions induced in SNM. The main challenging in interrogate SNMs is related to distinguish between the secondary neutrons from the SNMs and neutron-induced fission reactions from the neutron source used for interrogation. To cope with this task, we are developing neutron-in neutron-out technique, namely the TENA method. The schematic drawing of the portable neutron interrogation system which will be loaded to a vehicle is arranged as seen in Fig. 2. DD-IEC and tensioned metastable fluid detector (TMFD) are used as neutrons generator and detectors, respectively, in the method. The method is based on the fact that ~30% of fission neutrons from SNMs is above DD fusion neutron energy of 2.45 MeV. Therefore, thermal and/or epi-thermal neutrons originated from the 2.45 MeV mono-energetic DD neutrons hit SNMs which emits secondary neutrons by induced fission reactions. Then TMFDs system which, has the advantages of scanning the energy is used to detect the secondary neutrons from the SNMs. Results from experiments carried out for detecting 10 g of highly-enriched uranium (HEU) revealed that, the proposed system capable to identify the existence of HEU with 96% confidence level.

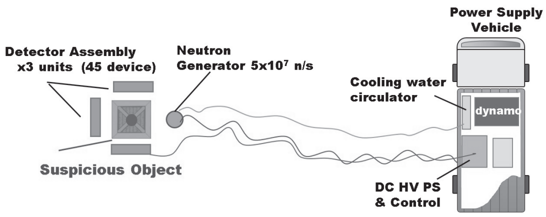


Figure 2. Schematic drawing of the portable neutron interrogation system for detection of shielded SNMs hidden in suspicious objects

4. Development of a 320 GHz Far Infrared Interferometer for High Density Plasma in Heliotron J

Understanding the physics of high-density plasmas is one of the important topics in fusion plasma science. Multi-channel FIR interferometer is a powerful tool to measure electron density profile in such a high density and high temperature plasma. We have been developing a new interferometer system with stable, high-power, 320 GHz semiconductor oscillators in Heliotron J as a replacement of current interferometer system using an HCN laser. We have constructed a test stand of the interferometer system and have checked the characteristics of 320 GHz semiconductor oscillators, a detector, characteristics of beam splitters and a vacuum window.

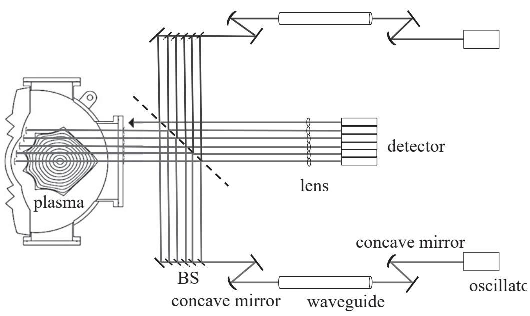


Fig.3 Basic design of a new multi-channel FIR interferometer in Heliotron J

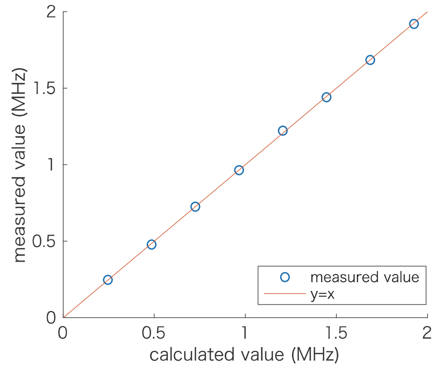


Fig. 4 Beat frequency of detected beat signal. The measured frequency agreed well with the setting value

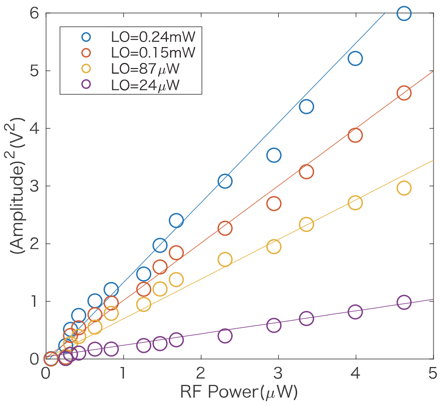


Fig. 5 Response of detector intensity to RF & LO power

Figure 3 shows the basic schematic of multi-channel FIR interferometer design in Heliotron J. The system is a Michelson type heterodyne interferometer where two 320 GHz semiconductor oscillators are employed as light sources. The oscillator for LO produces fixed frequency wave, and the other for RF produces variable frequency wave.

On the test stand of interferometer, we have successfully detected the beat signal which has the beat frequency between two input signals, RF and LO. Here, the LO frequency was fixed at 320.16GHz, and the RF frequency was scanned from 320.16 GHz+0.2MHz to 320.16 GHz +2MHz. Figure 4 shows the relationship between the frequency of detected beat signal and expected beat frequency from the setting value, which shows that observed beat frequency agrees well with the expected one.

The response of the detector has been investigated by scanning the LO and RF power, as shown in Fig.5. The input signal power was set low such that LO power was 24μW and the RF power was less than 1μW. Based on the basic characteristics obtained in this experiment, we will design and construct a new multi-channel FIR interferometer system for Heliotron J.

Collaboration Works

西南物理研究所（中華人民共和国）、IPP, Greifswald（ドイツ）、University of Wisconsin（米国），反射計を用いた電子密度分布・揺動解析，長﨑百伸

IPP, Greifswald（ドイツ），電子サイクロトロン電流駆動の理論解析，長﨑百伸

Purdue University（米国），張力準安定流体中性子検出器を用いた核燃料物質非破壊検知技術に関する研究，増田開

Univ. Wisconsin（米国）、Oak Ridge National Laboratory（米国）、Max Plank Institute（ドイツ）、Stuttgart Univ.（ドイツ）、CIEMAT（スペイン）、Australian National Univ.、（オーストラリア）、Kharkov Institute（ウクライナ）、Southwest Institute of Physics（中華人民共和国），ヘリカル型装置における SOL/ダイバータプラズマに関する研究，水内亨，長﨑百伸，岡田浩之，小林進二，山本聡，南貴司

ANU（オーストラリア），データマイニングを用いた MHD 安定性解析，山本聡、長﨑百伸

Stuttgart University（ドイツ）、CIEMAT（スペイン），ヘリカル磁場配位における乱流揺動研究，大島慎介、長﨑百伸、水内亨、岡田浩之、南貴司、小林進二、山本聡

Stuttgart Univ.、CIEMAT（スペイン），先進閉じ込め配位，長﨑百伸、大島慎介、水内亨、岡田浩之、南貴司、小林進二、山本聡

CIEMAT（スペイン）、Kurchatov Institute（ロシア）、ORNL（米国），低磁気シアヘリカル装置における高速イオン励起 MHD 不安定性に関する研究, 山本聡、小林進二、長﨑百伸、大島慎介、水内亨

核融合科学研究所・双方向型共同研究，磁場分布制御を活用したプラズマ構造形成制御とプラズマ輸送改善，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J、CHS、LHED 装置における重水素プラズマの粒子輸送の研究，水内亨，山本聡，南貴司，大島慎介，小林進二，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，低磁気シアヘリオトロン配位における磁気島に対するプラズマ応答の研究，水内亨，岡田浩之，長﨑百伸，山本聡，小林進二，南貴司

核融合科学研究所・双方向型共同研究，ヘリオトロン J における ICRF 加熱を用いたプラズマの高性能化研究，水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡，木島茂，大島慎介，門信一郎

核融合科学研究所・双方向型共同研究，磁気シアが MHD 不安定性による閉じ込め性能劣化度に与える影響の研究，水内亨，岡田浩之，長﨑百伸，小林進二，山本聡，南貴司

核融合科学研究所・双方向型共同研究，多様な磁場配位を有するヘリカル系プラズマにおけるプラズマフローと磁気島の理解，水内亨，山本聡，小林進二，長﨑百伸，岡田浩之，南貴司，大島慎介

核融合科学研究所・双方向型共同研究，ヘリカル系プラズマにおけるアルヴェン固有モードに起因する高速イオン損失研究, 水内亨, 山本聡, 小林進二, 大島慎介，岡田浩之，南貴司，長﨑百伸，門信一郎

核融合科学研究所・双方向型共同研究，有限ビーム幅を考慮した電子バーンシュタイン波放射計測，水内亨，長﨑百伸，大島慎介，南貴司，山本聡，小林進二，岡田浩之

核融合科学研究所・双方向型共同研究，複合揺動計測によるヘリオトロン J の乱流構造解析，水内亨，長﨑百伸，岡田浩之，南貴司，小林進二，大島慎介

核融合科学研究所・双方向型共同研究，アルベン固有モードによる高速イオン異常輸送の物理過程とその制御に関する研究, 水内亨, 岡田浩之, 南貴司, 長﨑百伸，山本聡，大島慎介，小林進二

核融合科学研究所・双方向型共同研究，マルチチャンネルカロリーメーターによるダイバーター熱流束の計測, 水内亨, 大島慎介, 岡田浩之, 小林進二, 門信一郎

核融合科学研究所・双方向型共同研究，ヘリカルプラズマの不純物輸送に対する同位体効果の影響，水内亨，門信一郎，小林進二，山本聡，大島慎介，南貴司，岡田浩之，長﨑百伸

核融合科学研究所・双方向型共同研究，ヘリオトロン J における VUV 分光法を用いた不純物の計測と輸送の研究, 水内亨, 門信一郎, 岡田浩之, 山本聡, 南貴司，小林進二，長﨑百伸，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J におけるプラズマ高密度化実験，水内亨，門信一郎，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，閉じ込め改善現象に関する 3 次元効果の解明, 水内亨, 南貴司, 小林進二，門信一郎，岡田浩之，長﨑百伸，大島慎介，山本聡，木島滋

核融合科学研究所・双方向型共同研究，ヘリオトロンJにおけるビーム放射分光法を用いた乱流ダイナミクスの研究，水内亨，小林進二，大島慎介，岡田浩之，門信一郎，岡田浩之

核融合科学研究所・双方向型共同研究，電場・磁場揺動を用いた周辺乱流制御の試み—Heliotron J における乱流制御—，水内亨，大島慎介，小林進二，岡田浩之，長﨑百伸，南貴司，山本聡，門信一郎

核融合科学研究所・双方向型共同研究，ヘリカル装置における電極バイアスによるポロイダル粘性遷移の研究，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，荷電交換損失がヘリオトロンJのNBI加熱に与える影響，水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡

Financial Support

1. Grant-in-Aid for Scientific Research

増田開，基盤研究(B)，BNCT 薬物動態評価のための小型／超小型中性子源による B-10 定量分析法の開発

2. Others

長﨑百伸，（公財）関西エネルギー・リサイクル科学研究振興財団，第 21 回国際ステラレーターヘリオトロンワークショップ開催のため

長﨑百伸，（公財）京都大学教育研究振興財団，第 21 回国際ステラレーターヘリオトロンワークショップ開催のため

長﨑百伸，核融合科学研究所・一般共同研究，ECH/ECCDを用いた高エネルギー励起MHD不安定性の制御

長﨑百伸，核融合科学研究所・一般共同研究，次世代先進ヘリカル研究の現状と展望

長﨑百伸，公益財団法人京都文化交流コンベンションビューロー・京都らしい MICE 開催支援助成金，第 21 回国際ステラレーターヘリオトロンワークショップ開催のため

長﨑百伸，公益財団法人京都文化交流コンベンションビューロー・小規模 MICE 開催支援助成金，第 21 回国際ステラレーターヘリオトロンワークショップ開催のため

長﨑百伸，量子科学技術研究開発機構，原型炉における電子サイクロトロン電流駆動効率の改善と入射システムの検討

長﨑百伸，量子科学技術研究開発機構，原型炉における電子サイクロトロン電流駆動効率の改善と入射システムの検討

増田開，（株）アドバンテスト，電子銃周辺空間電荷効果計算

増田開，新エネルギー・産業技術総合開発機構，戦略的基礎技術高度化支援事業（プロジェクト委託型）/世界に先駆けた次世代インフラの構築の実現に資する技術/ポータブル核分裂物質非破壊検知装置によるテロ対策インフラ強化

大島慎介，（公財）京都大学教育研究振興財団，三次元装置における乱流・帯状流に対する水素同位体効果の検証

Publications

A. Ishizawa, Y. Kishimoto, T.-H. Watanabe, H. Sugama, K. Tanaka, S. Satake, S. Kobayashi, K. Nagasaki, Y. Nakamura， Multi-machine analysis of turbulent transport in helical systems via gyrokinetic simulation，Nuclear Fusion，57，66010，2017

B. Archambault, A. Hagen, K. Masuda, N. Yamakawa, R.P. Taleyarkhan，Threshold Rejection Mode Active Interrogationof SNMs Using Continuous Beam DD Neutrons with Centrifugal and Acoustic Tensioned Metastable Fluid Detectors，IEEE Transactions on Nuclear Science，64，1781-1788，2017

K. Nagasaki, K. Sakamoto, N. Inklin, S. Kobayashi, H. Shidara, H. Zushi, M. Sato，Quarter Centrudy Operation of GYCOM Gyrotrons in Heliotron Devices, Kyoto University，Scientific Production Enterprise, GYCOM 25，2017

K. Torgasin, K. Mishima, H. Zen, K. Yoshida, H. Negm, M. Omer, T. Kii, K. Nagasaki, K. Masuda, H. Ohgaki，Thermally assisted photoemission effect on CeB6 and LaB6 for application as photocathodes，Physical Review of Accelerators and Beams Special Topics，https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.20.073401，2017

K. Torgasin, K. Morita, H. Zen, K. Masuda, T. Katsurayama, T. Murata, S. Suphakul, H. Yamashita, T. Nogi, T. Kii, K. Nagasaki, H. Ohgaki，Properties of quarter-wavelegnth coaxial cavity for triode-type thermionic RF gun，Japanese Journal of Applied Physics，https://doi.org/10.7567/JJAP.56.096701，2017

S. Yamamoto, K. Nagasaki, S. Kobayashi, K. Nagaoka, A. Cappa, H. Okada, T. Minami, S. Kado, S. Ohshima, S. Konoshima, Y. Nakamura, A. Ishizawa, G.M. Weir, N. Kenmochi, Y. Ohtani, X. Lu, Y. Tawada, D. Kokubu, T. Mizuuchi, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD on Heliotron J, Nuclear Fision, 57, 12, 2017

T. Kobayashi, S. Kobayashi, X.X. Lu, N. Kenmochi, K. Ida, S. Ohshima, S. Yamamoto, S. Kado, D. Kokubu, K. Nagasaki, H. Okada, T. Minami, Y. Otani, T. Mizuuchi, Response of a core coherent density oscillation on electron cyclotron resonance heating in Heliotron J plasma, Physics of Plasmas, 25, 12513, 2018

増田開，Nuclear Fusion Based Neutron Sources, 日本中性子科学会誌「波紋」，27，3，113-116，2017

大島慎介，清水昭博，多点ラングミュアプローブによる長距離相関実験（Long Range Correlation Experiments with Multiple Langmuir Probes)，プラズマ・核融合学会誌，94，1，3-11，2017017

Presentations

増田開，Development of a portable neutron source based on inertial electrostatic confinement fusion and its application to active interrogation of special nuclear materials ，レーザー・加速器中性子と応用に関する国際会議(CLES/LANSA 2017），パシフィコ横浜，2017.4.18-21

K. Nagasaki，Recent Results from Heliotron J Experiments，3rd UNIST-Kyoto University Workshop on Physics Validation and control of turbulent and MHD in fusion plasmas，京都大学吉田キャンパス，2017.5.8-9

H. Yamashita, K. Masuda, T. Nogi, K. Torgasin, H. Zen, T. Kii, K. Nagasaki, H. Ohgaki，The Influence of Initial Current Density Distribution on the Emittance Reduction，IPAC2017，bella center copenhagen denmark，2017.5.14-19

増田開，R&D on Portable Active Interrogation System for Detecting Shielded Special Nuclear Materials，NCT Europe 2017，Sonthofen, Germany，2017.6.27-29

長﨑百伸，福山淳，出射浩，坂本宜照，諫山明彦，原型炉の電子サイクロトロン電流駆動効率の改善と入射システムの検討状況，第 6 回原型炉設計合同特別チーム全体会合，QST 六ヶ所核融合研究所，2017.7.4

M.A. Bakr, K. Masuda, T. Misawa, Y. Takahashi, Y. Kitamura, M. Yoshida, N. Yamakawa, A. Matsuda, Development of an Active Interrogation system of Special Nuclear Materials By use of Tensioned Metastable Fluid Detector and Compact Neutron Source Based on Inertial Electrostatic Confinement Fusion ，NOP2017，奈良春日野国際フォーラム，2017.7.5-8

山下大樹，増田開，怪方向位相空間分布の自己線形化現象への陰極上電流密度分布による影響評価，2017 年秋の学会，北海道大学，2017.9.13-15

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kaso, K. Nagasaki, N. Kenmochi, Y, Ohtani, X.X. Lu, R. Matoike, M. Motoshima, S. Konoshima, T. Mizuuchi，Role of magnetic topology and isotope mass on long range correlation and turbulence in Helitrton-J，ISHW2017，紫蘭会館，2017.10.2-6

T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, X. X. Lu, N. Kenmochi, Y. Ohtani, K. Nishioka, L. Zang, G. Weir, D. L. Yu, S. Konoshima, A. Ishizawa, Y. Nakamura ，Configuration Control Effects on Confinement, Transport and Stability in a Helical-Axis Heliotron Device, Heliotron J，ISHW2017，紫蘭会館，2017.10.2-6

S. Yamamoto, K. Nagasaki, A. Cappa, K. Nagaoka, S. Kobayashi, E. Ascasibar, F. Castejon, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konochima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshime, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki,G.M. Weir，Suppression of Fast-ion-driven MHD Instabilities by ECH/ECCD in Stellarator/Heliotron，ISHW2017，紫蘭会館，2017.10.2-6

A. Ishizawa, Y. Kishimoto, T.-H. Watanabe, H. Sugama, K. Tanaka, S. Satake, S. Kobayashi, K. Nagasaki, Y. Nakamura, Gyrokinetic analysis of turbulent transport in LHD and Heliotron J plasmas，ISHW2017, 紫蘭会館，2017.10.2-6

K. Masuda，Compact and Intence IEC Neutron Generator Development and Applications Aneutronic Polywell Reactor，The 19th Japan-US Workshop，関西大学，2017.10.17-19

K. Torgasin，Application of TMFD as a neutron detector for SNM Interrogation System，The 19th Japan-US Workshop，関西大学，2017.10.17-19

M. Yoshida，Development of Portable DD-IEC Neutron Source for SNM Interrogation System at Kyoto University，The 19th Japan-US Workshop，関西大学，2017.10.17-19

2018.2.27-28

高田真人, 福田武司, 長﨑百伸, 岡田浩之, 南貴司, 門信一郎, 小林進二, 山本聡, 大島慎介, 木島滋, Xiangxun Lu, 水内亨, 2 チャンネルマイクロ波反射計を用いた密度揺動計測によるヘリオトロン J の閉じ込め特性に関する研究, Plasma 2017 Conference, 姫路商工会議所, 2017.11.20-24

渡邉真太郎, 長﨑百伸, 水内亨, 南貴司, 小林進二, 岡田浩之, 門信一郎, 山本聡, 大島慎介, 木島滋, 中村祐司, 石澤明宏, 呂湘潯, 田野平駿, 土師直之, 米村裕馬, 岡崎悠, 金沢友美, 山本皓貴, ヘリオトロン J における ECH 非吸収ミリ波計測に関する研究, Plasma 2017 Conference, 姫路商工会議所, 2017.11.20-24

大島慎介, 岡田浩之, Zang Lin,小林進二, 山本聡, 南貴司, 門信一郎, 長﨑百伸, 釼持尚輝, 大谷芳明, Lu X.X., 的池遼太, 木島滋, 水内亨, ヘリオトロン J における乱流に対する同位体効果の実験検証, Plasma 2017 Conference, 姫路商工会議所, 2017.11.20-24

出射浩, 坂本宜照, 長﨑百伸, 福山淳, 坂本慶司, 井出俊介, 宇藤裕康, 染谷洋二, 原型炉設計合同特別チーム, 原型炉における電子サイクロトロン加熱電流駆動用ランチャーの概念検討, Plasma 2017 Conference, 姫路商工会議所, 2017.11.20-24

長﨑百伸, ECH/ECCD を用いた高エネルギー粒子励起 MHD 不安定性の制御, Plasma 2017 Conference, 姫路商工会議所, 2017.11.20-24

坂本宜照, 朝倉伸幸, 徳永晋介, 相羽信行, 松山顕信, 若月琢馬, 宮田良明, 林伸彦, 井出俊介, 星野一生, 本間裕貴, 三善悠矢, 長﨑百伸, 出射浩, 福山淳, 前川孝, 新谷吉郎, 柴田欣秀, 宇藤裕康, 染谷洋二, 日渡良爾, 飛田健次, 原型炉設計合同特別チーム, 原型炉概念における物理設計の進展, Plasma 2018 Conference, 姫路商工会議所, 2017.11.20-24

長﨑百伸, 磁場配位制御に関連したヘリオトロン J 実験, NIFS 研究会「次世代先進ヘリカル配位開発に向けたヘリカル研究の現状と展望」, NIFS, 2018.1.9

K. Nagasaki, S. Yamamoto, S. Kobayashi, H. Okada, T. Minami, S. Kado, S. Ohshima, S. Konoshima, Y. Nakamura, A. Ishizawa, X.X. Lu, P. Adulsiriswad, N. Haji, T. Kanazawa, Y. Mizokawa, S. Tanohira, K. Yamamoto, N. Yonemura, S. Watanabe, R. Matoike, T. Mizuuchi, Response of Plasma Performance to Heating and Current Drive in Heliotron J, Japan-Korea Workshop on Physics and Technology of Heating and Current Drive in Fuison Plasmas, 京都大学エネルギー理工学研究所・エネルギー複合機構研究センター北 4 号棟,

Advanced Plasma Energy Research Section

T. Mizuuchi, Professor
T. Minami, Associate Professor
S. Kobayashi, Assistant Professor

1. Introduction

The current subjects of this research section are to study the properties of high temperature plasmas in order to control and improve the plasma energy confinement from the physical viewpoint of nuclear fusion research. The experimental and theoretical investigations for the optimization of the helical-axis heliotron configuration are in progress under the collaboration with other groups of the international/national institutes and also groups of other universities under the auspices of the Collaboration Program of the Lab. Complex Energy Processes, IAE and the Collaborative Research Program of NIFS (National Institute for Fusion Science).

In this report, a remarkable result obtained in the Heliotron J experimental study in FY2017 is reported focusing on radial electric shear formation in high density NBI plasmas based on poloidal flow velocity measurement.

2. Radial electric shear formation in high density NBI plasmas based on poloidal flow velocity measurement [1].

In order to investigate the relation between the confinement improvements and the spatial structure of the radial electric field in the magnetically confined fusion plasmas, a diagnostic system for the poloidal flow velocity measurement has been developed in Heliotron J based on the charge exchange recombination spectroscopy (CXRS). In this study, the poloidal flow velocity was measured in a high density NBI plasmas produced by a novel gas fueling method and the radial electric field and its shear were calculated in the high density plasmas.

The poloidal CXRS system consists of the objective optics, bundle fiber, camera lens monochromator and CCD camera [2]. The system can measure the poloidal flow velocity and the ion temperature of the carbon ion with the observation region of r/a = 0.2-0.9. The CCD framing rate is 400Hz at maximum. The time evolution of the high density experiment with the novel gas fueling method is shown in Fig. 1. The plasma was sustained by a balanced-NBI heating with 600 kW total port-through power. A high density plasma was formed after the turned-off of high intensity gas puffing (HIGP) which is applied at t = 230 – 240 ms. The line averaged electron density increased from $\bar{n}_e = 1.1\times10^{19}$ m^{-3} to 4.6×10^{19} m^{-3} by HIGP. After that the electron density kept constant at t = 260 – 280ms, while the plasma stored energy (W_p) increased significantly from 1.1 to 5.2 kJ, which indicates an increase in the temperature and/or a flattening of the pressure profile.

Figure 2 shows the radial profiles of the electron density, the parallel flow velocity ($V_\parallel$) and the poloidal flow velocity (V_θ) under the low density (t = 230 ms) and the high density (t = 270 ms) conditions. The parallel flow velocity is measured with the CXRS system in which the sightline is set to be parallel to the magnetic field line [3]. Here the radial resolution is in the range of $\Delta r/a$ = 0.02 to 0.1. The co-directed parallel flow is defined as the direction of plasma current which increases the rotational transform. For the poloidal flow, the positive direction is defined as the ion diamagnetic direction. Since the plasma was heated by the balanced NBI, the external momentum input from NBI was expected to be small. In the case of the low density plasma, the parallel flow is in co-direction and the poloidal flow velocity is almost

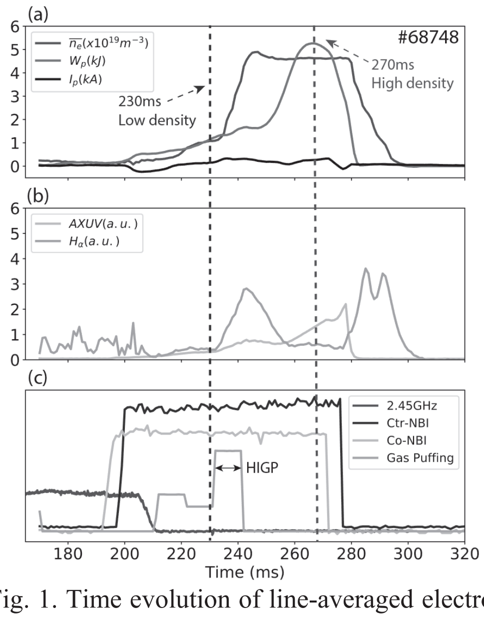


Fig. 1. Time evolution of line-averaged electron density $\bar{n}_e$, stored energy (W_p), toroidal current (I_p), AXUV intensity, H_α intensity, heating and gas puffing obtained in high density NBI plasmas.

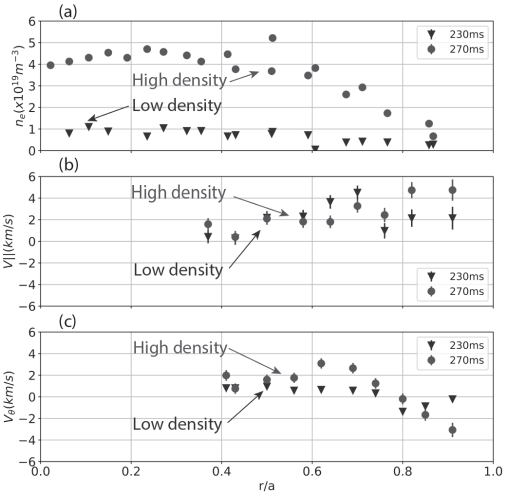


Fig.2 Radial profiles of (a) electron density, (b) parallel flow and (c) poloidal flow velocity in the case of low density (triangle) and high density plasmas (circle).

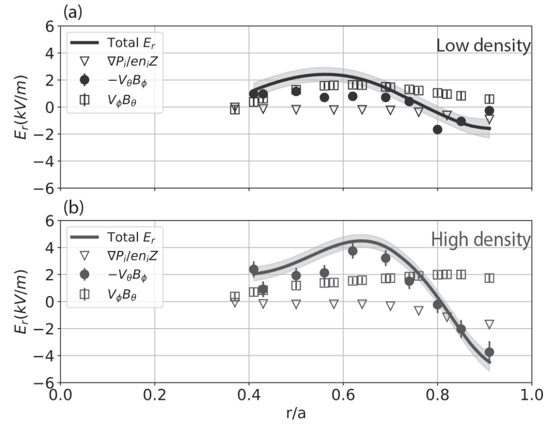


Fig.3 Radial profiles of radial electric field for (a) low density and (b) high density conditions. Each E_r components are plotted: poloidal flow $V_\theta \times B_\phi$ (circle), toroidal flow $V_\phi \times B_\theta$ (square), pressure gradient (triangle) as well as the total E_r.

to be zero at the region of $0.4 < r/a < 0.9$. In the high density case, a poloidal flow velocity shear was observed at the peripheral region ($0.7 < r/a < 0.9$). On the other hand, no significant difference was observed on the parallel flow.

Considering the momentum force balance equation, the radial electric field (E_r) is evaluated with the following equation,

$$E_r = \nabla P_i/en_iZ_i - (V_\theta \times B_\phi - V_\phi \times B_\theta) \quad (1)$$

where ∇P_i is the pressure gradient, e, n_i and Z_i are the electron charge, the ion density and the charge number of the ion, B_θ and B_ϕ are the magnetic field strength in the poloidal and the toroidal direction, respectively. In this case, the fully ionized carbon ion (C^{6+}) is considered as the ion species. To calculate the toroidal flow velocity (V_ϕ), the parallel and the poloidal flow velocity is converted using the formula: $V_\phi = (V_\parallel - V_\theta \sin \alpha) / \cos \alpha$, where α is the pitch angle between the field line and the toroidal direction. Figure 3 shows the radial profile of E_r and the three components ($V_\theta \times B_\phi$, $- V_\phi \times B_\theta$ and $\nabla P_i/en_iZ_i$) in the case of the low density and the high density plasmas, respectively. Under the condition, it is confirmed that the radial electric field is dominated by the poloidal flow component $V_\theta \times B_\phi$, since the toroidal flow $V_\phi \times B_\theta$ and the pressure gradient components $\nabla P_i/en_iZ_i$ are relatively small.

In the case of the low density plasma as shown in Fig. 3(a), E_r at the region of $0.4 < r/a < 0.9$ is almost to be zero. In the case of the high density plasma in Fig. 3(b), on the contrary, a strong negative E_r with large E_r shear is observed at peripheral region ($0.7 < r/a < 0.9$), which is mainly contributed by the poloidal flow shear. The radial electric field in the high density plasma is consistent with the probe data in the previous high density experiment [7]. At the region of $0.4 < r/a < 0.7$ in the high density condition, on the contrary, a positive E_r was observed. Since the positive E_r has been usually observed in the low density ECH plasmas of Heliotron devices, we should discuss the neoclassical particle flux condition with comparison to the neoclassical transport analysis. The E_r shear ($\delta E_r/\delta r$) in the high density plasma at $r/a = 0.8$ is calculated to be -650 kV/m^2, which is much larger than that in the case of the low density plasmas (-210 kV/m^2). In such the case, an improvement in the global energy confinement time was observed. The energy confinement time at the low density condition (8 ms) increased to 17 ms at the high density one. These results indicate that the formation of the E_r shear contributes to the improvement in the energy confinement due to the HIGP method. As shown in Fig. 1, on the contrary, an H-mode transition has not been observed in this discharge. The relation between the formation of the large E_r shear (and position) and the H-mode transition obtained in HIGP method of Heliotron J [4] will be discussed in the near future.

In conclusion, the installation of the new poloidal CXRS systems in Heliotron J enabled us to reveal the spatial structure of the poloidal flow in the high density NBI plasmas. The evaluation of the radial electric field based on the momentum force balance equation shows that the large E_r shear (-650 kV/m^2) is formed at the peripheral region ($r/a = 0.8$) under the high density condition produced by the novel gas fueling method. This indicates that the formation of large E_r shear at the peripheral region is related to the significant improvement in the energy confinement by the HIGP method.

[1] X.X. Lu, S. Kobayashi, et al., accepted to Plasma Fusion Research (2018).
[2] X.X. Lu, et al., submitted to Fusion Eng. Design.
[3] H.Y. Lee, et al., Plasma Phys. Cont. Fusion 55 (2013) 035012.
[4] S. Kobayashi, et al., submitted to Nuclear Fusion.

Collaboration Works

西南物理研究所（中華人民共和国）、CEIMAT（スペイン），SMBI 法の応用，水内亨

IPP, Greifswald（ドイツ），Electron acceleration by non-resonant microwave launch and its application to assist NBI plasma startup，小林進二

Univ. Wisconsin（米国），Study on parallel flow and neoclassical viscosity in magnetically confined plasmas, 小林進二

Univ. Wisconsin（米国）、Oak Ridge National Laboratory（米国）、Max Plank Institute（ドイツ）、Stuttgart Univ.（ドイツ）、CIEMAT（スペイン）、Australian National Univ.、（オーストラリア）、Kharkov Institute（ウクライナ）、Southwest Institute of Physics（中華人民共和国），ヘリカル型装置における SOL/ダイバータプラズマに関する研究，水内亨，長﨑百伸，岡田浩之，小林進二，山本聡，南貴司

Stuttgart Univ.、CIEMAT（スペイン），先進閉じ込め配位，長﨑百伸、大島慎介、水内亨、岡田浩之、南貴司、小林進二、山本聡

CIEMAT（スペイン）、Kurchatov Institute（ロシア）、ORNL（米国），低磁気シアヘリカル装置における高速イオン励起 MHD 不安定性に関する研究, 山本聡、小林進二、長﨑百伸、大島慎介、水内亨

PPPL（米国），低磁気シアヘリカルプラズマにおける高速イオンの異常輸送ならびに損失機構に関する研究，山本聡、小林進二

核融合科学研究所・双方向型共同研究，磁場分布制御を活用したプラズマ構造形成制御とプラズマ輸送改善，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J、CHS、LHED 装置における重水素プラズマの粒子輸送の研究，水内亨，山本聡，南貴司，大島慎介，小林進二，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，低磁気シアヘリオトロン配位における磁気島に対するプラズマ応答の研究，水内亨，岡田浩之，長﨑百伸，山本聡，小林進二，南貴司

核融合科学研究所・双方向型共同研究，ヘリオトロン J における ICRF 加熱を用いたプラズマの高性能化研究，水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡，木島茂，大島慎介，門信一郎

核融合科学研究所・双方向型共同研究，高性能磁場閉じ込めプラズマを目指した粒子補給法の検討（ヘリオトロン J におけるプラズマ高密度化に向けた粒子補給法の模索），水内亨，小林進二，岡田浩之，

核融合科学研究所・双方向型共同研究，磁気シアが MHD 不安定性による閉じ込め性能劣化度に与える影響の研究，水内亨，岡田浩之，長﨑百伸，小林進二，山本聡，南貴司

核融合科学研究所・双方向型共同研究，多様な磁場配位を有するヘリカル系プラズマにおけるプラズマフローと磁気島の理解，水内亨，山本聡，小林進二，長﨑百伸，岡田浩之，南貴司，大島慎介

核融合科学研究所・双方向型共同研究，ヘリカル系プラズマにおけるアルヴェン固有モードに起因する高速イオン損失研究, 水内亨, 山本聡, 小林進二, 大島慎介，岡田浩之，南貴司，長﨑百伸，門信一郎

核融合科学研究所・双方向型共同研究，有限ビーム幅を考慮した電子バーンシュタイン波放射計測, 水内亨，長﨑百伸，大島慎介，南貴司，山本聡，小林進二，岡田浩之

核融合科学研究所・双方向型共同研究，複合揺動計測によるヘリオトロン J の乱流構造解析，水内亨，長﨑百伸，岡田浩之，南貴司，小林進二，大島慎介

核融合科学研究所・双方向型共同研究，アルベン固有モードによる高速イオン異常輸送の物理過程とその制御に関する研究, 水内亨, 岡田浩之, 南貴司, 長﨑百伸，山本聡，大島慎介，小林進二

核融合科学研究所・双方向型共同研究，マルチチャンネルカロリーメーターによるダイバーター熱流束の計測, 水内亨, 大島慎介, 岡田浩之, 小林進二, 門信一郎

核融合科学研究所・双方向型共同研究，ヘリカルプラズマの不純物輸送に対する同位体効果の影響，水内亨，門信一郎，小林進二，山本聡，大島慎介，南貴司，岡田浩之，長﨑百伸

核融合科学研究所・双方向型共同研究，ヘリオトロン J における VUV 分光法を用いた不純物の計測と輸送の研究, 水内亨, 門信一郎, 岡田浩之, 山本聡，南貴司，小林進二，長﨑百伸，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J におけるプラズマ高密度化実験，水内亨，門信一郎，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，閉じ込め改善現象に関する 3 次元効果の解明, 水内亨, 南貴司，小林進二，門信一郎，岡田浩之，長﨑百伸，大島慎介，山本聡，木島滋

核融合科学研究所・双方向型共同研究，ヘリオトロンJにおけるビーム放射分光法を用いた乱流ダイナミクスの研究，水内亨，小林進二，大島慎介，岡田浩之，門信一郎，岡田浩之

核融合科学研究所・双方向型共同研究，電場・磁場揺動を用いた周辺乱流制御の試み—Heliotron Jにおける乱流制御—，水内亨，大島慎介，小林進二，岡田浩之，長﨑百伸，南貴司，山本聡，門信一郎

核融合科学研究所・双方向型共同研究，ヘリカル装置における電極バイアスによるポロイダル粘性遷移の研究，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，燃焼炉心プラズマ研究に向けた高エネルギー粒子物理と熱化粒子新古典理論の統合，水内亨，岡田浩之，小林進二，山本聡，南貴司

核融合科学研究所・双方向型共同研究，荷電交換損失がヘリオトロンJのNBI加熱に与える影響，水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡

核融合科学研究所・LHD 共同研究，超高速荷電交換再結合分光装置の開発に基づくトロイダル回転速度の揺動計測，小林進二

核融合科学研究所・一般共同研究，京都大学におけるヘリオトロン磁場閉じ込めプラズマ研究に関するアーカイブス活動，水内亨

核融合科学研究所・一般共同研究，干渉計のための完全デジタル型位相計の開発，南貴司

日米科学技術協力事業（核融合分野），先進ヘリカル装置おけるビーム放射分光計測開発，小林進二

Financial Support

1. Grant-in-Aid for Scientific Research

小林進二，基盤研究(C)，ビーム放射分光イメージング開発に基づく H モード遷移前駆振動における乱流揺動の研究

2. Others

水内亨，核融合科学研究所，双方向型共同研究

Publications

K. Hata, K. Fukuda, T. Mizuuchi, Natural Convection Heat Transfer From Vertical 5×5 Rod Bundles in Liquid Sodium, Journal of Heat Transfer, 139, 3, 032502-1-032502-11, 2017

N. Kenmochi, T. Minami, C. Takahashi, S. Mochizuki, K. Nishioka, S. Kobayashi, K. Nagasaki, Y. Nakamura, H. Okada, S. Kado, S. Yamamoto, S. Ohshima, S. Konoshima, G.M. Weir, Y. Otani, T. Mizuuchi, Characteristics of electron internal transport barrier in Heliotron J, Plasma Physics and Controlled Fusion, 59, 5, 055013-1-055013-8, 2017

A. Ishizawa, Y. Kishimoto, T.-H. Watanabe, H. Sugama, K. Tanaka, S. Satake, S. Kobayashi, K. Nagasaki, Y. Nakamura, Multi-machine analysis of turbulent transport in helical systems via gyrokinetic simulation, Nuclear Fusion, 57, 6, 066010-1-066010-13, 2017

Y. Ohtani, K. Tanaka, T. Minami, S. Ohshima, K. Nagasaki, T. Akiyama, Y. Nakamura, H. Okada, S. Kado, S. Kobayashi, S. Yamamoto, N. Kenmochi, X. Lu, S. Konoshima, T. Mizuuchi, Initial Results of Density Modulation Experiment for Study of Hydrogen Isotope Effects on Particle Transport in Heliotron J, Journal of the Physical Society of Japan, 86, 6, 064501-1-064501-5, 2017

Y. Takeiri, T. Morisaki, M. Osakabe, M. Yokoyama, S. Sakakibara, H. Takahashi, Y. Nakamura, T. Oishi, G. Motojima, S. Murakami, K. Ito, A. Ejiri, S. Imagawa, S. Inagaki, M. Isobe, S. Kubo, S. Masamune, T. Mito, I. Murakami, K. Nagaoka, K. Nagasaki, K. Nishimura, M. Sakamoto, R. Sakamoto, T. Shimozuma, K. Shinohara, H. Sugama, K. Y. Watanabe, J. W. Ahn, N. Akata, T. Akiyama, N. Ashikawa, J. Baldzuhn, T. Bando, E. Bernard, F. Castejón, H. Chikaraishi, M. Emoto, T. Evans, N. Ezumi, K. Fujii, H. Funaba, M. Goto, T. Goto, D. Gradic, Y. Gunsu, S. Hamaguchi, H. Hasegawa, Y. Hayashi, C. Hidalgo, T. Higashiguchi, Y. Hirooka, Y. Hishinuma, R. Horiuchi, K. Ichiguchi, K. Ida, T. Ido, H. Igami, K. Ikeda, S. Ishiguro, R. Ishizaki, A. Ishizawa, A. Ito, Y. Ito, A. Iwamoto, S. Kamio, K. Kamiya, O. Kaneko, R. Kanno, H. Kasahara, D. Kato, T. Kato, K. Kawahata, G. Kawamura, M. Kisaki, S. Kitajima, W.H. Ko, M. Kobayashi, S. Kobayashi, T. Kobayashi, K. Koga, A. Kohyama, R. Kumazawa, J.H. Lee, D. López-Bruna, R. Makino, S. Masuzaki, Y. Matsumoto, H. Matsuura, O. Mitarai, H. Miura, J. Miyazawa, N. Mizuguchi, C. Moon, S. Morita, T. Moritaka, K. Mukai, T. Muroga, S. Muto, T. Mutoh, T. Nagasaka, Y. Nagayama, N. Nakajima, Y. Nakamura, H. Nakanishi, H. Nakano, M. Nakata, Y. Narushima, D. Nishijima, A. Nishimura, S. Nishimura, T. Nishitani, M. Nishiura, Y. Nobuta, H. Noto, M. Nunami, T. Obana, K. Ogawa, S. Ohdachi, M. Ohno, N. Ohno, H. Ohtani, M. Okamoto, Y. Oya, T. Ozaki, B. J. Peterson, M. Preynas, S. Sagara, K. Saito, H. Sakaue, A. Sanpei, S. Satake, M. Sato, T. Saze,

O. Schmitz, R. Seki, T. Seki, I. Sharov, A. Shimizu, M. Shiratani, M. Shoji, C. Skinner, R. Soga, T. Stange, C. Suzuki, Y. Suzuki, S. Takada, K. Takahata, A. Takayama, S. Takayama, Y. Takemura, Y. Takeuchi, H. Tamura, N. Tamura, H. Tanaka, K. Tanaka, M. Tanaka, T. Tanaka, Y. Tanaka, S. Toda, Y. Todo, K. Toi, M. Toida, M. Tokitani, T. Tokuzawa, H. Tsuchiya, T. Tsujimura, K. Tsumori, S. Usami, J.L. Velasco, H. Wang, T.-H. Watanabe, T. Watanabe, J. Yagi, M. Yajima, H. Yamada, I. Yamada, O. Yamagishi, N. Yamaguchi, Y. Yamamoto, N. Yanagi, R. Yasuhara, E. Yatsuka, N. Yoshida, M. Yoshinuma, S. Yoshimura, Y. Yoshimura, Extension of the operational regime of the LHD towards a deuterium experiment, Nuclear Fusion, 57, 10, 102023-1-102023-10, 2017

S. Yamamoto, K. Nagasaki, S. Kobayashi, K. Nagaoka, A. Cappa, H. Okada, T. Minami, S. Kado, S. Ohshima, S. Konoshima, Y. Nakamura, A. Ishizawa, G.M. Weir, N. Kenmochi, Y. Ohtani, X. Lu, Y. Tawada, D. Kokubu, T. Mizuuchi, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD on Heliotron J, Nuclear Fusion, 57, 12, 126065-1-126065-9, 2017

S. Kobayashi, X.X. Lu, K. Ida, T. Kobayashi, M. Yoshinuma, S. Kado, S. Ohshima, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, D.L. Yu, Y. Nakamura, A. Ishizawa, S. Nishimura, K. Nishioka, S. Konoshima, T. Mizuuchi, Development of ultra-fast charge exchange recombination spectroscopy for temperature and flow velocity fluctuation measurements in Heliotron J, 44th EPS Conference on Plasma Physics, 2017

X.X. Lu, S. Kobayashi, R. Seki, K.Y. Watanabe, D.L. Yu, K. Nagasaki, S. Kado, H. Okada, T. Minami, S. Ohshima, S. Yamamoto, Y. Otani, N. Kenmochi, A. Ishizawa, Y. Nakamura, S. Konoshima, T. Mizuuchi, Heat transport analysis in high density NBI plasmas of Heliotron J, 44th EPS Conference on Plasma Physics, 2017

T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, X.X. Lu, N. Kenmochi, Y. Ohtani, K. Nishioka, L. Zang, G. Weir, D.L. Yu, S. Konoshima, A. Ishizawa, Y. Nakamura, Configuration Control Effects on Confinement, Transport and Stability in a Helical-Axis Heliotron Device, Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), 2017

T. Minami, T. Akiyama, Y. Itoh , S. Ohshima, H. Nakanishi, I. Yamada, H. Funaba, R. Yasuhara , Development of high speed full digital processing phase detector for interferometer using the Nd:YAG Thomson scattering ADC , International Stellarator-Heliotron Workshop (ISHW2017), 2017

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kado, K. Nagasaki, N. Kenmochi, Y. Ohtani, X.X. Lu, R. Matoike, M. Motoshima, S. Konoshima, T. Mizuuchi, Role of magnetic topology and isotope mass on long range correlation and turbulence in Heliotron-J , International Stellarator-Heliotron Workshop (ISHW2017), 2017

S. Yamamoto, K. Nagasaki, Á. Cappa, K. Nagaoka, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD in stellarator/heliotron, International Stellarator-Heliotron Workshop (ISHW2017), 2017

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, Y. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi, Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Heliotron J , International Stellarator-Heliotron Workshop (ISHW2017), 2017

N. Kenmochi, T. Minami, C. Takahashi, K. Nishioka, S. Kobayashi, K. Nagasaki, Y. Nakamura, H. Okada, S. Kado, S. Yamamoto, S. Ohshima, S. Kobayashi, T. Mizuuchi, Effects of Rational Surface on Electron Internal Transport Barrier Formation in Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), 2017

N. Nishino, Y. Ishida, T. Mizuuchi, H. Okada, S. Ohshima, S. Kobayashi, T. Minami, S. Kado, S. Yamamoto, K. Nagasaki, H. Kawazome, Reconstruction of 3D information on peripheral fluctuation using fast camera image and magnetic field calculation in Heliotron J , International Stellarator-Heliotron Workshop (ISHW2017), 2017

Y. Matsumoto, S. Kobayashi, R. Seki, Contribution of Re-entering Particles to NBI Heating in Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), 2017

