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Institute of Advanced Energy
Kyoto University

ANNUAL REPORT

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京都大学エネルギー理工学研究所

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Institute of Advanced Energy
Kyoto University

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Japan

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FOREWORD

The Institute had continued to thrive through the first midterm period (2004–2009) under the new system (conversion of national universities to independent corporate entities). Efforts during the period yielded fruitful results in the advanced energy science and technology fields of plasma systems, bioenergy, lasers, quantum energy, and more. Research activities and external funding were all sound.

In 2009, we were disappointed by the result that our application to the Joint Usage/Research Center (MEXT) program with the proposal of Advanced Energy Science and Technology Center came to unapproved despite our full efforts. We try to apply for it again this year; we this time propose the Zero-Emission Energy Center, the name of which is more specific and easier to be understood by society than the last proposal. We made some improvement for laboratory buildings. A building received the complete renovation. The building had been utilized for the thermal phenomena analysis using a sodium loop. The complete sodium and the loop were removed, and the building provides an experimental space for new projects. Another renovation was underwent for another building. These renovations will facilitate our research activities. In addition, antiseismic reinforcement work on the main building reaches the last year. The work will completes in December, and the completion improves our research environment further. The Global COE program “Energy Science in the Global Warming Era” (2008–2012) runs well.

We now start the second midterm period, based on our fruitful results and activities done in the first period. Intensifying worldwide concern regarding energy supplies and global warming drives our efforts, and energy issues demand urgent priority. We shall renew our efforts in the new period, through research and education on advanced energy science and technology, to cope with these critical issues and contribute to the benefit of future generations.

It is our great pleasure to issue this Annual Report. We hope that it provides you with a good understanding of the activities of the Institute of Advanced Energy, Kyoto University.

March 2010

（署名）

Yukio H. OGATA
Director
Institute of Advanced Energy
Kyoto University

3. BRIEF HISTORY OF THE INSTITUTE OF ADVANCED ENERGY

The Institute, established in 1971 as the Institute of Atomic Energy, was renamed on May 11, 1996, to the Institute of Advanced Energy upon its consolidation with the Plasma Physics Laboratory. The new name represents its current research interests in advanced, socially acceptable energy systems across the domains