A. Ishizawa, Y. Kishimoto, T.-H. Watanabe, H. Sugama, K. Tanaka, S. Satake, S. Kobayashi, K. Nagasaki, Y. Nakamura, Gyrokinetic analysis of turbulent transport in LHD and Heliotron J plasmas, International Stellarator-Heliotron Workshop (ISHW2017), 2017

L. Zang, D.L. Yu, T. Mizuuchi, S. Kobayashi, S. Ohshima, N. Kenmochi, X.X. Lu, C.Y. Chen, J. Cheng, W.L. Zhong, Y.G. Li, Y. Ohtani, S. Konoshima, S. Yamamoto, K. Nagasaki, N. Nishino, H. Okada, T. Minami, K. Nagasaki, Y. Nakamura, B.B. Feng, Z.B. Shi, L.W. Yan, M. Xu, X. R. Duan, Heliotron J team and HL-2A team, Effects of intensive gas pulse fuelling in Heliotron J and some comparisons with HL-2A , International Stellarator-Heliotron Workshop (ISHW2017), 2017

H. Matsuura, Y. Yamamoto, S. Ohshima, T. Mizuuchi, Y. Suzuki, Construction of calorimeter system for divertor heat flux monitoring, International Stellarator-Heliotron Workshop (ISHW2017), 2017

M.M. Islam, Y. Nakashima, S. Kobayashi, N. Nishino, K. Ichimura, T. Iijima, M.S. Islam, T. Yokodo, G. Lee, T. Yoshimoto, S. Yamashita, M. Yoshikawa, J. Kohagura, M. Hirata, R. Minami, T. Kariya, R. Ikezoe, M. Ichimura, M. Sakamoto, T. Imai, Study of Plasma behavior during ECRH injection in the GAMMA 10 SMBI experiments, IOP Conf. Series: Journal of Physics: Conf. Series, 959, 12007, 2017

Presentations

S. Kobayashi, X.X. Lu, K. Ida, T. Kobayashi, M. Yoshinuma, S. Kado, S. Ohshima, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, D.L. Yu, Y. Nakamura, A. Ishizawa, S. Nishimura, K. Nishioka, S. Konoshima, T. Mizuuchi, Development of ultra-fast charge exchange recombination spectroscopy for temperature and flow velocity fluctuation measurements in Heliotron J, 44th EPS Conference on Plasma Physics, Waterfront Hall, 2017.6.26-30

X.X. Lu, S. Kobayashi, R. Seki, K.Y. Watanabe, D.L. Yu, K. Nagasaki, S. Kado, H. Okada, T. Minami, S. Ohshima, S. Yamamoto, Y. Otani, N. Kenmochi, A. Ishizawa, Y. Nakamura, S. Konoshima, T. Mizuuchi, Heat transport analysis in high density NBI plasmas of Heliotron J, 44th EPS Conference on Plasma Physics, Waterfront Hall, 2017.6.26-30

小林進二，高性能磁場閉じ込めプラズマを目指した粒子補給法の検討 （開放端磁場プラズマにおける高密度化に向けた粒子供給と中性粒子挙動），筑波大学プラズマ研究センターシンポジウム，つくばイノベーションプラザ，2017.8-3-4

H. Okada, K. Nagasaki, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, N. Kenmochi, Y. Otani, X. Lu, K. Ida, K. Watanabe, Nagaoka, T. Kobayashi, G. Motojima, R. Seki, K.H. Kasahara, Y. Suzuki, M. Yokoyama, A. Ishizawa, Y. Nakamura, N. Nishino, Y. Nakashima, G. Weir, S. Murakami8, S. Konoshima, T. Mizuuchi, Studies of Magnetic Field Configuration in Heliotron J, 1st Asia-Pacific Conference on Plasma Physics, Jinniu Hotel, 2017.9.18-23

T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, X.X. Lu, N. Kenmochi, Y. Ohtani, K. Nishioka, L. Zang, G. Weir, D.L. Yu, S. Konoshima, A. Ishizawa, Y. Nakamura, Configuration Control Effects on Confinement, Transport and Stability in a Helical-Axis Heliotron Device, Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kado, K. Nagasaki, N. Kenmochi, Y. Ohtani, X.X. Lu, R. Matoike, M. Motoshima, S. Konoshima, T. Mizuuchi, Role of magnetic topology and isotope mass on long range correlation and turbulence in Heliotron-J, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kado, K. Nagasaki, N. Kenmochi, Y. Ohtani, X.X. Lu, R. Matoike, M. Motoshima, S. Konoshima, T. Mizuuchi, Role of magnetic topology and isotope mass on long range correlation and turbulence in Heliotron-J, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

S. Yamamoto, K. Nagasaki, Á. Cappa, K. Nagaoka, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD in stellarator/heliotron, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

T. Minami, T. Akiyama, Y. Itoh, S. Ohshima, H. Nakanishi, I. Yamada, H. Funaba, R. Yasuhara, Development of high speed full digital processing phase detector for interferometer using the Nd:YAG Thomson scattering ADC, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, Y. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi, Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Heliotron J，International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

N. Kenmochi, T. Minami, C. Takahashi, K. Nishioka, S. Kobayashi, K. Nagasaki, Y. Nakamura, H. Okada, S. Kado, S. Yamamoto, S. Ohshima, S. Kobayashi, T. Mizuuchi，Effects of Rational Surface on Electron Internal Transport Barrier Formation in Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

N. Nishino, Y. Ishida, T. Mizuuchi, H. Okada, S. Ohshima, S. Kobayashi, T. Minami, S. Kado, S. Yamamoto, K. Nagasaki, H. Kawazome，Reconstruction of 3D information on peripheral fluctuation using fast camera image and magnetic field calculation in Heliotron J，International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

Y. Matsumoto, S. Kobayashi, R. Seki，Contribution of Re-entering Particles to NBI Heating in Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

A. Ishizawa, Y. Kishimoto, T.-H. Watanabe, H. Sugama, K. Tanaka, S. Satake, S. Kobayashi, K. Nagasaki, Y. Nakamura, Gyrokinetic analysis of turbulent transport in LHD and Heliotron J plasmas，International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

L. Zang, D.L. Yu, T. Mizuuchi, S. Kobayashi, S. Ohshima, N. Kenmochi, X.X. Lu, C.Y. Chen, J. Cheng, W.L. Zhong, Y.G. Li, Y. Ohtani, S. Konoshima, S. Yamamoto, K. Nagasaki, N. Nishino, H. Okada, T. Minami, K. Nagasaki, Y. Nakamura, B.B. Feng, Z.B. Shi, L.W. Yan, M. Xu, X.R. Duan, Heliotron J team and HL-2A team，Effects of intensive gas pulse fuelling in Heliotron J and some comparisons with HL-2A，International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

H. Matsuura, Y. Yamamoto, S. Ohshima, T. Mizuuchi, Y. Suzuki，Construction of calorimeter system for divertor heat flux monitoring，International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

H. Takahashi, K. Nagaoka, K. Mukai, M. Yokoyama, S. Murakami, S. Ohdachi, T. Bando, Y. Narushima, H. Nakano, M. Osakabe, K. Ida, M. Yoshinuma, R. Seki, K. Tanaka, M. Nakata, T. Oishi, M. Goto, S. Morita, T.I. Tsujimura, S. Kubo, T. Kobayashi, T. Ido, A. Shimizu, T. Tokuzawa, K. Nagasaki, T. Morisaki, Y. Takeiri and the LHD Experiment Group，Confinement characteristics of ion ITB plasmas with deuterium in the LHD，International Stellarator-Heliotron Workshop (ISHW2017)，Shiran-Kaikan, Kyoto University，2017.10.2-6

K. Nagasaki, S. Yamamoto, K. Nagaoka, Á. Cappa, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir，Control of Energetic-Particle-Driven MHD Instabilities by ECH/ECCD, Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

T. Minami, Na. Kenmochi, Y. Yonemura, C. Takahashi, G. Weir, K. Nishioka, K. Nagasaki, H. Okada, S. Kado, S. Yamamoto, S. Ohshima, S. Konoshima, Y. Nakamura, A. Ishizawa, T. Mizuuchi，Effect of 3D magnetic structure on electron internal transport barrier formation in Heliotron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

Y. Yonemura, T. Minami, N. Kenmochi, R. Yasuhara, S. Kobayashi, K. Nagasaki, H. Okada, S. Kado, S. Yamamoto, S. Ohshima, S. Konoshima, Y. Nakamura, X. Lu, S. tanohira, N. Haji, S. Watanabe, H. Okazaki, T. Kanazawa, K. Yamamoto, T. Mizuuchi，Development of multi-pass Thomson scattering measurement system in Heliotron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

H. Naoyuki, T. Mizuuchi, N. Nishino, S. Kobayashi, T. Minami, H. Okada, S. Kado, S. Yamamoto, K. Nagasaki, S. Ohshima, X. Lu, S. Tanohira, S. Watanabe, Y. Yonemura, T. Kanazawa, K. Yamamoto, H. Okazaki, S. Konoshima, Y. Nakamura, A. Ishizawa，Analyses of fast camera images for edge-plasma fluctuation characteristics during L-H transition in Heliotron J high-density plasma，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Tanohira, S. Kobayashi, X. Lu, T. Minami, H. Okada, K. Nagasaki, S. Yamamoto, S. Ohshima, S. Kado, S. Nishimura, Y. Narushima, S. Satake, T. Kanazawa, K. Yamamoto, H. Okazaki, S. Watanabe, N. Haji, Y. Yonemura, Y. Nakamura, A. Ishizawa, S. Konoshima, T. Mizuuchi，Poloidal flow measurement with Charge-eXchange Recombination Spectroscopy in Heliotron J(2)，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Watanabe, K. Nagasaki, T. Mizuuchi, T. Minami, S. Kobayashi, H. Okada, S. Kado, S. Yamamoto, S. Oshima, S. Konoshima, Y. Nakamura, A. Ishizawa, X. Lu, S. Tanohira, N. Haji, Y. Yonemura, H. Okazaki, T. Kanazawa, K. Yamamoto，Study of ECH stray millimeter wave radiation measurement in Heliotron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Yamamoto, Y. Tawada, K. Ogawa, M. Isobe, S. Kobayashi, K. Nagasaki, P. Adulsiriswad, H. Okada, S. Kado, T. Minami, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, N. Kenmochi, Y. Ohtani, X. Lu, T. Mizuuchi，Study of interplay between fast-ions and MHD instabilities in Heliotron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi, X. Lu, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, H. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi，Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Helitoron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Kado, A. Iwata, T. Kanazawa, H. Okada, S. Yamamoto, T. Minami, S. Kobayashi, K. Nagasaki, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, T. Mizuuchi，Application of Near-Infrared Spectroscopy to Heliotron J Plasma，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kado, K. Kazunobu, N. Kenmochi, Y. Ohtani, X.X. Lu, R. Matoike, S. Konoshima, T. Mizuuchi，The Study of Isotope Effect on Turbulence in Heliotron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

H. Okazaki, G. Motojima, H. Okada, K. Nagasaki, Y. Nakamura, S. Kado, S. Kobayashi, S. Konoshima, T. Minami, S. Yamamoto, S. Ohshima, X. Lu, T. Kanazawa, K. Yamamoto, S. Tanohira, S. Watanabe, N. Haji, Y. Yonemura, T. Mizuuchi，Optimization study of cryogenic hydrogen pellet injection for fueling in Heliotron J, Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

Y. Yamamoto, H. Matsuura, S. Ohshima, T. Mizuuchi，Heat flux monitor by improvement of Heliotron J divertor probe array，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Yoshioka, S. Masamune, S. Kunita, M. Emori, H. Makizawa, C. Tada, A. Sanpei, H. Himura, T. Akiyama, A. Mizuchi, K. McCollam, D.D. Hartog，Initial results from supersonic gas injection experiment for fueling in RELAX RFP，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

M. Yoshikawa, J. Kohagura, Y. Shima, M. Chikatsu, M. Sakamoto, R. Minami, N. Ezumi, Y. Nakashima, R. Yasuhara, I. Yamada, H. Funaba,T. Minami, N. Kenmochi，Development of Thomson scattering system in the tandem mirror GAMMA 10/PDX，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

M.M. Islam, Y. Nakashima, S. Kobayashi, N. Nishino, K. Hosoi, K. Ichimura, M. S. Islam, K. Fukui, M. Ohuchi, T. Yokodo, G. Lee, S. Yamashita, T. Yoshimoto, M. Yoshikawa, J. Kohagura, M. Hirata, R. Ikezoe, M. Ichimura, M. Sakamoto, T. Imai，Investigation of Plasma Behavior during ECRH Injection in the GAMMA 10 SMBI Experiments，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

Advanced Energy Research Section

Antonio José Junqueira Botelho, Visiting Professor
(Full Professor, Graduate Program in Political Sociology,
IUPERJ/Universidade Candido Mendes,
Rua da Assembleia 10 Sala 702 – Centro
CEP 20011-901 - Rio de Janeiro – RJ, Brazil)

1. Summary

The author spent three months (Dec. 1, 2017-Feb. 28, 2018) as a visiting professor at the Uji campus of Kyoto University, hosted by the Associate Professor Hooman Farzaneh research group Multiple Benefits Assessment of the Low Emission Development Strategies in Asia Pacific Cities.

During this period the author participated as co-organizer and session commentator in the February,1-3, 2018 Japan-Brazil Joint Workshop "Towards Sustainable Urban Energy Systems: Experiences from Asia and Latin America" and as a presenter in the February, 3, 2018 3rd International Workshop on Clean Energy Development in Asian Cities with the paper "Governing the Urban Commons: Experimentalist Governance for Resilient Climate Co-Benefits Governance Regime." Subsequently he made a presentation to Ohgaki -sensei Laboratory, Quantum Radiation Energy Research Section, Advanced Energy Research Division, Institute of Advanced Energy, Kyoto University Uji Campus, on 27 March 2018 entitled "Governing the Urban Commons of Kuala Lumpur: Experimentalist Governance for Resilient Climate Co-Benefits Regime."

Here the author reports about his investigation on the development of local governance studies for implementation in 6 Asian megacities: Delhi, Kuala Lampur, Seoul, Shangai, Sidney and Tokyo.

2. Introduction

The overall project aims to develop and demonstrate a new strategic planning mechanism for achieving multiple benefits of Low Emission Development Strategies (LEDS) in Asia-Pacific cities, together with a robust analytical framework that can be used to assess those benefits during the development and implementation process. The research: 1) plans to develop a modelling framework in order to quantify the effect of LEDS on four main areas of energy systems, environment, public health and local economy at the city level; 2) create an executive package of policies with an assessment of implementation challenges in each city and 3) develop a strategic plan of the urban multiple benefits of LEDS based on the comparative analysis among the selected cities as the main output of this research.

The six global cities which are evaluated in detail in this research consists of: Tokyo, Sydney, Shanghai, Kuala Lumpur, Seoul and Delhi. The research focus is on 'Buildings', 'Waste' and 'Transport' as the key sectors as they can offer substantial urban climate mitigation potential through the implementation of LEDS in the selected cities.
Project link:
http://www.apn-gcr.org/resources/items/show/2078

3. Experimentalist Governance for Resilient Climate Co-Benefits Regime in Asian Mega Cities

A main challenge facing Asian mega cities seeking win-win intervention towards a sustainable maximization of climate co-benefits lies in the complex governance of policy implementation. These urban commons such as as Greater Kuala Lumpur, Malaysia, are nested within multiple governmental levels (federal, regional, state, metropolitan, province, county and municipal) and have diverse institutional arrangements for the provision of services and infrastructure to their population as well as for the promotion of development and a healthy environment. Further, they also have contrasting arrangements for both aggregating and processing demands (shaping patterns of collective action), delivering results (implementation) and communicating outputs to their different constituencies. Thus, the practical politics of urban climate co-benefits policy implementation is fraught with conflict and misunderstandings. These are further amplified in the urban commons by the long-term, fragmented and uncertain nature of the co-benefits. This paper suggests that the experimentalist governance may contribute to the construction of a resilient governance framework for the implementation of policy towards climate co-benefits. The approach was originally developed to provide a resilient, self-evolving analytic routine for the design of experimentalist governance of sticky, complex, multi-level policy problems under conditions of strategic uncertainty. As it is informed by a pragmatic, practice-oriented experimentalism theory, it promotes deliberation and self-calculation in recursive relations among actors with diverse interests and views, analogously one can suggest that it may also incorporate the diverse and contradictory relations among urban commons' governmental actors and stakeholders, as well as recipient citizens, the last critical link in the implementation phase. The wide scope of recent applications of experimentalism governance to build alternative frameworks for the promotion of policy regimes in contexts characterized by strategic uncertainty, including global and transnational climate change regimes, seem to indicate the promise of its application to the implementation of climate co-benefits policy in urban commons.

Advanced Energy Research Section

Linge Zang, Foreign Visiting Researcher
(Associate Professor in Southwestern Institute of Physics, No 5, Huangjing Road, Shuangliu County, Chengdu, Sichuan 610225, China)

1. Introduction

The author spent six months (Oct, 2nd, 2017-Mar, 29th, 2018) as a guest associate professor at the Uji campus of Kyoto University, hosted by the Heliotron J group.

Here the author reports about the investigation on an edge localized low-frequency Alfvén eigenmode (LF-AE) in Heliotron J.

In theory, discrete Alfvén eigenmodes (AEs) existing in the gap of Alfvén continuum [1] could be destabilized by tapping the free energy source associated with the energetic particle pressure gradient through wave-particle interaction [2]. An evidence for this theory is the recent experiment which shows that AEs are more destabilized in on-axis beam case than in off-axis case in DIII-D [3]. On the other hand, AE induced lost ions is commonly observed in experiment [4]. The loss of energetic ion could reduce the heating efficiency of alpha particle or beam/RF. AEs has caused up to 70% loss of injected fast beam ions in the DIII-D tokamak [5]. In addition, lost ion could directly hit the first wall, break the surface material and cause damage to the device. AE is one of the most concerned instabilities for ITER [6,7]. Therefore, study of AEs is an important issue for future fusion devices.

2. Experimental results

(1)Plasma conditions for mode observation

The LF-AE is steadily observed in NBI heated, co-current flowing plasmas in standard configuration of Heliotron J. In a dedicated experiment day of *FY*2017 for LF-AE study, a fix-conditioned discharge series of seven shots was performed for profile measurements. The experimental conditions are as follows: standard configuration, with rotational transform 0.554-0.558 in the vacuum condition; co-NBI power of 180*kW* and ctr-NBI power of nearly zero; total plasma current up to 1.25*kA* in co-direction; averaged electron density $n_e = (0.5–1.5)\times10^{19}\ m^{-3}$; central electron temperature $T_e(0) \sim 0.2$-0.4 *keV*.

Figure 1 shows a typical discharge when LF-AE is observed. EPM of 90-80*kHz* is observed throughout the discharge. Observed frequency of LF-AE is about 40-20*kHz* in this discharge. Fluctuation power of LF-AE is comparable with EPM. Mode frequency decreases as averaged density ramps up. Sidebands are simultaneously observed sometimes. Plasma current for the mode emergence is I_p=0.91kA in co-direction.

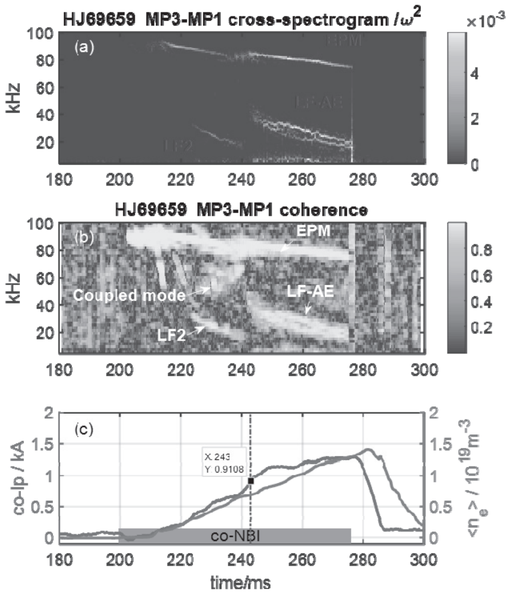


Figure 1. (a)Cross spectrogram of two toroidally separated mirnov coils, MP3 and MP1. (b) Coherence-gram of MP3 and MP1; (c) Plasma current and averaged density.

(2)Mode characteristics

Density fluctuation of LF-AE measured by a beam-emission spectroscopy system locates at *rho* > 0.71, and peaks at *rho* = 0.86-0.91. Toroidal mode number is n=1 (or -3, 5). Mode rotates in ion diamagnetic direction, and poloidal mode number is quite high, m~7-8. High mode number is confirmed by both mirnov coils and fast imaging camera. High m number induced significant Doppler shift from the background poloidal flow. The real frequency is calculated with,

$$f^* = f_{ob} - V_\theta k_\theta/2\pi \qquad (1)$$

V_θ is the background poloidal flow is measured by a Langmuir probe array or a poloidal CXRS system. Doppler corrected frequency, say, real frequency of LF-AE is about 34-46 kHz with the total axis magnetic field B_0=1.28T. Figure 2 shows real frequency f^* linearly depends on $B_0/\langle n_e\rangle^{1/2}$, indicating the mode is an Alfvén eigenmode.

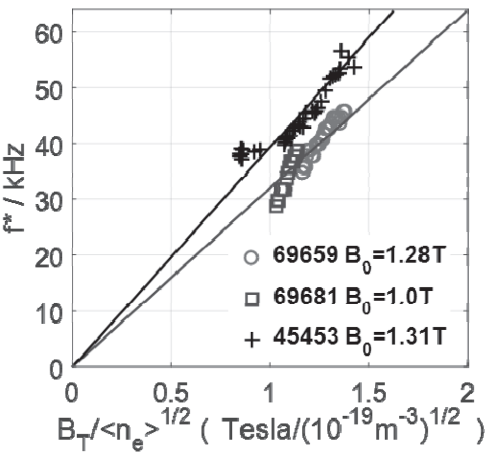


Figure 2. Dependence of real frequency *f** on $B_0/<n_e>^{1/2}$. NBI powers for shot 69659 and 69681 are both 180*kW*. NBI power for shot 45453 is e is 560kW.

(3)Comparison with Simulation

STELLGAP code calculates the shear Alfvén gap structure for 3D configurations (stellarators, RFPs, 3D tokamaks) [8]. Calculation is done by STELLGAP ver.6, taking into account the effect of coupling between shear Alfvén wave and sound wave. Sound wave spectra is invisible because it is so dense and removed. Calculation is based on low beta approximation [9]. Continua is calculated for Nf=1 mode family, which is consisted of, *n*=1: *m*=0~4, *n*=3: *m*=3~8, *n*=5: *m*=6~12... *n*=29: *m*=46~60. Total 150 modes are included. Figure 9 shows the result of STELLGAP. In figure 9 (a), a low-frequency gap is observed under 50 *kHz*. Expanded view for *f* < 50 *kHz* is show in In figure 9 (b). The grey bar indicates the experimental mode observation region of real frequency and radial position.

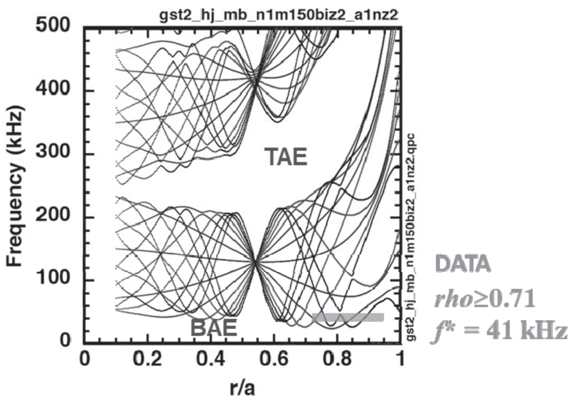


Figure 3. Dependence of real frequency *f** on $B_0/<n_e>^{1/2}$. NBI powers for shot 69659 and 69681 are both 180*kW*. NBI power for shot 45453 is 560kW.

(4)Nonlinear interaction between LF-AE bands and a very-low-frequency (VLF) mode

Sidebands of LF-AE is observed in some circumstances, as shown figure 1. Nonlinear interaction among bands of LF-AE and a very low frequency (<10 kHz) m=0/n=0 mode is observed using bicoherence technique, as show in figure 4. This observation might be an evidence for the very recent simulation work on the saturation mechanism of Alfvén eigenmode due to nonlinear interactions between low frequency zonal structure (LFZS) and beta-induced Alfvén eigenmode (BAE) [10].

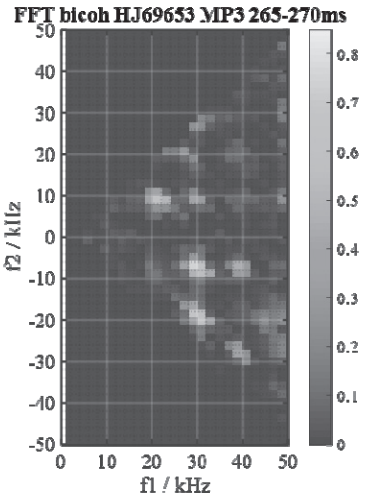


Figure 4. Bicoherence-gram of a mirnov signal. The spot shows high bicoherence among LF-AE bands and a very low frequency (8~9 kHz) mode.

[1] D. A. D'Ippolito and J. P. Goedbloed 1980 *Phys. Plasmas* **22** 1091

[2] Rosenbluth M N and Rutherford P H 1975 *Phys. Rev. Lett.* **34** 1428–31

[3] Heidbrink W W, Van Zeeland M A, Austin M E, Bass E M, Ghantous K, Gorelenkov N N, Grierson B A, Spong D A and Tobias B J 2013 *Nucl. Fusion* **53**

[4] Pinches S D, Kiptily V G, Sharapov S E, Darrow D S, Eriksson L G, Fahrbach H U, García-Mũoz M, Reich M, Strumberger E and Werner A 2006 *Nucl. Fusion* **46**

[5] Duong H H, Heidbrink W W, Strait E J, Petrie T W, Lee R, Moyer R A and Watkins J G 1993 *Nucl. Fusion* **33** 749–65

[6] ITER Physics Expert Group on Energetic Particles Heating and Current Drive, ITER Physics Basis Editors and ITER EDA Naka Joint Work Site Mukouyama Naka-machi Naka-gun Ibaraki-ken Japan 1999 *Nucl. Fusion* **39** 2471–95

[7] Fasoli A et al 2007 *Nucl. Fusion* **47**

[8] Spong D A, Sanchez R and Weller A 2003 *Phys. Plasmas* **10** 3217–24

[9] Chu M S, Greene J M, Lao L L, Turnbull A D and Chance M S 1992 *Phys. Fluids B Plasma Phys.* **4** 3713–21

[10] Qiu Z, Chen L and Zonca F 2016 *Nucl. Fusion* **56**

Advanced Energy Materials Research Section

K. Matsuda, Professor
T. Hinoki, Associate Professor
Y. Miyauchi, Associate Professor
S. Kondo, Program-Specific Associate Professor
K. Jimbo, Assistant Professor
K. Shinokita, Program-Specific Assistant Professor

1. Introduction

We are working on basic and applied research of nano-materials from a viewpoint of optics and material science. Our research aims at exploring new physical and chemical phenomena leading to applications of novel nano-materials including carbon nanotubes, layered transition metal dichalcogenides, perovskite for efficient utilization of light energy and development of future optoelectronic devices with ultra-low energy consumption. The Multi-Scale Testing and Evaluation Research Facility are also used for development of new composite materials. Followings are main research achievements in the year of 2017.

1. Physical Mechanism of Enhanced Photovoltaic Performance of Perovskite Solar Cells via Polymer Interface Engineering

Solar cells based on methylammonium lead halide pervoskites ($CH_3NH_3PbX_3$, X=I, Br, Cl) have been attracted much attention in recent several years. Since 2010, the power conversion efficiency of perovskite solar cells has improved drastically through improvements and engineering of solvents, interfaces, and materials. However, some emergent issues in $CH_3NH_3PbX_3$ remain to be solved for the future industrial applications. The strategy of interface engineering of the perovskite layer in perovskite solar cells is expected to result in further enhancements of the photovoltaic conversion efficiency (PCE) of perovskite solar cells via minimizing the charge recombination loss.

Here we demonstrate a high current-voltage (stabilized power output) PCE of 20.4% (19.9%) in $CH_3NH_3PbI_3$ PSCs under reverse scanning conditions by incorporating a solution-processed polymer layer of poly(methyl methacrylate) (PMMA) between the perovskite photoactive layer and the hole transport layer (Fig. 1). Moreover, we use steady-state and time-resolved photoluminescence spectroscopy and impedance spectroscopy to reveal the mechanism of the enhancement of the photovoltaic performance and its stability by the PMMA layer in a $CH_3NH_3PbI_3$ perovskite solar cells device. The morphology modification, surface passivation, and protection of the perovskite layer by the insulating PMMA layer substantially contribute to the enhancement of photovoltaic performance and its stability despite a slight reduction of the charge extraction efficiency. The demonstrated high PCEs and insights obtained into the working mechanism of the PMMA layer pave the way for the industrial application of $CH_3NH_3PbI_3$ perovskite solar cells.

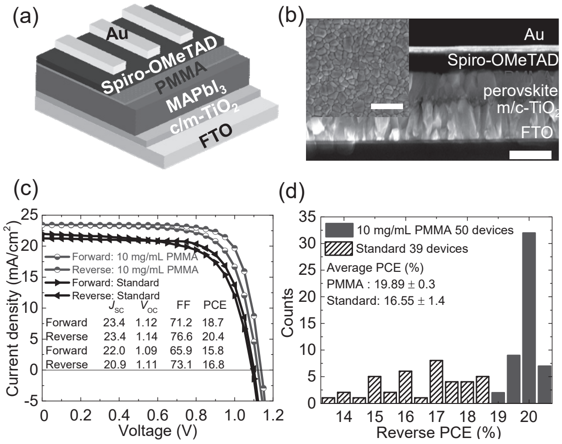


Fig. 1 (a) Schematic of device structure. (b) Cross-sectional SEM image of the device. (c) Photovoltaic performance of perovskite solar cell with and without PMMA layer. (d) Histograms of photovoltaic performance under reverse scanning conditions.

2. Polarization-Sensitive and Broadband High Performance GeS Photodetectors

In the past decade, the research on two-dimensional (2D) layered materials, such as graphene and transition metal dichalcogenides, has progressed rapidly, driven by their extraordinary mechanical, electrical, and optical properties. The discovery of new 2D materials with novel physical properties has attracted substantial interest from researchers. The exceptional optical properties of the layered 2D materials, along with ease of integration in conventional optoelectronic device systems, indicate their high potential for use in applications related to photodetection, imaging, and telecommunications. Recently, extensive works on optoelectronic devices (e.g., photodetectors) based on 2D layered materials have been reported.

We studied highly polarization sensitive, broadband, and high-temperature-operation photodetectors based on multilayer germanium sulfide (GeS). The GeS photodetector shows a high photoresponsivity of about 6.8×10^3 A/W, an extremely high specific detectivity of 5.6×10^{14} Jones, and broad spectral response in the wavelength range of 300-800 nm with fast response time. More importantly, the GeS photodetector has high polarization sensitivity to incident linearly polarized light, which provides another degree of freedom for photodetectors. Tremendously enhanced photoresponsivity is observed with temperature increase, and high responsivity is achievable at least up to 423 K. These attributes of high photocurrent generation in a wide temperature range, broad spectral response, and polarization sensitivity coupled with environmental stability indicate that the proposed GeS photodetector is very suitable for optoelectronic applications.

3. Novel Carrier Transport and Photoresponse in GeSe/MoS_2 HeterojunctionDiodes

Simple stacking of thin van der Waals 2D materials with different physical properties enabled us to create heterojunctions with novel functionalities and new potential applications. We fabricated a new 2D material *p–n* heterojunction of GeSe/MoS_2 and studied its carrier transport and photoresponse properties (Fig. 2). Substantial rectification with a very high contrast ($> 10^4$) through the potential barrier in the vertical-direction tunneling of heterojunctions was observed. The negative differential transconductance with high peak-to-valley ratio ($> 10^5$) due to the series resistance change of GeSe, MoS_2, and HJs at different gate voltages was observed. Moreover, strong and broad-band photoresponse via the photoconductive effect were also demonstrated. We expect the explored multifunctional properties of the GeSe/MoS_2 heterojunctions to be important for understanding the carrier transport and photoresponse of 2D–material heterojunctions for achieving their use in various new applications in the electronics and optoelectronics fields.

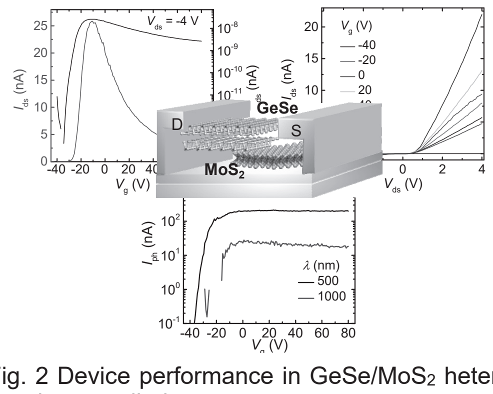


Fig. 2 Device performance in GeSe/MoS_2 heterojunction *p–n* diode.

4. Novel Silicon Carbide Composites with Particle Dispersion in Matrix

Silicon carbide (SiC) is one of very attractive engineering ceramics in particular for severe environment. Silicon carbide composites basically require weak fiber/matrix interphase like carbon (C) or boron nitride (BN). The interphase material and its thickness are keys to determine mechanical properties. However precise control of the interphase is the critical issue in particular for large scale production and affects material cost significantly. The objective of this work is to develop novel SiC composites without fiber/matrix interphase by applying particle dispersion in SiC matrix.

Silicon carbide composites were fabricated by CVI method and LPS method. Silicon carbide with C matrix was formed by mixture of SiC source gas and C source gas in CVI composites. Silicon carbide with BN matrix was formed by mixture of SiC powder and BN powder in LPS composites as shown in Fig. 3. Mechanical properties were characterized by tensile test and flexural test before and after exposure in air up to 1750C. Microstructures and fracture surfaces were characterized by FE-SEM.

Both SiC composites with C and with BN in matrix have uniform microstructure through thickness. They showed ductile fracture behavior with fiber pullouts. The technique was applied to fabricate 10 mm diameter tube for fuel cladding of light water reactor. Thermal shock test was carried out using the composite tube. The tube was heated to 1200 ℃ in air, kept 30 min and dropped to ambient temperature water. The composite tube kept original shape without apparent damage, although the monolithic ceramic SiC tube was completely fractured.

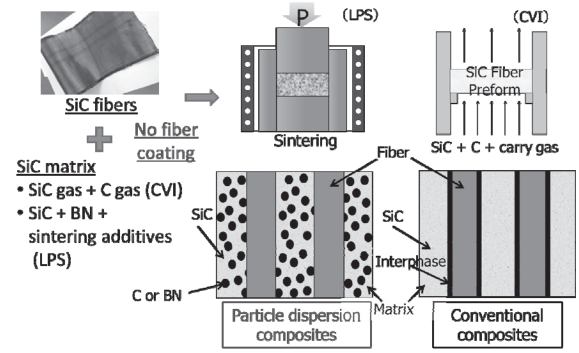


Fig. 3 Development of particle dispersion SiC composites.

Collaboration Works

University of Bordeaux（フランス），単一ナノ物質における先端分光，松田一成

Politecnico di Torino（イタリア）、Oak Ridge National Laboratory（米国），セラミックス材料の接合強度評価技術開発，檜木達也

Oak Ridge National Laboratory（米国），原型炉プラズマ対向機器開発のための要素技術の工学的評価（Phenix），檜木達也

OECD NEA，Generation IV International Forum，GFR system，檜木達也

OECD NEA，The Expert Group on Accident Tolerant Fuels for Light Water Reactors (EGATFL)，檜木達也

国立大学法人東北大学金属材料研究所，ホットラボ用小型ダイバータプラズマ模擬試験装置を用いた照射損傷試料の重水素吸蔵に関する研究，近藤創介

国立大学法人東北大学金属材料研究所，原子力用 SiC および SiC/SiC 複合材料の中性子照射効果，檜木達也，近藤創介

Financial Support

1. Grant-in-Aid for Scientific Research

松田一成，特別研究員奨励費，原子層ヘテロ構造の光科学と太陽電池応用

松田一成，新学術領域研究（研究領域提案型），原子層人工ヘテロ構造における新規光物性と光学応用

松田一成，基盤研究(S)，原子層物質におけるバレースピンフォトニクスの創生と応用

宮内雄平，新学術領域研究（研究領域提案型），偏光分解分光イメージングによる原子層局所形態・光物性相関の研究

宮内雄平，挑戦的萌芽研究，遷移金属ダイカルコゲナイド超薄膜におけるバレー分極緩和メカニズムの解明

宮内雄平，若手研究(A)，極限ナノ物質の複合化による新奇創発量子物性の誘起とその応用

近藤創介，若手研究(A)，炭化ケイ素の照射欠陥－高温水腐食相関解明とその防食の実証

篠北啓介，研究活動スタート支援，原子層物質におけるバレースピン分極の物理の完全解明と制御

2. Others

松田一成，（公財）旭硝子財団，極限二次元単層ナノ物質におけるグリーンフォトニクスの開拓

松田一成，（公財）中谷医工計測技術振興財団，複合機能変換過程研究推進のため

宮内雄平，（公財）光科学技術研究振興財団，カーボンナノチューブの近赤外アップコンバージョン発光を用いた生体深部の高解像イメージング手法の開拓

宮内雄平，（公財）村田学術振興財団，原子層半導体におけるバレー分極状態の空間マッピングとその制御

宮内雄平，（公財）中谷医工計測技術振興財団，カーボンナノチューブの近赤外アップコンバージョン蛍光を用いた生体イメージング

宮内雄平，国立研究開発法人科学技術振興機構，原子層ヘテロ構造の光物性・機能開拓

檜木達也，中小企業経営支援等対策費補助金，高効率航空機エンジン向け SiC/SiC 複合材料製造工法の開発

篠北啓介，（公財）新世代研究所，ATI 研究助成 2017 年度

Publications

G. Povie, Y. Segawa, T. Nishihara, Y. Miyauchi, K. Itami, Synthesis of a carbon nanobelt, Science, 356, 172-175, 2017

S. Kondo, C.M. Parish, T. Koyanagi, Y. Katoh , Equilibrium shapes and surface selection of nanostructures in 6H-SiC，Applied Physics Letters，110，14，142106，2017

C.M. Parish,T. Koyanagi, S. Kondo, Y. Katoh , Irradiation-induced beta to alpha SiC transformation at low temperature，Scientific Reports，7，1198，2017

T. Koyanagi, Y. Katoh, J.O. Kiggans, T. Hinoki, H.E. Khalifa, C.P. Deck, C.A. Back，Irradiation resistance of silicon carbide joint at light water reactor–relevant temperature，Journal of Nuclear Materials，488，150-159，2017

K. Mae, H. Toyama, E. Nawa-Okita, D. Yamamoto, Y-J.

Chen, K. Yoshikawa, F. Toshimitsu, N. Nakashima, K. Matsuda, A. Shioi, Self-organized micro-spiral of single-walled carbon nanotubes, Scientific Reports, 7, 5267, 2017

S. Mouri, W. Zhang, D. Kozawa, Y. Miyauchi, G. Eda, K. Matsuda, Thermal dissociation of inter-layer excitons in MoS2/MoSe2 hetero-bilayers , Nanoscale , 9 , 6674-6679, 2017

A. Hessein, F. Wang, H. Masai, K. Matsuda, A. Abd El-Moneim, Improving the stability of CdS quantum dot sensitized solar cell using highly efficient and porous CuS counter electrode , Journal of Renewable and Sustainable Energy, 9, 23504, 2017

E .Salamatova, A.V. Cunha, K. Shinokita, T.l.C. Jansen, M. Pshenischnikov, Hydrogen bond and lifetime dynamics in diluted alcohols, Physical Chemistry Chemical Physics, 19, 41, 27960-27967, 2017

D. Tan, W. Zhang, X. Wang, S. Koirala, Y. Miyauchi, K. Matsuda, Polarization-sensitive and broadband germanium sulfide photodetectors with excellent high-temperature performance , Nanoscale , 9 , 12425-12431, 2017

S. Sakurada, Y. Uemura, H. Fujita, K. Azuma, T. Toyama, N. Yoshida, T. Hinoki, S. Kondo, Y. Hatano, M. Shimada, D. Buchenauer, T. Chikada, Y. Oya, Impact of Annealing on Deuterium Retention Behavior in Damaged W, Fusion Science and Technology, 1, 4, 2017

S. Mouri, W. Zhang, D. Kozawa, Y. Miyauchi, G. Eda, K. Matsuda, Thermal dissociation of inter-layer excitons in MoS2/MoSe2 hetero-bilayers, Nanoscale, 9, 7686, 2017

Y. Katoh, D. Clark, Y. Ueda, Y. Hatano, M. Yoda, A.S. Sabau, T. Yokomine, L.M. Garrison, J.W.i Geringer, A. Hasegawa, T. Hinoki, M. Shimada, D. Buchenauer, Y. Oya. T. Muroga, Progress in the U.S./Japan PHENIX Project for the Technological Assessment of Plasma Facing Components for DEMO Reactors, Fusion Science and Technology, 72, 222-232, 2017

F. Yang, H.E. Lima, F. Wang, M. Ozaki, A. Shimazaki, J. Liu, N.B. Mohamed, K. Shinokita, Y. Miyauchi, A. Wakamiya, Y. Murata, K. Matsuda, Roles of polymer layer in enhanced photovoltaic performance of perovskite solar cells via interface engineering, Advanced Materials Interface, 4, 24, 1701256, 2017

N.B. Mohamed, H.E. Lim, F. Wang, S. Koirala, S. Mouri, K. Shinokita, Y. Miyauchi, K. Matsuda, Long radiative lifetimes of excitons in monolayer transition-metal dichalcogenides MX2 (M = Mo, W, X = S, Se), Applied Physics Express, 11, 1, 15201, 2017

L. Hong, T. Nishihara, Y. Hijikata, Y. Miyauchi, K. Itami, Unidirectional molecular assembly alignment on graphene enabled by nanomechanical symmetry breaking, Scientific Reports, 8, 2333, 2017

Presentations

K. Jimbo, Observing Suppression of Synchrotron Oscillation Amplitudes , 2017 International Particle Accelerator Conference, Copenhagen, Denmark , Bella Center, 2017.5.14-19

T. Hinoki, S. Yanagawa, K. Shimoda, High Temperature Mechanical Properties of BN Particle Dispersion SiC Composites , The 12th Pacific Rim Conference on Ceramic and Glass Technology, Hilton Waikoloa Village, 2017.5.21-26

奥平早紀, Upconversion photoluminescence imaging of carbon nanotubes in mice tissues, 第 14 回光物質科学研究討論会, 湖邸滋びわこクラブ, 2017.6.16-17

山岡隆央, Fabrication and optical properties of atomically thin WSe2/MoTe2 van der Waals heterostructure, 第 14 回光物質科学研究討論会, 湖邸滋びわこクラブ, 2017.6.16-17

W. Zhang , Optical properties of transition metal dichalcogenide monolayers under carrier density modulation, 第 14 回光物質科学研究討論会, 湖邸滋びわこクラブ, 2017.6.16-17

X. Wang, 2D materials FETs fabrication by dry-transfer process, 第 14 回光物質科学研究討論会, 湖邸滋びわこクラブ, 2017.6.16-17

T. Hinoki, Development of Silicon Carbide Composites for Nuclear Application, さくらサイエンスプラン過酷環境に耐える材料開発とその評価手法, 京都大学宇治キャンパス, 2017.6.24

S. Kondo, Effects of Energetic Particle Bombardment on Silicon Carbide, さくらサイエンスプラン過酷環境に耐える材料開発とその評価手法, 京都大学宇治キャンパス, 2017.6.24

K. Matsuda, Novel Optical Phenomena of Nano-Carbon and Atomically Thin Two-Dimensional Materials, 18th International Conference on the Science and Application of Nanotubes and Low-dimensional Materials, Federal University of Minas Gerais, 2017.6.25-30

宮内雄平，低次元ナノ物質の光物性工学とその応用，第 24 回京都大学宇治キャンパス産学交流会，京都大学宇治キャンパス，2017.6.28

K. Matsuda，Optical Properties and Application of Atomically Thin Two-Dimensional Materials，AM-FPD2017，京都駅キャンパス龍谷大学響ホール，2017.7.6

宮内雄平，Up-conversion photoluminescence of CNTs and its enhancement by defect engineering，Defect Chemistry and Physics of Low Dimensional Materials, Telluride Intermediate School，2017.7.11-15

松田一成，Optical science of atomically thin two-dimensional material and its artificial hetero-structure，CEMS Topical Meeting on Emergent 2D Materials 2017，大河内記念ホール，2017.7.20-21

篠北啓介，極限二次元単層ナノ物質におけるグリーンフォトニクスの開拓，旭硝子財団助成研究発表会，ホテルグランドヒル市ヶ谷，2017.7.27

D. Tan，GeSe/MoS2 heterojunction diode for optoelectronic applications，応用物理学会第 78 回秋季学術講演会，福岡国際会議場，2017.9.5-8

山岡隆央，Optical properties of atomically thin WSe2/MoTe2 van der Waals heterostructure，応用物理学会第 78 回秋季学術講演会，福岡国際会議場，2017.9.5-8

奥平早紀，Near-infrared up-conversion photoluminescence imaging of carbon nanotubes in mice tissues, 応用物理学会第 78 回秋季学術講演会，福岡国際会議場，2017.9.5-8

K. Shinokita, X. Wang, Y. Miyauchi, K. Matsuda，Ultrafast Carrier Dynamics in Two-Dimensional Transition Metal Dichalcogenids，第 53 回フラーレン・ナノチューブ・グラフェン総合シンポジウム，京都大学おうばくプラザ，2017.9.13-15

檜木達也，川崎寛治郎，篠田富士雄，波多野雄治，時谷政行，タングステンと等方性黒鉛の低温接合，日本原子力学会 2017 年秋の大会，北海道大学札幌キャンパス，2017.9.13-15

近藤創介，前田有輝，深見一弘，檜木達也，SiC 高温水腐食へ及ぼす照射欠陥の影響，日本原子力学会 2017 年秋の大会，北海道大学札幌キャンパス，2017.9.13-15

東奎介，戸苅陽大，周啓来，波多野雄治，吉田直亮，近藤創介，檜木達也，近田拓未，大矢恭久，欠陥導入タングステン中の水素同位体滞留量に及ぼす炭素・ヘリウム照射影響，日本原子力学会 2017 年秋の大会，北海道大学札幌キャンパス，2017.9.13-15

檜木達也，1600℃級耐水蒸気セラミックス複合材料の開発，京大テックフォーラム「エネルギー材料科学の最先端」，新丸ビル京都アカデミアフォーラム，2017.9.20

檜木達也，柳川翔平，川崎寛治郎，篠田富士雄，SiC の表面改質による $Yb_2Si_2O_7$ 層の形成，日本セラミックス協会第 30 回秋季シンポジウム，神戸大学六甲台地区，2017.9.19-21

蒲江，Zhang Wenjin，松岡拓史，小林佑，高口祐平，宮田耕充，Lain-Jong Li，松田一成，宮内雄平，竹延大志，電解質を用いた単層遷移金属ダイカルコゲナイド発光素子，日本物理学会 2017 年秋季大会，岩手大学上田キャンパス，2017.9.21-24

松田一成，2 次元遷移金属カルコゲナイド・人工ヘテロ構造の光物性，日本物理学会 2017 年秋季大会，岩手大学上田キャンパス，2017.9.21-24

D. Tan，GeSe/MoS2 heterojunction diode for highly sensitive and broadband photodetectors，GRAPHENE WEEK 2017，Divani Caravel Hotel，ATHENS, GREECE，2017.9.25-29

檜木達也，炭化珪素材料の照射クリープ挙動に及ぼす組成の影響，大洗研究会，東北大学金属材料研究所，2017.10.4-5

松田一成，原子膜ヘテロ構造の光物性，平成 29 年度第二回研究会「低次元ナノマテリアルの最前線」，HAZU，2017.10.16-17

宮内雄平，低次元ナノ系の光物性，平成 29 年度第二回研究会「低次元ナノマテリアルの最前線」，HAZU，2017.10.16-17

宮内雄平，原子層物質のバレー励起子光物性，応用電子物性分科会研究例会-二次元層状物質研究の最前線-，東京工業大学 EEI 棟 1F 多目的ホール，2017.10.19

松田一成，Optical Dynamics of Transition Metal Dichalcogenides and its Hetero-structures，8th A3 Symposium on Emerging Materials，Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences，2017.10.25-28

近藤創介，Effect of Irradiation on Corrosion Resistance of SiC, 第 18 回核融合炉材料国際会議（ICFRM18），リンクステーションホール青森，2017.11.5-10

T. Hinoki，High temperature mechanical properties of

BN particle dispersion SiC composites, Composites at Lake Louise 2017(CALL)meeting, Fairmont Chateau Lake Louise Alberta, Canada, 2017.11.12-16

島崎雅史, Control of luminescence properties in atomically-thin semiconductors, Kyoto-Ajou-Zhejiang Joint Symposium on Energy Science, 浙江大学, 2017.11.28-30

Y. Miyauchi , Linewidth and carrier screening effects on exciton valley relaxation in monolayer transition metal dichalcogenides, The 3rd International Conference on 2D Materials and Technology (ICON-2DMAT 2017) , Nanyang Technological University , 2017.12.11-15

T. Hinoki, SiC Composites Development Related to GFR in Japan, 25TH SYSTEM STEERING COMMITTEE, OECD NEA , 2017.12.14-15

T. Hinoki, Silicon Carbide Composites Development for the Use in Steam Environment above 1500c , , Politecnico di Torino, 2017.12.17-18

宮内雄平, 原子層物質の励起子バレー緩和, CUPAL ワークショップ, 東京理科大学森戸記念館, 2017.12.20

T. Hinoki, S. Yanagawa, K. Kawasaki, F. Shinoda, Formation of Yb2Si2O7 layer by surface treatment of SiC, ICACC'18, Hilton Daytona Beach Resort and Ocean Center, 2018.1.21-26

S. Kondo, Y. Maeda, K. Fukami, S. Mouri, T. Hinoki, Effect of irradiation defects on SiC dissolution in aqueous solution, ICACC'18, Hilton Daytona Beach Resort and Ocean Center, 2018.1.21-26

F. Yang, H.E. Lim, M. Ozaki, A. Shimazaki, Y. Miyauchi, A. Wakamiya, Y. Murata, K. Matsuda, Roles of Polymer Layer in Interfacial Engineering Perovskite Solar Cells with High Photovoltaic Performance, AP-HOPV18, 北九州国際会議場, 2018.1.28-30

檜木達也, SiC／SiC 複合材料の適用動向と最近の進展, 株式会社日立製作所, 2018.2.2

篠北啓介, 王暁凡, 宮内雄平, 松田一成, 単層 WSe2 における電子正孔バレー分極緩和過程, 日本物理学会第 73 回年次大会, 東京理科大学野田キャンパス, 2018.3.22-25

K. Matsuda, Studies of Optical Phenomena in Atomically Thin Two-dimensional Material and its Heterostructure for Novel Application, ISPlasma2018, 名城大学, 2018.3.4-8

王暁凡, 篠北啓介, 林宏恩, モハメッド ヌル バイズラ, 宮内雄平, 松田一成, Carrier dynamics in 3-layer ReS2 studied by ultrafast spectroscopy, 第 54 回フラーレン・ナノチューブ・グラフェン総合シンポジウム, 東京大学伊藤国際学術研究センター 伊藤謝恩ホール, 2018.3.10-12

W. Zhang, K. Matsuda, Y. Miyauchi, Photoluminescence properties of monolayer MoS2 in an aqueous solution, APS March Meeting, Los Angeles Convention Center, 2018.3.5-9

F. Yang, H.E. Lim, J. Liu, Y. Ishikura, K. Shinokita, Y. Miyauchi, A. Wakamiya, Y. Murata, K. Matsuda, Flexiblity perovskite solar cells with high photovoltaic performance using solution processed tin oxide nanoparticle, 第 65 回応用物理学会春季学術講演会, 早稲田大学西早稲田キャンパス, 2018.3.17-20

神保光一, 加速器を使わないコンパクト中性子源, 日本物理学会第 73 回年次大会, 東京理科大, 野田キャンパス, 2018.3.22-25

波多野雄治, 史鵬, 向鑫, 外山健, 近藤創介, 檜木達也, CuCrZr 合金および酸化物分散強化 Cu 合金の水素同位体吸収・放出特性, 日本原子力学会 2018 年春の年会, 大阪大学吹田キャンパス, 2018.3.26-28

Advanced Laser Science Research Section

T. Nakajima, Associate Professor

1. Introduction

The main interest of our research group is to investigate not only the fundamental phenomena induced by laser but also the possible application of laser induced phenomena in one way or the other to contribute to the efficient use of laser-based devices in energy science. In this year we focus on the two subjects, i.e., rapid in-situ synthesis of metal-polymer nanocomposite films using a CO_2 laser and the interference through the resonant Auger processes via multiple core-excited states pumped by x-ray pulse.

2. Rapid in-situ synthesis of metal-polymer nanocomposite films using a CO_2 laser

The synthesis of various kinds of nanoparticles (NPs) and their applications are of great interest in recent years. For the efficient and reliable use of NPs a uniform dispersion of NPs is the key. If NPs are dispersed in an inorganic or organic matrices such materials are called nanocomposites, which are of more recent interest, because the introduction of the various kinds of filler into the inorganic or organic matrix can result in the improvement of mechanical, electrical, and optical properties of the matrix itself if the filler is appropriately chosen. In this work we demonstrate a very rapid and scalable synthesis of metal-polymer nanocomposite films with a CO_2 laser at a very modest laser power.

The fabrication procedure of metal-polymer nanocomposite films we newly develop in this work is very simple and quick. Briefly, the mixture of the solution of polyvinyl alcohol (PVA) and the solution of silver nitrate ($AgNO_3$) is cast on a cover glass and then spin-coated to prepare the $AgNO_3$-PVA film. After drying the $AgNO_3$-PVA film in air the film is irradiated by the CO_2 laser for several seconds at the laser power of 1W to obtain the Ag-PVA nanocomposite film. The optical and morphological properties of the fabricated Ag-PVA nanocomposite film are presented in Fig. 1. Although the $AgNO_3$-PVA film is practically transparent before CO_2 laser irradiation the irradiated are of the film gradually turns to yellow, as we see in Fig. 1(a). Correspondingly, the optical properties change as we see in Fig. 2(b): a broad peak of the surface plasmon (SP) of silver appears as the irradiation time becomes longer from 0 to 10 seconds. Then, up to the irradiation of 20 seconds the height and width of SP stays nearly the same (not shown

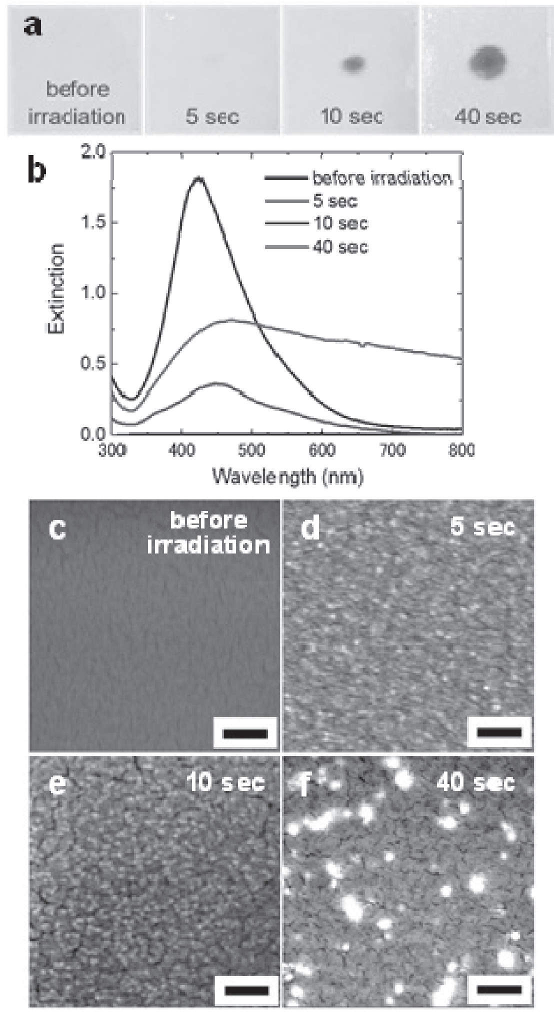


Fig. 1 (a) Photos and (b) optical absorption spectra of the films after the different irradiation times at the CO_2 laser power of 1W. (c)-(f) SEM images of the corresponding Ag-PVA films.

here). After that the height of SP gradually becomes smaller and exhibits a tail on the long wavelength side. This change of the spectra of SP implies that the aggregation of NPs starts to take place if the irradiation time is long. Indeed, this interpretation is confirmed by the SEM analysis shown in Figs. 1(c)-1(f). We also try the fabrication of Ag-PEG (polyethylene glycol) films using the same procedure to find that it works.

Thus, we have successfully demonstrated a rapid in-situ synthesis of metal-polymer nanocomposite films within several seconds using a CO_2 laser. The new fabrication method we have developed in this work can be useful to quickly synthesize a variety of polymer-metal nanocomposite films for various purposes.

3. Interference through the resonant Auger process via multiple core-excited states

The advent of x-ray free electron lasers (XFELs) has enabled us to study some of the inner-shell processes of atoms and molecules in a time-dependent manner. The decay of a resonantly produced core-excited state into the continuum, which is termed as RA process, is one of the important inner-shell processes, and it has been under the intensive studies using XFELs. Under the intense x-ray pulse the excitation and decay processes are expected to be very different from those by the weak x-ray pulse or synchrotron radiation, and therefore, the RA processes induced by the intense x-ray pulse can lead to the new realm of rich physics. In this work we theoretically investigate the RA processes via multiple (two) core-excited states, and demonstrate that the RA process under such situations can exhibit an interference pattern in the energy-resolved electron spectra.

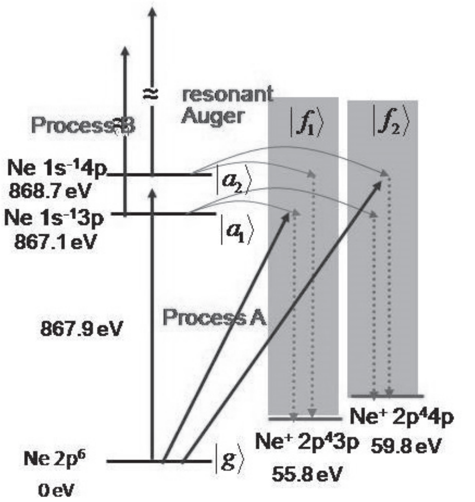


Fig. 3 Level scheme of the model for the resonant Auger processes.

Fig. 3 shows the level scheme of our model to describe the resonant Auger processes induced by the intense and resonant x-ray pulse. To be most specific we choose the Ne atom, and numerically solve the time dependent Schrödinger equation. The calculated energy-resolved electron spectra by including all possible ionization processes (=RA process + Process A + Process B), RA process and Process A, and RA process only are shown in Figs. 4(a)-4(c), respectively. For all three cases (Figs. 4(a)-4(c)) the line shapes turn out to be asymmetric with multiple peak structures. However, the peak positions and the line shape are all different, depending on the ionization processes included for the calculations. The asymmetric line splitting in Figs. 4(a)-4(c) is attributed to the Rabi oscillations between the ground and core-excited states. The barely visible peak around 811.2 eV in Fig. 4(c) is more significant in Figs. 4(a) and 4(b) when the direct ionization process (process A) is included. This is primarily due to the interference between the two pathways, "ground state→ core-excited state→f_1 continuum" and "ground state →f_1 continuum". After the detailed analysis we con-

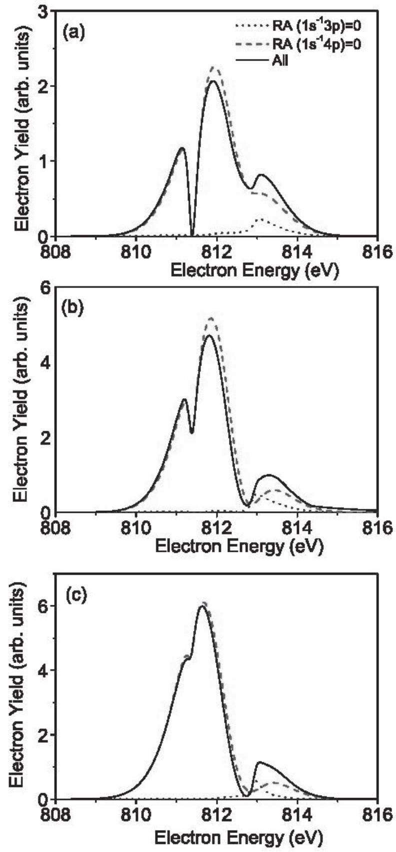


Fig. 4 Energy-resolved electron spectra associated with the f1 continuum calculated by including (a) all processes, (b) RA process, and Process A, and (c) RA process only. The peak intensity of the x-ray pulse is 5×10^8 W/cm^2. Processes A and B are those described in Fig. 3.

firm that the shape of the energy-resolved electron spectra labeled as "All" in Figs. 4(a)-4(c) is mainly determined by the two factors, i.e., the Rabi oscillations between the ground and two core-excited states and the interference between the RA process and Process A.

To summarize, we find that the excitation of the multiply core-excited states by the resonant x-ray pulse results in a new kind of interference through the resonant Auger decay, and the energy-resolved electron spectra exhibit the additional structure which originates from interference through the resonant Auger process via the two core-excited states.

Collaboration Works

宇宙科学研究所（ルーマニア），高強度超短パルスレーザーによって誘起される非摂動相互作用の理論研究，中嶋隆

中国計量学院・講師（中華人民共和国），アト秒パルスのキャラクタリゼーション，中嶋隆

インド工科大学カンプール（インド），ナノ素材の超高速温度測定法の開発，中嶋隆

Financial Support

中嶋隆，（公財）天田財団，国際会議等参加助成

Publications

L. Deng, T. Nakajima, S. Gong，Transparency under double detuning-induced stimulated Raman adiabatic passage in atoms with hyperfine structure，Physical Review A，95，63828，2017

S. Chatterjee, T. Nakajima，Interference through the resonant Auger process via multiple core-excited states, Physical Review A，96，63406，2017

S.K. Maurya, Y. Uto, K. Kashihara, N. Yonekura, T. Nakajima，Rapid formation of nanostructures in Au films using a CO2 laser，Applied Surface Science，427, 961-965，2017

Presentations

C.R. Locke, T. Kobayashi, T. Nakajima, and K. Midorikawa，Reduction and resource recycling of high-level radioactive wastes through nuclear transmutation – new scheme foe selective ionization of palladium isotopes，Asian Nuclear prospects 2016，東北大学，2016.10.24-27

T. Nakajima，Peculiar behavior in the growth of plasmonic nanobubbles，Photonics 2016，インド工科大学カーンプル校，2016.12.5-8

宇都裕貴，樫原和彦，中嶋隆，レーザー照射によるナノ複合薄膜のその場創成，第 64 回応用物理学会春季学術講演会，パシフィコ横浜，2017.3.14-17

Maurya Sandeep, 宇都裕貴, 中嶋隆, 金薄膜への CO2 レーザー照射によるナノ構造化，第 64 回応用物理学会春季学術講演会, パシフィコ横浜, 2017.3.14-17
西川隼人，中嶋隆，CO2 レーザー照射による低環境負荷型ナノ複合薄膜のその場創成，応用物理学会第 78 回秋季学術講演会，福岡国際会議場，2017.9.5-8

樫原和彦，宇都裕貴，中嶋隆，CO2 レーザー照射によってその場生成された高分子-金属ナノ粒子(PVA/Ag)複合膜の SEM 分析, 応用物理学会第 78 回秋季学術講演会，福岡国際会議場，2017.9.5-8

樫原和彦，西川隼人，中嶋隆，スパッタ成膜と CO2 レーザー照射プロセスの繰返しによって尖鋭化された Au 薄膜のナノ構造, 応用物理学会第 78 回秋季学術講演会，福岡国際会議場，2017.9.5-8

T. Nakajima，First observation of the number-density-dependent growth of plasmonic nanobubbles，ALT17，Hanwha Resorts Haeundae Tivoli，2017.9.10-15

T. Nakajima，In-Situ Fabrication of Polymer/Metal Nanocomposite Films using a Mid-Infrared Laser，Metanano2017，Far Eastern Federal University，2017.9.18-22

樫原和彦，西川隼人，中嶋隆，スパッタ成膜と CO2 レーザー照射プロセスの繰り返しによって高密度化された Au 薄膜のナノ構造，レーザー学会学術講演会 38 回年次大会，みやこめっせ，2018.1.24-26

樫原和彦，西川隼人，中嶋隆，CO2 レーザー照射によってその場生成された高分子-金属ナノ粒子複合膜の粒径および粒子密度制御，レーザー学会学術講演会 38 回年次大会，みやこめっせ，2018.1.24-26

西川隼人，樫原和彦，中嶋隆，CO2 レーザーを用いた低環境負荷型ナノ複合膜の高速その場創成，レーザー学会学術講演会 38 回年次大会，みやこめっせ，2018.1.24-26

西川隼人，中嶋隆，CO2 レーザー照射による高密度な低環境負荷型ナノ複合薄膜のその場創成，応用物理学会第 65 回春季学術講演会，早稲田大学，2018.3.17-20

西川隼人，樫原和彦，中嶋隆，スパッタ蒸着と CO2 レーザー照射の繰り返しによる Au および Ag ナノ構造の尖鋭化，応用物理学会第 65 回春季学術講演会，早稲田大学，2018.3.17-20

Advanced Energy Structural Materials Research Section

A. Kimura, Professor
K. Morishita, Associate Professor
K. Yabuuchi, Assistant Professor
Z. Zhexian, Program-Specific Assistant Professor
J. Gao, Program-Specific Researcher
Y. Hayashi, Program-Specific Researcher

1. Introduction

Materials R&D is essential for safe and efficient operation of advanced nuclear energy systems in the near future. This section takes up a mission of materials R & D for advanced nuclear energy systems such as fusion reactors and Gen-IV nuclear systems. Current main researches are as follows:

(1) ODS steels R&D for ATF claddings: After Fukushima incident accident tolerant fuel (ATF) cladding R&D was proposed by DOE and the issues for materials R&D for ATF application have been discussed including resistance to corrosion/oxidation, strength and radiation tolerance. Among the candidate materials, FeCrAl-ODS steels were selected as most feasible material for ATF claddings and R&D of FeCrAl-ODS steels has been performed in this division as a national program to develop an innovative material with high performance.

(2) Structural materials integrity: Stress corrosion cracking susceptibility of structural materials in nuclear power plants has been examined for SUS316L and 310S by means of slow strain rate test in hydrogenated water (Fig.1). SUS310S is much more resistant to SCC indicating almost no occurrence of SCC, while SUS316L suffers a severe TGSCC in hot water dissolved with 1.4 ppm hydrogen at 340 °C.

(3) Multi-scale modeling: Radiation damage processes in nuclear materials take place at a wide variety of time and length scales. So-called the multiscale viewpoint is required to understand the processes. To do this, modeling effort has been made using several computational techniques complementarily such as molecular dynamics, ab-initio quantum calculations, kinetic Monte-Carlo, rate-equation theory analysis, FEM and CFD.

(4) Radiation damage mechanism of fission nuclear structural materials: For the sake of the highly efficient and safe operation of nuclear fission reactors, the mechanisms of irradiation embrittlement and stress corrosion cracking have been investigated. Small specimen test technique for evaluation of structural integrity has been developed towards extension of operation period of light water reactors.

2. Hydrogen-assisted SCC

The susceptibility to stress corrosion cracking (SCC) was evaluated for solution-annealed 316LSS by slow strain rate test in hot water below 288°C with dissolved-hydrogen (DH) up to 1.4 ppm using a loop shown in Fig.1. SCC was never observed in the specimens tested in water dissolved with oxygen up to 10 ppm at 288°C. In the hydrogenated water, however, SCC occurred in the late stage of deformation accompanied by necking. The oxide film thickness increases with temperature up to 288°C. The SCC susceptibility reduced with test temperature below 288°C. SCC occurred in the water with DH=0.4 and 1.4 ppm at 288°C, while at 220°C the SCC occurred at the highest DH condition only. This indicates a combining effect of DH and test temperature. Test temperature dependence can be interpreted in terms of anodic reaction rate, hydrogen diffusion rate and hydrogen trapping ability. The SCC observed in this study is interpreted in terms of hydrogen-assisted SCC which is accompanied by work hardening, corrosion and hydrogen absorption. The dependence of HASCC on both the test temperature and DH content was reasonably explained by corrosion assisted hydrogen production while suppressing the formation of protective oxide film on the specimen surface and hydrogen-induced reduction of cohesive force of lattice of austenitic stainless steel.

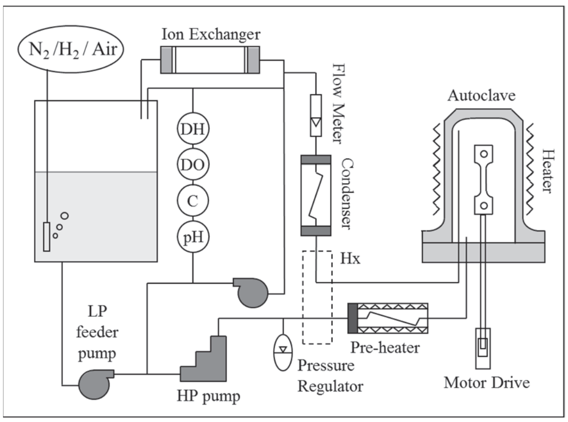


Fig. 1: Schematic view of hot water circulating loop

3. Optimizing maintenance strategy of a reactor pressure vessel using 3D-CFD and FEM based probabilistic pressurized thermal shock analysis

The structural integrity of RPVs is important part of nuclear power plant safety. The RPV contains reactor core and coolant, which is regarded as irreplaceable. In addition, the RPV is known to be exposed to neutron irradiation that makes the RPV steels brittle. When a large amount of coolant water is injected into the reactor at a loss-of-coolant accident (LOCA), the reactor vessel is rapidly cooled down concurrently with the PTS loadings. In this situation, the cold plume may form near the inner surface of the RPV, leading to the RPV walls under high stress conditions. Since the RPV steel usually becomes brittle under the environment of neutron irradiation, the high stress occurred at the PTS events may lead the RPV to fracture. It is therefore necessary to understand the performance of RPVs during the PTS loading for keeping the integrity of RPVs.

In this study, the deterministic and probabilistic integrity evaluations are made to investigate the integrity of entire RPV during PTS loading. For the deterministic integrity evaluation, the 3D-CFD simulation is performed to determine an accurate transient 3D temperature distribution in RPV by considering the cold plume cooling effect. Thermal-elastic-plastic analysis obtained by FEM is also carried out to analyze the residual stress caused by the weld-overlay cladding of RPV (Fig.2). Results of the fracture mechanics analysis obtained by FEM are applied to determine SIF of the assumed cracks in the RPV. Crack tip plastic zone is taken into consideration in the analysis, which clarifies the dependence of SIF on position inside the RPV. For the probabilistic integrity evaluation, the crack size dependence is also introduced into the evaluation. Combined with the distribution of fracture toughness included as part of the master curve, the dependence of the fracture probabilities on the position inside the RPV is obtained. Finally, the spatial distribution of fracture probabilities in RPV is used to optimize the priority of the inspection and maintenance on the RPV.

Fig. 2: Example distributions of temperature and stress on the inner RPV wall after 1200s

4. Irradiation effects on microstructure evolution and properties of materials

High energy particle irradiation leads to the formation of oversaturated interstitials and vacancies. The behavior of the point defects is responsible for the evolution of the microstructure, which may cause degradation, (or development), of the mechanical properties of the material. Hence, the elucidation of the behavior of point defects is essential for understanding the mechanisms responsible for the changes in mechanical properties. In our study, the microstructure evolution under particle irradiation has been investigated experimentally and computationally.

We has investigatd the irradiaton effect of tungsten (W), which is a candidate material for fusion divertar, using an ion accerelator (DuET: Fig. 3). We found that the microstructure evolusion under ion irradiation depends on the crystal orientation using W single crystals with {001} and {011} surfcace orientation for ion-irradiation (Fig. 4). Defect zone depth is deeper in {001} crystal than in {011} crystal. The mechanism has been discussed with DFT, MD, and so on. The knowledge obtained in this study is fruitful for fusion diverter design and integrity.

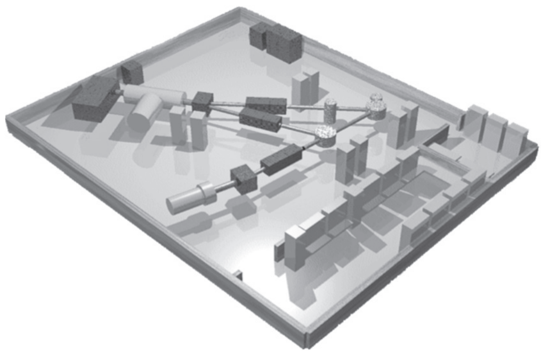


Fig. 3: Ion-accelerator (DuET)

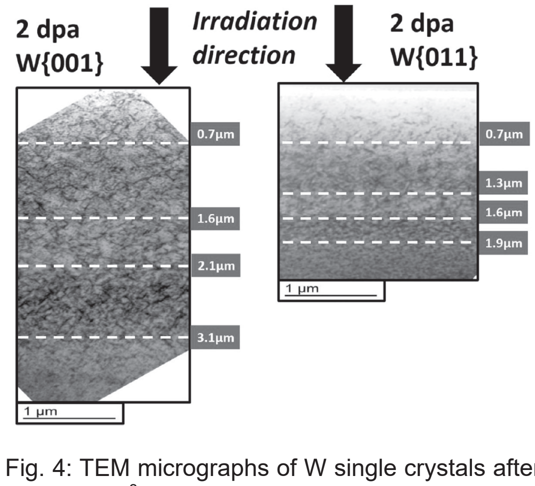


Fig. 4: TEM micrographs of W single crystals after 6.4 MeV Fe^{3+} ions.

Collaboration Works

韓国原子力研究所（大韓民国），Effects of neutron irradiation on ODS ferritic steels，木村晃彦

イリノイ大学（米国），ODS steels R&D for next generation nuclear systems，木村晃彦

Russian Research Center, Kurchatov Institute（ロシア），Irradiation effects on high Cr ODS steels，木村晃彦

中国科学技術院近代物理研究所（中華人民共和国），Helium Implantation Experiment on Advanced ferritic stels，木村晃彦

UCSB（米国），Advanced ferritic stels R&D，木村晃彦

韓国先進科学技術大学（大韓民国），Corrosion behavior of advanced ferritic steels，木村晃彦

PSI（スイス），In-situ creep behavior of ODS steels under ion irradiations，木村晃彦

Pacific Northwest 国立研究所（米国），Resistance to neutron irradiation in ODS ferritic steels，木村晃彦

KAIST（大韓民国），Corrosion Properties of Nuclear Materials，木村晃彦

Nuclear Materials Research Division, KAERI（大韓民国），Evaluation of radiation tolerance of ODS steels under neutron irradiation，木村晃彦

CEA/DEN/SACLAY/DMN/SRMP （フランス），Hydrogen and Helium Implantation Experiment on Nano-scaled Oxide Dispersion Strengthened Steels，木村晃彦

Mechanical Properties and Mechanics Group ORNL（米国），Evaluation of radiation tolerance of ODS steels under neutron irradiation，木村晃彦

Bochvar Institut（ロシア），IAEA-CRP Pound robin test，木村晃彦

CIEMAT（スペイン），IAEA-CRP Pound robin test，木村晃彦

FEI STU（スロバキア），IAEA-CRP Pound robin test，木村晃彦

JRC European Commission- Petten, JRC-Institute for Energy and Transport，IAEA-CRP Pound robin test，木村晃彦

HZDR（ドイツ），IAEA-CRP Pound robin test，木村晃彦

KIT（ドイツ），IAEA-CRP Pound robin test，木村晃彦

University of Michigan（米国），IAEA-CRP Irraadiation campaign，木村晃彦

University of New Mexico（米国），Radiation effects on FeCrAl-ODS ferritic steels for application to radiation torelant fuel cladding，木村晃彦

UCSB（米国），Helium effects on FeCrAl-ODS ferritic steels for application to fusion blanket，木村晃彦

Institute of Modern Physiscs, CAS（中国），Radiation effects on advanced nuclear structural materials，木村晃彦

Myongji University（韓国），Irradiation hardening and microstructural evokution of RAFS，木村晃彦

Chonquin University （中国），Identification of nano-scaled oxide particles in super ODS steels，木村晃彦

Institute of Modern Physics-CAS（中国），Effects of heavy-ion irradiation on the phase stability of oxide particles in super ODS steels，木村晃彦

Australian Nuclear Science and Technology Organization（オーストラリア），IAEA-CRP Pound robin test，木村晃彦

Financial Support

1. Grant-in-Aid for Scientific Research

藪内聖皓，若手研究(B)，強度因子の異なる欠陥が混在する組織における材料強度評価モデルの構築

2. Others

木村晃彦，中小企業経営支援等対策費補助金，究極の高均一性・高磁気特性・高生産性 Nd-Fe-B 焼結磁石の製造装置開発

木村晃彦，（株）京都マテリアルズ，社会インフラの長寿命化に資するさびの構造解明

木村晃彦，科学研究費補助金（基盤(B)分担者），圧力容器鋼に形成されるレイトブルーミング相の同定と脆化への役割に関する研究

木村晃彦，九州大学応用力学研究所・共同利用・共同研究，Fe-Mn モデル合金における特異な照射硬化とナノサイズの Mn 析出物形成の相関

木村晃彦，中部電力（株），実機圧力容器の照射脆化評価手法の構築に関する研究

木村晃彦，中部電力（株），内面内張材の腐食に及ぼす照射影響に関する研究

木村晃彦，日本原子力研究開発機構，改良ステンレス鋼被覆管の製造・加工・品質検査技術に係る基礎試験及び基礎データ整備

森下和功, 原子力環境整備促進・資金管理センター，炭素鋼の脆化予測モデルの構築

Publications

E. Hasenhuetl, R. Kasada, Z. Zhang, K. Yabuuchi, A. Kimura，Ion-irradiation effect on strain rate sensitivity of nanoindentation hardness of tungsten single crystal，Materials Transactions，58，4，580-586，2016

E. Hasenhuetl, R. Kasada, Z. Zhang, K. Yabuuchi, Y-J. Huang, A. Kimura，Evaluation of ion-irradiation hardening of tungsten single crystals by nanoindentation technique considering material pile-up effect，Materials Transactions，58，5，749-756，2016

P. Song, Z. Zhang, K. Yabuuchi, A. Kimura，Helium bubble formation behavior in ODS ferritic steels with and without simultaneous addition of Al and Zr，Fusion Engineering and Design，125，396-401，2017

E. Hasenhuetl, Z. Zhang, K. Yabuuchi, P. Song, A. Kimura，Crystal orientation dependence of ion-irradiation hardening in pure tungsten，Nuclear Instruments and Methods in Physics Research B，397，11-14，2017

S. Yamashita, F. Nagase, M. Kurata, T. Nozawa, S. Watanabe, K. Kirimura, K. Kakiuchi, T. Kondo, K. Sakamoto, K. Kusagaya, S. Ukai, A. Kimura，Technical Basis of Accident Tolerant Fuel Updated Under a Japanese R&D Project，Proc. of 2017 Water Reactor Fuel Performance Meeting (WRFPM2017)，A-173_F-176，2017

K. Sakamoto, M. Hirai, S. Ukai, A. Kimura, A. Yamaji, K. Kusagaya, T. Kondo, S. Yamashita，Overview of Japanese Development of Accident Tolerant FeCrAl-ODS Fuel Claddings for BWRs，Proc. of 2017 Water Reactor Fuel Performance Meeting (WRFPM2017)，A-033_D-033，2017

A. Kimura, S. Yuzawa, K. Sakamoto, M. Hirai, K. Kusagaya, S. Yamashita，Welding Technology R&D of Japanese Accident Tolerant FeCrAl-ODS Fuel Claddings for BWRs，Proc. of 2017 Water Reactor Fuel Performance Meeting (WRFPM2017)，A-059_F-059，2017

E. Hasenhuetl, Z. Zhang, K. Yabuuchi, A. Kimura，Effect of displacement damage level on the ion-irradiation affected zone evolution in W single crystals，Journal of Nuclear Materials，495，314-321，2017

T. Ishizaki, Y. Maruno, K. Yabuuchi, S. Kondo, A. Kimura，Development of High Irradiation Resistant and Corrosion Resistant Oxide Dispersion Strengthened Austenitic Stainless Steels，Part of the The Minerals, Metals & Materials Series book series (MMMS)，605-615，2017

A. Konno, N.H. Oono, S. Ukai, S. Kondo, O. Hashitomi, A. Kimura，He-Cavity Accumulation at Oxide Particle-Matrix Interface in Ni-Base ODS Superalloy，Materials Transactions，58，12，1636-1639，2017

N. Y. Iwata, R. Kasada, A. Kimura, T. Okuda，Effects of MA environment on the mechanical and microstructural properties of ODS ferritic steels，Fusion Engineering and Design，126，24-28，2017

W. Han, P. Liu, X. Yi, Q. Zhan, F. Wan, K. Yabuuchi, H. Serizawa, A. Kimura，Impact of friction stir welding on recrystallization of oxide dispersion strengthened ferritic steel，Journal of Materials Science & Technology，34，1，209-213，2017

P. Song, D. Morrall, Z. Zhang, K. Yabuuchi, A. Kimura，Radiation response of ODS ferritic steels with different oxide particles under ion-irradiation at 550 °C，Journal of Nuclear Materials，502，76-85，2017

K. Morishita, T. Nakasuji, X. Ruan, Evaluation of the energetics of copper-vacancy clusters in Fe, Nuclear Instruments and Methods B, 393, 101-104, 2017

T. Nakasuji, K. Morishita, X. Ruan, Monte-Carlo simulation of defect-cluster nucleation in metals during irradiation，Nuclear Instruments and Methods B，393，110-113, 2017

X. Ruan, T. Nakasuji, K. Morishita, 3D CFD and FEM Evaluations of RPV Stress Intensity Factor during PTS Loading, E-Journal of Advanced Maintenance, 9, 2, 84-90, 2017

X. Ruan, T. Nakasuji, K. Morishita, Coupled 3D CFD and FEM assessments of RPV stress intensity factor

during PTS events, Proceedings of ICAPP 2017 (2017 International Congress on Advances in Nuclear Power Plants), 17136 (9 pages), 2017

X. Ruan, T. Nakasuji, K. Morishita , Optimizing Maintenance Strategy of a reactor pressure vessel using 3D-CFD and FEM based probabilistic pressurized thermal shock analysis, Proceedings of the ASME 2017 Pressure Vessels & Piping Conference (ASME PVP 2017), 65072(10 pages), 2017

森下和功, 連載講座材料挙動と計算機シミュレーションの接点:第 1 回原子力材料挙動のカイネティックス計算と実験への期待, 日本原子力学会誌(AtomoΣ), 59, 11, 649-653, 2017.11

Presentations

A. Kimura, T. Takayma, W. Han, K. Yabuuchi, P. Dou, Dispersion control of oxide particles in FeCrAl-ODS ferritic steels for application to ATF cladding , FiMPART2017, Bordeaux Convention Center, France, 2017.7.9-12

T. Ishizaki, Y. Maruno, K. Yabuuchi, S. Kondo, A. Kimura, Development of High Irradiation Resistance and Corrosion Resistance Oxide Dispersion Strengthed Austenitic Stainless Steels, 18th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, Marriott Portland Downtown Waterfront, Portland, USA , 2017.8.13-17

Zhexian Zhang, Siwei Chen, Jin Gao, Peng Song, 藪内聖皓, 木村晃彦, Ion-irradiation effects on FeCrAl-ODS ferritic steels, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

J. Gao, K. Yabuuchi, A. Kimura, H. Kanai, M. Ando, H. Tanigawa, Effect of helium on the characteristics of dislocation loops in F82H and Fe-8Cr ferritic alloy, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

Huang Yen-Jui, Kousuke Kawakita, 木村晃彦, SCC mapping of SUS316L and SUS310S in hydrogenated hot water, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

宋鵬, 藪内聖皓, 木村晃彦, Phase stability of oxide particles in ODS ferritic steels under ion-irradiation, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

Daniel Morrall, 藪内聖皓, 木村晃彦, Tensile properties and microstructure of ODS added austenitic stainless steel, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

奥野慎, 藪内聖皓, 木村晃彦, 江里幸一郎, 高熱負荷 W-モノブロックの損傷評価(2), 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

小林凌也, 藪内聖皓, 木村晃彦, 熊野秀樹, クラッド熱影響を受けた実機圧力容器鋼の照射脆化評価(2), 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

湯澤翔, 藪内聖皓, 木村晃彦, 坂本寛, 平井睦, 山下真一郎, 事故耐性型 ODS 鋼燃料被覆管の接合技術開発(2), 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

前田透真, 鵜飼重治, 林重成, 大野直子, 柴田博紀, 坂本寛, 鳥丸忠彦, 皆藤威二, 木村晃彦, FeCrAl-ODS 鋼の高温加熱時の酸化挙動, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

金野杏彩, 大野直子, 鵜飼重治, 近藤創介, 橋冨興宣, 木村晃彦, γ'析出型 Ni 基超合金における γ'の高温重照射影響評価, 日本金属学会 2017 年（第 161 回）秋期講演大会, 北海道大学, 2017.9.6-8

S. Yamashita, F. Nagase, M. Kurata, T. Nozawa, S. Watanabe, K. Kirimura, K. Kakiuchi, T. Kondo, K. Sakamoto, K. Kusagaya, S. Ukai, A. Kimura, Technical Basis of Accident Tolerant Fuel Updated Under a Japanese R&D Project, WRFPM2017, Ramada Plaza Jeju, Korea, 2017.9.10-14

K. Sakamoto, M. Hirai, S. Ukai, A. Kimura, A. Yamaji, K. Kusagaya, T. Kondo, S. Yamashita, Overview of Japanese Development of Accident Tolerant FeCrAl-ODS Fuel Claddings for BWRs, WRFPM2017, Ramada Plaza Jeju, Korea, 2017.9.10-14

A. Kimura, S. Yuzawa, K. Sakamoto, M. Hirai, K. Kusagaya, S. Yamashita, Welding Technology R&D of Japanese Accident Tolerant FeCrAl-ODS Fuel Claddings for BWRs, WRFPM2017, Ramada Plaza Jeju, Korea, 2017.9.10-14

木村晃彦, 湯澤翔, 藪内聖皓, 坂本寛, 平井睦, 山下真一郎, 草ケ谷和幸, 改良ステンレス鋼燃料被覆管の BWR 装荷に向けた研究開発(2) (5)溶接法・検査方法の検討, 日本原子力学会 2017 年秋の大会, 北海道大学, 2017.9.13-15

山下真一郎, 渡部清一, 桐村一生, 垣内一雄, 近藤貴夫, 野澤貴史, 坂本寛, 草ヶ谷和幸, 鵜飼重治,

木村晃彦，安全性向上に資する新型燃料の既存軽水炉への導入に向けた研究開発(1)全体概要，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

坂本寛，平井睦，鵜飼重治，木村晃彦，山路哲史，草ヶ谷和幸，近藤貴夫，井岡郁夫，山下真一郎，加治芳行，安全性向上に資する新型燃料の既存軽水炉への導入に向けた研究開発 (2)BWR 用 FeCrAl-ODS 鋼，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

A. Kimura，Dispersion control of oxide particles for high performance ODS ferritic steels，EUROMAT2017，Thessaloniki Concert Hall, Greece，2017.9.17-22

N. Iwata, S-h. Noh, Y-s. Ha, A. Kimura，Enhancement of tensile elongation in Al-Zr added high-Cr ODS steels by microstructure control，EUROMAT2017，Thessaloniki Concert Hall, Greece，2017.9.17-22

R. Kobayashi, K. Yabuuchi, A. Kimura, H. Yuya, M. Ohyama，Evaluation of Fracture Toughness of RPVS of Decommissioning BWR --Microstructure of Cladding HAZ before Irradiation--，20th Meeting of the International Group of Radiation Damage Mechanisms in Pressure Vessel Steels (IGRDM20)，Parador de Santiago de Compostela, Spain，2017.10.16-20

A. Kimura, K. Yabuuchi, T. Takayama, W. Han, Z. Zhang, D. Chen, P. Song, P. Dou, C. Zhang，Dispersion Control of Oxide Particles by Small Additions of Group IV Elements in FeCrAl-ODS Ferritic Steels，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

K. Yabuuchi, A. Kimura, D. Nguyen-Manh, S. Dudarev，Effects of Transition Metal on Point Defect Behavior in bcc Tungsten，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

Z. Zhang, K. Yabuuchi, J. Gao, P. Song, D. Morrall, N. Oono, S. Ukai, A. Kimura，475°C-Embrittlement of FeCrAl-ODS Steels after Simulated Tube Processing，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

H. Kanai, M. Ando, H. Tanigawa, K. Yabuuchi, A. Kimura，Dual Ion Irradiation Effects on F82H and its Ferrite Model Steel，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

Y.J. Huang, K. Kawakita, A. Kimura，SCC Behavior of SUS316L and SUS310S in Fusion Relevant Environments，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

P. Song, K. Yabuuchi, A. Kimura，Helium-Bubbles Evolution in ODS Ferritic Steels with Different Oxide Particles，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

D. Morrall, J. Gao, K. Yabuuchi, A. Kimura，Tensile Properties and Microstructure of Zr-Added Austenitic Stainless Steel，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

S. Okuno, K. Yabuchi, A. Kimura, K. Ezato，Damaging Process of High Heat Loaded Cu-Tube Installed W-Monoblock，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

R. Kobayashi, K. Yabuuchi, A. Kimura, H. Yuya，Evaluation of Impact Properties of Reactor Pressure Vessel Steel Heat-affected by Cladding Procedure，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

S. Yuzawa, K. Yabuuchi, A. Kimura, K. Sakamoto, M. Hirai, S. Yamashita，Welding of Accident Tolerant FeCrAl-ODS Fuel Claddings for application to LWRs，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，青森リンクステーション，2017.11.5-10

木村晃彦，原子炉材料の耐照射性発現機構研究の現状と課題，日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

藪内聖皓，木村晃彦，タングステンの照射下微細組織発達に及ぼす鉄原子の影響，日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

J. Gao, K. Yabuuchi, A. Kimura, H. Kanai, M. Ando, H. Tanigawa，Dislocation loop raft formation in Fe3+ irradiated pure Fe at 300°C，日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

宋鵬，藪内聖皓，木村晃彦，Post-implantation annealing behavior of 15Cr-ODS ferritic steel，日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

D. Morrall, Z. Zhang, J. Gao, K. Yabuuchi, A. Kimura, T. Ishizaki, Y. Maruno，Precipitate properties in mechanically alloyed Zr added austenitic stainless steel，日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

大友康平，小林凌也，藪内聖皓，木村晃彦，熊野秀樹，クラッド熱影響を受けた実機圧力容器鋼の照射脆化評価（3），日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

山﨑祐希，湯澤 翔，藪内聖皓，木村晃彦，坂本寛，平井睦，山下真一郎，事故耐性型 ODS 鋼燃料被覆管の接合技術開発（3），日本金属学会 2018 年春期（第 162 回）講演大会，千葉工業大学新習志野キャンパス，2018.3.19-21

森下和功，原子力システム安全の評価に関する研究，平成 28 年度京都大学エネルギー理工学研究所附属エネルギー複合機構研究センター共同研究成果報告会，京都大学エネルギー理工学研究所北 4 号棟大会議室，2017.4.7

森下和功，事故炉廃止措置リスク学，第 2 回事故炉廃止措置のためのリスク管理技術研究会，日本原子力研究開発機構東京事務所，2017.4.13

X. Ruan, T. Nakasuji, K. Morishita，Coupled 3D CFD and FEM Assessments of RPV Stress Intensity Factor during PTS Events，2017 International Congress on Advances in Nulear Power Plants (ICAPP2017)，Hotel Fujita Fukui and The Westin Miyako Kyoto，2017.4.24-28

X. Ruan, T. Nakasuji, K. Morishita，Optimizing Maintenance Strategy of a Reactor Pressure Vessel using 3D-CFD and FEM based Probabilistic Pressurized Thernak Shock Analysis，ASME 2017 Pressure Vessels and Piping Conference (ASME PVP2017)，Hilton Waikoloa Village, Waikoloa, Hawaii, USA，2017.7.16-20

森下和功，事故炉廃止措置のハザードとリスクをテーマにした学生教育，第 4 回事故炉廃止措置のためのリスク管理技術研究会，日本原子力研究開発機構廃炉国際共同研究センターCLADS,福島県富岡，2017.7.24

中筋俊樹，阮小勇，森下和功，リスクを活用した合理的な圧力容器保全のための研究，日本保全学会第 14 回学術講演会，愛媛県松山市ひめぎんホール，2017.8.2-4

阮小勇，中筋俊樹，森下和功，保全の視点に立脚した原子炉圧力容器の確率論的健全性評価，日本保全学会第 14 回学術講演会，愛媛県松山市ひめぎんホール，2017.8.2-4

村吉範彦，森下和功，構造モデル化手法を用いた原子力利用に関する議論の全体像把握方法の検討，日本保全学会第 14 回学術講演会，愛媛県松山市ひめぎんホール，2017.8.2-4

村吉範彦，森下和功，構造モデル化手法を用いたエネルギー環境問題の全体像把握方法の検討―風力発電の諸問題を題材に－，エネルギー環境教育学会第 12 回全国大会，福井県美浜町エネルギー環境教育体験館「きいぱす」，2017.8.19-21

阮小勇，中筋俊樹，森下和功，加圧熱衝撃事象における原子炉圧力容器の健全性評価，日本機械学会 2017 年度年次大会，埼玉大学，2017.9.3-6

Y. Watanabe, K. Morishita, T. Nakasuji，Computational Study of Microstructural Evolution of RAFM Steel under Irradiation，The 8th International Symposium of Advanced Energy Science，Kihada Hall, Obaku Plaza, Kyoto University, Uji Campus, Kyoto Japan，2017.9.5-7

中筋俊樹，阮小勇，森下和功，圧力容器鋼の照射脆化予測高度化のためのモデリング，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

村吉範彦，森下和功，構造モデル化手法を用いた原子力利用に関する議論の全体像把握，日本原子力学会 2017 年秋の大会，北海道大学，2017.9.13-15

中筋俊樹，阮小勇，森下和功，圧力容器鋼の照射脆化予測高度化のためのモデリング，日本原子力学会 2017 年秋の大会学生ポスターセッション，北海道大学，2017.9.13-15

村吉範彦，森下和功，構造モデル化手法を用いた原子力利用に関する議論の全体像把握，日本原子力学会 2017 年秋の大会学生ポスターセッション，北海道大学，2017.9.13-15

阮小勇，中筋俊樹，森下和功，加圧熱衝撃事象における原子炉圧力容器の確率論的構造健全性評価，日本原子力学会 2017 年秋の大会学生ポスターセッション，北海道大学，2017.9.13-15

森下和功，事故炉廃止措置のハザードとリスクをテーマにした学生教育，日本原子力学会 2017 年秋の大会材料部会企画セッション，北海道大学，2017.9.13-15

K. Morishita, T. Nakasuji, X. Ruan, Energetics of Defect Clusters Produced in Fusion Structural Materials during Irradiation，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，Link Station Hall

Aomori, Aomori, Japan，2017.11.5-10

T. Nakasuji, K. Morishita, X. Ruan，Reaction Rate Theory Based Analysis of Microstructural Evolution in Fusion Structural Materials during Irradiation，The 18th International Conference on Fusion Reactor Materials (ICFRM-18), Link Station Hall Aomori, Aomori, Japan, 2017.11.5-10

Y. Watanabe, K. Morishita, M. Ando, H. Tanigawa, Multiscale Modeling of Helium Effects on Micro-structural Evolution of RAFM-Steel: Reaction Rate Theory Based Analysis，The 18th International Conference on Fusion Reactor Materials (ICFRM-18)，Link Station Hall Aomori, Aomori, Japan，2017.11.5-10

森下和功，核融合新スパコン運用に関する総合討論，炉工学・炉材料モデリングサブクラスターからの要望，シミュレーションクラスター合同会合（平成 29 年度第 1 回），量子科学技術研究開発機構東京事務所，2017.12.22

渡辺淑之，森下和功，安堂正巳，谷川博康，核融合炉構造材料の照射下ミクロ構造変化のモデル化～キャビティ形成挙動の照射条件依存性に関する反応速度論解析，平成 29 年度材料照射研究会副題：照射効果（II），京都大学エネルギー理工学研究所、北 4 号棟 4 階大会議室，2018.1.10-12

中筋俊樹，森下和功，照射下材料内の欠陥集合体の核生成プロセスのモデル化（2）核生成経路の損傷速度依存性，平成 29 年度材料照射研究会副題：照射効果（II），京都大学エネルギー理工学研究所、北 4 号棟 4 階大会議室，2018.1.10-12

中筋俊樹，森下和功，圧力容器鋼照射脆化予測高度化に関するモデリング，平成 29 年度材料照射研究会副題：照射効果（II），京都大学エネルギー理工学研究所、北 4 号棟 4 階大会議室，2018.1.10-12

森下和功，趣旨説明とシミュレーションクラスター合同会合の報告，シミュレーションクラスター炉工学・炉材料モデリングサブクラスター会合，京都大学エネルギー理工学研究所、北 4 号棟 4 階大会議室，2018.1.12

Complex Plasma Systems Research Section

S. Kado, Associate Professor
S. Yamamoto, Assistant Professor

1. Introduction

Magnetic fusion has some key features which make it an attractive option in a future energy mix: (1) inherent safety features; (2) waste which will not be a burden for future generations; (3) no greenhouse gases; and (4) the capacity for large scale energy production. The required raw materials for the fuel are abundantly and widely available in the Earth. The combination of these features provides magnetic fusion the potential to make a substantial contribution to satisfying world energy demand later this century and beyond. The development of magnetic fusion as a commercial reactor of electricity requires the solution to the physics problems of plasma transport and magneto-hydrodynamics. The goal of the fusion plasma research is the discovery of a magnetic configuration that can efficiently confine a high density plasma at a high temperature for a sufficiently long confinement time to produce net thermonuclear power. The point is to deepen the understanding of fusion plasma dynamics and to create key innovative technologies to make magnetic fusion a practical energy source. This research section seeks to investigate the confinement optimization of high-temperature plasmas in the helical-axis heliotron line. For the experimental and theoretical investigation of this theme, the plasma device of Heliotron J has been operated to study the magnetic configuration effects of ”hot plasma” confinement in Heliotron J. In particular, heating and fuelling, confinement and diffusion mechanisms and their diagnostics are of great importance. Recent results of this section in FY2017 are as follows:

2. Behavior of Highly Charged Impurity Ion Spectra in Hydrogen Pellet Injection Experiments

Imperfectly ionized impurity atoms of medium to high atomic number enhance a cooling of plasma, since these atoms absorb electron energy by further excitation or ionization, followed by a radiative decay. Many of the line spectra from these atoms/ions are in the vacuum ultraviolet (VUV) region. In order to monitor these impurity spectra in Heliotron J, we use a VUV spectrometer system at 16 - 40 nm.

Last fiscal year, we found that the VUV detector (Hamamatsu: F2224-21PFFX) that consists of a micro-channel plate (MCP) and a phosphor screen(SCR) was damaged presumably due to aged deterioration (Fig. 1). MCP was replaced with a same type while the SCR was renewed from an aluminium metal-back electrode with type P20 phosphor to that of Indium Tin Oxide (ITO) with type P43. Peak emission wavelength of the phosphor P43 is 545 nm and the decay time is 1 ms. Investigation on VUV intensity using typical heliotron J plasma discharges revealed that the gain of the renewed MCP was slightly lower than that of the previous one. On the other hand, the SCR gives the similar brightness with lower bias. We have thus determined the operational biases for MCP and SCR for the ordinary case to be 1.64 kV and 2.01 kV, respectively – those had been 1.3 kV and 3.0 kV respectively.

Figure 2 shows the temporal evolution of the spectral line intensities in the VUV region for a hydrogen pellet injection experiment (shot #68550). Magnetic configuration was "standard" with the counter clockwise magnetic field viewed from top. The pellet 0.8 mm in diameter was injected at 229 ms of the discharge timer.

It is known that the ionic species emit stronger radiation roughly at the electron temperature of its ionization energy. The ablation of the pellet decreased the electron temperature, which lead to a decrease in the spectra of highly-charged ions. On the other hand, O II (ionization energy of 35.1 eV) was enhanced. As the temperature recovered, the spectra from the higher charge-states started to increase with increasing order of ionization energy; C IV（64.5 eV), O VI(77.4 eV), O V(113.9 eV), and OVI (138.1 eV). After 260 ms, highly charged metal ions such as Fe XVI (489 eV) became dominant.

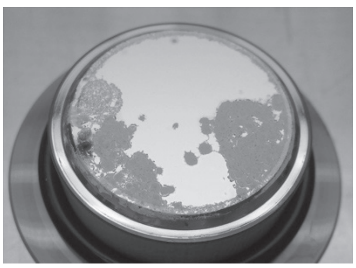


Fig. 1 Damaged phosphor screen. A discharge trace as well as aged deterioration of the surface can be observed.

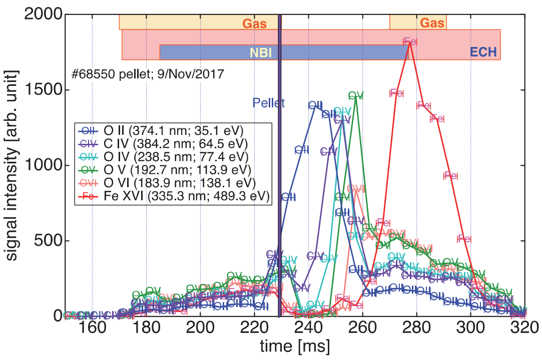


Fig. 2 Temporal evolution of the intensity of the impurely line spectra in VUV region [#66550]. Timings of the electron cyclotron heating (ECH), neutral beam injection (NBI), gas-puff control signal (Gas) and pellet injection were displayed. VUV signal intensity was not calibrated. The wavelength and ionization energy for each line were informed.

This observation suggests the effectiveness of investigating the behaviour of the lower charge-state ions, such as O II, C IV and O VI to monitor the effect of pellet ablation to the plasma parameters that is important in considering the particle fuelling scenario in fusion devices.

3. External Control of Fast-particle-driven MHD Instabilities by ECH/ECCD in Helical Plasmas

To establish some methods of stabilization and/or control of fast-particle (FP) driven magnetohydrodynamics (MHD) instabilities is required for a deuterium-tritium fusion reactor because they could enhance anomalous transport and/or induce loss of alpha particles. FP-driven MHD instabilities such as energetic particle modes (EPMs) and global Alfvén eigenmode (GAEs), are observed in tangential NBI-heated plasmas of stellarator/heliotron (S/H), Heliotron J, TJ-II and LHD. We utilize the ECH and ECCD in order to mitigate and eventually suppress the observed FP-driven MHD instabilities in three devices because both EC power deposition and driven current can be highly localized with a known location and good controllability. Since the stability of FP-driven MHD instabilities depend upon the magnetic configuration, comparative studies among these devices based on similarities and differences in the configuration are useful to investigate the impact of ECH/ECCD on FP-driven MHD instabilities and finally to have a comprehensive understanding of AE physics in S/H. Heliotron J and TJ-II have similar plasma/device parameters, e.g. low toroidal field period ($N_f = 4$) and low magnetic shear but different rotational transform. On the other hand, LHD has high $N_f = 10$ and high magnetic shear.

When magnetic shear is increased by EC-driven plasma current, the observed FP-driven MHD instabilities are suppressed or mitigated. In Heliotron J with almost zero vacuum magnetic shear, both negative and positive magnetic shear induced by co- and counter-EC driven plasma current suppress the observed EPMs and GAEs, as shown in Fig. 3. The experimental result and numerical calculation of shear Alfvén spectrum indicate that continuum damping whose rate is related to magnetic shear regardless of its sign is a key physical mechanism to mitigate the EPMs. In addition, the change of the shear Alfvén continuum by EC-driven plasma current strongly affects the existence and stability of AEs because the radial gap structure depends on *s*.

The FP-driven MHD instabilities are also suppressed by both on- and off-axis ECH in the TJ-II plasmas. On the other hand, some FP-driven MHD instabilities are stabilized and the others are destabilized by ECH depending on ECH power and deposition location in the Heliotron J and LHD plasmas. Figure 4 shows the dependence of GAE amplitude on ECH power and deposition location in Heliotron J. Here, the deposition location is controlled by changing the injection angle of EC wave. The GAE amplitude decreases with increasing ECH power for on-axis ECH. When ECH deposition is close to the GAE location $r/a \sim 0.6$, the GAE amplitude is larger than that for on-axis ECH. These dependences indicate that both the change of fast ion profile by ECH through the change of electron density and temperature, and/or the collisional damping due to trapped fast electrons may affect the AE stability.

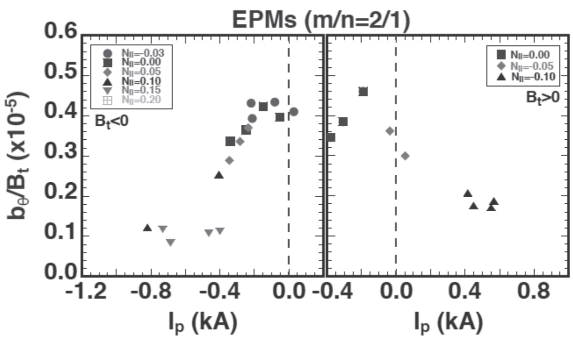


Fig. 3 Dependence of EPM amplitude on EC-driven current, which induces magnetic shear, in Heliotron J.

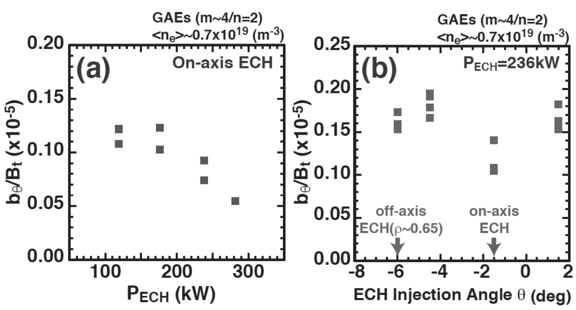


Fig. 4 Dependence of GAE amplitude on (a) ECH power and (b) ECH injection angle in Heliotron J.

Collaboration Works

Univ. Wisconsin（米国）、Oak Ridge National Laboratory（米国）、Max Plank Institute（ドイツ）、Stuttgart Univ.（ドイツ）、CIEMAT（スペイン）、Australian National Univ.、（オーストラリア）、Kharkov Institute（ウクライナ）、Southwest Institute of Physics（中華人民共和国），ヘリカル型装置における SOL/ダイバータプラズマに関する研究，水内亨，長﨑百伸，岡田浩之，小林進二，山本聡，南貴司

ANU（オーストラリア），データマイニングを用いた MHD 安定性解析，山本聡、長﨑百伸

Stuttgart University（ドイツ）、CIEMAT（スペイン），ヘリカル磁場配位における乱流揺動研究，大島慎介、長﨑百伸、水内亨、岡田浩之、南貴司、小林進二、山本聡

Stuttgart Univ.、CIEMAT（スペイン），先進閉じ込め配位，長﨑百伸、大島慎介、水内亨、岡田浩之、南貴司、小林進二、山本聡

CIEMAT（スペイン）、Kurchatov Institute（ロシア）、ORNL（米国），低磁気シアヘリカル装置における高速イオン励起 MHD 不安定性に関する研究, 山本聡、小林進二、長﨑百伸、大島慎介、水内亨

PPPL（米国），低磁気シアヘリカルプラズマにおける高速イオンの異常輸送ならびに損失機構に関する研究，山本聡、小林進二

核融合科学研究所・双方向型共同研究，磁場分布制御を活用したプラズマ構造形成制御とプラズマ輸送改善，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J、CHS、LHED 装置における重水素プラズマの粒子輸送の研究，水内亨，山本聡，南貴司，大島慎介，小林進二，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，低磁気シアヘリオトロン配位における磁気島に対するプラズマ応答の研究，水内亨，岡田浩之，長﨑百伸，山本聡，小林進二，南貴司

核融合科学研究所・双方向型共同研究，ヘリオトロン J における ICRF 加熱を用いたプラズマの高性能化研究，水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡，木島茂，大島慎介，門信一郎

核融合科学研究所・双方向型共同研究，磁気シアが MHD 不安定性による閉じ込め性能劣化度に与える影響の研究，水内亨，岡田浩之，長﨑百伸，小林進二，山本聡，南貴司

核融合科学研究所・双方向型共同研究，多様な磁場配位を有するヘリカル系プラズマにおけるプラズマフローと磁気島の理解，水内亨，山本聡，小林進二，長﨑百伸，岡田浩之，南貴司，大島慎介

核融合科学研究所・双方向型共同研究，ヘリカル系プラズマにおけるアルヴェン固有モードに起因する高速イオン損失研究, 水内亨, 山本聡, 小林進二, 大島慎介，岡田浩之，南貴司，長﨑百伸，門信一郎

核融合科学研究所・双方向型共同研究，有限ビーム幅を考慮した電子バーンシュタイン波放射計測，水内亨，長﨑百伸，大島慎介，南貴司，山本聡，小林進二，岡田浩之

核融合科学研究所・双方向型共同研究，アルベン固有モードによる高速イオン異常輸送の物理過程とその制御に関する研究, 水内亨, 岡田浩之, 南貴司, 長﨑百伸，山本聡，大島慎介，小林進二

核融合科学研究所・双方向型共同研究，マルチチャンネルカロリーメーターによるダイバーター熱流束の計測, 水内亨, 大島慎介, 岡田浩之, 小林進二, 門信一郎

核融合科学研究所・双方向型共同研究，ヘリカルプラズマの不純物輸送に対する同位体効果の影響，水内亨，門信一郎，小林進二，山本聡，大島慎介，南貴司，岡田浩之，長﨑百伸

核融合科学研究所・双方向型共同研究，ヘリオトロン J における VUV 分光法を用いた不純物の計測と輸送の研究, 水内亨, 門信一郎, 岡田浩之, 山本聡, 南貴司，小林進二，長﨑百伸，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J におけるプラズマ高密度化実験，水内亨，門信一郎，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，閉じ込め改善現象に関する 3 次元効果の解明, 水内亨, 南貴司, 小林進二，門信一郎，岡田浩之，長﨑百伸，大島慎介，山本聡，木島滋

Financial Support

Grant-in-Aid for Scientific Research
門信一郎，基盤研究(C)，近赤外領域の分光法を用いた核融合プラズマ診断法の新展開

Publications

S. Yamamoto, K. Nagasaki, S. Kobayashi, K. Nagaoka, A. Cappa, H. Okada, T. Minami, S. Kado, S. Ohshima, S. Konoshima, Y. Nakamura, A. Ishizawa, G.M. Weir, N. Kenmochi, Y. Ohtani, X. Lu, Y. Tawada, D. Kokubu, T. Mizuuchi, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD on Heliotron J, Nuclear Fusion, 57, 12, 126065-1-9, 2017

T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, X.X. Lu, N. Kenmochi, Y. Ohtani, K. Nishioka, L. Zang, G. Weir, D.L. Yu, S. Konoshima, A. Ishizawa, Y. Nakamura, Configuration Control Effects on Confinement, Transport and Stability in a Helical-Axis Heliotron Device, Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), 2017

S. Yamamoto, K. Nagasaki, Á. Cappa, K. Nagaoka, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD in stellarator/heliotron, International Stellarator-Heliotron Workshop (ISHW2017), 2017

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi4, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, Y. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi, Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), 2017

Presentations

Á. Cappa, E. Ascasíbar, F. Castejón, M. Liniers, D. Pace, M.A. Van Zeeland, S. Yamamoto, K. Nagasaki, K. Nagaoka, T. Ido, A. Shimizu, R. Seki, H. Yamaguchi, M. Osakabe, W.W. Heidbrink, E.D. Fredrickson, S. Sharapov, M. García-Munoz, Status of EP-12: Identification of AE control actuators and preliminary assessment for ITER, 18th ITPA-EP Meeting, Sevilla University, 2017.4.16-28

S. Kobayashi, X.X. Lu, K. Ida, T. Kobayashi, M. Yoshinuma, S. Kado, S. Ohshima, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, D.L. Yu, Y. Nakamura, A. Ishizawa, S. Nishimura, K. Nishioka, S. Konoshima, T. Mizuuchi, Development of ultra-fast charge exchange recombination spectroscopy for temperature and flow velocity fluctuation measurements in Heliotron J, 44th EPS Conference on Plasma Physics, Waterfront Hall, 2017.6.26-30

門信一郎，プラズマの分光診断〜理科教材から核融合最前線まで〜，第 24 回京都大学宇治キャンパス産学交流会，宇治キャンパス北４号棟第会議室，2017.6.28

H. Okada, K. Nagasaki, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, N. Kenmochi, Y. Otani, X. Lu, K. Ida, K. Watanabe, Nagaoka, T. Kobayashi, G. Motojima, R. Seki, K.H. Kasahara, Y. Suzuki, M. Yokoyama, A. Ishizawa, Y. Nakamura, N. Nishino, Y. Nakashima, G. Weir, S. Murakami8, S. Konoshima, T. Mizuuchi, Studies of Magnetic Field Configuration in Heliotron J, 1st Asia-Pacific Conference on Plasma Physics, Jinniu Hotel, 2017.9.18-23

S. Yamamoto, D. Pretty, B. Blackwell, E. Ascasibar, R. Jimenez-Gomez, K. Nagasaki, Application of Data Mining to Plasma Fluctuation, データ駆動プラズマ物理研究の開拓，キャンパスプラザ京都，2017.9.14-15

T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, X.X. Lu, N. Kenmochi, Y. Ohtani, K. Nishioka, L. Zang, G. Weir, D.L. Yu, S. Konoshima, A. Ishizawa, Y. Nakamura, Configuration Control Effects on Confinement, Transport and Stability in a Helical-Axis Heliotron Device, Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

S. Yamamoto, K. Nagasaki, Á. Cappa, K. Nagaoka, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD in stellarator/heliotron, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, Y. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi, Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Heliotron J, International Stellarator-Heliotron Workshop (ISHW2017), Shiran-Kaikan, Kyoto University, 2017.10.2-6

S. Yamamoto, Energetic particles/AEs control, 17th Coordinated Working Group Meeting, Shiran-Kaikan, Kyoto University, 2017.10.6

門信一郎, 理科教科書とプラズマアウトリーチ活動との接点, 高校生向けアウトリーチ活動に関する講演会, 核融合科学研究所, 2017.11.14

K. Nagasaki, S. Yamamoto, K. Nagaoka, Á. Cappa, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir, Control of Energetic-Particle-Driven MHD Instabilities by ECH/ECCD, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

S. Yamamoto, Y. Tawada, K. Ogawa, M. Isobe, S. Kobayashi, K. Nagasaki, P. Adulsiriswad, H. Okada, S. Kado, T. Minami, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, N. Kenmochi, Y. Ohtani, X. Lu, T. Mizuuchi, Study of interplay between fast-ions and MHD instabilities in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi, X. Lu, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, H. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi, Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Helitoron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

S. Kado, A. Iwata, T. Kanazawa, H. Okada, S. Yamamoto, T. Minami, S. Kobayashi, K. Nagasaki, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, T. Mizuuchi, Application of Near-Infrared Spectroscopy to Heliotron J Plasma, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

H. Okazaki, G. Motojima, H. Okada, K. Nagasaki, Y. Nakamura, S. Kado, S. Kobayashi, S. Konoshima, T. Minami, S. Yamamoto, S. Ohshima, X. Lu, T. Kanazawa, K. Yamamoto, S. Tanohira, S. Watanabe, N. Haji, Y. Yonemura, T. Mizuuchi, Optimization study of cryogenic hydrogen pellet injection for fueling in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

山本皓基, 岡田浩之, 笠原寛史, 門信一郎, 山本聡, 南貴司, 小林進二, 長﨑百伸, 大島慎介, 中村祐司, 石澤明宏, 木島滋, 呂湘潯, 岡崎悠, 金沢友美, 田野平駿, 渡邊真太郎, 土師直之, 米村裕馬, 水内亨, ヘリオトロンJプラズマにおける有限要素法を用いたイオンサイクロトロン周波数帯加熱解析, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

T. Kanazawa, S. Kado, H. Kawazome, H. Okada, S. Yamamoto, T. Minami, S. Kobayashi, K. Nagasaki, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, X. Lu, H. Okazaki, K. Yamamoto, S. Tanohira, S. Watanabe, N. Haji, Y. Yonemura, T. Mizuuchi, Evaluation of applicability of atomic helium line intensity ratio method to electron temperature and density measurement in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

R. Yano, T. Kaneko, H. Kawazome, S. Kado, T. Kanazawa, K. Tsunose, N. Nishino, T. Mizuuchi, Recognition of 2-D CT image by nural network in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

A.Terakado, M. Sakamoto, N. Ezumi, K. Nojiri, T. Mikami, S. Togo, T. Iijima, T. Yokodo, K. Sawada, S. Kado, Y. Nakashima, Measurement of Plasma During Detach-Attach Transition by Transient Heat Flux to Divertor Simulation Plasma on GAMMA 10/PDX, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

S. Yamamoto, LHD experiment group, シンポジウム 9: LHD における重水素実験の開始と今後の展望: MHD 現象, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

A Terakado, M Sakamoto, N Ezumi, K Nojiri, T Mikami, S Togo, T Iijima, T Yokodo, K Sawada, S Kado, Y Nakashima, Measurements of hydrogen molecular rovibrational temperature with high temperature target in divertor simulation plasma on GAMMA 10/PDX, The 26th International Toki Conference (ITC-26) & The 11th Asia Plasma and Fusion Association Conference(APFA-11), Ceratopia Toki, Toki, Gifu, Japan, 2017.12.5-8

S. Yamamoto, Studies of fast-ion-driven MHD instabilities in stellarators/heliotrons, US-Japan MHD workshop, Naka Fusion Institute, 2018.3.5-9

S. Yamamoto, Heliotron J results in terms of bumpy field, US-Japan JIFT workshop, 京都大学宇治キャンパスエネ研北 4, 2018.3.22-23

岩田晃拓, 門信一郎, 金沢友美, 岡田浩之, 山本聡, 本島厳, 岡崎悠, 南貴司, 小林進二, 長﨑百伸, 大島慎介, 中村祐司, 石澤明宏, 木島滋, 木島滋, 水

内亨，ヘリオトロンJにおける可視・近赤外簡易分光システムの相互感度較正，日本物理学会 第73回年次大会，東京理科大学野田キャンパス，2018.3.22-25

Clean Energy Conversion Research Section

Ryoji Hiwatari, Visiting Professor
(National Institutes for Quantum and Radiological Science and Technology)

1. Introduction

Fusion energy is considered as a candidate of the future energy source, which requires zero or low CO_2 emission for a sustainable energy mix. To demonstrate energy production, the experimental reactor ITER is now under construction. The first electric power generation will be planned in a demonstration reactor (DEMO) following ITER. Conceptual design activity of DEMO is progressed among ITER member countries.

In Japan, national-wide DEMO design activity has started in 2015, and Japan's DEMO concept is now being developed to aim at (1) steady power generation over several hundred MW, (2) plant availability toward commercialization, and (3) self-sufficiency of tritium fuels. Japan's DEMO concept of JA DEMO Model 2014 was proposed based on the operational flexibility from pulse to steady-state operations [1]. Even in the steady-state DEMO, pulsed operation is required for commissioning phase and suitable for early demonstration of fusion electricity by moderate plasma performance. The major radius of 8.5 m enables to supply CS flux sufficient for plasma current ramp-up inductively for steady-state operation with fusion power of P_f=1.5 GW, and for 2 hours pulsed operation with P_f=1 GW.

A commissioning process of Japan's DEMO is also developed. Tritium ratio control enables to increase fusion power step by step with keeping high plasma density required for exhaust heat handling by divertor detachment. Fusion power can be started from about 400 MW with the normalized beta value β_N 2.0 similar to those of ITER. The plasma density $1.0\text{x}10^{19}$ m^{-3} is also similar to that of ITER. In short, a reliable commissioning operation is found to be possible based on the ITER operation experience. Core plasma performance such as confinement improvement factor (HH) and the ratio of greenwald density limit (f_{NGW}) is found to be kept constant during commissioning. The commissioning process will be applied to the analysis on DD start-up scenario, in which the external tritium supply of fusion fuel is not required.

2. Overall concept of Japan's DEMO

The present Japan's DEMO concept is proposed as JA DEMO 2014 [1]. Major constraints of JA DEMO 2014 are divertor heat-handling and flux supply by the central solenoid (CS) coil. First, divertor heat-handling is the most critical issue to determine the fusion power and the net electric power. Considering the experimental database, reliable radiation fraction f_{rad}=0.7 was applied, and maximum heat load on the divertor target less than 10 MW/m^2 was found to be foreseeable for fusion power P_f=1.5-2.0 GW by the 2D divertor simulation. The water-cooled tungsten mono-block with Cu-alloy pipes as plasma-facing component similar to ITER divertor design is applied to handle the heat load up to around 10MW/m^2 in the DEMO divertor concept [1]. Second, for operation flexibility, a medium size major radius around 8 m secures the staged operation by accommodating a CS coil large enough to enable a two-hour pulse discharge. The bird's-view of JA DEMO 2014 is shown in Figure 1.

The plasma operation is based on the H-mode discharge sustained by driven current and bootstrap current. The bootstrap current fraction f_{bs} is expected to be 61%, and the current drive power P_{ADD} results in 83.7MW by the NBI current drive system. The blanket system is a water-cooled ceramic breeder concept, which consists of a mixed bed of Li_2TiO_3 pebbles and $Be_{12}Ti$ pebbles and structure material F82H. The blanket system is replaced through the vertical ports, and the divertor (which consists of W armor and Cu-alloy target) is done through the lower ports, shown in Figure 1. Because of neutron irradiation effect on Cu alloy of the divertor target, the lifetime of divertor is shorter than that of blanket. Hence, considering difference of each lifetime of blanket and divertor, the blanket and the divertor can be independently replaced through each port. The toroidal field (TF) coil concept is based on the Ni_3Sn conductor and the radial-plate system like the ITER TF coil concept.

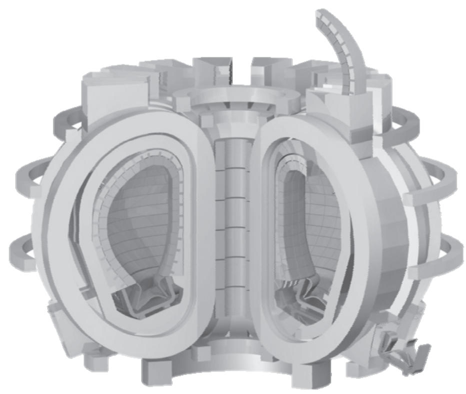


Fig.1: Bird's-view of the present Japan's DEMO concept "JA DEMO 2014"

3. Role of commissioning process in operation plan for Japan's DEMO

An operation plan for Japan's DEMO is defined as a critical task, because it shows how to demonstrate respective mission of DEMO. In this fiscal year, core plasma commissioning process, which is a part of the operation plan, has been investigated. The commissioning process of core plasma contains a series of the initial H/DD discharge, a pulsed DT discharge, and a steady state DT discharge. The key point as for commissioning process of core plasma is compatibility between fusion output control and divertor detachment control. In other words, plasma density has to be kept high during control of fusion output for keeping detachment condition in the divertor. We investigate such commissioning process by using tritium ratio control with systems code.

4. Development of commissioning process by tritium ratio control

In order to keep compatibility between fusion output control and divertor detachment one, tritium ratio control is applied to control the fusion power output [2]. The systems code TPC [3] is improved to install the function of tritium ratio control.

It is preferable that plasma operation starts with the similar parameter range like ITER standard operation, because the operation control is supposed to be well-established.

Fig. 2 shows the commissioning process starting with the operation parameter similar to the ITER standard operation. The operation point OP1 with tritium ratio f_{nT} 0.05 shows the fusion power P_f 400MW, safety factor q_s 3.0, normalized beta β_N 2.0. Those parameters are consistent with the ITER standard operation point. However, confinement improvement factor HH and the ratio of greenwald density limit f_{nGW} are 1.3 and 1.2, respectively, which are advanced than of ITER. Hence, development of plasma performance as for HH and f_{nGW} is a key issue to demonstrate this commissioning process.

In this commissioning process, plasma performance such as β_N is improved with increase of tritium ration f_{nT}, then the fusion power is increased under the constant plasma performance parameters (HH and f_{nGW}) and current drive power P_{NBI}~100MW. From the operation point OP3, the gross electric power become larger than the internal consumed power, then the net electric power is produced. That means that grid connection will be possible from the operation point OP3.

During increase of tritium ratio f_{nT}, the current drive fraction f_{CD} is also increased step by step. In the initial operation point OP1, the current drive fraction f_{CD} is about 45%, and it increase step by step with increase of the tritium ratio f_{nT}. Finally, the current drive fraction will be achieved to 100%, which means the full current drive condition (steady state operation condition).

In the final operation point OP5, all parameters such P_f, β_N, HH and f_{nGW} are the rating operation parameters with tritium ratio f_{nT}=0.5. The net electric power will be about 200MWe.

5. Summary

The present concept of Japan's DEMO is introduced, and its overall characteristics are explained. Then, as this fiscal year progress, the operation plan and the commissioning process are investigated. By applying the tritium ratio control, the commissioning process starting with parameter range similar to ITER standard operation is developed under the condition of constant plasma performance of HH and f_{nGW}. This result is also applicable to DD start-up scenario, which is investigated in Kyoto Univ. [4].

References

[1] Y. Sakamoto et al., 25th IAEA Int. Conf. on Fusion Energy (2014) FIP/3-4Rb.

[2] R. Hiwatari et al., Fusion Engineering and Design 86 (2011) 1099–1102

[3] T. Goto et al., Plasma and Fusion Researc

[4] S. Konishi, et al., Journal of plasma and fusion research 76, 1309-1312, 2000

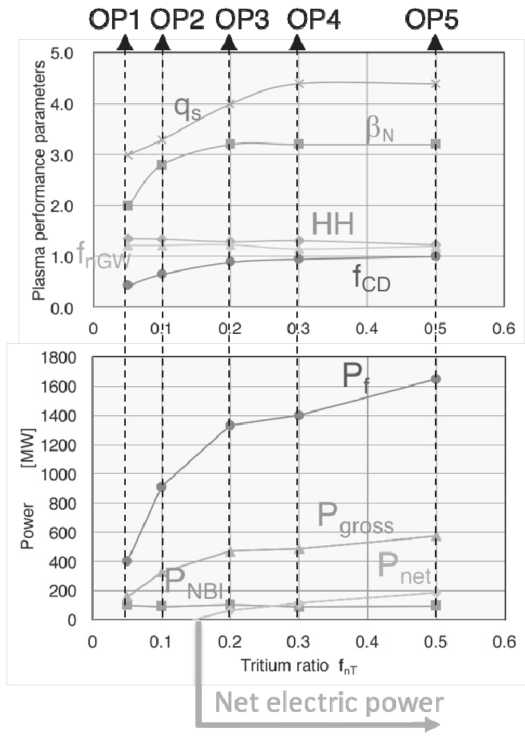


Fig.2: Commissioning process of Japan's DEMO. The tritium ratio is applied to control the fusion power with keeping high plasma density compatible with divertor detachment control. Current drive fraction is also increased step by step, and finally it achieved to the steady state condition (full current drive condition).

Clean Energy Conversion Research Section

Toshiaki Kato, Visiting Associate Professor
(Tohoku University)

1. Introduction

The atomically thin layered materials have attracted intense attention because of its superior electrical and optical features. In this project, we focused on two of layered materials; (i) single-walled carbon nanotubes (SWNTs), which is a tube structure made from the graphene sheet and (ii) transition metal dichalcogenide (TMD) having layered structures with transition metal and chalcogen atoms. Although, both of them include huge potential for fabrication of various energy harvesting devices, there remains several crucial issues for their practical use. Then, we attempted to solve some important issues relating with these materials through this project.

2. Chirality controlled synthesis of SWNTs

SWNTs are promising candidate for high performance optoelectrical devices due to the unique 1-dimension structure. Since the physical properties of SWNTs strongly depend on the chirality, obtaining SWNTs with particular chirality remains as a critical issue in this scientific community. Based on the previous studies, the catalyst size, component, and crystal structures are proven to be contributed to decide SWNTs chirality. However, effect of catalyst surface state on chirality control is seldom being studied.

The surface state of catalyst is controlled by our newly established catalyst pretreatment process. The annealing of catalyst nanoparticles under the high vacuum condition with slightly adding small amount of reactive gas species can control the oxidation degree of catalyst surface.

Based on the systematic investigations, it is found that the catalyst surface state can be very sensitive to nucleate specific type of chirality species. The significant change of chirality from (6,5) to (6,4) SWNTs are observed by controlling the surface state of catalyst (Fig. 1) [1]. Through the adjustment of catalyst surface state, high purity (57%) (6,4) SWNTs are grown for the first time (Fig. 1(b)).

To elucidate the mechanism of chirality selective nucleation by changing the surface state of catalyst, systematic investigations have been carried out. The detailed measurements with X-ray absorption fine structure (XAFS) shows about 50 % of oxidized Co catalyst (CoOx) were reduced by the pretreatment. The activation energy of SWNTs growth near the lower threshold of growth temperature increases with the catalyst pretreatment, which is consistent with the results of first-principle calculations, where the binding energy between cap structure of SWNTs and CoOx catalyst increase by reducing catalyst surface. Theoretical calculation also reveals that the most preferred chiral angel shifts to a lower direction through the reduction of Co catalyst. This is also in good accordance with the experimental results. Based on these results, it is revealed that the combination of diameter (to small diameter) and chiral angle (to small angle) shift through the change of catalyst surface state can cause the drastic shift of chirality species from (6,5) to (6,4) SWNTs (Fig. 1(a)(b)).

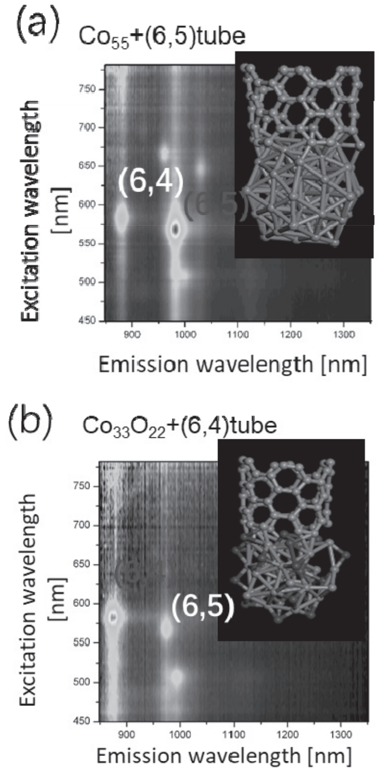


Fig. 1: Photoluminescence-excitation (PLE) map and corresponding first principle calculation model of (a) (6,5) and (b) (6,4) dominant SWNTs grown from catalyst (a) without and (b) with pretreatment.

3. Transparent and flexible solar cell

Atomic scale 2D sheets attract intense attention due to their superior electrical, mechanical, and optical features. TMD is known as a true 2D material with excellent semiconducting properties. TMD is one of the most attractive materials for future high performance transparent and flexible solar cells due to their atomically thin structure, band gap in visible light range, and high optical transparency. Although the solar cell of TMD has been widely investigated by many groups, those are based on the pn junction type solar cell. Since complicated structures are required to form pn junction structures in TMD such as dual gate electrodes or position selective doping, the device size of pn junction solar cell with TMD is limited within very small region (few μm). The Schottky type solar cell is known as another type of solar cell and it is possible to scale up the device up to the practical size because of the simple device structures. However, the detailed study of Schottky type solar cell with TMD has not been reported. Because the Schottky barrier is formed at the contact region between electrode and TMD, it is important to select appropriate electrode pairs for end of electrodes (Fig. 2(a)). In this study, we have investigated the combination of end electrodes and the distance of each electrode to obtain the better performance.

We used tungsten diselenide (WSe_2) and tungsten disulfide (WS_2) as a TMD materials. A Schottky-type solar cell was fabricated via mechanical exfoliation from bulk WSe_2 and WS_2 crystal. First, we attempted to find a suitable electrode pair for Schottky-type solar cells with WSe_2 and WS_2. Since the contact structure between the electrode and TMD is basically governed by the work function difference of each material, we systematically measured the work function (WF) of various metals used as electrodes by photoelectron yield spectroscopy. Since "as exfoliated few-layered WSe_2" is naturally p-doped by some impurities, the Fermi energy of our WSe_2 can be assumed to be around 5 eV. Thus, Ti (WF = 4.9 eV) or Pd (WF = 5.08 eV) can work as an Ohmic contact for few-layered WSe_2, whereas Ni (WF = 4.52 eV), which has the lowest work function in this measurement, can form a large Schottky barrier at the contact region with WSe_2. A Schottky-type solar cell with an asymmetric electrode pair was fabricated with various electrodes. A clear difference in source-drain current (I_{DS})-source-drain voltage (V_{DS}) could be observed depending on the electrode pair under light illumination with a solar simulator. The efficiency clearly depended on the work function difference between two electrodes (ΔWF), and a higher efficiency could be obtained with higher ΔWF (Pd-Ni), which is consistent with our concept, where Ni and Pd can form large and small Schottky barriers to operate as power-generation and carrier-collect regions, respectively (Fig. 2(b)).

The electrode distance is also important factor to decide the dynamics of optically-generated carriers. Then the distance of both electrodes was systematically adjusted between 0.5 to 14 μm. It is found that the highest efficiency can be given with 2.2 μm distance. The photocurrent mapping measurements revealed that the suitable distance should be decided by the balance of exciton diffusion length and momentum transfer distance of separated carriers. Based on these optimizations of electrodes

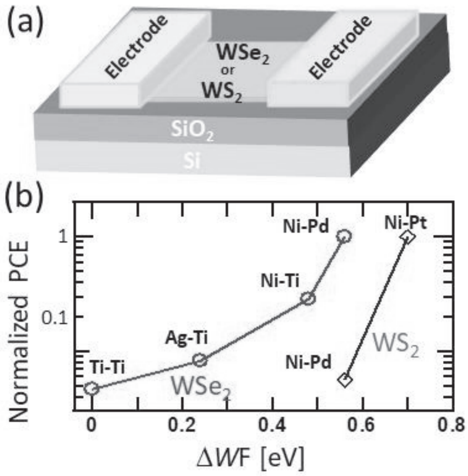


Fig. 2: Schematic illustration of our device structures of Schottky solar cell with few-layered TMD. (b) Plot of normalized PCE as a function of ΔWF.

and distance, the power conversion efficiency (PCE) can be reached up to 0.7 %, which is over 3000 times higher than that before the optimization (symmetric electrodes with long distance). This power conversion efficiency is the highest value for solar cell with similar TMD thickness.

4. Summary

In this project, we have realized two distinguished results. For chirality controlled synthesis of SWNTs, an innovative chirality-control method has been developed based on surface state control of Co catalyst. High purity (6,4) SWNTs growth is realized for the first time. For the case of TMD study, scalable method for fabricating transparent and flexible solar cell is developed by using Schottky type device configuration. Through the optimization of device structures such as combination of electrode pairs, distance of electrode, and TMD geometry, PCE of 0.7% is achieved, which is the highest value within TMD-based solar cell.

References

[1] B. Xu, T. Kaneko, Y. Shibuta, and T. Kato, Sci. Rep. 7 (2017) 11149-1- 9.

[2] T. Akama, W. Okita, R. Nagai, C. Li, T. Kaneko, and T. Kato, Sci. Rep. 7 (2017) 11967-1-10.

Chemical Reaction Complex Processes Research Section

T. Nohira, Professor
T. Kodaki, Associate Professor
T. Ymamoto, Assistant Professor

1. Introduction

In this research section, we studies on electrochemistry, materials science, genetic engineering and protein engineering. We also apply them to the development of efficient solar silicon production process and the efficient utilization of bioenergy.

In this fiscal year, we have researched the development of a novel production process of solar silicon and the highly efficient production of bioethanol.

2. Development of a Novel Production Process of Solar Silicon Using Molten Salt Electrodeposition

In the conventional industrial production process of crystalline Si solar cells, ingots of solar-grade Si (SOG-Si) are once prepared, and then they are sliced into wafers by diamond wire saws. However, this process has several problems such as the large kerf loss and the complex process of cell production. If high-quality crystalline Si films are prepared directly on desired substrates at a low cost, a new production process of crystalline Si solar cells will be realized.

From this background, we proposed a new electrodeposition process of crystalline silicon, as shown in Fig. 1 [1]. Here, molten KF–KCl is used as an electrolyte and $SiCl_4$ as a silicon source. We especially selected the molten KF–KCl because both KF and KCl are highly soluble to water. Thus, the adhered salt is easily removed by water washing. Moreover, high purity $SiCl_4$, which is commercially available at a low cost, is able to be used as a silicon source. When gaseous $SiCl_4$ is introduced into the molten KF–KCl, the following reaction occurs:

$$SiCl_4 + 6F^- \rightarrow SiF_6^{2-} + 4Cl^- \quad (1)$$

Thus, when the concentration of F^- ion is adjusted beforehand, the resultant molten salt after the introduction of $SiCl_4$ gas is the same as the molten KF–KCl containing K_2SiF_6. Another advantage of the use of KF–KCl molten salt is the elimination of chlorine in $SiCl_4$ by Cl_2 gas evolution on the carbon anode, which realizes the fixed composition of molten salt as well as the reuse of recovered Cl_2 for the production of $SiCl_4$.

We first explored the optimized conditions, i.e., K_2SiF_6 concentration and current density, for electrodepositing compact and smooth Si films in molten KF–KCl at 923 K. Secondly, we investigated the feasibility of $SiCl_4$ gas as a silicon source. Finally, we examined the effect of the experiment temperature elevated from 923 K to 1023 K on the crystallinity of Si films.

Fig. 2 shows a cross-sectional SEM image of the sample electrodeposited at 100 mA cm^{-2} for 50 minutes in the melt containing 2.0 mol% K_2SiF_6 at 923 K. Compact and smooth Si layers with 70-80 µm thickness were obtained on the both side of a silver plate. EDX analysis revealed that the composition was 100 at.%-Si within the detection limit. Fig. 3 show an XRD pattern of the deposit prepared at 70.4 mA cm^{-2} for 30 minutes, which confirms that the obtained film was crystalline Si. Raman spectroscopy also indicated that the obtained deposit was crystalline Si. From the various experiments, the optimum condition for

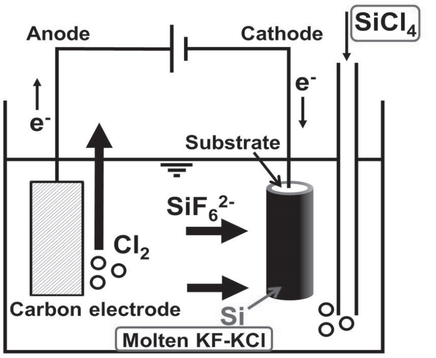


Fig. 1. Principle of the electrodeposition process of crystalline Si films in KF–KCl molten salt using $SiCl_4$ as a silicon source [1].

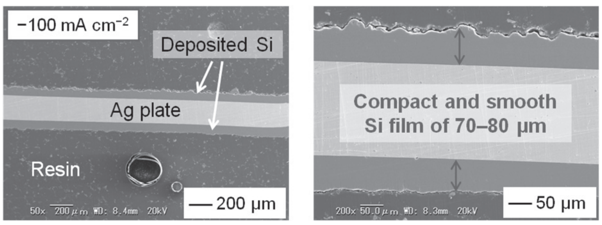


Fig. 2. Cross-sectional SEM images of silicon films electrodeposited on a silver plate in molten KF–KCl–K_2SiF_6 (2.0 mol%) at 923 K. Current density: 100 mA cm^{-2}.

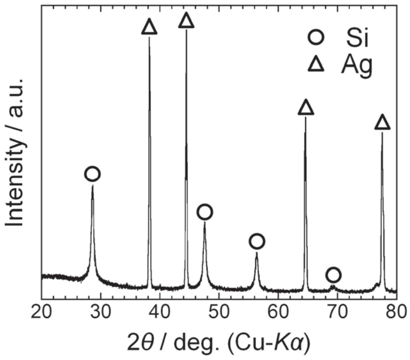


Fig. 3. An XRD pattern of a silicon film electrodeposited on a silver plate in molten KF–KCl–K_2SiF_6 (2.0 mol%) at 923 K. Current density: 70.4 mA cm^{-2}.

obtaining compact and smooth Si films has been found to be the K_2SiF_6 concentration range of 2.0–3.5 mol% and the current density range of 50–200 mA cm^{-2}.

In order to investigate the feasibility of $SiCl_4$ as a silicon source, 2.88 mol% of $SiCl_4$ gas was introduced into a blank KF–KCl molten salt. After the introduction, cyclic voltammetry was performed on a silver electrode to check the existence of Si(IV) ions. The obtained cyclic voltammogram showed a couple of redox peaks which is indicative for Si(IV) ions. The concentration of Si(IV) ions was estimated to be 2.30 mol% from the height of peak current density. Galvanostatic electrolysis was conducted on a silver wire at 155 mA cm^{-2} for 30 minutes. From a cross-sectional SEM image of the sample, the formation of silicon film was confirmed.

The crystallinity of Si films electrodeposited at 923 K was analyzed by electron backscattering diffraction (EBSD). The results showed that the average crystallite size was below 1 μm. In order to enhance the crystal growth during the electrodeposition, the experiment temperature was raised to 1023 K. In an SEM image of the sample, the columnar Si crystallites were observed. The EBSD analysis revealed that the largest crystallite size was ca. 10 μm in width and 35 μm in length. Thus, it was confirmed that the crystallite size significantly increased when the electrodeposition temperature was raised to 1023 K.

3. Efficient Bioethanol Production from Cellulose using Ionic Liquid

Cellulose is the most abundant natural compound among woody biomass and expected to be a source for biofuel such as bioethanol. However, rigid crystal structure of cellulose makes it difficult to hydrolyze to glucose. Recently, pretreatment with ionic liquid was found to be effective for hydrolysis of cellulose by cellulase [2].

In this fiscal year, effects of various ionic liquids including 1-Allyl-3-methylimidazolium Chloride ([Amim]Cl), 1-Butyl-3-methylimidazolium Chloride ([Bmim]Cl), 1-Butyl-3-methylimidazolium Acetate ([Bmim][OAc]), and 1-Ethyl-3-methylimidazolium Acetate ([Emim][OAc]) on ethanol fermentation were examined extensively.

At first, the effects of concentrations of [Bmim]Cl on ethanol fermentation from glucose were examined (Fig. 4). Ethanol was produced sufficiently under the conditions of less than 200 mM [Bmim]Cl. Then, ethanol fermentation was examined in the presence of 200 mM of [Amim]Cl, [Bmim]Cl, [Bmim][OAc] or [Emim][OAc] (Fig. 5). Ethanol was shown to be fermented with these four ionic liquids, although amount of ethanol was different between each of the ionic liquids.

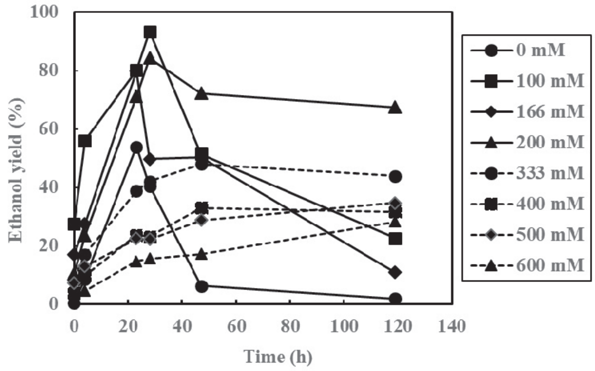


Fig. 4. Ethanol fermentation in the presence of various concentrations of [Bmim]Cl.

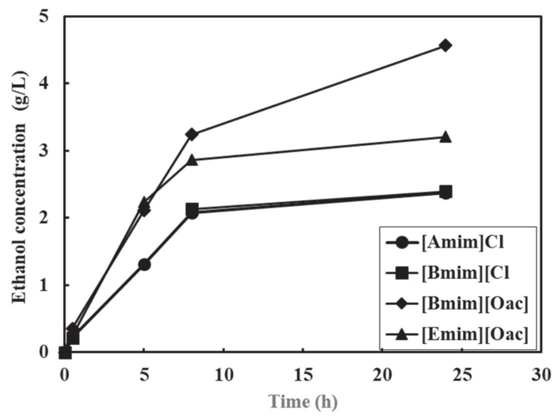


Fig. 5. Ethanol fermentation in the presence of [Amim]Cl, [Bmim]Cl, [Bmim][OAc] or [Emim][OAc].

These researches were partly supported by grants to T. N. from JST-CREST and MEXT (16H02410).

References

[1] K. Maeda, K. Yasuda, T. Nohira, R. Hagiwara, and T. Homma, *J. Electrochem. Soc.*, **162**, D444 (2015).
[2] I. Kilpeläinen, H. Xie, A. King, M. Granstrom, S. Heikkinen, D. S. Argyropoulos, *J. Agric. Food Chem.*, **55**, 9142 (2007).

Financial Support

1. Grant-in-Aid for Scientific Research

野平俊之，基盤研究(A)，シリカ直接電解還元と液体合金カソードを用いた高生産性太陽電池用シリコン製造法

2. Others

野平俊之，科学技術振興機構，溶融塩中における電解還元・化学還元を用いたガラス固化体からのLLFP 回収プロセスの開発(1)

野平俊之，京都府 MICE 開催支援助成金，京都大学エネルギー理工学研究所第 8 回国際シンポジウム

野平俊之，住友電気工業（株），溶融塩を利用した高融点材料の電解に関する共同研究

野平俊之，電力中央研究所，陽極におけるヨウ素、臭素発生挙動把握と回収方法検討

山本貴之，（公財）関西エネルギー・リサイクル科学研究振興財団，高機能性を有するカリウムイオン電池用新規イオン液体電解質の開発

山本貴之，（公財）泉科学技術振興財団，イオン液体電解質を用いたカリウムイオン電池用高容量合金負極材料の開発

Publications

H. Usui, Y. Domi, K. Fujiwara, M. Shimizu, T. Yamamoto, T. Nohira, R. Hagiwara, H. Sakaguchi, Charge–Discharge Properties of a Sn_4P_3 Negative Electrode in Ionic Liquid Electrolyte for Na-Ion Batteries, ACS Energy Letters, 2, 5, 1139-1143, 2017

K. Matsumoto, E. Nishiwaki, T. Hosokawa, S. Tawa, T. Nohira, R. Hagiwara, Thermal, Physical, and Electrochemical Properties of Li[N(SO_2F)$_2$]-[1-Ethyl-3-methylimidazolium][N(SO_2F)$_2$] Ionic Liquid Electrolytes for Li Secondary Batteries Operated at Room and Intermediate Temperatures, The Journal of Physical Chemistry C, 121, 17, 9209-9219, 2017

Y. Katasho, K. Yasuda, T. Nohira, Behaviors of Si, B, Al, and Na during Electrochemical Reduction of Borosilicate Glass in Molten $CaCl_2$, Journal of the Electrochemical Society, 164, 7, D478-D485, 2017

K. Yasuda, T. Shimao, R. Hagiwara, T. Homma, T. Nohira, Electrolytic Production of Silicon Using Liquid Zn Alloy in Molten $CaCl_2$, Journal of the Electrochemical Society, 164, 8, H5049-H5056, 2017

C. Ding, T. Nohira. R. Hagiwara, Electrochemical performance of $Na_2Ti_3O_7$/C negative electrode in ionic liquid electrolyte for sodium secondary batteries, Journal of Power Sources, 354, 30, 10-15, 2017

T. Yamamoto, T. Yamaguchi, T. Nohira, R. Hagiwara, A. Fukunaga, S. Sakai, K. Nitta, Structural and Electrochemical Properties of Hard Carbon Negative Electrodes for Sodium Secondary Batteries Using the Na[FSA]–[C_3C_1pyrr][FSA] Ionic Liquid Electrolyte, Electrochemistry, 85, 7, 391-396, 2017

T. Yamamoto, K. Matsumoto, R. Hagiwara, T. Nohira, Physicochemical and Electrochemical Properties of K[N(SO_2F)$_2$]–[N-Methyl-N-propylpyrrolidinium][N(SO_2F)$_2$] Ionic Liquids for Potassium-Ion Batteries, The Journal of Physical Chemistry C, 121, 34, 18450-18458, 2017

H. Nohira, T. Nohira, Dynamic correlation diagrams for sigmatropic reactions based on orbital phase conservation theory, Journal of Theoretical and Computational Chemistry, 16, 6, 1750055, 2017

J. Hwang, K. Matsumoto, T. Nohira, R. Hagiwara, Electrochemical Sodiation-desodiation of Maricite $NaFePO_4$ in Ionic Liquid Electrolyte, Electrochemistry, 85, 10, 675-679, 2017

H. Nohira, T. Nohira, Minimum Change of “Shapes” of Molecular Orbitals in the Elementary Chemical Reactions and a New Perspective of Quantum Chemistry, Forma, 32, SII11-SII15, 2017

M. Zhong, X. Yang, K. Yasuda, T. Homma, T. Nohira, Effect of Si Addition on the Electrochemical Reduction Rate of SiO_2 Granules in Molten $CaCl_2$, Metallurgical and Materials Transactions B, 49, 1, 341-348, 2018

J. Hwang, K. Matsumoto, Y. Orikasa, M. Katayama, Y. Inada, T. Nohira, R. Hagiwara, Crystalline maricite NaFePO4 as a positive electrode material for sodium secondary batteries operating at intermediate temperature, Journal of Power Sources, 377, 80-86, 2018

H. Kadowaki, Y. Katasho, K. Yasuda, T. Nohira, Electrolytic Reduction of Solid Al_2O_3 to Liquid Al in Molten $CaCl_2$, Journal of the Electrochemical Society, 165, 2, D83-D89, 2018

M. Zhong, K. Yasuda, T. Homma, T. Nohira, Purity and Minority Carrier Lifetime in Silicon Produced by Direct Electrolytic Reduction of SiO_2 in Molten $CaCl_2$, Electrochemistry, 86, 2, 77-81, 2018

Y. Katasho, K. Yasuda, T. Nohira, Electrochemical reduction behavior of simplified simulants of vitrified radioactive waste in molten $CaCl_2$, Journal of Nuclear Materials, 503, 290-303, 2018

Presentations

小瀧努，バイオマスエネルギーを知っていますか？，第 22 回エネルギー理工学研究所公開講演会，京都大学宇治キャンパス 宇治おうばくプラザ きはだホール，2017.5.13

K. Yasuda, K. Saeki, R. Hagiwara, T. Homma, T. Nohira, Electrodeposition of Crystalline Si Films in KF–KCl Melts Using $SiCl_4$ Gas as a Si Source, The 6th Asian Conference on Molten Salt Chemistry and Technology, Hyundai Hotel, Gyeongju, Korea, 2017.6.13-16

Y. Norikawa, K. Yasuda, T. Nohira, A New Electrodeposition Process of Metallic Ti Films Utilizing Water-soluble KF–KCl Molten Salts, The 6th Asian Conference on Molten Salt Chemistry and Technology, Hyundai Hotel, Gyeongju, Korea, 2017.6.13-16

J. Hwang，松本一彦，野平俊之，萩原理加，Electrochemical Behavior of Maricite $NaFePO_4$ as a Positive Electrode Material for Na Secondary Battery Operating at Intermediate-temperature，第 19 回化学電池材料研究会ミーティング，日本化学会会館，2017.6.13-14

岡田春輝，松本一彦，野平俊之，萩原理加，中温イオン液体中における $Li_2FeP_2O_7$ 正極の充放電特性，第 19 回化学電池材料研究会ミーティング，日本化学会会館，2017.6.13-14

片所優宇美，安田幸司，野平俊之，Electrochemical Reduction of Simulated Vitrified Waste in Molten $CaCl_2$，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

法川勇太郎，安田幸司，野平俊之，Electrodeposition of Titanium Films from Ti(III) Ions Utilizing Water-Soluble KF–KCl Molten Salt，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

馬元嘉，井戸彬文，安田幸司，野平俊之，溶融 $CaCl_2$ 中での液体 Si–Zn 合金からの Si 析出時における降温速度の影響，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

青山慧伍，安田幸司，野平俊之，Electrochemical Nitriding of Iron in Molten LiBr–KBr–CsBr–Li_3N，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

日高浩司，安田幸司，野平俊之，Electrochemical Synthesis of Diamond in Molten LiCl–KCl–K_2CO_3–KOH，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

駒井誠人，小瀧努，野平俊之，1-ブチル-3-メチルイミダゾリウムクロリドを用いた高効率バイオエタノール生産，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

井手達也，法川勇太郎，安田幸司，野平俊之，易水溶性 KF–KCl 溶融塩を用いたタングステン電析，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

加藤友規，安田幸司，野平俊之，Electrodeposition of Crystalline Silicon Films on Various Carbon Substrates in Water-soluble KF–KCl Molten Salt，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

渡邉祐作，法川勇太郎，安田幸司，野平俊之，溶融フッ化物中における希土類合金の電気化学的形成と新規なリサイクル法への応用，第 77 回マテリアルズ・テーラリング研究会，加藤山崎教育基金軽井沢研修所，2017.7.27-29

T. Nohira, R. Hagiwara, K. Matsumoto, C. Ding, A. Fukunaga, S. Sakai, K. Nitta, Sodium-Ion Batteries Using FSA-Based Ionic Liquids, The 68th Annual Meeting of ISE, Providence, RI, USA, 2017.8.26-9.1

T. Nohira, K. Yasuda, A New Electrolytic Production Process of Solar Silicon Using Liquid Zn Alloy Cathode in Molten Salt, 2017 International Forum on Liquid Salts for Energy Storage Materials, China Automotive Battery Research Institute, Beijin, China, 2017.9.3-5

K. Yasuda, Y. Ma, A. Ido, M. Zhong, R. Hagiwara, T. Nohira, Production of Silicon Ingot for Solar Cells Utilizing Volatile Metal Flux and Solidification Refining, The 8th International Symposium of Advanced Energy Science, Uji Campus, Kyoto University, 2017.9.5-7

T. Yamamoto, T. Nohira, Development of sodium secondary batteries using ionic liquid electrolytes, The 8th International Symposium of Advanced Energy Science, Uji Campus, Kyoto University, 2017.9.5-7

片所優宇美，安田幸司，野平俊之，LLFP 分離回収を目的とした溶融塩中における模擬ガラス固化体

の電解還元，原子力学会 2017 年秋の大会，北海道大学 札幌キャンパス，2017.9-13-15

飯塚政利，太田宏一，大釜和也，小藤博英，野平俊之，柔軟性の高い MA 回収・核変換技術の開発(1) 研究開発の目的と全体計画，原子力学会 2017 年秋の大会，北海道大学 札幌キャンパス，2017.9-13-15

法川勇太郎，安田幸司，野平俊之，沼田昴真，粟津知之，真嶋正利，易水溶性フッ化カリウム–塩化カリウム混合溶融塩を用いた金属チタンの平滑膜電析，表面技術協会第 136 回講演大会，金沢工業大学扇が丘キャンパス，2017.9-14-15

T. Nohira, R. Hagiwara, K. Matsumoto, C. Ding, A. Fukunaga, S. Sakai, K. Nitta，Intermediate Temperature Sodium-Ion Batteries Using Amide Ionic Liquids，High Temperature Batteries for Stationary Energy Storage Workshop，Trondheim, Norway，2017.9.19-20

萩原理加，松本一彦，田和慎也，黄珍光，Shubham Kaushik，実藤俊太，王雨申，野平俊之，山本貴之，坂口裕樹，薄井洋行，道見康弘，薮内直明，趙文，イオン液体を基軸とする中温作動型蓄電デバイス，第 58 回電池討論会，福岡国際会議場，2017.11.14-16

岡田春輝，松本一彦，野平俊之，萩原理加，高リチウムイオン分極が液体中における $Li_2FeP_2O_7$ 正極の中温作動に及ぼす影響，第 58 回電池討論会，福岡国際会議場，2017.11.14-16

Y. Wang, T. Hosokawa, K. Matsumoto, T. Nohira, R. Hagiwara，Effects of high Na+ fraction on sodiumu secondary battery performance in the $Na[N(SO_2F)_2]$-$[C_1C_1im][N(SO_2F)_2]$ system，第 58 回電池討論会，福岡国際会議場，2017.11.14-16

安田幸司，馬元嘉，井戸彬文，萩原理加，本間敬之，野平俊之，溶融 $CaCl_2$ 中における液体 Zn 陰極上での SiO_2 電解還元反応，第 41 回電解技術討論会，京都大学吉田キャンパス，2017.11.21-22

駒井誠人，小瀧努，野平俊之，イミダゾリウム系イオン液体を用いたバイオエタノール生成における発酵へのイオン液体の影響，第 8 回イオン液体討論会，東京農工大学小金井キャンパス，2017.11.23-24

H. Onuma, K. Kubota, S. Muratsubaki, T. Yamamoto, K. Matsumoto, T. Nohira, R. Hagiwara, S. Komaba，Negative Electrode Performance of Graphite for K-Ion Batteries by Utilizing Ionic Liquid Electrolyte，4th International Conference on Sodium Batteries，Kagurazaka campus, Tokyo University of Science，2017.11.28-30

加藤友規，安田幸司，野平俊之，溶融 KF-KCl-K_2SiF_6 中における Si(IV)イオンの電気化学挙動と結晶性 Si 電析，第 49 回溶融塩化学討論会，関西大学 千里山キャンパス，2017.11.30-12.1

法川勇太郎，安田幸司，沼田昴真，粟津知之，真嶋正利，野平俊之，易水溶性 KF-KCl 溶融塩を用いて電析した金属チタン膜の形態および特性評価，第 49 回溶融塩化学討論会，関西大学千里山キャンパス，2017.11.30-12.1

渡邉祐作，法川勇太郎，安田幸司，野平俊之，LiF-CaF_2-NdF_3 中におけるネオジム-鉄族合金の電気化学的合成，第 49 回溶融塩化学討論会，関西大学千里山キャンパス，2017.11.30-12.1

井手達也，法川勇太郎，安田幸司，後藤健吾，細江晃久，野平俊之，易水溶性 KF-KCl 溶融塩中におけるタングステン電析，第 49 回溶融塩化学討論会，関西大学 千里山キャンパス，2017.11.30-12.1

日高浩司，安田幸司，野平俊之，溶融 LiCl-KCl-K_2CO_3-KOH 系におけるダイヤモンドの電解合成とその特性，第 49 回溶融塩化学討論会，関西大学 千里山キャンパス，2017.11.30-12.1

青山慧伍，安田幸司，前田和幸，粟津知之，野平俊之，溶融 LiBr-KBr-CsBr を用いた鉄の電気化学的窒化反応の温度依存性，第 49 回溶融塩化学討論会，関西大学 千里山キャンパス，2017.11.30-12.1

大石哲雄，矢口未季，安田幸司，小西宏和，野平俊之，溶融 LiCl-KCl 中における各種酸化物と希土類イオンとの反応，第 49 回溶融塩化学討論会，関西大学 千里山キャンパス，2017.11.30-12.1

法川勇太郎，安田幸司，沼田昴真，粟津知之，真嶋正利，野平俊之，易水溶性 KF–KCl 溶融塩を用いた金属チタン膜の電析，2017 年度第 3 回関西電気化学研究会，大阪大学吹田キャンパス，2017.12.2

青山慧伍，安田幸司，前田和幸，粟津知之，野平俊之，溶融 LiBr–KBr–CsBr–Li_3N 中における鉄の電気化学的窒化, 2017 年度第 3 回関西電気化学研究会，大阪大学吹田キャンパス，2017.12.2

日高浩司，安田幸司，野平俊之，LiCl–KCl–K_2CO_3–KOH 溶融塩中におけるダイヤモンドの電解合成，2017 年度第 3 回関西電気化学研究会，大阪大学吹田キャンパス，2017.12.2

片所優宇美，安田幸司，野平俊之，溶融 $CaCl_2$ 中における模擬ガラス固化体の電解還元，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

加藤友規，楊肖，安田幸司，野平俊之，溶融

$KF–KCl–K_2SiF_6$ 中における結晶性 Si 電析とその物性測定，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

法川勇太郎，安田幸司，沼田昂真，栗津知之，真嶋正利，野平俊之，溶融 LiF–LiCl 中における Ti(III) イオンの電気化学的挙動，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

渡邉祐作，法川勇太郎，安田幸司，大石哲雄，野平俊之，溶融 $LiF–CaF_2–DyF_3$ 中におけるジスプロシウム－鉄族合金の電気化学的形成，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

井手達也，法川勇太郎，安田幸司，後藤健吾，細江晃久，野平俊之，溶融 $KF–KCl–WO_3$ 中における平滑タングステン電析，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

大石哲雄，矢口未季，安田幸司，小西宏和，野平俊之，溶融塩と合金隔膜を用いた希土類分離プロセスにおける合金隔膜の長寿命化，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

楊肖，安田幸司，野平俊之，アランバード，月橋文孝，$CaCl_2$ 系溶融塩中における SiO_2 の溶解と Si 膜の電析，電気化学会第 85 回大会，東京理科大学葛飾キャンパス，2018.3.9-11

山本貴之，イオン液体電解質を用いたナトリウム二次電池用負極材料の開発，次世代 ESICB セミナー 2018-1，京都大学桂キャンパス，2018.3.12

法川勇太郎，安田幸司，沼田昂真，栗津知之，真嶋正利，野平俊之，フッ化物–塩化物高温溶融塩を用いて電析した金属チタンの形態および特性評価，表面技術協会第 137 回講演大会，芝浦工業大学豊洲キャンパス，2018.3.12-13

T. Nohira, K. Yasuda, Y. Norikawa, K. Saeki, T. Kato, T. Ide，Electrodeposition of Si, Ti and W from water-soluble KF-KCl molten salts，Reactive Metal Workshop，MIT，2018.3.16-17

K. Yasuda, K. Saeki, K. Maeda, R. Hagiwara, T. Nohira, Electrodeposition of crystalline Si films in KF-KCl molten salts using SiCl4 as a Si source，Reactive Metal Workshop，MIT，2018.3.16-17

駒井誠人，小瀧努，野平俊之，イミダゾリウム系イオン液体を用いたセルロース・キシラン混合物からのバイオエタノール生産，日本化学会第 98 春季年会，日本大学理工学部　船橋キャンパス，2018.3.20-23

三浦涼介，金村祥平，大森孝，金子昌章，浅野和仁，野平俊之，坂村義治，ガラスの溶解技術(4)化学還元による模擬ガラス固化体からの LLFP 分離回収，原子力学会 2018 年春の年会，大阪大学吹田キャンパス，2018.3.26-28

楊肖，安田幸司，野平俊之，月橋文孝，$CaCl_2$-CaO 融体中の石英ガラスの溶解とシリコンの電析，資源素材学会 2018 年度春季大会，東京大学本郷キャンパス，2018.3.27-29

Molecular Nanotechnology Research Section

H. Sakaguchi, Professor
T. Kojima, Assistant Professor
T. Nakae, Assistant Professor

1. Introduction

Nanotechnology is essential for highly efficient energy use. Our group studies the basics of assembling small molecules into the advanced materials and devices in energy sector with high efficiency. We have already developed several unique techniques which are totally new molecular assembling methodology such as 'electro-chemical Epitaxial Polymerization' and 'Two-Zone Chemical Vapor Deposition (2Z-CVD)' which enable to produce molecular wires on metal surface from small molecules. By using these techniques, organic electronic devices such as field-effect transistors and organic solar cells will be developed. Main research achievements in Molecular Nanotechnology Research Section in 2017 are described below.

2. Strain-induced skeletal rearrangement of a polycyclic aromatic hydrocarbon on a copper surface

Strain-induced rearrangements of aromatic carbon rings have been observed in graphene structures. As a typical example, a mechanical stress in graphene triggers a Stone-Wales rearrangement, a typical reaction of carbon allotropes that yields a defect composed of two heptagonal and two pentagonal rings fused together. Such defects play an important role in the formation of curved graphene and fullerenes. Therefore, it is crucial to control the rearrangements of sp^2-carbon skeletal structures in order to synthesize nanocarbon materials. For macromolecules such as graphene intramolecular rearrengements feasibly occur because such local reactions do not strictly affect the total energy of the huge systems. For small polycyclic aromatic hydrocarbons (PAHs), on the other hand, it has been difficult to induce skeletal rearrengements in conventional organic synthesis. The preceding mechanochemical procedures for aromatic compounds cannot induce unimolecular reactions but can induce sp^3-hybridized polymerizations because of the enormous increase in intermolecular interactions. Other synthetic methods under severe conditions, such as flash vacuum pyrolysis, are required to undermine the aromaticity in the transition states and to obtain intramolecularly rearranged PAHs. Therefore, the exploration of PAH reaction schemes will be a significant step towards understanding the mechanisms underlying the reaction and repair of defects in carbon allotropes, and towards designing and fabricating further functional nanocarbon materials.

Recently, we demonstrate a reaction scheme for the skeletal rearrangement of PAHs on a metal surface using high-resolution noncontact atomic force microscopy (AFM) (Figure 1). We produced a well-designed PAH-diazuleno[1,2,3-cd:10,20,30-fg] pyrene (DAPH)-adsorbed flatly onto Cu(001), in which two azuleno moieties are highly strained by their mutual proximity by a combination of organic synthesis and on-surface cyclodehydrogenation,. This local strain drives the rearrangement of one of the azuleno moieties into a fulvaleno moiety, which has never been reported so far. Our proposed thermally driven, strain-induced synthesis on surfaces will pave the way for the production of a new class of nanocarbon materials that conventional synthetic techniques cannot attain.

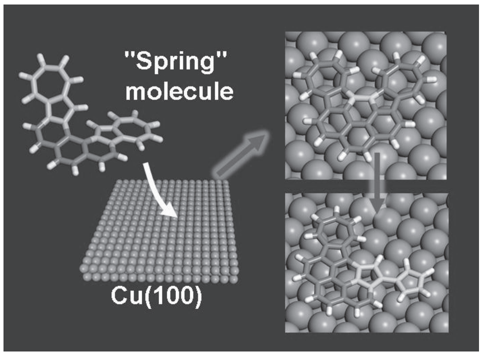


Figure 1. Schematic illustrations of strain-induced skeletal rearrangement of a poly-cyclic aromatic hydrocarbon on a copper surface.

3. Wide graphene nanoribbons produced by inter chain fusion of poly(*p*-phenylene) via 2-Zone CVD

Graphene nanoribbons (GNRs), quasi-one-dimensional graphene strips, have shown great potential for electronics, optoelectronics, and photonics. These properties strongly depend on width and edge structure of them. Therefore, precisely controlled width and edge structure are required for desired properties. Bottom-up synthesis of GNRs is a one of suitable method to satisfy these requirements because of definition of their edge structures and widths by the shape of precursors. Atomically precise synthesis of armchair-edged GNRs have already been achieved under ultra-high vacuum (UHV) condition. However, given GNRs in this method were low yield and density was still low. Therefore, it was difficult to develop organic electronic devices with them. To develop devices, high-yield fabrication of assembled GNR films, isolation, and device fabrication are required.

We have developed 2Z-CVD to produce densely-packed, parallelly-aligned self-assembled GNRs on Au(111) under low vacuum condition from halogenated polycyclic aromatic hydrocarbon (PAH) precursors. This technique successfully produced a series of armchair-edged GNRs in high yield. Attractive features of this method originate from an independent temperature-control of radical-generation process (zone 1) and the growth process (zone 2) (Figure 2), which afforded GNRs in high yield without using UHV conditions. The precursor was sublimated to the Au(111) substrate in zone 2 by passing through zone 1 in a quartz tube. The mechanism is supposed to involve radical generation in zone 1, polymerization of the radicals on the Au(111) substrate in zone 2, and subsequent dehydrogenation to form GNRs.

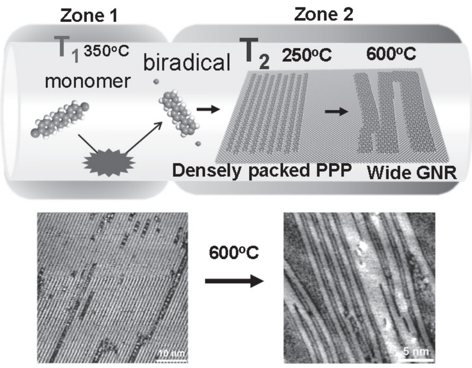


Figure 2. Schematic illustrations of 2Z-CVD instrument and STM images of transformation of PPP into wide GNR with interchain fusion.

On the other hand, according to theoretical calculations, armchair-edged GNRs (AGNRs) with widths less than 10 nm should have a suitable bandgap for semiconducting devices due to quantum confinement. However, most GNRs prepared by bottom-up synthesis reach widths less than 2 nm, because in general, the fabrication of wide GNRs using a bottom-up method requires high-molecular weight precursors which have disadvantages such as high sublimation temperature and low solubility. Moreover, it is difficult to produce GNRs with width less than 10 nm via top-down method because of limitation of electron beam focusing in lithography process.

Recently, we succeeded in producing wide graphene nanoribbons (GNRs) with the width of up to 7.2 nm fabricated via 2Z-CVD using 4,4-dibromo-*p*-terphenyl as the precursor. Densely packed arrays of poly(*p*-phenylene) produced on Au(111) using this method could be converted into wide GNRs via interchain fusion by thermal annealing. The GNRs thus produced exhibited good semiconducting properties in FET devices.

4. Orientation and electro structures of multi-layered GNRs produced by 2Z-CVD

The orientation and electronic structure of multilayered graphene nanoribbons with an armchair-edge (AGNRs) were determined by low-temperature scanning tunneling microscopy in this study. The orientation of AGNRs was found to be an edge-on structure when positioned as a top layer, while previous reports showed a face-on structure for monolayered AGNRs on Au(111). According to density functional theory calculations, AGNRs in a top layer preferentially form as edge-on structures rather than face-on structures due to the balance of CH−π and π−π interactions between AGNRs. Scanning tunneling spectroscopy (STM) and DFT calculations revealed that the electronic structures of multilayered AGNRs are similar to those in a gas-phase due to the lack of interaction between AGNRs and the Au(111) substrate. The observation of AGNRs in mutilayers might suggest the conformation-assisted mechanism of dehydrogenation when there is no contact with the Au(111) substrate. This result implies that GNRs can be produced not only on metal but also on other substrates such as insulators. Our investigations of the dehydrogenation reaction of prepolymers in a multilayer system show that it is possible to carry out efficient on-surface synthesis without a metal substrate. We believe our findings can be applied to future electronic and optoelectronic devices made of GNRs.

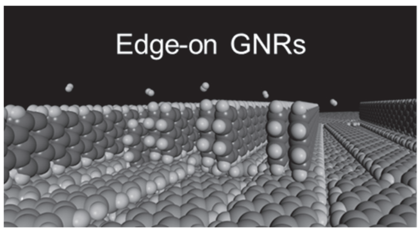


Figure 3. Schematic illustrations of Edge-on GNRs on multilayered GNRs.

References
1. *Nat. Commun.*, **2017**, *8*, 16089.
2. *Chem. Commun.*, **2017**, *53*, 7034.
3. *Langmuir*, **2017**, *33*, 10439.

Financial Support

Grant-in-Aid for Scientific Research

坂口浩司，新学術領域研究（研究領域提案型），表面分子アーキテクト技術を用いる新規グラフェン細線の合成

坂口浩司，新学術領域研究（研究領域提案型），表面重合した新規ナノ炭素細線の分子レベル電子計測

坂口浩司，基盤研究(B)，自己組織化ナノ炭素細線間反応による細孔炭素物質の合成と機能

坂口浩司，挑戦的萌芽研究，表面パズル化反応を用いる炭素ナノベルトの創成

小島崇寛，若手研究(B)，革新的酸素還元触媒を指向した 2D 炭素材料の精密合成

中江隆博，若手研究(B)，非対称エッジ修飾グラフェンナノリボンの精密合成

Publications

M. Saito, Y. Suda, S. Furukawa, T. Nakae,T. Kojima, H. Sakaguchi， Formation of Dibenzopentalane-linking Polymers under the Two-Zone CVD and Wet Conditions, Chemistry Letters，46，8，1099-1101，2017

S. Song, T. Kojima, T. Nakae, H. Sakaguchi，Wide graphene nanoribbons produced by interchain fusion of poly(p-phenylene) via two-zone chemical vapor deposition，Chemical Communications，53，7034-7036，2017

A. Shiotari, T. Nakae, K. Iwata, S. Mori, T. Okujima, H. Uno, H. Sakaguchi, Y. Sugimoto, Strain-induced skeletal rearrangement of a polycyclic aromatic hydrocarbon on a copper surface，Nature Communications，8，16089，2017

S. Song, G. Huang, T. Kojima, T. Nakae, H. Uno, H. Sakaguchi， Interchain-linked Graphene Nanoribbons from Dibenzo[g,p]chrysene via Two-zone Chemical Vapor Deposition, Chemistry Letters, 46, 10, 1525-1527, 2017

H. Uno, K. Tagawa, S. Mori, T. Okujima, M. Takase, T. Nakae， Synthesis and Properties of Bicyclo[2.2.2]octadiene- and Benzene-fused Bis(thiaporphyrin)s，Bulletin of the Chemical Society of Japan，90，12，1375-1381，2017

T. Kojima, Y. Bao, C. Zhang, S. Liu, H. Xu, T. Nakae, K.P. Loh, H. Sakaguchi，Orientation and Electronic Structures of Multilayered Graphene Nanoribbons Produced by Two-Zone Chemical Vapor Deposition， Langmuir，33，40，10439-10445，2017

H. Yonemura, Y. Naka, M. Nishino, H. Sakaguchi, S. Yamada，Effect of Gold Nanoparticle on Photon Upconversion based on Sensitized Triplet–Triplet annihilation in Polymer Films，Molecular Crystals and Liquid Crystals，654，1，196-200，2017

H. Yonemura, Y. Futaoka, T. Taniguchi, H. Sakaguchi, S. Yamada，Effect of Silver Nanoparticle on Singlet Exciton Fission in Rubrene Films，Molecular Crystals and Liquid Crystals，654，1，209-213，2017

A. Shiotari, K. Tanaka, T. Nakae, S. Mori, T. Okujima, H. Uno, H. Sakaguchi, Y. Sugimoto，Chiral Discrimination and Manipulation of Individual Heptahelicene Molecules on Cu(001) by Noncontact Atomic Force Microscopy, The Journal of Physical Chemistry C, 2017

Z. Xu, T. Kojima, W. Wang, K. Kaushik, A. Saliniemi, T. Nakae, H. Sakaguchi，On-surface synthesis of graphene clusters from a Z-bar-linkage precursor with quaterphenylbranches，Materials Chemistry Frontiers，2017

塩足亮隼，中江隆博，宇野英満，坂口浩司，杉本宜昭，機能性有機分子創成のための分子ひずみを駆使した表面合成法，機能材料（シーエムシー出版），37，12，60-67，2017

小島崇寛，坂口浩司，金属表面を巧みに利用したグラフェンナノリボンの合成–ボトムアップ法による精密合成，化学（化学同人），73，2，68-69，2017

T. Nakae, H. Sakaguchi，Surface Synthesis of Molecular Wire Architectures，Molecular Archtectonics: The Third Stage of Single Molecule Electronics Ed. by T. Ogawa, Springer，467-486，2017

H. Uno, T. Nakae, T. Okujima, S. Mori，Synthesis of Rigid π Organic Molecular Architectures and Their Applications in Single-Molecule Measurement，Molecular Archtectonics: The Third Stage of Single Molecule Electronics Ed. by T. Ogawa, Springer，439-465，2017

Presentations

中江隆博，金の表面を使い"発電する"炭素リボンを組立てる，第 22 回エネルギー理工学研究所公開講演会，京都大学宇治キャンパス 宇治おうばくプラザきはだホール，2017.5.13

坂口浩司，生物模倣触媒を用いる機能性ナノ炭素細線の合成，応用物理学会関西支部平成 29 年度第 1

回講演会「マテリアルデザインとグリーンデバイスの最前線〜関西発、イノベーションと若手研究者からの発信〜」，イーグレひめじ，2017.5.26

坂口浩司，表面分子アーキテクト技術を用いる新規グラフェン細線の合成，分子アーキテクト二クス第8回領域会議，大阪大学豊中キャンパス国際棟シグマホール，2017.6.3

T. Kojima, T. Nakae, H. Sakaguchi , Conformation-assisted synthesis of acene-type graphene nanoribbons on Au(111)，International Symposium on Pure & Applied Chemistry (ISPAC)2017，Hotel Continental Saigon, Ho Chi Minh City, Vietnam，2017.6.8-11

中江隆博，坂口浩司，表面重合した新規ナノ炭素細線の分子レベル電子計測，新学術領域研究「π造形科学 : 電子と構造のダイナミズム制御による新機能創出」第 4 回領域全体会議，マリンパレス鹿児島，2017.7.1-3

坂口浩司，生物模倣触媒によるグラフェンナノリボンの表面合成，第 53 回フラーレン・ナノチューブ・グラフェン総合シンポジウム，京都大学宇治おうばくプラザ，2017.9.13-15

Zhen Xu，小島崇寛，中江隆博，坂口浩司，2 ゾーン化学気相成長法を用いるアセン型 GNR の表面合成，新学術領域研究「π造形科学：電子と構造のダイナミズム制御による新機能創出」第４回公開シンポジウム，東京工業大学大岡山キャンパス，2017.10.19-20

中江隆博，小島崇寛，坂口浩司，自己組織化が誘起するグラフェンナノリボンの 2 次元ネットワーク形成，分子アーキテクトニクス第 9 回領域全体会議，愛媛大学城北キャンパス，2017.12.3

中江隆博，小島崇寛，坂口浩司，自己組織化が誘起するグラフェンナノリボンの 2 次元ネットワーク形成，分子アーキテクト二クス第 8 回研究会，愛媛大学城北キャンパス，2017.12.4-5

H. Sakaguchi , Biomimetic on-surface synthesis of graphene nanoribbons，Global Research Efforts on Energy and Nanomaterials (GREEN 2017)，GIS Taipei Tech Convention Center, Taipei, Taiwan，2017.12.22-24

T. Nakae, H. Sakaguchi , Synthesis of Functional Nanocarbon Molecules by Surface-induced Conformation-controlled Mechanism，International Congress on Pure & Applied Chemistry (ICPAC) 2018，Sokhalay Angkor Resort & Spa, Siem Reap, Cambodia , 2018.3.7-10

Biofunctional Chemistry Research Section

T. Morii, Professor
E. Nakata, Associate Professor
S. Nakano, Assistant Professor

1. Introduction

A transition to renewable energy technologies requires new chemistry to learn from nature. Nature has found fantastic solutions to convert solar energy to produce chemicals and to utilize them in the exceptionally efficient manners for almost 3 billion years. It is our challenge to understand the efficient bioenergetic processes of nature and to construct bio-inspired energy utilization systems. The research interests in our group focus on the design of biomacromolecules and their assemblies for molecular recognition, catalysis and signal transduction in water, the solvent of life. We take synthetic, organic chemical, biochemical and biophysical approaches to understand the biological molecular recognition and chemical reactions. Proteins and protein/nucleic acids assemblies are explored to realize biomimetic function of biological systems, such as visualization of cellular signals by fluorescent biosensors, directed self-assembly of peptides and proteins to build up nanobiomaterials, tailoring artificial receptors and enzymes based on the complex of RNA and a peptide or a protein, and reconstitution of the functional assemblies of receptors and enzymes on the nanoarchitectures. Followings are main research achievements in fiscal year 2017.

2. Design of modular protein tags for orthogonal covalent bond formation at specific DNA sequences

Simultaneous formation of specific covalent linkages at nucleotides in given DNA sequences demand distinct orthogonal reactivity of DNA modification agents. Such highly specific reactions require well-balanced reactivity and affinity of the DNA modification agents. Conjugation of a sequence-specific DNA binding zinc finger protein and a self-ligating protein tag provides a modular adaptor that expedites formation of a covalent bond between the protein tag and a substrate-modified nucleotide at a specific DNA sequence. The modular adaptor stably locates a protein of interest fused to it at the target position on DNA scaffold in its functional form. Modular adaptors with orthogonal selectivity and fast reaction kinetics to given specific DNA sequences enable site-specific location of different protein molecules simultaneously. Three different modular adaptors consisting of zinc finger proteins with distinct DNA sequence specificities and self-ligating protein tags with different substrate specificities achieved orthogonal covalent bond formation at respective sequences on the same DNA scaffold with an overall coassembly yield over 90%. Application of this unique set of orthogonal modular adaptors enabled construction of a cascade reaction of three enzymes from xylose metabolic pathway on DNA scaffold.

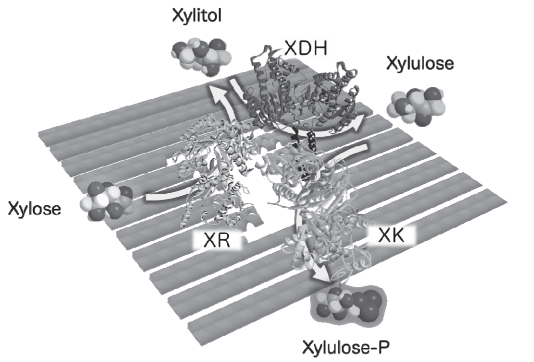


Figure 1. A schematic illustration of a cascade reaction of three enzymes from xylose metabolic pathways (XR, XDH and XK) constructed on the DNA scaffold.

3. DNA origami scaffolds as templates for functional tetrameric Kir K^+ Channels

In native systems, scaffolding proteins play important roles in assembling proteins into complexes to transduce signals. This concept is yet to be applied to the assembly of functional transmembrane protein complexes in artificial systems. To address this issue, DNA origami has the potential to serve as scaffolds that arrange proteins at specific positions in complexes. Herein, we report that Kir3 K^+ channel proteins are assembled through zinc finger protein (ZFP) adaptors at specific locations on DNA origami scaffolds. Specific binding of the ZFP fused Kir3 channels and ZFP based adaptors on DNA origami were confirmed by atomic force microscopy and gel electrophoresis. Furthermore, the DNA origami with ZFP binding sites nearly tripled the K^+ channel current activity elicited by heterotetrameric Kir3 channels in HEK293T cells. Thus, our method provides a useful template to control the oligomerization states of membrane protein complexes in vitro and in living cells.

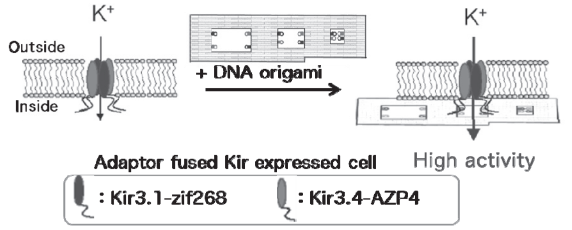


Figure 2. A schematic illustration for the regulation of the function of DNA binding adaptor fused Kir K+ channel by adding DNA origami scaffold.

4. A diversity-oriented library of fluorophore-modified receptors constructed from a chemical library of synthetic fluorophores

Fluorescent biosensors are important tools for the specific detection and quantification of a wide range of target molecules in the fields of therapeutics and diagnostics. We have developed a method for construction of ribonucleopeptide (RNP) receptor-based fluorescent sensors. Rev peptide-RRE RNA complex was utilized as a scaffold of RNA-oriented RNP library constructed by introducing randomized RNA sequences into the RNA subunit. RNP receptors that specifically binds to the given target molecule can be selected from the RNP library by applying in vitro selection method. The variation in the nucleotide sequence of the selected RNA subunit generally confers the RNP receptors with various affinities to the given target and overall structures. Such a group of RNA receptor library gives a fluorophore-modified RNP (F-RNP) library by complexing with fluorophore-modified Rev peptide. Fluorescent RNP sensors can be screened from the F-RNP library.

In order to establish a new method for the construction of diverse-oriented F-RNP library (DOFRL), a diverse-oriented fluorophore-modified Rev peptide library (DOFPL) was prepared by using a diverse-oriented fluorophore library (DOFL). This method enabled to screen the F-RNP sensors constructed from the specific RNP receptor of interest. DOFLs that contains four types of fluorescent scaffolds with chemically diverse building blocks and chloroacetyl (CA) group, CXCA, TPGCA, CORCA, and CyRCA, were utilized. DOFLs were introduced to cysteine-modified Rev (CRev) peptide through the alkylation of thiol group after conversion of CA group into iodoacetyl group. The yields of F-CRev ranged from 10% to 75%.

The F-RNP library was constructed by complexing with a RNA subunit of adenosine-binding RNP receptors, An16, after removing unreacted fluorophores by ether extraction. F-RNP library was screened to select F-RNPs that showed apparent fluorescence intensity changes in response to the addition of 500 μM Ado. In total, 263 F-RNPs were constructed by complexation of An16 RNA and the F-CRev peptides. Totally, 18 F-RNPs showed I/I_0 values over 1.3 in the preliminary screening. After purification of each F-CRev peptide by HPLC, 9 of 13 F-RNPs showed similar or higher relative fluorescence intensity changes compared to those observed in the preliminary screening. One of selected F-RNP, An16/CXCA1 complex, showed binding ability for the substrate adenosine with slightly lower affinity than that of the parent RNP receptor.

This strategy effectively converted an Ado-binding RNP receptor with a given ligand-binding property to a fluorescent Ado sensor. Thus, a novel method was developed for the construction of a library of fluorophore-modified RNP receptors converted from a DOFL.

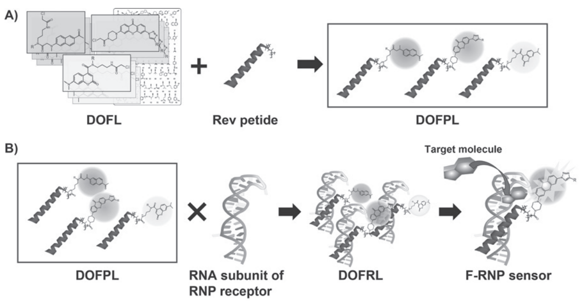


Figure 3. A schematic illustration for the screening of fluorophore-modified RNPs (F-RNP). (A) A diversity-oriented fluorophore library (DOFL) was converted to a diversity-oriented fluorophore-modified Rev (F-Rev) peptides library (DOFPL). (B) A diversity-oriented F-RNP library (DOFRL) was constructed by complexation of an RNA subunit of an Ado-binding RNP receptor and the DOFPL. The DOFRL was then screened by evaluation of the relative fluorescence intensity in the absence and presence of the target (Ado) to allow for the selection of F-RNP sensors for Ado with high relative fluorescence intensity changes.

The presented work was supported in part by the Grants-in-Aid for Scientific Research (KAKENHI) from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan to T.M. (17H01213), E.N. (No. 15H05492 and 17H05440) and S.N. (No. 26810090). And the other projects in progress were also supported by KAKENHI from MEXT to T.M. (17K19199 and 17H05529).

Collaboration Works

国立シンガポール大学（シンガポール），イノシトール誘導体の生理活性評価，森井孝

Ghent University（ベルギー），クロスリンク反応性を内在する機能性生体高分子によるケミカルバイオロジーの開拓，森井孝

Nanyang Technological University（シンガポール），RNP 分子認識の 1 分子計測，森井孝

POSTECH（韓国），蛍光性バイオセンサーの構築，森井孝

POSTECH（韓国），RNA 分子センサーの構築，森井孝

Seoul National University（韓国），特定空間に配置された酵素複合体の構築，森井孝

Ewha Womans University（韓国），小分子による酵素機構の解明，森井孝・中田栄司・Rajendran Arivazhangan

Vanderbilt University School of Medicine（米国），Topoisomerase 反応の可視化，森井孝・中田栄司・Rajendran Arivazhangan

Financial Support

1. Grant-in-Aid for Scientific Research

森井孝，新学術領域研究（研究領域提案型），活性酸素種による翻訳後修飾を検出する蛍光バイオセンサー

森井孝，基盤研究(A)，人工代謝経路を内包するナノ空間「複合触媒コンパートメント」の創出

森井孝，挑戦的萌芽研究，トリプレットリピート病の鍵を握る RNA 凝集体の直接観察と検出法の開発

中田栄司，新学術領域研究（研究領域提案型），分子コンビナートよる非天然化合物合成システムの創製

中田栄司，若手研究(A)，DNA ナノリアクターで構築する高効率な人工光合成システム

2. Others

仲野瞬，（公財）京都大学教育研究振興財団，生成物解離を促進する設計による回転数に優れた人工 RNA-ペプチド複合体酵素の作製

Publications

T.M. Nguyen, E. Nakata, M. Saimura, H. Dinh, T. Morii, Design of Modular Protein-Tags for the Orthogonal Covalent Bond Formation at Specific DNA Sequences, Journal of the American Chemical Society，139，8487-8496，2017

Y. Inaba, K. Watanabe, M. Kitamatsu, E. Nakata, A. Harada, T. Ohtsuki，Ultrasound-dependent cytoplasmic internalization of a peptidesonosensitizer conjugate，Bioorganic & Medicinal Chemistry，25，4212-4217，2017

S. Nakano, T. Tamura, R.K. Das, E. Nakata, Y.-T. Chang, T. Morii，A diversity-oriented library of fluorophore-modified receptors constructed from a chemical library of synthetic fluorophores，ChemBioChem，18，2212-2216，2017

Y. Park, D. Nim-anussornkul, T. Vilaivan, T. Morii, B.H. Kim, Facile conversion of ATP-binding RNA aptamer to quencher-free molecular aptamer beacon，Bioorganic & Medicinal Chemistry Letters，28，77-80，2017

T. Kurokawa, S. Kiyonaka, E. Nakata, M. Endo, S. Koyama, E. Mori, N.H. Tran, H. Dinh, Y. Suzuki, K. Hidaka, M. Kawata, C. Sato, H. Sugiyama, T. Morii, Y. Mori, DNA Origami Scaffolds as Templates for Functional Tetrameric Kir3 K^+ Channels，Angewandte Chemie International Edition，130，2616-2621，2017

A. Rajendran, E. Nakata, S. Nakano, T. Morii，Nucleic acids-templated enzyme cascades, ChemBioChem, 18，696-716，2017

T. Morii，A Bioorganic Chemistry Approach to Understanding Molecular Recognition in Protein-Nucleic Acid Complexes，Bulletin of the Chemical Society of Japan，90，1309-1317，2017

中田栄司，森井孝，酵素を"1 分子ずつ"狙った場所に配置する – 多段階反応を効率的に進行させる分子コンビナートをつくる，Academist Journal，2017

中田栄司，森井孝，ナノレベル間隔で異なる酵素を並べる！─複雑な多段階反応を可能にする分子コンビナートへの挑戦─，化学 2017 年 11 月号，2017

中田栄司，森井孝，効率的な多段階酵素反応を実現する分子コンビナート，バイオサイエンスとインダストリー2018.1，2017

Presentations

E. Nakata, T. Morii，DNA Binding Adaptors to Locate Multiple Enzymes on DNA scaffold，ISPAC_2017，Hotel Continental Saigon, Ho Chi Minh City, Vietnam，2017.6.10

森井孝，中田栄司 ，活性酸素種による翻訳後修飾を検出する蛍光バイオセンサー，新学術領域研究「酸素生物学」平成 29 年度第 5 回班会議，大阪大学（吹田キャンパス）銀杏会館 3 階阪急電鉄・三和銀行ホール，2017.6.17

中田栄司，森井孝，高効率な多段階酵素反応を実現する DNA ナノリアクターの創製酵素を"1 分子ずつ"狙った場所に配置する，生体機能関連化学部会若手の会第 29 回サマースクール，松江ニューアーバンホテル，2017.7.10

仲野瞬，RNA-ペプチド複合体を用いた機能性分子ライブラリー，生体機能関連化学部会若手の会第 29 回サマースクール, 松江ニューアーバンホテル，2017.7.10

田嶋竣介，中田栄司，才村正幸，森井孝，蛍光タンパク質を基本骨格とした一酸化窒素センサーの機能評価，生体機能関連化学部会若手の会第 29 回サマースクール，松江ニューアーバンホテル，2017.7.10

中田栄司，森井孝，分子コンビナートよる非天然化合物合成システムの創製，新学術領域「生合成リデザイン」第 2 回公開シンポジウム，北海道大学フロンティア応用科学研究棟，2017.8.5

T. Morii，Chemistry of spatially organized biological molecules，ACBI，ウランバートル，2017.9.1-4

T. Morii，Spatially organized enzymes drive artificial metabolic pathways，Symposium on exploring novel principles for highly efficient utilization of solar energy 2017，京都大学宇治キャンパス，2017.9.7

中田栄司，Nguyen Minh Thang，才村正幸，Dinh Huyen，森井孝，直交性を有するモジュール型アダプターによる複数の酵素を配置した分子スイッチボード，第 11 回バイオ関連化学シンポジウム，東京大学弥生キャンパス，2017.9.6-8

仲野瞬，田村友樹，Das Raj Kumar，中田栄司，Chang Young-Tae，森井孝，蛍光分子ライブラリーとリボヌクレオペプチドリセプターを利用したセンサーの作製，第 11 回バイオ関連化学シンポジウム，東京大学弥生キャンパス，2017.9.6-8

田嶋竣介，中田栄司，才村正幸，森井孝，蛍光タンパク質を基本骨格とした一酸化窒素センサーの機能評価，第 11 回バイオ関連化学シンポジウム，東京大学弥生キャンパス，2017.9.6-8

H. Dinh, E. Nakata, T. Morii，Activity of the assembled enzyme on DNA scaffold，第 11 回バイオ関連化学シンポジウム，東京大学弥生キャンパス，2017.9.6-8

A. Rajendran, S.-J. Park, E. Nakata, Y. Kwon, T. Morii，Assembly of DNA Rotaxane and Catenane Inside a DNA Origami Frame，第 11 回バイオ関連化学シンポジウム，東京大学弥生キャンパス，2017.9.6-8

T. Morii，Assembling Enzymes on a DNA scaffold by modular protein-tag，A3RONA，China，2017.9.15-17

E. Nakata, T. Morii，酵素を"1 分子ずつ"狙った場所に配置する-試験管内での高効率な多段階反応システムへの挑戦-，2nd NNBS，志賀島国民宿舎，2017.10.23-24

E. Nakata, T. Morii，DNA Binding Adaptors to Locate Multiple Enzymes on DNA scaffold，Nano-S&T-2017，Hilton Hotel Sea Hoak，2017.10.26

中田栄司，生物から学んだ分子コンビナートへの挑戦，特別講演会，京都大学宇治キャンパス，2017.10.28

中田栄司，森井孝，DNA ナノ構造体上に酵素を配置した分子コンビナート，「統合物質創製化学研究推進機構」国内シンポジウム，京都大学宇治キャンパス，2017.10.30-31

A. Rajendran，DNA Nanotechnology and It's Medical Applications，2017ICEM-SFBMS，Kaohsiung medical university，2017.11.10-11

A. Rajendran, S.-J. Park, E. Nakata, Y. Kwon, T. Morii，Construction of Topologically Interlocked DNAs Inside a DNA Scaffold，第 44 回国際核酸化学シンポジウム/日本核酸化学会第 1 会年会 The 44th International Symposium on Nucleic Acids Chemistry /The 1st Annual Meeting of Japan Society of Nucleic Acids Chemistry，東京理科大学葛飾キャンパス図書館大ホール，2017.11.14

T. M. Nguyen, E. Nakata, M. Saimura, H. Dinh, T. Morii，Orthogonal Modular Adaptors to Locate Three Enzymes for Cascade Reaction on DNA Scaffold，第 44 回国際核酸化学シンポジウム/日本核酸化学会第 1 会年会 The 44th International Symposium on Nucleic Acids Chemistry /The 1st Annual Meeting of Japan Society of Nucleic Acids Chemistry，東京理科大学葛飾キャンパス図書館大ホール，2017.11.14

S. Nakano, T. Tamura, Das Raj Kumar, E. Nakata, Y.T. Chang, T. Morii, Selection of biosensors from a library of fluorescent ribonucleopeptide receptors constructed from a synthetic fluorophore library，第 44 回国際核酸化学シンポジウム/日本核酸化学会第 1 回年会 The 44th International Symposium on Nucleic Acids Chemistry /The 1st Annual Meeting of Japan Society of Nucleic Acids Chemistry，東京理科大学葛飾キャンパス図書館大ホール，2017.11.15

H. Dinh, E. Nakata, T. Morii, Reaction of enzymes in the ordered assembly states on DNA nanostructures，第 44 回国際核酸化学シンポジウム/日本核酸化学会第 1 会年会 The 44th International Symposium on Nucleic Acids Chemistry /The 1st Annual Meeting of Japan Society of Nucleic Acids Chemistry，東京理科大学葛飾キャンパス図書館大ホール，2017.11.15

中田栄司，森井孝，「酵素を“１分子ずつ”狙った場所に配置する」，第１回生命現象の可視化に向けた研究会，大阪大学蛋白質研究所，2017.11.22

中田栄司，森井孝, DNA ナノ構造体上に複数種類の酵素を配置した分子コンビナート，第 6 回植物二次代謝フロンティア研究会，淡路島夢舞台国際会議場，2017.12.11

E. Nakata, T. Morii, DNA Binding Adaptors to Locate Multiple Enzymes on DNA Scaffold, ISBC2017
The Second International Symposium on Biofunctional Chemistry，Kihada Hall, Uji Campus, Kyoto University，2017.12.14

T.M. Nguyen, E. Nakata, M. Saimura, H. Dinh, T. Morii, Assembly of multiple enzymes on a DNA scaffold, ISBC2017 The Second International Symposium on Biofunctional Chemistry，Kihada Hall, Uji Campus, Kyoto University，2017.12.14-15

A. Rajendran, S-J. Park, E. Nakata, Y. Kwon, T. Morii, DNA rotaxane and catenane inside a DNA nanostructure, ISBC2017 The Second International Symposium on Biofunctional Chemistry，Kihada Hall, Uji Campus, Kyoto University，2017.12.14-15

中田栄司，森井孝，酵素を“1 分子ずつ”狙った場所に配置する-生物から学んだ分子コンビナートへの挑戦-，講演会，北九州工業高等専門学校，2018.1.17

中田栄司，森井孝，酵素を“1 分子ずつ”狙った場所に配置する-生物から学んだ分子コンビナートへの挑戦-，第 11 回バイオ＆マテリアル講演会，久留米工業高等専門学校，2018.1.18

P. Lin, T. Nguyen, H. Dinh, E. Nakata, T. Morii, Efficiency of The Enzyme Cascade Reaction on a DNA Scaffold，日本化学会第 98 春季年会 2018，日本大学理工学部船橋キャンパス，2018.3.20-23

H. Dinh, E. Nakata, M. Kinoshita, T. Morii，Reaction of Carbonic Anhydrase assembled on DNA scaffold ，日本化学会第 98 春季年会 2018，日本大学理工学部船橋キャンパス，2018.3.20-23

A. Rajendran, S.J. Park, E. Nakata, Y. Kwon, T. Morii, Supramolecular Assemblies of Mechanically Interlocked Components Inside a DNA Origami Frame，日本化学会第 98 春季年会 2018，日本大学理工学部船橋キャンパス，2018.3.20-23

T. Nguyen, E. Nakata, M. Saimura, T. Morii, Sequence Specific Modular Adaptors for Orthogonal Location of Multiple Enzymes on a DNA scaffold，日本化学会第 98 春季年会 2018，日本大学理工学部船橋キャンパス，2018.3.20-23

小西宏明，Dinh Huyen，中田栄司，仲野瞬，森井孝，DNA ナノ構造体を鋳型にしたナノリポソーム，日本化学会第 98 春季年会 2018，日本大学理工学部船橋キャンパス，2018.3.20-23

中田栄司，Dinh Huyen，才村正幸，森井孝，多数のタンパク質を配置した DNA ナノ構造体の構築，日本化学会第 98 春季年会 2018，日本大学理工学部船橋キャンパス，2018.3.20-23

中田栄司，森井孝，酵素を“1 分子ずつ”狙った場所に配置した DNA ナノリアクターの創製，日本物理学会第 73 回年次大会（2018 年），東京理科大学野田キャンパス，2018.3.24

中田栄司，森井孝，非天然化合物合成を目指した分子コンビナートの創製，生物機能化学シンポジウム，京都大学宇治キャンパス，2018.3.26

Structural Energy Bioscience Research Section

M. Katahira, Professor
T. Nagata, Associate Professor
T. Mashima, Assistant Professor

1. Introduction

We explore the way how biomolecules such as proteins (involving enzymes) and functional nucleic acids (DNA and RNA) work at atomic resolution based on structural biology with NMR. We determine both static and dynamical structures with the aid of our own development of the new methodology and elucidate the underlying mechanism of functions of these biomolecules. Structural biological approach is also applied to analyze enzymes involved in degradation of wood biomass at atomic resolution. The analysis is useful to develop the way to extract energy and valuable materials that can be used as starting materials of various products from the wood biomass. Thus, we pursue to contribute to the paradigm shift from oil refinery to biorefinery. Followings are main research achievements in the year of 2017.

2. Toward better utilization of woody biomass: Structural and functional analysis of wood degrading enzymes

Glutathione-S transferases (GSTs) of wood degrading fungi are involved in cellular detoxification and metabolism. Here, we chose GSTs of lignin selective fungi (selective white-rot fungi) *Ceriporiopsis subvermispora*, CsGST63524 and CsGST83044, and characterized their activities. Firstly, we developed high-yield *E. coli* expression systems for each of them. For both CsGSTs, GSH-conjugation activity toward 1-chloro-2,4-dinitrobenzene and GSH-peroxidase activity toward cumene hydroperoxide were found. pH and temperature preferences for GSH-conjugation activity of both CsGSTs were identified to be pH 8.0 – 9.0 and 40°C, respectively. Furthermore, fluorescent compounds, methylumbelliferyl acetovanillone was used for etherase activity monitoring, while 5-chloromethylfluorescein diacetate and 4-methylumbelliferyl acetate were used for esterase activity monitoring. Interestingly, CsGST83044 had both etherase and esterase activities. CsGST63524 showed only esterase activity, which was much higher than that of CsGST83044. Structural analyses for both CsGSTs are currently in progress to elucidate the origin of the functional diversity.

3. Functional characterization of human deaminases, APOBEC3G, -3F, and -3B

APOBEC3G (A3G), which is an anti-HIV1 factor, is a cytidine deaminase. We previously showed that the C-terminal domain (CTD) of A3G has capabilities of sliding along single-stranded DNA (ssDNA) and deaminating the target CCC (C being deaminated). A3G CTD exhibits higher activity toward CCC in long ssDNAs than short ones and CCC located close to the 5'-end than to the 3'-end. Here, we used real-time NMR method to examine the deamination of two CCCs located separately on substrate ssDNA. We observed a loss of the deamination preference between the two CCCs when either the substrate or non-substrate ssDNA concentration was increased. Increasing of the nonsubstrate ssDNA concentration resulted in the elevation of the deamination activity first, but the reduction next. These findings indicate that A3G CTD undergoes intersegmental transfer for a target search.

APOBEC3F (A3F) is another anti-HIV1 factor, which deaminates the cytidine of TC in ssDNA. Here, we comprehensively characterized the deaminase activity and ssDNA binding of A3F CTD. The deaminase activity of A3F-CTD was shown to be affected by the nucleic acid residues adjacent to TC, and that TTCA/G are the most preferred sequence. The amino acid residues in the loops surrounding the catalytic center were identified to be responsible for the deaminase activity and ssDNA binding by mutational analysis. The functions of these residues were rationally interpreted by inspecting the co-crystal structure of A3A-ssDNA and the known roles of the equivalent amino acid residues found in other APOBEC3 proteins. A3F CTD was shown to be active in a wide pH range, 5.5 - 9.5, with similar activity. Furthermore, the N214H mutant exhibited a dramatically increased activity at pH 5.5.

Human APOBEC3B (A3B) is also an ssDNA-specific cytidine deaminase, which is causally related to human cancers. We applied a real-time NMR method to elucidate the deamination properties of A3B CTD. A3B CTD showed higher activity toward its target sequence in short ssDNA and a target sequence located near the center of ssDNA; these properties are quite different from those of A3G, which is described above. A rational interpretation of the unique properties of A3B CTD is as follows: After nonspecific binding to ssDNA, A3B CTD slides only for a relatively short distance and tends to dissociate from the ssDNA before reaching the target sequence.

4. In-cell NMR studies of DNA and RNA in human living cells for better understanding of biological events

In living cells, DNA and RNA function under extremely crowded conditions. Therefore, the structure and interaction of DNA and RNA in living cells are supposed to be different from those under dilute *in vitro* conditions. In-cell NMR is a promising method to obtain such information. Here, we introduced DNA and RNA, both of which are known to form the hairpin structure *in vitro*, into human cells by means of pores formed by bacterial toxin streptolysin O and subsequent resealing by calcium ions. It was revealed by analysis with confocal laser scanning fluorescence microscopy that introduced DNA and RNA are distributed throughout the nuclei without the formation of foci. The amounts distributed throughout the cytoplasm were mush less. Then, we succeeded in observing NMR signals of DNA and RNA in living human cells for the first time (Figure 1). Observed imino proton signals directly indicated that DNA and RNA form the similar hairpin structures in cells as were seen *in vitro*. Our method is applicable for the direct observation of NMR signals of other DNAs and RNAs in living human cells to explore their structure and interaction, providing information for understanding intracellular biological events.

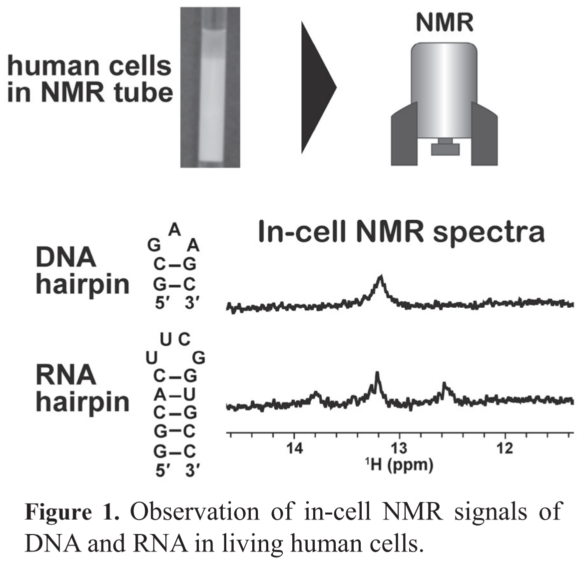


Figure 1. Observation of in-cell NMR signals of DNA and RNA in living human cells.

5. Observation of conformational change of TLS upon binding to various nucleic acids

Translocated in liposarcoma (TLS) protein, also known as fused in sarcoma (FUS), is a multifunctional RNA/DNA-binding protein. Its interactions with RNA and DNA are involved in various regulatory processes, such as gene expression, miRNA processing, genomic integrity, etc. Recent studies reportedly showed that the C-terminal region of TLS binds to a promoter-associated non-coding RNA (pncRNA) that is transcribed from the 5′ upstream region of *cyclin D1* (*CCND1*). This interaction may induce the N-terminal region of TLS to inhibit histone acetyltransferase activity of CBP/p300 on *CCND1* through its allosteric regulation, but the regulation has been little understood. This year, we have investigated the conformational change of TLS in response to many RNAs/DNAs by fluorescence-based assays. Fluorescence anisotropy experiments showed that some RNAs/DNAs bind to TLS with the same affinity as pncRNA. However, the extent of structural change of TLS depends on RNAs/DNAs. These findings implied that TLS could change its structure by factors other than the degree of affinity with RNAs/DNAs.

6. Structure determination of T:T mismatch-specific alkylation compound in complex with DNA for its therapeutic application

The myotonic dystrophy type 1 (DM1) is caused by an abnormal expansion of the CTG trinucleotide repeats. The CTG repeats form a hairpin structure with T (thymine):T mismatches. The alkylation of the T:T mismatch could hinder the transcription of the CTG repeat DNA and thus prevent DM1 from occurring. Prof. Nagatsugi (Tohoku Univ.) invented a compound that specifically alkylates the T:T mismatch. We determined the structure of the compound in complex with DNA after alkylation by NMR. Combination of HSQC and HMBC spectra identified that a T is alkylated at the N3 position by this compound (Figure 2). The elucidated complex structure helps further development of the compound for its therapeutic application to DM1.

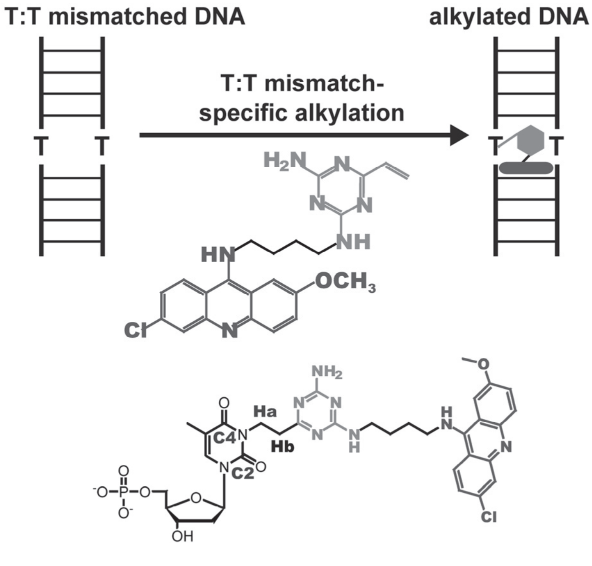


Figure 2. Structure of a T:T mismatch-specific alkylation compound in complex with DNA.

Collaboration Works

香港中文大学（中国），修飾塩基を含んだ機能性核酸の構造解析，片平正人

Gyeongsang National University（韓国），タンパク質との相互作用による核酸の構造遷移に関する解析，片平正人

Financial Support

1. Grant-in-Aid for Scientific Research
片平正人，新学術領域研究 (研究領域提案型)，RNA アプタマー・スイッチング素子・蛋白質のスライディングの動作原理の解明と活用

片平正人，挑戦的萌芽研究，細胞の外と内とで蛋白質捕捉活性がオフからオンに切り替わる機能性 RNA の創製

永田崇，新学術領域研究（研究領域提案型），機能性核酸の細胞内動的構造解析と DNA 変換酵素のスライディングの活写

永田崇，基盤研究(C)，癌・幹細胞増殖性維持に関わる翻訳抑制複合体の形成原理と創薬に向けた分子基盤の構築

真嶋司，基盤研究(C)，プリオンの異常化を抑制する四重鎖核酸の分子設計と抑制メカニズムの解明

近藤敬子，若手研究(B)，転写抑制とテロメア長短縮に寄与する TLS 蛋白質-非コード核酸相互作用の解析

山置佑大，若手研究(B)，細胞内外で活性をスイッチする機能性核酸の In-cell NMR 法等を用いた創製

神庭圭佑，若手研究(B)，HIV の Vif タンパク質による宿主細胞を利用したヒト抗ウイルス因子排斥機構の解明

2. Others
片平正人，科学技術振興機構，芳香族モノマー GHP/SHP 生産用高活性酵素の開発 : NMR を用いた構造生物学的手法による酵素の高度化

片平正人，国際協力機構，JICA イノベーティブアジア事業（第 1 バッチ）

Publications

Y. Kawasaki, T. Endo, A. Fujiwara, K. Kondo, M. Katahira, T. Nittani, M. Sato, M. Takeda, Elongation pattern and fine structure of the sheaths formed by Thiothrix nivea and Thiothrix fructosivorans, Int. J. Biol. Macromol., 95, 1280-1288, 2017

A. Lee, Y. Seo, S. Choi, K. Ryu, H. Cheong, S. Lee, M. Katahira, C. Park, J. Lee, NMR elucidation of reduced B-Z transition activity of PKZ protein kinase at high NaCl concentration, Biochem. Biophys. Res. Commun., 482, 335-340, 2017

E. Obayashi, R.E. Luna, T. Nagata, P. Martin-Marcos, H. Hiraishi, C.R. Singh, J.P. Erzberger, F. Zhang, H. Arthanari, J. Morris, R. Pellarin, C. Moore, I. Harmon, E. Papadopoulos, H. Yoshida, M.L. Nasr, S. Unzai, B. Thompson, E. Aube, S. Hustak, F. Stengel, E. Dagraca, A. Ananbandam, P. Gao, T. Urano, A.G. Hinnebusch, G. Wagner, K. Asano，Molecular Landscape of the Ribosome Pre-initiation Complex during mRNA Scanning: Structural Role for eIF3c and Its Control by eIF5，Cell Reports，18，2651-2663，2017

Y. Yamaoki, T. Nagata, T. Mashima, M. Katahira，Development of an RNA aptamer that acquires binding capacity against HIV-1 Tat protein via G-quadruplex formation in response to potassium ions，Chemical Communications，53，7056-7059，2017

Y. Nomura, K. Yamazaki, R. Amano, K. Takada, T. Nagata, N. Kobayashi, Y. Tanaka, J. Fukunaga, M. Katahira, T. Kozu, Y. Nomura, Y. Haishima, H. Torigoe, T. Sakamoto，Conjugating two RNA aptamers improves binding affinity for AML1 Runt domain，The Journal of Biochemistry，162，431-436，2017

R. Iwaoka, T. Nagata, K. Tsuda, T. Imai, H. Okano, N. Kobayashi, M. Katahira，Structural insight into recognition of r(UAG) by Musashi-1 RBD2, and construction of a model of Musashi-1 RBD1-2 bound to the minimum target RNA，Molecules，22，E1207，2017

R. Iwaoka, T. Nagata, K. Tsuda, T. Imai, H. Okano, N. Kobayashi, M. Katahira，Backbone and side chain assignments of the second RNA-binding domain of Musashi-1 in its free form and in complex with 5-mer RNA, Biomol NMR Assign，11，265-278，2017

L. Wan, T. Nagata, R. Morishita, A. Takaori-Kondo, M. Katahira，Observation by real-time NMR, and interpretation of length- and location-dependent deamination activity of APOBEC3B，ACS Chemical Biology，12, 11，2704-2708，2017

L. Wan, T. Nagata, M. Katahira, Influence of the DNA sequence/length and pH on deaminase activity, as well as the roles of the amino acid residues around the catalytic center of APOBEC3F, Physical Chemistry Chemical Physics, 20, 3109-3117, 2018

K. Kamba, T. Nagata, M. Katahira, The C-terminal cytidine deaminase domain of APOBEC3G itself undergoes intersegmental transfer for a target search, as revealed by real-time NMR monitoring, Physical Chemistry Chemical Physics, 20, 2976-2981, 2018

Y. Yamaoki, A. Kiyoishi, M. Miyake, F. Kano, M. Murata, T. Nagata, M. Katahira, The first successful observation of in-cell NMR signals of DNA and RNA in living human cells, Physical Chemistry Chemical Physics, 20, 2982-2985, 2018

K. Usui, A. Okada, S. Sakashita, M. Shimooka, T. Tsuruoka, S. Nakano, D. Miyoshi, T. Mashima, M. Katahira, Y. Hamada, DNA G-wire formation using an artificial peptide is controlled by protease activity, Molecules, 22, E1991, 2018

K. Takada, R. Amano, Y. Nomura, Y. Tanaka, S. Sugiyama, T. Nagata, M. Katahira, Y. Nakamura, T. Kozu, T. Sakamoto, Characterisation of an aptamer against Runt domain of AML1 (RUNX1) by NMR and mutational analyses, FEBS Open Bio, 8, 264-270, 2018

K. Onizuka, A. Usami, Y. Yamaoki, T. Kobayashi, M. Hazemi, T. Chikuni, N. Sato, K. Sasaki, M. Katahira, F. Nagatsugi, Selective alkylation of T-T mismatched DNA using vinyldiaminotriazine-acridine conjugate, Nucleic Acids Research, 46, 1059-1068, 2018

M. Takeda, K. Kondo, S. Sanda, D. Kan, I.K. Borges, I. Suzuki, M. Katahira, Enzymatic degradation of β-1,4-linked N-acetylglucosaminoglucan prepared from Thiothrix nivea, International Journal of Biological Macromolecules, 109, 323-328, 2018

M.I. Lin, T. Nagata, M. Katahira, High yield production of fungal manganase peroxidases by E. coli through soluble expression, and examination of the activities, Protein Expression and Purification, 145, 45-52, 2018

K. Kondo, T. Mashima, T. Oyoshi, R. Yagi, R. Kurokawa, N. Kobayashi, T. Nagata, M. Katahira, Plastic roles of phenylalanine and tyrosine residues of an RGG motif of TLS/FUS in binary and ternary complex formation with the G-quadruplex structures of telomeric DNA and TERRA, Scientific Reports, 8, 2864, 2018

A. Kitada, S. Takeoka, K. Kintsu, K. Fukami, M. Saimura, T. Nagata, M. Katahira, K. Murase, A Hydronium Solvate Ionic Liquid: Facile Synthesis of Air-Stable Ionic Liquid with Strong Brønsted Acidity, Journal of the Electrochemical Society, 165, H121-H127, 2018

T. Hayashi, T. Matsuda, T. Nagata, M. Katahira, M. Kinoshita, Mechanism of protein-RNA recognition: Analysis based on statistical mechanics of hydration, Physical Chemistry Chemical Physics, 2018

W.H. Wan Osman, M.I. Lin, K. Kondo, T. Nagata, M. Katahira, Characterization of the glutathione S-transferases that belong to the GSTFuA class in *Ceriporiopsis subvermispora*: Implications in intracellular detoxification and metabolism of wood-derived compounds, Int. J. Biol. Macromolecule., 113, 1158-1166, 2018

H. Nishimura, A. Kamiya, T. Nagata, M. Katahira, T. Watanabe, Direct evidence for α ether linkage between lignin and carbohydrates in wood cell walls Scientific. Reports, 2018

Presentations

片平正人，Structural analysis of protein non-coding RNA interaction，長鎖非コード RNA 勉強会，東京大学，2017.5.18

Y. Yamaoki, T. Mashima, T. Nagata, M. Katahira, Invention of RNA aptamer and ribozyme whose activities switch on in response to potassium ion via G-quadruplex formation, 6th International Meeting on Quadruplex Nucleic Acids, Czech Republic, 2017.5.31-6.3

永田崇，機能性核酸の細胞内動的構造解析と DNA 変換酵素のスライディングの活写，新学術領域「動的構造生命」領域会議，ザ・ルイガンズ，福岡県，2017.6.5-7

N. Kobayashi, T. Nagata, C. Kojima, T. Fujiwara, Highly automated NMR signal assignments using peak-noise recognition assisted by Deep Neural Networks, Gordon Research Conference. Computational Aspects-Biomol NMR, Grand Summit Hotel Sunday River.(Newy,ME,USA), 2017.6.11-16

神庭圭佑，永田崇，片平正人，APOBEC3G のストランド間移動の実時間 NMR 検出，第 17 回日本蛋白質科学会年会，仙台国際センター，2017.6.20-22

林孟宜，近藤敬子，永田崇，片平正人，High yield production, activity analysis and homologous modeling of soluble fungal manganese peroxidases expressed in E. coli，第 17 回日本蛋白質科学会年会，仙台国際セン

ター，2017.6.20-22

真嶋司，小澤 駿介，N. Hamad，米田竜馬，黒川理樹，永田崇，片平正人，TLS/FUS の RNA 認識機構と結合に伴うコンフォメーション変化の研究，第 17 回日本蛋白質科学会年会，仙台国際センター，2017.6.20-22

M. Katahira，Functioning mechanism and its application of RNA aptamer, switching device and sliding of protein, 新学術領域「柔らかな分子系」国際シンポジウム，ロイトン札幌，北海道，2017.6.26-28

徳永有希，大城理志，永田崇，近藤敬子，片平正人，渡辺隆司，NMR 法によるセルラーゼ糖質結合モジュール-リグニン間相互作用の解明，第 31 回セルラーゼ研究会，佐久平プラザ 21，長野県，2017.7.8-8

Y. Tokunaga, S. Oshiro, K. Kondo, T. Nagata, H. Nishimura, M. Katahira, T. Watanabe，NMR Analysis of Interaction Mechanism between Carbohydrate Binding Module of Cellulase and Lignin，The 2nd Asia Research Node Symposium on Humanosphere Science，京都大学，2017.7.19-21

真嶋司，小澤 駿介，N. Hamad，米田竜馬，黒川理樹，永田崇，片平正人，TLS/FUS の非コード RNA の認識機構の構造学的研究, 第 19 回日本 RNA 学会年会，富山国際会議場，2017.7.19-21

野口龍磨，佐藤慎一，勝田陽介，片平正人，山置佑大，福田将虎，A-to-I RNA 編集により誘起するグアニン四重鎖構造，第 19 回日本 RNA 学会年会，富山国際会議場，2017.7.19-21

N. Hamad, T. Mashima, Y. Yamaoki, K. Kondo, R. Kurokawa, T. Nagata, M. Katahira，Conformational change detection of translocated in liposarcoma，TLS，upon binding to various RNAs, 第19回日本RNA 学会年会，富山国際会議場，2017.7.19-21

N. Hamad, T. Mashima, Y. Yamaoki, K. Kondo, T. Nagata, M. Katahira， Analysis of conformational changes of translocated in liposarcoma，TLS，upon binding to promoter-associated non-coding RNA，pncRNA，3rd International Conference on New Horizons in Basic and Applied Science，Hurghada，Egypt，2017.8.5-7

D. Kashiwabara, S. Sanda, Y. Kawasaki, A. Fujiwara, K. Kondo, M. Katahira, M. Takeda， Structural analysis of the microtube formed by Sphaerotilus montanus，The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜，Kyoto University，2017.9.5-7

A. Kitada, K. Fukami, M. Saimura, T. Nagata, M. Katahira， A hydronium solvate ionic liquid， The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜, Kyoto University，2017.9.5-7

Y. Matsushita, M. Hashiura, N. Terashima, D. Aoki, H. Nishimura, T. Watanabe, M. Katahira, K. Fukushima, Analysis of condensed lignin structure for advanced biomass ulilization, The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜, Kyoto University, 2017.9.5-7

T. Watanabe, H. Nishimura, C. Qu, M. Yamada, S. Sakon, T. Kishimoto, M. Nakamura, K. Kondo, T. Nagata, M. Katahira， Structural analysis of lignocellulosic biomass byb solution-state NMR for future biorefinery, The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜，Kyoto University，2017.9.5-7

N. Watanabe, T. Kinase, T. Nagata, M. Katahira, K. Harada, T. Sakamoto， Development of RNA binding peptides based on tertiary structural information， The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜，Kyoto University，2017.9.5-7

M. Horiuchi, T. Nagata, M. Katahira, Y. Kobashigawa, Y. Suzuki, M. Ochiai， Development of the artificial multi-domain enzymes immobilized on the curdlan sheet at low cost, The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜，Kyoto University，2017.9.5-7

G. Matsuda, T. Nagata, M. Katahira, Y. Kobashigawa, K. Imadome， Structure-function relationship of Epstein-Barr Virus EBNA3C NLS and transport receptor, The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜，Kyoto University，2017.9.5-7

M. Katahira， Purification， enzymatic characterization and structural analysis of proteins involved in wood biomass degradation， The 8th International Symposium of Advanced Energy Science 〜 Interdisciplinary Approach to Zero-Emission Energy 〜, Kyoto University, 2017.9.5-7

H. Takaya, R. Yoshida, K. Isozaki, T. Yokoi, T. Shanoh, H. Nishimura， K. Kondo， T. Watanabe， M. Katahira， M. Nakamura， Ruthenium-bound Peptide Catalyst directed toward Artificial Peroxidase for Lignin Degradation， 第 64 回有機金属化学討論会，東北大学，2017.9.7-9

北田敦，竹岡駿，近都康平，深見一弘，才村正幸，永田崇，片平正人，邑瀬邦明，18-crown-6 を用いるヒドロニウム溶媒和イオン液体の基礎物性，2017 年電気化学秋季大会，長崎大学，2017.9.10-11

三田修平，河﨑雄太，浜口悠貴，近藤敬子，片平正人，武田穣，硫黄酸化細菌由来の β-1,4-N-アセチルグルコサミノグルカンのリゾチーム感受性，第 69 回日本生物工学会大会，早稲田大学，2017.9.11-14

飯田真美子, 真嶋司, 山置佑大, 永田崇, 片平正人, プリオンアプタマーはアルツハイマー病に関与するプリオン蛋白質と Aβ オリゴマーの複合体の形成を阻害する，第 55 回日本生物物理学会年会，熊本大学，2017.9.19-21

万里，永田崇，片平正人，基質 DNA の長さ、濃度、及び標的配列位置が APOBEC3F の脱アミノ活性に及ぼす影響，第 55 回日本生物物理学会年会，熊本大学，2017.9.19-21

近藤敬子, 真嶋司, 大吉崇文, 黒川理樹, 小林直宏, 永田崇，片平正人，テロメア長短縮をもたらす TLS/FUS 蛋白質とテロメア DNA および TERRA のグアニン四重鎖との複合体に関する NMR 解析，第 55 回日本生物物理学会年会, 熊本大学, 2017.9.19-21

高谷光，吉田亮太，磯碕勝弘，横井友哉，社納貴文，西村裕志，近藤敬子，渡辺隆司，片平正人，中村正治，リグニンの資源化を目指した Ru 結合型ペプチド人工酵素の創製，第 66 回高分子討論会，愛媛大学，2017.9.20-22

M. Katahira，Structural Change of Protein Caused by Non-Coding RNA，and Distinct Difference in Enzymatic Behavior among APOBEC3 Proteins as Revealed by Real-time NMR Method，2017 Taiwan-Japan Biomedical Symposium on Magnetic Resonance，National Cheng Kung University，Tainan，2017.10.15-17

前田亜鈴悠, 宋晶, 西真郎, 黒澤佳奈子, 市川淳子，塩谷美夏，山置佑大，永田崇，片平正人，山田美紗登，西村裕志，渡辺隆司，大田ゆかり，Sphingobium sp. YG1 由来 guaiacylglycerol-β-guaiacyl ether - Cα 位酸化酵素の酵素学的解析とその利用，第 62 回リグニン討論会，名古屋大学，2017.10.26-27

嶋根康弘，黒澤佳奈子，市川淳子，前田亜鈴悠，布浦拓郎，山置佑大，永田崇，片平正人，吉田亮太，中村正治，磯崎勝弘，渡辺隆司，大田ゆかり，フラグメント分子軌道法を活用したリグニン β-O-4 還元開裂酵素の機能改変，第 62 回リグニン討論会，名古屋大学，2017.10.26-27

K. Onizuka, A. Usami, Y. Yamaoki, T. Kobayashi, M. Hazemi, T. Chikuni, M. Katahira, F. Nagatsugi，Selective alkylation of T-T mismatched bases in DNA，The 44th International Symposium on Nucleic Acids Chemistry，Tokyo University of Science，2017.11.14-16

T. Mashima, T. Nagata, N. Hamad, S. Ozawa, Y. Yamaoki, K. Kondo, H. Watanabe, R. Yoneda, T. Uchihashi, R. Kurokawa, M. Katahira，Interaction between non-coding RNA and TLS/FUS protein，and structural change，The 44th International Symposium on Nucleic Acids Chemistry，Tokyo University of Science，2017.11.14-16

S. Masoud, Y. Yamaoki, Y. Ma, M. Katahira, K. Nagasawa，Interaction of a cyclic tetraoxazole with i-motif DNA and its effects on this structure，The 44th International Symposium on Nucleic Acids Chemistry，Tokyo University of Science，2017.11.14-16

L. Wan, T. Nagata, R. Morishita, A. Takaori-Kondo, M. Katahira，Characterization of the cytidine deamination properties of human APOBEC3B by real-time NMR，which are quite different from those of APOBEC3G，The 44th International Symposium on Nucleic Acids Chemistry，Tokyo University of Science，2017.11.14-16

真嶋司，ハマッド ネスリン，小澤駿介，渡辺大輝，内橋貴之，米田竜馬，黒川理樹，永田崇，片平正人，非コード RNA と TLS/FUS タンパク質の相互作用様式と結合に伴う TLS/FUS の大きな構造変化，第 56 回 NMR 討論会，首都大学東京，2017.11.14-16

岩岡諒，永田崇，津田健吾，今井貴雄，岡野栄之，小林直宏，片平正人，RNA 結合タンパク質 Musashi-1 の RBD2:r（GUAGU）複合体溶液構造決定と標的 RNA 選択メカニズムの解明，第 56 回 NMR 討論会，首都大学東京，2017.11.14-16

山置佑大，清石彩華，三宅雅之，加納ふみ，村田昌之，永田崇，片平正人，In-cell NMR 法によるヒト細胞内 DNA および RNA の観測，第 56 回 NMR 討論会，首都大学東京，2017.11.14-16

小林直宏，永田崇，服部良一，新家粧子，Julia M. Wurz, Peter Guntert，児嶋長次郎，藤原敏道，深層学習により強化された NMR 立体構造解析，第 56 回 NMR 討論会，首都大学東京，2017.11.14-16

T. Nagata, H. Yoshida, S. Unzai, T. Urano, K. Asano, E. Obayashi，Interactions between eukaryotic initiation factors implicated during ribosomal scanning and start codon recognition，第 56 回 NMR 討論会，首都大学東京，2017.11.14-16

片平正人，ノンコーディング RNA との相互作用を介した TLS/FUS タンパク質の機能発現機構に関する構造学的研究，未来へのバイオ技術 勉強会「長

鎖非コード RNA 研究の進歩と可能性」, バイオインダストリー協会，東京都，2017.11.27

片平正人，TLS/FUS タンパク質と非コード RNA の認識機構の解明と結合に伴う TLS/FUS の大きな構造変化の検出，2017 年度生命科学系学会合同年次大会，神戸ポートアイランド，2017.12.6-9

神庭圭佑，永田崇，片平正人，ストランド間移動に依存するヒト抗ウイルス因子 APOBEC3G の酵素活性の促進と阻害，2017 年度生命科学系学会合同年次大会，神戸ポートアイランド，2017.12.6-9

渡邊なつき，武田有未，S. Colin，永田崇，片平正人，河野俊之，坂本泰一，HIV-1 の Rev ペプチド変異体の調製とペプチド変異体と RRE RNA の相互作用の NMR 解析，2017 年度生命科学系学会合同年次大会，神戸ポートアイランド，2017.12.6-9

岩岡諒，永田崇，津田健吾，今井貴雄，岡野栄之，小林直宏，片平正人，立体構造解析及びモデリングによる Musashi1 タンパク質 RNA 結合ドメインの標的 RNA 認識機構の解明，2017 年度生命科学系学会合同年次大会，神戸ポートアイランド，2017.12.6-9

N. Hamad, T. Mashima, H. Watanabe, T. Uchihashi, R. Kurokawa, T. Nagata, M. Katahira，The effect of different target nucleic acids on the structural change of TLS，2017 年度生命科学系学会合同年次大会，神戸ポートアイランド，2017.12.6-9

片平正人，RNA アプタマー・スイッチング素子・蛋白質のスライディングの動作原理の解明と活用，新学術領域「柔らかな分子系」領域会議，沖縄残波ロイヤルホテル，沖縄県，2017.12.12-14

永田崇，小瀧努，中田栄司，森井孝，片平正人，木材分解酵素の構造機能相関研究~木質バイオマスの有効活用へ向けた取り組み~エネルギー複合機構研究センター第 8 回談話会，京都大学，2018.1.5

片平正人，ゼロエミッションエネルギーとバイオマスの活用，韓国・昌原大学付設科学英才教育院学生向け講演会，京都大学，2018.1.9

M. Katahira，Biomass Energy ，Winter Seminar on Human Security Development and Energy Science ，Kyoto University，2018.1.17

臼井健二，坂下峻吾，岡田亜梨紗，下岡正幸，鶴岡孝章，真嶋司，片平正人，酵素反応により核酸構造を変化させる人工ペプチドによる刺激応答感覚素子の構築，分子ロボティクス年次大会（併催分子ロボット倫理シンポジウム），東北大学，2018.3.5-6

永田崇，DNA 変換酵素のスライディングと核酸の細胞内動的構造の NMR による研究，生体機能化学セミナー，京都大学，2018.3.26

Advanced Energy Utilization Division

A. Rajendran, Junior Associate Professor

1. Introduction

DNA topoisomerases (Topos) regulate the DNA topology such as overwinding or underwinding that arises due to the intertwined nature of the DNA double helices.[1] These enzymes also play important roles in various biological processes such as replication, transcription, recombination, and chromosome condensation and segregation. During the DNA replication and transcription, overwinding of the DNA duplex occurs. If it is not relaxed, it eventually stops the functions of the enzymes involved in replication process. Topos control these topological conditions by transiently cleaving the phosphodiester bond, which generates a Topo-DNA cleavage complex. Once the winding stress is resolved, the enzyme-mediated DNA break is resealed. This process is critical for the healthy cells to survive and function normally, and failure to reseal the DNA break can ultimately lead to cell death. Topos involve in step-by-step processes such as binding of Topo to DNA, ATP driven strand passage, strand cleavage by Topo, formation of Topo-DNA cleavage complex, religation of cleaved DNA, and catalytic cycle after DNA cleavage/enzyme turnover. All these steps are of great interest as potential targets for the development of anticancer drugs.[2] Despite the development of various Topo-inhibitors, the mechanisms of action of these anticancer drug molecules are not well known. For instance, it is not well understood at which step of the enzyme reaction is inhibited by a particular drug molecule. Also, typical methods such as ethidium bromide assay, to measure the topoisomerase inhibitory activity are not suitable for real-time observation of the reaction. Thus, to understand the Topos reaction and the mechanisms of the inhibitors, it is necessary to develop a versatile method.

2. Supramolecular assemblies of the mechanically interlocked components inside a DNA origami frame

As the Topo enzymes target the topologically constrained DNAs, the mechanically interlocked supramolecular DNA assemblies can be considered to be the potential targets to investigate the Topo functions and their inhibitors.[3] Topologically interesting structures such as Borromean rings, catenanes, and knots have already been prepared by using DNA.[4] Also, the complexity of the catenane[5] and rotaxane[6] structures were increased by constructing them by the DNA origami method. [7-9] However, the fabrication of the duplex DNA catenanes and rotaxanes to the relatively larger and complex DNA nanostructures such as DNA origami has not yet been realized. These molecular assemblies have potential applications such as the functional components for molecular switches and motors, novel platforms for the investigation of the function of proteins, analysis of protein inhibitors, and so on. Recently, I have been collaborating with the research groups of Prof. Takashi Morii (IAE, Kyoto University) and Prof. Youngjoo Kwon (Ewha Womans University) for the nanofabrication of the topologically interlocked supramolecular assemblies.

In this work, we have developed a novel method by the combination of scaffolded DNA origami – a method to fold DNA into the arbitrary 2D and 3D structures as templates,[7-9] and high-speed atomic force microscopy (HS-AFM)[10-15] for the screening of Topo-inhibitors. As for the target structures for the Topo reactions, we have constructed topologically interlocked DNA catenane- and rotaxane-like structures inside a DNA origami frame (Figure 1a). The formation of the DNA origami frame and the insertion of the catenane- and rotaxane-like structures were successfully characterized by agarose gel electrophoresis (Figure 1b) and HS-AFM (Figure 1c). To increase the stability of these functional structures, the nicks in these structures were sealed by using T4 DNA ligase. The ligation was also confirmed by the thermal treatment of these structures, where the ligated samples were stable at high temperature incubation while the unligated samples failed to keep the folded structures. The experimental conditions such as the amount of salt, annealing temperatures, concentration of the DNA strands were optimized. The purification and quantification methods to get rid of

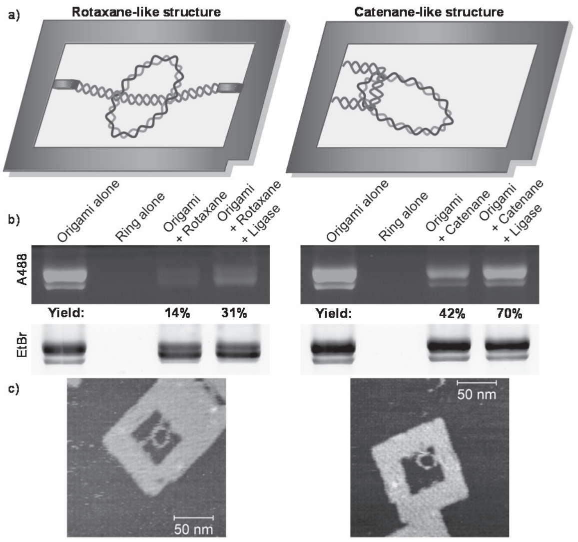


Figure 1. (a) Schematic illustration of the DNA rotaxane (left) and catenane (right) inside a DNA origami frame, (b) confirmation of the formation of topologically interlocked structures inside the origami by agarose gel electrophoresis, and (c) AFM images of the respective structures.

the excessive staples and unbound catenane/rotaxane rings were also established. Further, we have investigated the stability of the DNA origami frame and the catenane/rotaxane ring structures in the presence of various kinds of Topo inhibitors. Both the origami and the DNA ring are stable against the Topo inhibitors for several hours at room temperature. This indicated that the DNA origami based analysis of Topo inhibitors could be successfully carried out. We are now investigating the Topo reactions on these functional structures. After successful investigation of the Topo reactions, these structures will be used for the screening of Topo inhibitors. Such a screening will be carried out by the direct and real-time characterization methods such as HS-AFM and fluorescence imaging. Apart from the Topo reactions and inhibitor screening, the fabrication of the topologically interlocked structures within a DNA origami nanostructure is also promising in the fields of molecular switches, motors, sensors, and logic devices.[4]

3. References

[1] C. A. Austin, K. L. Marsh, R. A. Wasserman, E. Willmore, P. J. Sayer, J. C. Wang, L. M. Fisher, *J. Biol. Chem.*, **1995**, *270*, 15739-15746.

[2] C. Wu, T. Li, L. Farh, L. Lin, T. Lin, Y. Yu, T. Yen, C. Chiang, N. Chan, *Science*, **2011**, *333*, 459-462.

[3] J. L. Nitiss, E. Soans, A. Rogojina, A, Seth, M. Mishina, *Curr. Protoc. Pharmacol.*, **2012**, *57*, 3.3.1-3.3.27.

[4] T. L. Schmidt, A. Heckel, *Nano Lett.*, **2011**, *11*, 1739-1742.

[5] D. Han, S. Pal, Y. Liu, H. Yan, *Nat Nanotechnol.*, **2010**, *5*, 712-717.

[6] J. List, E. Falgenhauer, E. Kopperger, G. Pardatscher, F. C. Simmel, *Nat. Commun.*, **2016**, 7:12414.

[7] P. W. K. Rothemund, *Nature*, **2006**, *440*, 297-302.

[8] A. Rajendran, M. Endo, H. Sugiyama, *Curr. Protoc. Nucleic Acid Chem.*, **2012**, *48*, 12.9.1-12.9.18.

[9] A. Rajendran, E. Nakata, S. Nakano, T. Morii, *ChemBioChem*, **2017**, *18*, 696-716.

[10] A. Rajendran, M. Endo, H. Sugiyama, *Chem. Rev.,* **2014**, *114*, 1493-1520.

[11] A. Rajendran, M. Endo, K. Hidaka, H. Sugiyama, *Angew. Chem. Int. Ed.*, **2014**, *53*, 4107-4112.

[12] A. Rajendran, M. Endo, K. Hidaka, H. Sugiyama, *J. Am. Chem. Soc.*, **2013**, *135*, 1117-1123.

[13] A. Rajendran, M. Endo, K. Hidaka, P. L. T. Tran, J.-L. Mergny, R. Gorelick, H. Sugiyama, *J. Am. Chem. Soc.*, **2013**, *135*, 18575-18585.

[14] A. Rajendran, M. Endo, H. Sugiyama, *Angew. Chem. Int. Ed.*, **2012**, *51*, 874-890.

[15] A. Rajendran, M. Endo, Y. Katsuda, K. Hidaka, H. Sugiyama, *J. Am. Chem. Soc.*, **2011**, *133*, 14488-14491.

Financial Support

Grant-in-Aid for Scientific Research

Arivazhagan Rajendran，若手研究（B），Development of new method for screening anticancer drugs that target topoisomerases by using DNA origami

Publications

A. Rajendran, E. Nakata, S. Nakano, T. Morii , Nucleic-acid-templated enzyme cascades , ChemBioChem, 18, 696-716, 2017

Complex Energy Processes Research Section

M. Kinoshita, Professor
H. Okada, Associate Professor

1. Introduction

A. Theoretical Biophysics

A variety of self-assembling and ordering processes in biological systems, which occur at molecular levels, are sustaining life. Biopolymers, a great diversity of molecular and ionic species, or water is simply *material* when each of them is separately present. However, the complicated correlations among these material constituents can lead to *life*. We are elucidating those correlations, uncovering the mechanism of the biological self-assembly, and clarifying the roles of water by developing special theories based on statistical mechanics and morphometric thermodynamics. The achievements will provide important bases of nanobiotechnology. The current subjects are hydrophobic and hydrophilic hydrations, behavior of confined liquids, folding/unfolding mechanisms of proteins, molecular recognition, prediction of the native structure of a protein, enhancement of the thermal stability of membrane proteins, and functioning of ATP-driven proteins.

B. Plasma Physics

The major subjects are to study fast-ion confinement in plasma confinement devices and to investigate interactions between fast-ions and materials, such as a first wall and a vacuum vessel. The fast-ion confinement is a critical issue for the fusion reactor since the alpha particles produced in the D-T reaction should be utilized to heat plasma efficiently. Fast-ion profile and velocity distribution are investigated using ion cyclotron range of frequency (ICRF) minority heating in Heliotron J with special emphasis on the effect of the toroidal ripple of magnetic field strength (‘bumpiness’). In fusion reactors, fuel must be supplied since fuel particles decrease in the fusion reactions and escape continuously from the core plasma. Fueling using hydrogen-ice pellet is also our subject to generate high-density plasmas. This method is considered to have an advantage for core-plasma fueling. A small-size and slow-speed injector has been developed for plasmas in Heliotron J and the operation for fueling begins.

(A-1) Unified elucidation of the entropy-driven and -opposed hydrophobic effects [1]

Association of nonpolar solutes is generally believed to be entropy driven, which was shown to be true for the contact of small molecules, ellipsoids, and plates. However, it was reported with surprise that a model cavity-ligand binding is entropy opposed. How can these apparently conflicting behaviors be elucidated? Here we calculate the potential of mean force between hard-sphere solutes with various diameters in water and its entropic and enthalpic components using a statistical-mechanical theory for molecular liquids. It is shown that there is a very wide region where both of the two components are negative and large with the entropy-enthalpy compensation. Even for spheres, their contact is weakly entropy opposed when they are medium-sized. The entropic component (EC) is decomposed into physically insightful constituents by the aid of our morphometric approach. They provide us with useful information on the signs and magnitudes of contributions from the structural difference between the water near a single solute surface and that within the space confined between two solute surfaces and from the total volume available to the translational displacement of water molecules in the system. The decomposition enables us to identify the essential factors in discussing the EC: hydrogen-bonding properties and density structure of the water within the confined space and the degree of water crowding in the bulk. These are largely dependent on geometric characteristics of the solute pair such as solute shapes, sizes, and intersolute distance. Both of the entropy-driven and -opposed hydrophobic effects can be explained within the same theoretical framework.

(A-2) Hot-Spot Residues to be Mutated Common in G Protein-Coupled Receptors of Class A: Identification of Thermostabilizing Mutations Followed by Determination of Three-Dimensional Structures for Two Example Receptors [2]

G protein-coupled receptors (GPCRs), which are indispensable to life and also implicated in a number of diseases, construct important drug targets. For the efficient structure-guided drug design, however, their structural stabilities must be enhanced. An amino-acid mutation is known to possibly lead to the enhancement, but currently available experimental and theoretical methods for identifying stabilizing mutations suffer such drawbacks as the incapability of exploring the whole mutational space with minor effort and the unambiguous physical origin of the enhanced or lowered stability. In general, after the identification is successfully made for a GPCR, the whole procedure must be followed all over again for the identification for another GPCR. Here we report a theoretical strategy by which many different GPCRs can be considered at the same time. The strategy is illustrated for three GPCRs of Class A in the inactive state. We argue that a mutation of the residue at a position of N_{BW}=3.39 (N_{BW} is the Ballesteros-Weinstein number), a hot-spot residue, leads to substantially higher stability for significantly many GPCRs of Class A in the inactive state. The most stabilizing mutations of the residues with N_{BW}=3.39 are then identified for two of the three GPCRs, using the improved version of our free-energy function. These identifications are experimentally corroborated, which is followed by the determination of new three-dimensional (3D) structures for the two GPCRs. We expect that on the basis of the strategy, the 3D structures of many GPCRs of Class A can be solved for the first time in succession.

(B-1) Study of Fast-ion Generation by Combination Heating of ICRF and NBI in Heliotron J

Main purpose of this study is to optimize fast ion confinement by using ICRF heating in a helical-axis heliotron device, Heliotron J on the basis of results of several helical devices. For the research of the fast ion confinement in a three dimensional magnetic field, fast ions are generated by ICRF minority heating in combination with NBI heating in Heliotron J (R_0 = 1.2 m, a = 0.1-0.2 m, $B_0 \leq$ 1.5 T). The energy range is extended from the injection energy of the NBI beam E_0, 25 keV, to 60 keV during the ICRF pulse in the newly attempted low-ε_t configuration and medium density operation (1x10^{19} m^{-3}). This configuration is better in the fast ion generation and confinement than the high bumpiness configuration which is the best among the bumpiness scan. Here, the toroidicity and the bumpiness normalized by the helicity for the low-ε_t and the high bumpiness configurations are (0.77, -1.04) and (0.86, -1.16) in Boozer coordinates, respectively. They are key parameters in 1/ν regime of helical devices. The low-ε_t configuration is expected to have good confinement from the neo-classical theory. The Monte-Carlo calculation shows the advantage of the low-ε_t configuration for the generation and confinement of fast ions.

Using Monte-Carlo method with the experimental magnetic field and plasma parameters, the numerical calculation including orbit tracing, Coulomb collisions and ICRF acceleration has been performed in order to estimate the averaged behavior in whole torus for various configurations. The test ions (protons) in the calculation, which represent the NBI particles, start at the middle point of the NB path in a plasma with the NB energy of E_0, E_0/2 and E_0/3. The ratio of the ions of three energy values, is assumed to be 0.90, 0.07 and 0.03, respectively. The magnetic field configuration is the high bumpiness. Injected ions are lost in energy in colliding with bulk particles in a plasma and are accelerated or decelerated by the ICRF wave, then, ions spread in velocity space from the initial energy and pitch angle. The peak of the energy spectrum appears at just below E_0 and other injection energy peaks are very small. This result is different from the experiment one. The peak of E_0 does not appear and the population decreases gradually around E_0, and the peaks are clearly observed. One possible cause of this difference is the ratio of beam components. The spectrum will be changed if E_0/2 and E_0/3 components should be larger.

(B-2) Study of Density Control Using Hydrogen Ice-Pellet Injection

The ice-pellet injection system has been developed for the new particle supply method following the supersonic molecular beam injection (SMBI) under the bilateral collaboration program in Heliotron J. This method is considered to be effective specially to supply particles into the plasma core region. The conditions of the pellet injector are; injection speed is less than 300 m/s, and the diameter is less than 1 mm for the plasma parameters of Heliotron J. The pellet injection method is pneumatic propulsion using high-pressure helium gas. The injection test has been successfully done, then, the injection experiment to NBI and ECH+NBI plasmas is planned in this campaign. The density increase after pellet injection is very rapid and exceeds 5×10^{19} m^{-3} for NBI plasmas for the standard magnetic configuration of Heliotron J. Plasma stored energy decreases just after the injection since the energy is once lost partially in the ionization process of substantial particle source, then, increases up to 3.4 kJ from 1 kJ. The penetration length of pellet is investigated using Hα detector array for ECH+NBI plasmas. This parameter is important for the effectiveness of the particle supply in the plasma core. The increase of the Hα line is recognized from the edge sight-line (pellet injector side) to central line crossing the magnetic axis in a plasma. However, in some shots, the pellet penetrates through the plasma diameter, then; the optimization of the injection conditions is needed. The target plasma density and magnetic field configuration dependence are next subjects for the pellet injection experiment.

References

[1] M. Kinoshita and T. Hayashi, Phys. Chem. Chem. Phys. **19**, 25891 (2017).

[2] S. Yasuda, Y. Kajiwara, Y. Toyoda, K. Morimoto, R. Suno, So Iwata, T. Kobayashi, T. Murata, and M. Kinoshita, J. Phys. Chem. B **121**, 6341 (2017).

[3] H. Okada, et al., 21st International Stellarator-Heliotron Workshop (ISHW2017), 2-6 October 2017, Kyoto, Japan, P1-34.

[4] H. Okazaki, et al., Plasma Conference 2017, 20-24 November 2017, Himeji, Japan, 23P-09.

Collaboration Works

Università Ca' Foscari Venezia（イタリア），タンパク質折り畳みのメカニズムの解明と立体構造予測法の開発，木下正弘

Univ. Wisconsin（米国）、Oak Ridge National Laboratory（米国）、Max Plank Institute（ドイツ）、Stuttgart Univ.（ドイツ）、CIEMAT（スペイン）、Australian National Univ.、（オーストラリア）、Kharkov Institute（ウクライナ）、Southwest Institute of Physics（中華人民共和国），ヘリカル型装置における SOL/ダイバータプラズマに関する研究，水内亨，長﨑百伸，岡田浩之，小林進二，山本聡，南貴司

Stuttgart University（ドイツ）、CIEMAT（スペイン），ヘリカル磁場配位における乱流揺動研究，大島慎介、長﨑百伸、水内亨、岡田浩之、南貴司、小林進二、山本聡

Stuttgart Univ.、CIEMAT（スペイン），先進閉じ込め配位，長﨑百伸、大島慎介、水内亨、岡田浩之、南貴司、小林進二、山本聡

千葉大学大学院理学研究科，膜タンパク質を耐熱化させるアミノ酸置換の理論的予測法の開発，木下正弘，村田武士

核融合科学研究所・双方向型共同研究，磁場分布制御を活用したプラズマ構造形成制御とプラズマ輸送改善，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J、CHS、LHED 装置における重水素プラズマの粒子輸送の研究，水内亨，山本聡，南貴司，大島慎介，小林進二，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，低磁気シアヘリオトロン配位における磁気島に対するプラズマ応答の研究，水内亨，岡田浩之，長﨑百伸，山本聡，小林進二，南貴司

核融合科学研究所・双方向型共同研究，ヘリオトロン J における ICRF 加熱を用いたプラズマの高性能化研究，水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡，木島茂，大島慎介，門信一郎

核融合科学研究所・双方向型共同研究，高性能磁場閉じ込めプラズマを目指した粒子補給法の検討（ヘリオトロン J におけるプラズマ高密度化に向けた粒子補給法の模索），水内亨，小林進二，岡田浩之，

核融合科学研究所・双方向型共同研究，磁気シアが MHD 不安定性による閉じ込め性能劣化度に与える影響の研究，水内亨，岡田浩之，長﨑百伸，小林進二，山本聡，南貴司

核融合科学研究所・双方向型共同研究，多様な磁場配位を有するヘリカル系プラズマにおけるプラズマフローと磁気島の理解，水内亨，山本聡，小林進二，長﨑百伸，岡田浩之，南貴司，大島慎介

核融合科学研究所・双方向型共同研究，ヘリカル系プラズマにおけるアルヴェン固有モードに起因する高速イオン損失研究, 水内亨, 山本聡, 小林進二, 大島慎介，岡田浩之，南貴司，長﨑百伸，門信一郎

核融合科学研究所・双方向型共同研究，有限ビーム幅を考慮した電子バーンシュタイン波放射計測，水内亨，長﨑百伸，大島慎介，南貴司，山本聡，小林進二，岡田浩之

核融合科学研究所・双方向型共同研究，複合揺動計測によるヘリオトロン J の乱流構造解析，水内亨，長﨑百伸，岡田浩之，南貴司，小林進二，大島慎介

核融合科学研究所・双方向型共同研究，アルベン固有モードによる高速イオン異常輸送の物理過程とその制御に関する研究, 水内亨, 岡田浩之, 南貴司，長﨑百伸，山本聡，大島慎介，小林進二

核融合科学研究所・双方向型共同研究，マルチチャンネルカロリーメーターによるダイバーター熱流束の計測, 水内亨, 大島慎介, 岡田浩之, 小林進二，門信一郎

核融合科学研究所・双方向型共同研究，ヘリカルプラズマの不純物輸送に対する同位体効果の影響，水内亨，門信一郎，小林進二，山本聡，大島慎介，南貴司，岡田浩之，長﨑百伸

核融合科学研究所・双方向型共同研究，ヘリオトロン J における VUV 分光法を用いた不純物の計測と輸送の研究, 水内亨, 門信一郎, 岡田浩之, 山本聡，南貴司，小林進二，長﨑百伸，大島慎介

核融合科学研究所・双方向型共同研究，ヘリオトロン J におけるプラズマ高密度化実験，水内亨，門信一郎，長﨑百伸，岡田浩之

核融合科学研究所・双方向型共同研究，閉じ込め改善現象に関する 3 次元効果の解明, 水内亨, 南貴司，小林進二，門信一郎，岡田浩之，長﨑百伸，大島慎介，山本聡，木島滋

核融合科学研究所・双方向型共同研究，ヘリオトロン J におけるビーム放射分光法を用いた乱流ダイナミクスの研究，水内亨，小林進二，大島慎介，岡田浩之，門信一郎，岡田浩之

核融合科学研究所・双方向型共同研究，電場・磁場

揺動を用いた周辺乱流制御の試み—Heliotron J における乱流制御—，水内亨，大島慎介，小林進二，岡田浩之，長﨑百伸，南貴司，山本聡，門信一郎

核融合科学研究所・双方向型共同研究，ヘリカル装置における電極バイアスによるポロイダル粘性遷移の研究，水内亨，長﨑百伸，岡田浩之，南貴司，門信一郎，小林進二，山本聡，大島慎介

核融合科学研究所・双方向型共同研究，燃焼炉心プラズマ研究に向けた高エネルギー粒子物理と熱化粒子新古典理論の統合，水内亨，岡田浩之，小林進二，山本聡，南貴司

核融合科学研究所・双方向型共同研究，荷電交換損失がヘリオトロン J の NBI 加熱に与える影響, 水内亨，岡田浩之，南貴司，小林進二，長﨑百伸，山本聡

Financial Support

木下正弘，基盤研究(B)，膜蛋白質を耐熱化させるアミノ酸置換の理論的予測法の確立

Publications

A. Koyama, K. Fukami, Y. Imaoka, A. Kitada, T. Sakka, T. Abe, K. Murase, M. Kinoshita, Dynamic Manipulation of Local pH within Nanopore Triggered by Surface-Induced Phase Transition, Physical Chemistry Chemical Physics, 19, 16323-16328, 2017

S. Yasuda, Y. Kajiwara, Y. Toyoda, K. Morimoto, R. Suno, S. Iwata, T. Kobayashi, T. Murata, M. Kinoshita, Hot-Spot Residues to be Mutated Common in G Protein-Coupled Receptors of Class A: Identification of Thermostabilizing Mutations Followed by Determination of Three-Dimensional Structures for Two Example Receptors, Journal of Physical Chemistry B, 121, 26, 6341-6350, 2017

T. Hayashi, S. Yasuda, T. Škrbić, A. Giacometti, M. Kinoshita, Unraveling Protein Folding Mechanism by Analyzing the Hierarchy of Models with Increasing Level of Detail, Journal of Chemical Physics, 147, 12, 125102(1-12), 2017

M. Kinoshita, T. Hayashi, Unified Elucidation of the Entropy-Driven and -Opposed Hydrophobic Effects, Physical Chemistry Chemical Physics, 19, 25891-25904, 2017

M. Kinoshita, T. Hayashi, Entropic Enrichment of Cosolvent near a Very Large Solute Immersed in Solvent-Cosolvent Binary Mixture, Journal of Molecular Liquids, 247, 403-410, 2017

K. Amano, T. Hayashi, K. Hashimoto, N. Nishi, T. Sakka, Potential of Mean Force between Spherical Particles in an Ionic Liquid and its Decomposition into Energetic and Entropic Components: An Analysis Using an Integral Equation Theory, Journal of Molecular Liquids, 257, 121-131, 2018

T. Hayashi, T. Matsuda, T. Nagata, M. Katahira, M. Kinoshita, Mechanism of Protein-RNA Recognition: Analysis Based on Statistical Mechanics of Hydration, Physical Chemistry Chemical Physics, 20, 9167-9180 2018

N. Kenmochi, T. Minami, C. Takahashi, S. Mochizuki, K. Nishioka, S. Kobayashi, K. Nagasaki, Y. Nakamura, H. Okada, S. Kado, S. Yamamoto, S. Ohshima, S. Konoshima, G. M. Weir, Y. Otani, T. Mizuuchi, Characteristics of electron internal transport barrier in Heliotron J, Plasma Physics and Controlled Fusion, 055013, 2017

Y. Ohtani, K. Tanaka, T. Minami, S. Ohshima, K. Nagasaki, T. Akiyama, Y. Nakamura, H. Okada, S. Kado, S. Kobayashi, S. Yamamoto, N. Kenmochi,. X. Lu, S. Konoshima, T. Mizuuchi, Initial Results of Density Modulation Experiment for Study of Hydrogen Isotope Effects on Particle Transport in Heliotron J, Journal of the Physical Society of Japan, 064501, 2017

S. Yamamoto, K. Nagasaki, S. Kobayashi, K. Nagaoka, A. Cappa, H. Okada, T. Minami, S. Kado, S. Ohshima, S. Konoshima, Y. Nakamura, A. Ishizawa, G.M. Weir, N. Kenmochi, Y. Ohtani, X. Lu, Y. Tawada, D. Kokubu, T. Mizuuchi, Suppression of fast-ion-driven MHD instabilities by ECH/ECCD on Heliotron J, Nuclear Fusion, 126065, 2017

Presentations

T. Hayashi, S. Yasuda, T. Škrbić, A. Giacometti, .M. Kinoshita, Unraveling protein folding mechanism by analyzing the hierarchy of models with increasing level of detail, 第 55 回日本生物物理学会年会，熊本大学黒髪北地区，2017.9.19-21

Y. Kajiwara, S. Yasuda, M. Ikeguchi, T. Murata, M. Kinoshita, Physical origin of stabilization by a quadruple mutation for theadenosine A2a receptor in the active state, 第 55 回日本生物物理学会年会，熊本大学黒髪北地区，2017.9.19-21

S. Yasuda, Y. Kajiwara, Y. Toyoda, K. Morimoto, R.

Suno, S. Iwata, T. Kobayashi, T. Murata, M. Kinoshita, Theoretical Identification of Hot-Spot Residues to be Mutated Common in G Protein-Coupled Receptors of Class A，第 55 回日本生物物理学会年会，熊本大学黒髪北地区，2017.9.19-21

S. Hikiri, R. Nakano, N. Suzuki, S. Yasuda, Y. Kajiwara, M. Kinoshita, T. Murata，Identification of thermostabilizing mutations for a G- protein coupled receptor in the active state，第 55 回日本生物物理学会年会，熊本大学黒髪北地区，2017.9.19-21

安田賢司，梶原佑太，村田武士，木下正弘，サーモフィリックロドプシンの極めて高い熱安定性に対する統計熱力学的解析，日本生体エネルギー研究会第 43 回討論会，京都産業大学むすびわざ館，2017.12.19-21

S. Yasuda, Y. Kajiwara, T. Murata, M. Kinoshita，Statistical thermodynamics for remarkably high thermal stability of thermophilic rhodopsin，The Second Symposium of Chiral Molecular Science and Technology in Chiba University -Advanced Materials Science, Biology & Nanophotonics in Chiba-，千葉大学，2018.1.11-12

村田武士，木下正弘，統計熱力学に基づく膜タンパク質の熱安定化変異体予測法の開発，CREST／さきがけ合同成果報告会，「生命を解き明かす～タンパク質構造から見えてくる世界～」，ステーションコンファレンス東京，2018.1.26

S. Yasuda, Y. Kajiwara, Y. Toyoda, K.Morimoto, R. Suno, S. Iwata, T. Kobayashi, T. Murata, M. Kinoshita, Theoretical Identification of Hot-Spot Residues to be Mutated Common in G Protein-Coupled Receptors of Class A, Biophysical Society 62nd Annual Meeting, San Francisco, CA，2018.2.19

H. Okada, K. Nagasaki, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, N. Kenmochi, Y. Otani, X. Lu, K. Ida, K. Watanabe, Nagaoka, T. Kobayashi, G. Motojima, R. Seki, K. H. Kasahara, Y. Suzuki, M. Yokoyama, A. Ishizawa, Y. Nakamura, N. Nishino, Y. Nakashima, G. Weir, S. Murakami, S. Konoshima, T. Mizuuchi，Studies of Magnetic Field Configuration in Heliotron J，1st Asia-Pacific Conference on Plasma Physics，Chengdu, China，2017.9.18-23

T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, X.X. Lu, N. Kenmochi, Y. Ohtani, K. Nishioka, L. Zang, G. Weir, D.L. Yu, S. Konoshima, A. Ishizawa, Y. Nakamura, Configuration Control Effects on Confinement, Transport and Stability in a Helical-Axis Heliotron Device, Heliotron J，International Stellarator-Heliotron Workshop (ISHW2017)，Kyoto, Japan，2017.10.2-6

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kado, K. Nagasaki, N. Kenmochi, Y. Ohtani, X.X. Lu, R. Matoike, M. Motoshima, S. Konoshima, T. Mizuuchi，Role of magnetic topology and isotope mass on long range correlation and turbulence in Heliotron-J，International Stellarator-Heliotron Workshop (ISHW2017)，Kyoto, Japan，2017.10.2-6

S. Yamamoto, K. Nagasaki, Á. Cappa, K. Nagaoka, S. Kobayashi, E. Ascasíbar, F. Castejón, A. Ishizawa, M. Isobe, S. Kado, N. Kenmochi, S. Konoshima, M. Liniers, X. Lu, T. Minami, T. Mizuuchi, Y. Nakamura, M. Ochando, K. Ogawa, S. Ohshima, Y. Ohtani, H. Okada, M. Osakabe, Y. Suzuki, G.M. Weir，Suppression of fast-ion-driven MHD instabilities by ECH/ECCD in stellarator/heliotron，International Stellarator-Heliotron Workshop (ISHW2017)，Kyoto, Japan，2017.10.2-6

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi4, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, Y. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi，Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Heliotron J，International Stellarator-Heliotron Workshop (ISHW2017)，Kyoto, Japan，2017.10.2-6

H. Okada, K. Yamamoto, S. Kobayashi, S. Kado, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, H. Kasahara, S. Konoshima, N. Kenmochi, X. Lu, Y. Yonemura, S. Watanabe, N. Haji, P. Adulsiriswad, H. Okazaki, T. Kanazawa, Y. Nakamura, T. Mizuuchi，Magnetic Configuration Dependence of Energy Spectra of Fast Ions Generated in the Combination Heating of NBI and ICRF in Helitoron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Kado, A. Iwata, T.　Kanazawa, H. Okada, S. Yamamoto, T. Minami, S. Kobayashi, K. Nagasaki, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, T. Mizuuchi，Application of Near-Infrared Spectroscopy to Heliotron J Plasma，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

S. Ohshima, H. Okada, L. Zang, S. Kobayashi, S. Yamamoto, T. Minami, S. Kado, K. Kazunobu, N. Kenmochi, Y. Ohtani, X. X. Lu, R. Matoike, S. Konoshima, T. Mizuuchi，The Study of Isotope Effect on Turbulence in Heliotron J，Plasma Conference2017 (PLASMA 2017)，姫路商工会議所，2017.11.20-24

H. Okazaki, G. Motojima, H. Okada, K. Nagasaki, Y. Nakamura, S. Kado, S. Kobayashi, S. Konoshima, T. Minami, S. Yamamoto, S. Ohshima, X. Lu, T. Kanazawa,

K. Yamamoto, S. Tanohira, S. Watanabe, N. Haji, Y. Yonemura, T. Mizuuchi, Optimization study of cryogenic hydrogen pellet injection for fueling in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

山本皓基, 岡田浩之, 笠原寛史, 門信一郎, 山本聡, 南貴司, 小林進二, 長崎百伸, 大島慎介, 中村祐司, 石澤明宏, 木島滋, 呂湘潯, 岡崎悠, 金沢友美, 田野平駿, 渡邊真太郎, 土師直之, 米村裕馬, 水内亨, ヘリオトロンJプラズマにおける有限要素法を用いたイオンサイクロトロン周波数帯加熱解析, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

T. Kanazawa, S. Kado, H. Kawazome, H. Okada, S. Yamamoto, T. Minami, S. Kobayashi, K. Nagasaki, S. Ohshima, Y. Nakamura, A. Ishizawa, S. Konoshima, X. Lu, H. Okazaki, K. Yamamoto, S. Tanohira, S. Watanabe, N. Haji, Y. Yonemura, T. Mizuuchi, Evaluation of applicability of atomic helium line intensity ratio method to electron temperature and density measurement in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

M. Miyauchi, K. Matsumoto, H. Okada, H. Kawazome, T. Mizuuch, Development of a long time data aquisition system for discharge cleaning in Heliotron J, Plasma Conference2017 (PLASMA 2017), 姫路商工会議所, 2017.11.20-24

G. Motojima, H. Okada, H. Okazaki, R. Sakamoto, K. Nagasaki, H. Yamada, S. Kobayashi, T. Minami, N. Kenmochi, Y. Ohtani, Y. Nozaki, Y. Yonemura, S. Kado, Y. Nakamura, S. Konoshima, S. Ohsima, S. Yamamoto, T. Mizuuchi, Initial results of pellet injection experiments in Heliotron J, 16th CWGM (Coodinated Working Group Meeting), Madrid, Spain, 2018.1.18-20

3-2. AWARD

Rice husk biochar filter application for air quality improvement.

Advanced Atomic Energy Research Section
Hoseok Nam (D2)

Korea Environment Institute (KEI) was established in 1992 as Korea Environmental Technology Research Institute (KETRI) concern with a broad range of the future environmental issues such as climate change, environmental health, resource circulation, water environment, and environmental impact assessment, etc.

In 2017 International Paper & Idea Competition, I submitted a work on biochar filter derived from rice husk for the removal of toxic pollutant gas, trimethylamine (TMA) and H_2S. An activated rice husk (ARH) filter with copper impregnation shows the best performance which carbonized at 450°C as it eliminated the 400 ppm of TMA in 30 min and H_2S in 15 min. For economic analysis, production cost for biochar filter based on experimental equipment and material is calculated $6.5 per one filter and sensitivity analysis results in from $5.5 per one filter to $7.4 per one filter. It is assumed that production cost can make substantial reduction under the condition of mass production.

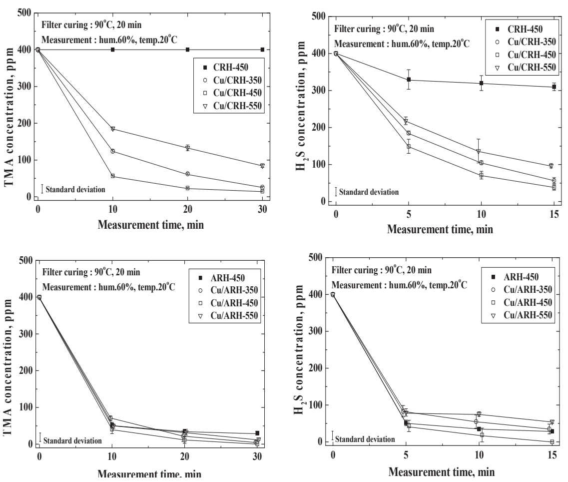


Fig. 1 Performances of biochar filter derived from rice husk.

Oral presentation award in 2017 fall meeting of The Atomic Energy Society of Japan.

Advanced Particle Beam Energy Research Section
Hiroki Yamashita (M2)

The Atomic Energy Society of Japan is the organization in Japan that aims to contribute towards progress in the development of atomic energy by seeking academic and technological advances pertaining to the peaceful use of atomic energy. Biannual meetings have been held every year, and 2017 fall meeting was held in Hokkaido University.

In 2017 fall meeting, I presented a work on the influence of the current density distribution on the cathode surface on the beam emittance evolution. Generation of electron beam with extremely small transverse emittance is decisive for accelerators being used in Free Electron Laser facilities. In recent studies, the mechanism of emittance evolution and the possibility for the emittance reduction by self-induced space charge forces were reported. According to these studies, emittance takes maximal value in the vicinity of cathode surface and then decreases to its minimal value which tends to be extremely low. There is thus possibility of generating electron beams with extremely low emittance according to the design of the injector system utilizing this phenomenon.

In this study, we have investigated the influence of initial electron beam profile on the beam emittance evolution. The emittance evolution with different current density distribution (flat-top, peak and hollow distribution) have been compared. The calculation in this study is performed by the two dimensional axial symmetric code KUAD2, which is a code for calculating trajectories in static fields. The SCSS thermionic gun was taken as the model for this study. The current density distribution on the cathode surface is modified, and the extracted current from the cathode is set to 1.0A and the beam energy at the gun exit is set to 500 keV.

As a result of calculations, the emittance evolutions change by varying initial current density distributions. The axial distance at the point of minimal emittance can be varied over wide range by changing the current density distribution on the cathode surface. The shortest axial distance of emittance minimum was obtained for peak profile. The hollow profile allows extending the axial distance of the point of the minimal emittance. The value of emittance minimum also depends strongly on initial current density distribution. To consider the effects of the initial beam profile could contribute to new approach for designing the low emittance electron injectors.

Student award at 19th US-Japan Workshop in Fusion Neutron Sources for Nuclear Assay and Ultimate Applications

Advanced Particle Beam Energy Research Section
Masaya Yoshida (M2)

The US-Japan workshop on Fusion Neutron Source has been held since 1998 alternately between United Statas and Japan. This workshop brought together expertise researchers in experiment, theory, modeling and applications in Inertial-electrostatic confinement (IEC) fusion neutron source related topics. The 19th workshop was held in Kansai University, Japan in October 2017. In this workshop, I received the best student presentation award.

The presentation title was “Development of Portable DD-IEC Neutron Source for the SNM Interrogation system at Kyoto University”. In this study, we introduced the design, fabrications, assembly and test operation of the ultra-compact DD-IEC neutron source with 17 and 8 cm anode and cathode diameters, respectively. The effect of the anode material in the neutron production rate was discussed, based on the experimental results using SUS and Titanium chambers. The results revealed that absorption of deuterium gas on Ti anode surface was saturated much more quickly than that on SUS anode surface. This factor increases neutron production rate of IEC neutron source by 2~3 times. Moreover, analysis of anode’s surface melting due to the electron jet after the 10 kW power was applied.

Poster Session Outstanding Achievement Award in the Irradiation Materials Meeting 2018

Advanced Energy Structural Materials Research Section
Toshiki Nakasuji (D3)

Irradiation Materials Meeting is an appropriate meeting at which irradiation materials researchers in Japan may discuss the fundamental questions and concerns in radiation effects on nuclear materials. This meeting was supported by the "Joint Usage/Research Program on Zero-Emission Energy Research, Institute of Advanced Energy, Kyoto University" and held at January, 2018.

Mr. Nakasuji made a good presentation on their effort on “Multiscale Modeling of Irradiation Embrittlement of RPV steels”. He received the Poster Session Award for their valuable unique ideas using Bayesian method. His future success is greatly anticipated.

Student Session Outstanding Achievement Award in the Japan Society of Maintenology

Advanced Energy Structural Materials Research Section
Norihiko Murayoshi (D3)

The Japan Society of Maintenology was founded in 2003 to establish "Maintenology" of nuclear power plants, other complex artifacts, and the natural environments, emerged by collecting a wide variety of information and knowledge of engineering, technology, natural science, sociology, and so on.

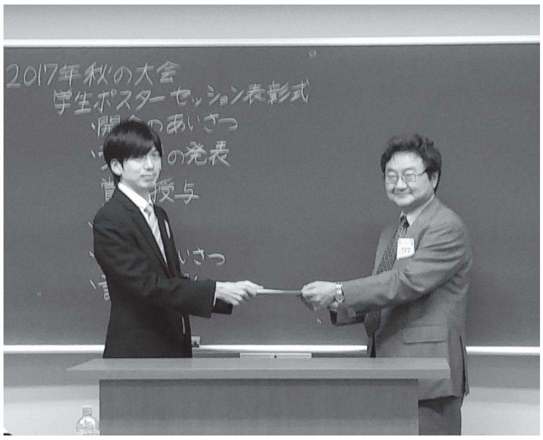
Mr. Murayoshi made an oral and poster presentations at the 2017 Annual Meeting. He was given the Student Session Award for their excellent social analysis and his research activities was largely encouraged.

AESJ 2017 Fall Meeting Student Poster Session: The Student Poster Session Award for their valuable unique ideas

Advanced Energy Structural Materials Research Section
Norihiko Murayoshi (D3)

The Atomic Energy Society of Japan was founded in 1959 as the only organization in Japan that aims to contribute towards progress in the development of atomic energy by seeking academic and technological advances pertaining to the peaceful use of atomic energy.

In the 2017 Fall Meeting held at Hokkaido University, Mr. Murayoshi made a good presentation on their effort on "Structurizing Public Understanding on Nuclear Energy", and received the Student Poster Session Award for their valuable unique ideas using the graph theory. His research activities was encouraged to be more enhanced.



2016 Annual Student Outstanding Lecture Award in the Atomic Energy Society of Japan

Advanced Energy Structural Materials Research Section
Xiaoyong Ruan (D2)

The Atomic Energy Society of Japan (AESJ) was founded in 1959 as the only organization in Japan that aims to contribute towards progress in the development of atomic energy by seeking academic and technological advances pertaining to the peaceful use of atomic energy.

Mr. Xiaoyong Ruan is a Ph.D. student in Kyoto university, Kyoto, Japan. He used to be a CAE Engineer in China. His current research interest lies in the deterministic and probabilistic fracture analysis of nuclear components and structures using finite element method.

He made oral presentation at the 2016 Annual Autumn Meeting of AESJ. He was given the 2016 Annual Student Outstanding Lecture Award at the 2016 Annual Spring Meeting of AESJ because he made an excellent presentation, and his research be applicable to engineering practice.

Best Student Presentation Award in 2017 International Congress on Advances in Nuclear Power Plants (ICAPP)

Advanced Energy Structural Materials Research Section
Xiaoyong Ruan (D3)

The International Congress on Advances in Nuclear Power Plants (ICAPP) provides a forum for leaders of the nuclear industry to exchange information, present results from their work, review the state of the industry, and discuss future directions and needs for the deployment of new nuclear power plant systems around the world. ICAPP will gather industry leaders in several invited lectures in plenary sessions.

Mr. Xiaoyong Ruan made oral presentation at the 2017 International Congress on Advances in Nuclear Power Plants (ICAPP) Meeting. He was given the Best Student Presentation Award because his research is useful in the nuclear power engineering, and he made an excellent presentation.

Honorable Mention (Ph.D. Category) Award in the 2017 ASME Pressure Vessels & Piping Conference (PVP)

Advanced Energy Structural Materials Research Section
Xiaoyong Ruan (D3)

The ASME PVP Conference promises to be the outstanding international technical forum for participants to further their knowledge-base by being exposed to diverse topics, and exchange opinions and ideas both from industry and academia in a variety of topics related to Pressure Vessel and Piping technologies for the Power and Process Industries. The PVP Conference is a great place to exchange ideas and to meet colleagues as we all work to create and advance Pressure Vessels and Piping technologies for our global community of practice. The PVP Conference is a recognized forum for fruitful exchange of ideas with participants from over 40 countries in Europe, Africa, the Middle East, Asia, the Americas, and the Oceania islands.

Mr. Xiaoyong Ruan made oral and poster presentation at the 2017 ASME PVP Meeting. He was given the Honorable Mention (Ph.D. Category) Award because his research fits engineering practice.

The 13th Encouragement Prize of Kansai Section Award of Atomic Energy Society of Japan

Advanced Energy Structural Materials Research Section
Xiaoyong Ruan (D3)

The Atomic Energy Society of Japan was founded in 1959 as the only organization in Japan that aims to contribute towards progress in the development of atomic energy by seeking academic and technological advances pertaining to the peaceful use of atomic energy.

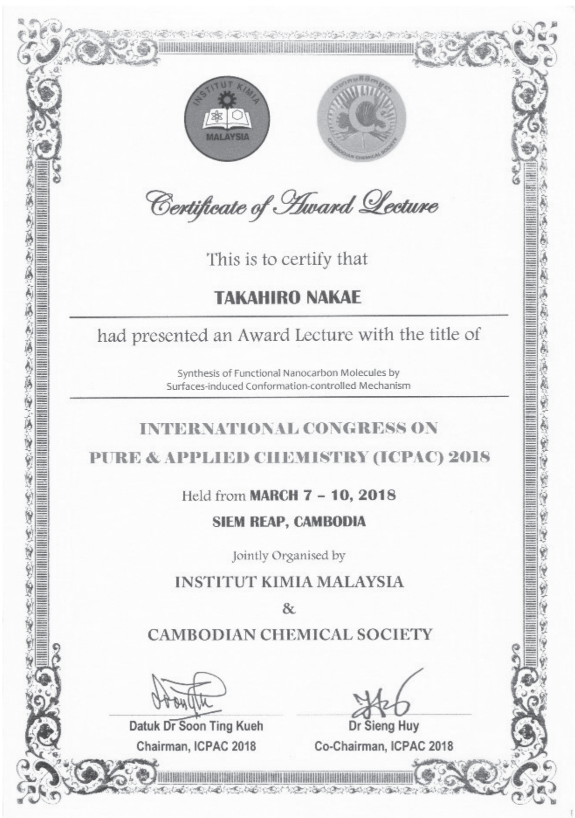
Mr. Xiaoyong Ruan made oral presentation at the 2017 Kansai Section of Atomic Energy Society of Japan Meeting. He was given the 13th Encouragement Prize of Kansai Section Award because his research suitable for engineering practice, and also he made a good presentation.

Symposium award of the international congress on pure and applied chemistry 2018 (Selected as a keynote lecture).

Molecular Nanotechnology Research Section
Takahiro Nakae (Assistant Professor)

The International Congress on Pure & Applied Chemistry (ICPAC) 2018 was organized by Cambodian Chemical Society (CCS) and Institut Kimia Malaysia (IKM), together with the Foundation for Interaction between Science and Technology (FIST) and Asia Chem Corporation (ACC) Japan. ICPAC is a major international scientific meeting covering all major areas of pure and applied chemistry. Over 200 attractive presentations provide professionals in Chemistry with opportunities for meaningful discussions and deep insights for future research.

In this symposium, I presented our recent work titled on "Synthesis of functional nanocarbon molecules by surface-induced conformation-controlled mechanism" as an award lecture. Surface-induced conformation-contolled mechanism can create new functional nanocarbon molecules. Additionally, this lecture was selected as a keynote lecture.


Certificate of Award Lecture

This is to certify that

TAKAHIRO NAKAE

had presented an Award Lecture with the title of

Synthesis of Functional Nanocarbon Molecules by Surfaces-induced Conformation-controlled Mechanism

INTERNATIONAL CONGRESS ON PURE & APPLIED CHEMISTRY (ICPAC) 2018

Held from MARCH 7 – 10, 2018

SIEM REAP, CAMBODIA

Jointly Organised by

INSTITUT KIMIA MALAYSIA

&

CAMBODIAN CHEMICAL SOCIETY

Datuk Dr Soon Ting Kueh
Chairman, ICPAC 2018

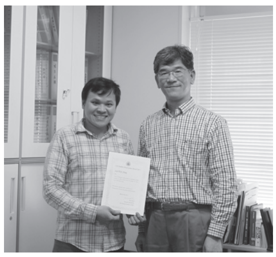
Dr Sieng Huy
Co-Chairman, ICPAC 2018

CSJ Student Presentation Award 2017

Biofunctional Chemistry Research Section
Nguyen Minh Thang (D3)

The chemical society of Japan (CSJ) was founded in 1878 to advance research in chemistry, has a history encompassing 130 years with a current membership exceeding 34,000 and is one of the most affluent academic societies in Japan, covering area on pure and applied chemistry. The Chemical Society of Japan holds the national meeting annually in spring, which covers all academic fields in Chemistry. Over 6,000 attractive presentations provide professionals in Chemistry with opportunities for meaningful discussion and deep insight for future research.

In the 97th Annual Meeting at Hiyoshi Campus, Keio University, Mr Nguyen Minh Thang won the CSJ student presentation award for his presentation entitled: "Orthogonal modular adaptors for assembling multiple enzymes on DNA scaffold". His talk presented the study aimed to develop a method to orthogonally locate multiple enzymes through covalent linkages at designed addresses on a DNA scaffold. The research was succeeded to develop three orthogonal modular adaptors that quickly and efficiently co-assembled on DNA origami scaffold. Three enzymes from the xylose pathway were successfully assembled at the designed positions on a DNA scaffold with precise distance control to enhance the efficiency of cascade reaction. The study contributed to understanding multi-enzyme cascades reaction and constructing an effective material conversion system in vitro.




CSJ Student Presentation Award 2017

NGUYEN, Thang

Title

3C4-12 Orthogonal modular adaptors for assembling multiple enzymes on DNA scaffold (Grad. Sch. Energy Sci., Kyoto Univ.) NGUYEN, Thang

We hereby present this certificate in recognition of your excellent presentation.

March 30, 2017

President
Hisashi Yamamoto
The Chemical Society of Japan

4. JOINT USAGE/RESEARCH PROGRAM

Joint Usage/Research Center Program “Zero Emission Energy Research”

It is an urgent task to find out the best solutions against the energy and environmental problem for ensuring the sustainable society on the earth. The new energy system for this purpose has to be an environmentally friendly or ecological one. Here, we should consider not only the energy sources but also the efficiency in the each phase of energy usage. The former should have good quality and enough quantity. The latter should be considered including the so-called “three Rs (Reduce, Reuse and Recycle)” in the energy system;

- Reduce of energy consumption, environmental pollutant such as greenhouse gas, waste-heat, hazardous waste, etc.
- Reuse of waste heat/energy, etc.
- Recycle of fuel, etc.

In order to realize them, only the extension of the present technology is not enough. Interdisciplinary studies with innovative ideas are indispensable to realize the energy system for next generation.

We propose a new concept of Zero Emission Energy as a typical model of Advanced Energy. IAE Zero Emission Energy Research aims at the realization of environmentally friendly energy system for sustainable society with minimum emission of environmental pollutants and with maximum utilization of energy and resources. Since FY2011, we had operated a project, “Joint Usage/Research Program on Zero Emission Energy”, which is the program authorized by the MEXT. We have started the second term of the Program from FY2016. Here, we aim to (1) promote interdisciplinary joint usage/research studies for Zero Emission Energy Science & Technology, (2) promote education & practical training for young researchers and (3) explore future horizon of Advanced Energy System for sustainable development. IAE provides many unique & attractive facilities for the Joint Usage/Research not only in the field of advanced plasma & quantum energy but also in the field of soft energy.

Poster of the 8th International Symposium

Many researchers have participated in this program. In FY2017 Joint Usage/Research collaborations of total 100 subjects (including one workshop) on Zero Emission Energy were performed with more than 264 visiting participants from 42 all-Japan Universities and Institutions including graduate/undergraduate students. The results of these collaborations are summarized in a report “IAE Joint Usage/Research Program on Zero Emission Energy 2017. Some of them were reported and discussed in a Research Summary Meeting of FY2017 held at Uji Campus on March 7, 2018. If you have interest to this collection, please contact to the Office of Zero Emission Energy Research.

In addition to the Joint Usage/Research collaborations, we organized "The 8th International Symposium of Advanced Energy Science ～Interdisciplinary Approach to Zero Emission Energy ～" on September 5 – 7, 2017 at Uji Obaku Plaza, Kyoto University. This symposium consists of oral and poster sessions, panel discussion, parallel seminars and satellite meeting. About 350 scientists and students including four foreign and five domestic invited speakers were participated in the symposium. In addition, several informal seminars and/or internship on Zero Emission Energy were also organized.(http://www.iae.kyoto-u.ac.jp/zero_emission/calendar/)

We are also operating “Zero Emission Energy Network” to share the knowledge of Advanced Energy and Zero Emission Energy with researchers in the fields of energy science and technology, since world-wide activities for Zero Emission Energy Research are indispensable for the realization of sustainable society.

List of Zero Emission Energy Joint Usage/Research Subjects in FY 2017

(Subject, Principal Researcher, IAE Key Person)

Production of Silicon Ingot for Solar Cells Utilizing Volatile Metal Flux and Solidification Refining
K. Yasuda, T. Nohira

Characterization and application of biomass originated from indigenous bacteria of activated sludge
M. Takeda, M. Katahira

Study of interaction between dislocation and irradiataion defects for evaluation of material degradation in nuclear structural materials
K. Fukumoto, A. Kimura

Photoinduced electron-transfer reactions of metal complexes as photosensitizers bound to the active site of enzyme
H. Takashima, E. Nakata

Effects of Magnetic Field and Metal Nanoparticles on Photocurrents of Dye-Metal Nanoparticle Composite Films
H. Yonemura, H. Sakaguchi

Design and development of functional organic materials for energy conservation-directed light-emitting devices
M. Shimizu, H. Sakaguchi

Mechanism Elucidation of Hydronium Solvate Ionic Liquids Using NMR
A. Kitada, M. Katahira

He and Heavy ion synergism on hydrogen isotope behavior in tungsten at higher temperature
Y. Oya, T. Hinoki

Analysis of condensed lignin structure for advanced biomass utilization
K. Fukushima, M. Katahira

Detoxification of endocrine disruptors by microbial enzymes
T. Hara, T. Morii

Development of thermal diffusivity and PALS measurement method aiming at an evaluation of neutron irradiated TEM-disk-size small specimen
M. Akiyoshi, S. Konishi

Chemical state analysis of light elements in advanced neutron multiplier for fusion reactor blanket
M. Nakamichi, K. Mukai

Development of photo-functional atomic layer heterostructures
Y. Miyata, Y. Miyauchi

Development of anode/electrolyte interface for advanced Na-ion battery
H. Sakaguchi, T. Nohira

Hydrogen isotope permeation behavior of ceramic coatings irradiated by heavy ions under higher temperature
T. Chikada, K. Yabuuchi

Micro-scale elastic property characteriztion of Tungsten fiber-reinforced tungsten composites (Wf/W) by nano-indentation and laser ultrasonics
H. Lee, S. Konishi

Theoretical design of the nanoscale materials
S. Okada, K. Matsuda

Influence of high temperature irradiation on hydrogen isotope retention and permeation in first wall and divertor materials for fusion reactors
Y. Hatano, T. Hinoki

Synergistic effects of electronic excitation and displacement damage in oxide/nitride ceramics
K. Yasuda, A. Kimura

Selective phonon-mode excitation in functional semiconductor materials for energy conversion by mid-infrared free-electron laser
K. Hachiya, H. Ohgaki

Study on energy state analysis of valence electrons of Li in advanced tritium breeding materials by EPMA-SXES
K. Sasaki, K. Mukai

Development of Organic-Inorganic Hybrid Film toward High-Performance Organic Thin-Film Solar Cells
T. Akiyama, H. Sakaguchi

Evaluation of compatibility of Ni-ODS superalloys with nuclear reactors
S. Ukai, A. Kimura

Modeling and Experimental Study on Damage Rate Effects on Bubbles/Voids Formation in Fusion Reactor Structural Materials
T. Yamamoto, A. Kimura

Mechanism of Radiation Resistance of Advanced Tungsten Alloys
A. Hasegawa, A. Kimura

Development of advanced soft-X ray tomographic diagnostic for dynamics study of self-organization to helical axis reversed field pinch and its modelling
S. Masamune, T. Mizuuchi

A study of potential distribution formed inside the cathode region in IEC device
M. Utsumi, K. Masuda

Investigation of hydrogen isotope retention mechanism in tungsten based materials under divertor plasma exposure in fusion reactors
Y. Ueda, A. Kimura

Effects of chromium and titanium concentration on low-temperature ductility of high-purity low-activation vanadium alloys
T. Nagasaka, A. Kimura

Photoenergy conversion System Based on Hybrid DNA/Inorganic Nanomaterials
K. Yamana, T. Morii

Evaluation of the stability of irradiation induced point defect clusters during annealing
S. Jitsukawa, A. Kimura

Dynamic Precipitation Behavior of Oxide Particles in Al-Added ODS Steel Model Alloy Powders
N. Iwata, A. Kimura

Mechanical Property of Ion-irradiated RAFMs by Ultra Micro-tensile Test
M. Ando, A. Kimura

High-Fluence Irradiation Behavior of Reduced Activation Fusion Reactor Materials
H. Tanigawa, T. Hinoki

Damage Formation Mechanism of Tungsten under Repetitive and Pulsed High-Heat Load Conditions (Part 6)
K. Ezato, A. Kimura

Structural analysis of lignin and lignin-carbohydrate complex by ultra-high sensitivity NMR for biorefinery
T. Watanabe, M. Katahira

On the wall erosion of tungsten materials by transient phenomena-like loads of fusion reactors
K. Ibano, S. Konishi

Clarification on formation mechanism of ion radiation-induced defects for silicon carbide materials
B. Tsuchiya, T. Hinoki

Development of the site-directed RNA mutagenesis for regulating an energy production in the cell
M. Fukuda, T. Morii

Highly efficient photochemical reactions induced by optimal laser pulses
Y. Ohtsuki, T, Nakajima

Development of innovative energy conversion devices based on the synergy between layered material and nitride semiconductor
S. Mouri, K. Matsuda

Change in thermal conductivity of heavy ion-irradiated Fe-based composite materials
N. Hashimoto, A. Kimura

Simulation of the interaction between plasma and hydrogen gas shock
N. Nishino, T. Mizuuchi

Local measurement of the recycling flux in the Heliotron J plasma using high wavelength-resolution spectroscopy of a helium atom near-infrared emission line
T. Shikama, S. Kado

Development of RNA binding peptides based on tertiary structural information
T. Sakamoto, T. Nagata

Theoretical Analysis on Natural Convection Heat Transfer from Vertical Rod Bundles in Liquid Sodium (Part 3)
K. Hata, T. Mizuuchi

Nonradiative annihilation process in garnet scintillators studied by infrared light pulses from free electron laser
M. Kitaura, H. Zen

Suppression of MOX fuel used in LWR swelling caused by development of gas babble resulted from He accumulated during long-term storage
H. Serizawa, T. Hinoki

Digital Imaging Spectrometry for Atomic Line Spectra in Fusion Plasma
M. Irie, S. Kado

A study on economic and technical impacts of mass integration of solar home system on power distribution system
B. Long, H. Ohgaki

Study of electron bunch length by measuring coherent synchrotron radiation with narrow-band detectors
N. Sei, H. Ohgaki

Structural studies on hierarchical molecular architectures created in microfluidic device
M. Numata, E. Nakata

A small-molecule-based technology for live-cell imaging of energy metabolism
S. Sato, T. Morii

Analysis of reaction mechanism of haloacid dehalogenase
T. Nakamura, T. Morii

Application of atmospheric pressure plasma jet in food industry
H. Matsuura, S. Kado

Interface structure between dielectric substrates and metal nanoparticles induced by ion irradiation ion irradiation and SPR measurements by STEM/EELS
T. Shibayama, T. Hinoki

Controlling the structural strain and force response of helicene molecules with high energy-conversion efficiency at the single-molecule level
A. Shiotari, H. Sakaguchi

Development of a program for tomographic reconstruction of HeI radiation distribution in Heliotron J
H. Kawazome, T. Mizuuchi

Effect of Hydrogen on Mechanical Properties in Tungsten
K. Sato, A. Kimura

Highly-efficient reduction of CO2 using porous electrodes controlled by the formation of surface-induced hydration structure of dissolved gasses
K. Fukami, M. Kinoshita

Nanoindentation of polymer monolith materials
K. Sakakibara, S. Konishi

Study of ballooning mode using high-speed camera in Heliotron J
Y. Takemura, S. Yamamoto

Computational study of irradiation condition dependence on microstructural evolution of RAFM steel under irradiation
Y. Watanabe, K. Morishita

Phase measurement of vacuum-ultraviolet pulse and control of electronic states
R. Itakura, T. Nakajima

A Study on Mechanical Property Evaluation of Silicon for MEMS by Nanoindentation
T. Nakata, S. Konishi

Structure-function relationship of Epstein-Barr Virus EBNA3C NLS and transport receptor
G. Matsuda, T. Nagata

Development of the artificial multi-domain enzymes immobilized on the curdlan sheet at low cost
M. Horiuchi, T. Nagata

Development of single-electron irradiation technique for microscopic track structure study
Y. Uozumi, H. Ohgaki

Supramolecular assembling regulation of bacterial cell division protein FtsZ and complexation with nucleic acid nanostructures
A. Onoda, E. Nakata

Analysis of radiation induced nano-clusters in RPV steels
H. Watanabe, A. Kimura

Development of nucleic-acids-based sensors for protein detection
M. Hagihara, T. Morii

Confirmation of the process of internalization by using ultrasound-enhanced cell-internalization
T. Otsuki, E. Nakata

Creation of structured target in the order of sub-micro meter for the generation of high-energy density state by high power laser
Y. Kishimoto, H. Sakaguchi

Development of breakdown method of malignant tumor by using mid-infrared free-electron laser
T. Kawasaki, H. Zen

Development of the zero emission energy oriented hypoxia-selective boron neutron capture agents
Y. Uto, E. Nakata

Impact of high energy ion irradiation on thermal and particle loading properties of plasma facing materials
K. Tokunaga, A. Kimura

Observation of fine temperature structure by using digital ECE
S. Inagaki, K. Nagasaki

High temperature corrosion of SiC/SiC composites
K. Shimoda, T. Hinoki

Molecular mechanism on uORF13p-mediated maintenance of mitochondrial membrane potential
Y. Aizawa, T. Morii

Development of multi-channel spectroscopic system for turbulence measurement
A. Fujisawa, S. Ohshima

Study on Rural Electrification by Renewable Energy in Sarawak and it's Impact on QOL
A.R. Nasrudin, H. Ohgaki

Study of plasma flow based on external momentum control using high energy neutral beam injection
Y. Nakashima, S. Kobayashi

Correlation measurements of electron cyclotron emission signals at two toroidal and poloidal positions in torus plasmas
Y. Yoshimura, K. Nagasaki

Soft matter iontronic devices driven by heat and electromagnetic fluctuations
N. Yonekura, T, Nakajima

Electrodeposition of Si thin films in molten salts for low-cost manufacturing of solar cells
X. Yang, T. Nohira

Biodegradability of Dissolved Organic Matter (DOM) in the Hypolimnion of Lake Biwa
Y. Shimizu, M. Katahira

One-dimensional migration of interstitial clusters under cascade damage condition
Y. Satoh, A. Kimura

Effect of external stress on radiation damage in explosion bonded Cu/steel joint
S. Ohnuki, A. Kimura

Development of material nanoprocessing with femtosecond-laser-induced plasmonic near-fields
G. Miyaji, K. Matsuda

Evaluation of mechanical properties of electrodeposited W alloy films
M. Miyake, S. Konishi

Studies on bio-photoreactions triggered by FEL irradiation
Y. Hayakawa, H. Ohgaki

Control of a phosphorescence emission from totally-organic compound by mode-selective molecular vibration with MIR-FEL
K. Yoshida, H. Ohgaki

Statistical analysis on edge turbulence fluctuation data in a toroidal plasma
Y. Nagashima, S. Ohshima

Boundary diagnostics using field corresponding double probe and rf heating in Heliotron J III
K. Uehara, T. Mizuuchi

Li-Site Migration of Li-Inserted Gamma-Fe2O3 during the Relaxation Process
S. Takai, T. Morii

Nonlinear effects on solids by KUFEL
A. Irizawa, H. Zen

Study of Deuterium Retention Property of Heavy Ions Beam Irradiated Tungsten Using Compact Divertor Plasma Simulator for Hot Laboratory
M. Yajima, T. Hinoki

Establishment of the method that explore the RNA G-quadruplex in cells
Y. Katsuda, T. Morii

Physical property analysis of the late blooming phase goverining the engineering lifetime of pressure vessel steels of light water reactor
Y. Matsukawa, A. Kimura

A new era of high energy particle irradiation research towards development of radiation tolerant nuclear structural materials (Zero emission energy workshop)
Y. Nagai, A. Kimura

5. COLLABORATION WORKS IN THE LABORATORY FOR COMPLEX ENERGY PROCESSES

Collaboration Works in The Laboratory for Complex Energy Processes

1. Introduction

The laboratory was established for research on advanced processes of energy production, conversion and application. Resource and energy problems as well as global warming problems become very serious in recent years. We have to concentrate all our knowledge and wisdom to find solutions to these problems. From such a viewpoint, the research targets of the laboratory should be focused on two specific fields, (i) "advanced studies of science and technology on plasma energy and quantum energy" and (ii) "innovative studies of nano-bio functional materials for power generation". Therefore, two sections (A2 and A3 mentioned below) are founded. In addition, a section of promotion for international collaborative research arranges and promotes international and domestic research collaborations.

In order to perform the research objectives of the Institute of Advanced Energy, it is essentially necessary to organize the cooperative research program with much close connection between related research fields in the institute. The laboratory takes charge of organizing and promoting the cooperative research project as a center of research activity in the Institute. The research staffs in the institute participate in specific projects to carry out their subjects. The scientists of other faculties in Kyoto University can also participate in the cooperative project to enhance the progress of research and educational activities. The laboratory also manages various functions such as symposium and seminar for related topics on energy field. The cooperative research activities will be published in a publication edited in the laboratory at the end of the year.

A1 Division of International and Industrial Partnership

This division promotes international collaborative research on advanced energy to lead the field of energy science and technology as a worldwide pioneer. For this purpose, the symposium and the workshop organized by institution member are supported. This section also promotes young researcher/student exchange, cooperative research activities and multi-lateral collaborative research with industries. Establishment of infrastructure and human resource development are also supported.

A2 Division of Plasma and Quantum Energy Research

This section promotes studies on advanced plasmas and quantum energy for realizing future energy systems, integrating plasma energy science and advanced energy material research. In particular, based on the results obtained in our related group, we aim at extending the research fields and contributing to human society by utilizing the existing key devices such as Heliotron J, DuET, MUSTER and inertial electrostatic confinement (IEC) device, which have been developed in IAE.

A3 Division of Soft Energy Science Research

This division promotes studies on emergent materials and systems for realizing next generation soft energy system. In particular, functional nano- and bio-materials to efficiently utilize solar energy and bio-energy are studied by integrating laser science, nanotechnology, and bio-technology. We aim at extending our research fields by utilizing the existing devices such as System for Creation and Functional Analysis of Catalytic Materials, SEMs, SPM, Solar Simulator, KU-FEL and various laser systems.

B Cooperative use of facilities and equipment

Facilities and equipment of the laboratory are provided to researches cooperated for the scientists in the university.

2. The cooperative research program

A brief summary of the cooperative research subjects carried out in FY2017 are shown next pages, which were proposed by researchers of IAE and selected by the program committee of the Laboratory.

The collaboration works in the Laboratory for Complex Energy Processes are consist of two categories of “Kiban (基盤)” and “Shorei, Kikaku-Chosa (奨励, 企画・調査)” cooperative researches. The former means a program to promote leading research themes of the institute projects, which are proposed by the each chair of the research sections of the Laboratory. The latter means a program to promote seeds research with respect to the institute projects and to promote the organization of seminar or symposium. Every researcher of IAE can make proposal to this category.

As a result, the research themes of 24 were applied and applications of 24 were accepted. The number of research subjects is listed in Table 1 according to the project categories.

Table 1 Number of the accepted research subjects according to the standard project theme

The whole sum 24

		category A			B	total
		A1	A2	A3		
Kiban	inside	1	1	1	0	3
	outside	0	0	0	0	0
Shorei/KikakuChosa	inside	4	9	8	0	21
	outside	0	0	0	0	0

"inside" or "outside" : Number

The individual research subjects are as follows

Kiban A1

"Supporting Activities on International and Industri-al Collaborative Research"

- H. Ohgaki and Staff Researcher of IAE (Kyoto Univ.)
- J. Qika (Univ. Sci. Tech. China)
- N. Sirilertworakul (National Science and Technology Davelopment Agency)
- C. Settakorn (Chiang mai University)
- L.C. Hiep (Vietnam National Univ. Ho CHI Mln)
- P. Kaung (Univ. Yangon)
- Y.U. Jeong (Korea Atom. Energy Res. Inst.)
- D. Wang (Shanghai Inst. App. Phy.)
- M. Abdrahim (Univ. Malaya)
- B. Funtamasan (King Mongkuts Univ. Tech. Thanburi)
- P. Pinpathomrat (Rajamangala Univ. Tech. Thanyaburi)
- I.K.Reksowardojo (Institute Technology Bandung)
- H. Saptadi (Univ. Gaja Mada)
- L. Bun (Institute Technology of Cambodia)
- W. Kyat (Yangon Technological University)
- K. Nathavong (National University of Laos)
-

Kiban A2

"Development of Advanced Plasma and Quantum Energy Studies"

- H. Okada, T. Mizuuchi,, S. Konishi, A. Kimura, K. Nagasaki, T. Minami, K. Morishita, K. Masuda, T. Hinoki,R. Kasada, S. Kado, S. Kobayashi, S. Yamamoto, S. Ohshima, K. Jinbo, K. Yabuuchi, ,K. Mukai, S. Konoshima (Inst. Adv. Energy, Kyoto Univ.)
- Y. Nakamura, (Grad. Sch. of Energy Sci., Kyoto Univ.)
- G. Motojima, T. Masuzaki, T. Oishi (National Inst. Fusion Sci.)
- Y. Nakajima (Univ. Tsukuba)
- N. Nishino (Hiroshima Univ.)

Kiban A3

"Research on establishment of Photo-Energy Nano Science"

- T. Nakajima and Researchers of Photo-Energy Nano-Science (Inst. Adv. Energy, Kyoto Univ.)

Shorei/Kikaku-Chosa A1

"**International Collaboration Research on Plasma Diagnostics Using**"

- K. Nagasaki, S. Yamamoto, K. Masuda, S. Ohshima, K. Sakamoto, T. Mizuuchi, T. Minami, H. Okada, S. Kado, S. Kobayashi, S. Konoshima (Inst. Ad. Energy, Kyoto Univ.)
- Y. Nakamura, A. Ishizawa (Grad. Sch. of Energy Sci., Kyoto Univ.)
- Y. Yoshimura (National Inst. Fusion Sci.)
- G.M. Weir, N. Marushchenko, H. Laqua (Max Plank Inst., Germany)
- T. Estrada, A. Cappa (CIEMAT, Spain)
- F. Volpe (Columbia University, USA)

"Visualizing the discussion points of is sues on utilization of nuclear energy systems in the world －Structure analysis of the information and knowledge on nuclear energy using system engineering methodology－"

. K. Morishita, (Inst. Adv. Energy, Kyoto Univ.)
- N. Murayoshi, R. Xiaoyong (Grad. Sch. Energy Sci., Kyoto Univ.)
- H. Iwakiri (Dep. Education, Univ. Ryukyu)
- S. Jitsukawa (Fukushima Col. Natl, Inst. Tech)

“International collaboration research on novel plasma initiation method using non-resonant microwave injection and its application to extended operational regime for high-temperature plasma experiments”

- S. Kobayashi, S. Ohshima, S. Yamamoto, H. Okada,K. Nagasaki, S. Kado, S. Konoshima, K.Sakamoto, K. Toushi (Inst. Adv. Energy, Kyoto Univ.)
- Y. Nakamura, X. Lu, A. Panith,S. Tanohira (Grad. Sch. Energy Sci., Kyoto Univ.)
- S. Murakami (Dep. Nucl. Eng., Kyoto Univ.)
- S. Okamura, Y. Takeiri, Y. Suzuki, K. Nagaoka, K. Mukai (National Inst. Fusion Sci.)
- Y. Nakashima (Univ. Tsukuba)
- S. Torsten ,H. Laqua (Max-Plank Institute for Plasma Physics)
- L. Hyunyong (Ecole Polytechnique Federale de Lausanne)
- ,

“US-Japan Collaborative Research on “Ion-irradiation Effects on Materials“

- A. Kimura, K. Morishita, T. Hinoki, R. Kasada, K. Yabuuchi, W. Han, S. Kondo (Inst. Adv. Energy, Kyoto Univ.)
- T. Shibayama, N. Hashimoto (Hokkaido Univ.)
- A. Hasegawa, K. Nagai (Tohoku Univ.)
- N. Sekimura (Univ. Tokyo)
- T. Muroga (National Inst. Fusion Sci.)
- H. Watanabe (Res. Inst. App. Mech. Kyushu Univ.)
- H. Tanigawa (JAEA)
- G. Was, G. Jiao, S. Taller (Univ. Michigan, USA)
- S. Maloy (LANL. USA)
- B. Weber (Univ. Tennessee, USA)
- S. Tumey (LLNL, USA)
- M. Toloczko (PNNL, USA)

Shorei/Kikaku-Chosa A2

“Evaluation of tritium breeding ratio (TBR) in fusion blanket mock-up using compact neutron source”

- K. Mukai, S. Konishi, F. Okino (Inst. Adv. Energy, Kyoto Univ.)

“Increasing neutron yield of discharge type fu sion device by materials science approach”

- R. Kasada (Institute For Material Research Tohoku Univ.)
- S. Konishi, K. Mukai, F. Okino. (Inst. Adv. Energy, Kyoto Univ.)

“Effects of irradiation-induced defects on the SiC corrosion”

- S. Kondo, T. Hinoki, (Inst. Adv. Energy, Kyoto Univ.)
- K. Fukami (Department of Materials Science and Engineering)

“Utilization of data science technology for establishment of high resilient energy system”

- K. Morishita, S. Kondo (Inst. Adv. Energy, Kyoto Univ.)
- T. Nakasuji, R. Xiaoyong (Grad. Sch. Energy Sci., Kyoto Univ.)
- H. Nakamura, D. Kato (National Inst. Fusion Sci.)
- Y. Kaneta (Akita National Coll. Tech.)
- Y. Watanabe, R. Hiwatari (JAEA)
- T. Narabayashi, Y. Yamamoto (Hokkaido. Univ.)

“Development of scintillator type lost ion probe with high time resolution”

- S. Yamamoto, K. Nagasaki, S. Kobayashi, , H. Okada, S. Kado, (Inst. Adv. Energy, Kyoto Univ.)

“Development of plasma diagnostic method using near-infrared Thomson scattered background light”

- T. Minami, T. Mizuuchi, S. Kado, H. Okada, S, Kobayashi, S. Yamamoto, S. Ohshima, S. Konoshima (Inst. Adv. Energy, Kyoto Univ.)
- N. Kenmochi (University of Tokyo)
- C. Takahashi ((National Inst. Fusion Sci.)

“Measurement of the impurity line spectra in Heliotron J for the plasma diagnostics”

- S. Kado, H. Okada, S. Yamamoto, T. Mizuuchi, K. Nagasaki, T. Minami, S. Ohshima, S. Kobayashi, S. Konoshima (Inst. Adv. Energy, Kyoto Univ.)
- Y. Nakamura (Grad. Sch. Energy Sci., Kyoto Univ.)

“Development of reduced activation ferritic/martensitic steels to improve irradiation damage tolerance.”

- K. Yabuuchi, A. Kimura (Inst. Adv. Energy, Kyoto Univ.)

“Development of velocity fluctuation evaluation technique based on time delay estimation with analytic signal”

- S. Ohshima, T. Mizuuchi, S. Kobayashi, H. Okada, K. Nagasaki, S. Yamamoto, S. Kado, S. Konoshima, (Inst. Adv. Energy, Kyoto Univ.)

Shorei/Kikaku-Chosa A3

"Development of a highly efficient bioethanol production yeast by protein"
- T. Kodaki (Inst. Adv. Energy, Kyoto Univ.)
- S.M.R. Khattab (Microbial Biotech. at Botany and Microbiology Dep., Al Azhar Univ., Assiut Branch)

"Study of structure-function relationships on wood degrading enzymes ~To utilize the woody biomass efficiently~"
- T. Nagata, M. Katahira, T. Morii, T. Kodaki, E. Nakata (Inst. Adv. Energy, Kyoto Univ.)

"Comprehensive understanding of structural transition of protein induced by binding of non-coding RNA by means of multiple analytical tools"
- M. Katahira, T. Morii, T. Nagata, E. Nakata, T. Mashima, K. Kondo (Inst. Adv. Energy, Kyoto Univ.)

"Direct and real-time analysis of the function of protein inhibitors by using DNA origami"
- A. Rajendran, T. Morii, E. Nakata, S. Nakano, M. Saimura (Inst. Adv. Energy, Kyoto Univ.)

"Sequence selective covalent bond formation between DNA and Protein"
- E. Nakata, T. Morii, T. Kodaki, M. Saimura S. Nakano, A. Rajendran (Inst. Adv. Energy, Kyoto Univ.)

"In-situ synthesis of conductive cellulose nano-composites using a mid-IR laser"
- T. Nakajima, T. Morii, E. Nakata, S. Nakano (Inst. Adv. Energy, Kyoto Univ.)
- K. Kashihara, H. Nishikawa (Grad. Sch. Energy Sci., Kyoto Univ.)

"Evaluation of the clustering effect for kinetic parameters of receptors by using DNA nanostructure scaffold"
- S. Nakano, T. Morii, E. Nakata, A. Rajendran, M. Saimura (Inst. Adv. Energy, Kyoto Univ.)

"Timing Jitter Measurement of Pump-Probe Measurement System Using MIR-FEL and Visible Picosecond Laser"
- H. Zen, T. Nakajima, H. Ohgaki, K. Masuda, T. Kii (Inst. Adv. Energy, Kyoto Univ.)

THE LABORATORY SEMINARS

Laboratory Seminars

The Laboratory promotes topical academic seminars in order to strengthen the research activities in each research section and to enhance the mutual cooperation among a lot of academic fields. The Laboratory also had a symposium on April 6, 2018 for discussions of the cooperative research results in FY2017.

In FY2017 seminars were held with following themes.

1. Topical Seminars

(1)**April 20, 2017**

H. Azechi
"Draw Dragon Dot Eyes: Laser Fusion Science".
Osaka University

(2)**Jun 15, 2017**

S. Okamura
"Research of magnetically confined plasma in ITER Era : taking sideway for a fresh view".
National Institute for Fusion Science

(3)**October 5, 2017**

Y. Sakawa
"Exploring Universe with large-scale lasers: Laser astrophysics".
Institute of Laser Engineering, Osaka University

(4) **October 13, 2017**

H. Hayashi
"Precursor-based synthesis of acenes and graphene nanoribbons".
Nara Institute of Science and Technology

(5) **November 2, 2017**

R. Hiwatari
"Status of DEMO Design and Fusion Energy R&D Strategy in Japan".
National Institute for Quantum and Radiological Science and Technology

(6)**November 11, 2017**

(7)**December 4, 2017**

(8) **January 5, 2018**

"Towards Promotion of Collaboration among Researchers in the IAE"

(9) **January 30, 2018**

S. Matsushita
"Chiral carbon materials produced by pyrolysis of conjugated polymers".
National Institute for Materials Science

(10) **March 5, 2018**

S. Nobusue
"Exotic conjugated hydrocarbons for functional soft matters".
Osaka University

(11) **March 6, 2018**

R. Oomachi
"1D carbon materials in CNT templates for FET applications".
Research Center for Materials Science, Nagoya University

(12) **March 9, 2018**

M. Nakano
"Novel Electron-Deficient Thienoacenes: Synthesis and Application for Organic Electronic Devices".
RIKEN Center for Emergent Matter Science

6. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS

Innovative strategy for highly efficient utilization of solar energy "Exploring novel principles for highly efficient utilization of solar energy"

The MEXT special budget project in its second year pursued three main research topics including efficient conversion of solar energy to electricity, production of solar fuels, and efficient conversion of biomasses to useful chemicals.

Efficient conversion of solar energy to electricity

Nanoporous electrodes play an important role in recent development of electrochemical devices such as batteries, super capacitors, sensors and photoelectrodes. Prof. Fukami has developed a theory to elicit the highest performance of nanoporous electrodes by an interdisciplinary approach between electrochemistry and biological physics. This approach enables to control the liquid state within confined nanopores, and thus it results in a high controllability of electrochemical reactions in nanopores. His group showed how the pH of the liquid in confined nanopores was locally tuned. This tuning was of importance in precise control of electrochemical reactions in nanopores.

Sodium secondary batteries are promising as low-cost and large-scaled electrical energy storage devices due to abundant sodium resources and large energy densities. However, most of the previous studies on sodium secondary batteries utilize flammable organic solvent-based electrolytes, which may lead to safety issues. Based on these backgrounds, Prof. Nohira's group havs developed nonflammable ionic liqu id electrolytes for sodium secondary batteries. Charge–discharge mechanism of a tin negative electrode for a sodium secondary battery was investigated at 363 K utilizing a Na[FSA]–K[FSA] (FSA = bis(fluorosulfonyl)amide) ionic liquid electrolyte. According to the results of galvanostatic intermittent titration technique (GITT) and ex situ X-ray diffraction (XRD) analysis, the formation potentials of Na–Sn alloy phases were clarified.

Prof. Sagawa's group studied the principle of polymer solar cells by his research entitled "Improvement of photovoltaic performance of polythiophene/antimony sulfide planar solar cells." Planar solar cells composed of glass/F-doped SnO_2/TiO_2/La-decorated or Zn-doped Sb_2S_3/ poly[(3-hexylthiophene)-2,5-diyl]/poly[3-(3-carboxypropyl)thiophene-2,5-diyl]/Au have been prepared and evaluated their photovoltaic performance. La- and Zn-introduction to Sb_2S_3 resulted in 33% and 57% improvement of power conversion efficiency as compared to pristine Sb_2S_3.

Prof. Ohgaki's group carried out a research on "Present Status and Applicaitons of KU-FEL on Energy Materials " at Institute of Advanced Energy, Kyoto University. KU-FEL can generate a wide range tunable laser from 3.5 to 23 micro-m wavelength (MIR) with high power (~30 mJ@5 micro-m). Present status and a few applications of KU-FEL will be presented. In addition, the newly developed THz light source (0.15-0.6 THz) will be introduced.

Production of solar fuels

The sequential metabolic reactions of the multiple enzymes confined in a compartment result in an extraordinary efficiency and specific production of target molecules. Understanding the effect of the spatial organization of the multiple enzymes is useful for the construction of in vitro sequential reaction systems. DNA nanostructures have been applied as scaffolds for the spatial organization of enzymes. Prof. Morii's group has developed methods that use sequence-specific DNA binding proteins as adaptors to stably locate the enzymes at specific positions on DNA scaffold. An artificial enzyme cascade of xylose reductase (XR) and xylitol dehydrogenase (XDH) based on the D-xylose metabolic pathway has been constructed by coassembling the enzymes on DNA origami. The XR/XDH cascade was further extended to xylulose kinase (XK) by using the orthogonal modular adaptors.

Prof. Sakaguchi's group demonstrates a synthesis of graphene nanoribbons (GNRs) by a new concept of "biomimetic heterogeneous catalysis" similar to the enzymatic reactions in biology like a "soft" manner, which is featured by homo chirality, transformation, self-assembly and adaptation, directing an optimized chemical reaction pathway to efficiently produce the product. Our developed two-zone chemical vapor deposition of the "Z-bar-linkage" precursors designed herein, exhibiting flexible as well as rigid geometry that allows them to adopt chiral (asymmetrical) conformations on a Au(111) surface, results in the efficient formation of acene-type graphene nanoribbons with a width of 1.45 nm through optimized cascade reactions.

Efficient conversion of biomasses to useful chemicals

Toward utilization of all three major components of wood biomass, cellulose, hemicellulose and lignin, enzymes involved in degradation of each component, GST, MnP, LPMO and GE, were expressed, purified and characterized enzymatically in Prof. Katahira's group. Some of them exhibited unique enzymatic activities. Structural analysis of these enzymes gave a hint for the origin of the unique activities. Integration of these enzymes for utilization of all components is in progress.

NIFS Bilateral Collaboration Research Program on Heliotron J

Since FY2004, the Heliotron J group at IAE, Kyoto University has joined the Bilateral Collaboration Research Program by National Institute for Fusion Science (NIFS), an Inter-University Research Institute. This unique collaboration program promotes joint researches bilaterally between NIFS and research institutes or research centers of universities that have unique facilities for nuclear fusion research. Under this collaboration scheme, the facilities operated in the different universities are open to all fusion researchers just as joint-use facilities of NIFS.

The main objective of the research in our Heliotron J group under this joint research program is to investigate experimentally/theoretically the transport and stability of fusion plasma in advanced helical-field, and to improve the plasma performance through advanced helical-field control in Heliotron J. Picked up in FY2017 are the following seven key-topics; (1) experimental observation of rational-surface effect on e-ITB formation, (2) relationship of density fluctuations to H-mode transition in high density plasmas, (3) Comprehensive study of fast ion behavior in ICRF+NBI heating, (4) long-rang correlation and hydrogen-isotope effect in edge turbulence, (5) suppression of fast-ion driven MHD instabilities using ECH/ECCD, (6) measurement of fast-ion loss accompanied with MHD fluctuations, (7) development of ice-pellet injector for stable operation.

Only some results from this collaboration in FY2017 are shortly reported below. An annual report for all of the collaboration subjects in this program will be published by NIFS.

Poloidal flow measurement by using Charge-eXchange Recombination Spectroscopy (CXRS) [1]: The radial electric field, E_r, in helical devices is a key parameter for the transport in low collisional plasmas. For the accurate estimation of E_r , improvement of the CXRS system for poloidal-flow velocity measurement was required, although the parallel-flow velocity has been measured successfully in Heliotron J. The key points for improvement are to enhance the S/N ratio for spectrum measurement and to increase the stability of the calibration of the absolute wave length. The spectrometer and the CCD camera are replaced new ones and the signal strength of 4 times is provided in comparison with the previous system. The wavelength calibration method is changed to use the line spectra from a Sm ramp. The resultant error of wave length becomes 9.1×10^{-4} nm from 2.8×10^{-3} nm. The corresponding errors in the velocity are to 0.51 km/s and 1.7 km/s, respectively. This is considered to be sufficient for the determination of poloidal velocity.

Interaction of fast ions and MHD instabilities [2]: The confinement of alpha particles from fusion reactions is important since alpha particles are utilized as heat source to sustain the burning plasma. MHD instabilities sometimes affect fast-ion confinement via resonant or non-resonant interactions. In Heliotron J, fast-ion-driven MHD instabilities, such as GAE, EPM, are observed. A lost-ion probe of Faraday-cup type was used for the measurement of fast-ion confinement, however, the high noise level prevents from the correct calibration of the detector. As a low-noise system, a scintillator type detector is introduced. The fluorescent light on the scintillator are divided into two detection systems, a set of PMTs and a CCD camera. For the fluctuation measurement with high time resolution, 9-channel PMT signals are used, of which frequency response is up to 200 kHz. EPM instability is observed in counter-NBI plasma by this detector in Heliotron J.

Suppression of fast-ion-driven MHD instabilities by using ECH/ECCD [3]: ECH and ECCD are utilized to control MHD instabilities in torus plasma confinement devices. When magnetic shear is increased by using EC-driven plasma current, the observed FP-driven MHD instabilities are suppressed or stabilized in Heliotron J and LHD and modified in TJ-II. Especially for Heliotron J having almost zero magnetic shear in a whole plasma region in vacuum, both negative and positive magnetic shear induced by co- and counter- EC-driven plasma current suppress the observed EPMs and GAEs. Regarding the ECCD effect on FP-driven MHD instabilities, continuum damping whose rate is related to the magnetic shear regardless of its sign is a key physical mechanism to suppress the observed FP-driven MHD instabilities according to experimental results of Heliotron J and TJ-II. The change of shear Alfvén spectrum induced by EC-driven plasma current affects the position and stability of TAEs in LHD with high magnetic shear.

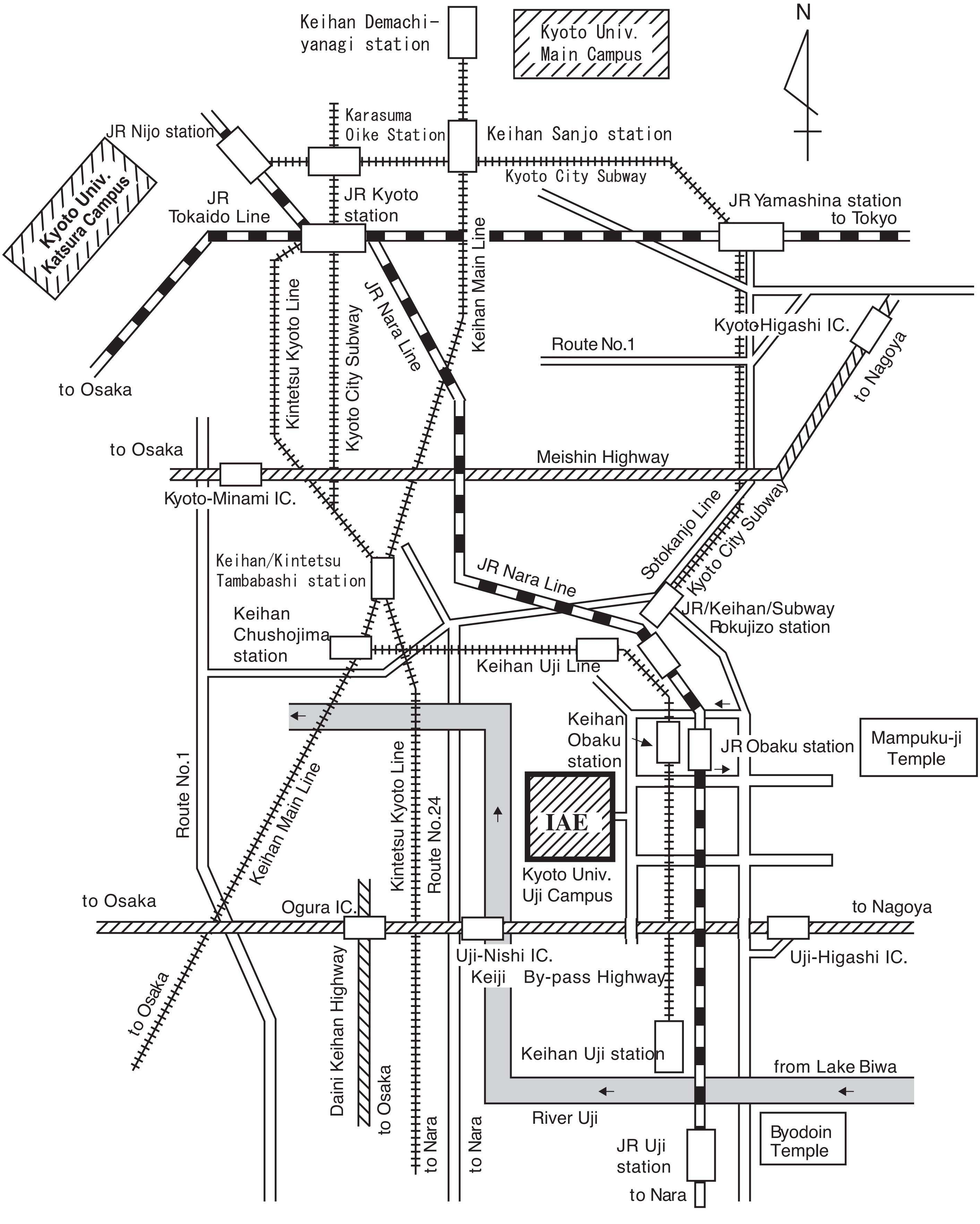
References

[1] S. Tanohira, et al., “Poloidal Flow Measurement with Charge-Exchange Recombination Spectroscopy in Heliotron J (2)”, Plasma Conf. 2017 (20-24 Nov. 2017, Himeji), 23P-12.

[2] S. Yamamoto, et al., “Study of interplay between fast-ions and MHD instabilities in Heliotron J”, Plasma Conf. 2017 (20-24 Nov. 2017, Himeji), 22Cp-05.

[3] K. Nagasaki, et al., “Control of Energetic-Particle-Driven MHD Instabilities by ECH/ECCD”, Plasma Conf. 2017 (20-24 Nov. 2017, Himeji), 22Ca-01.

7. HOW TO GET TO THE IAE



京都大学エネルギー理工学研究所 ANNUAL REPORT
Institute of Advanced Energy, Kyoto University

Gokasho, Uji, Kyoto 611-0011 Japan
Phone. +81-774-38-3400　Fax. +81-774-38-3411
E-mail: office@iae.kyoto-u.ac.jp
http: //www.iae.kyoto-u.ac.jp

〒611-0011　京都府宇治市五ケ庄
TEL 0774-38-3400　FAX 0774-38-3411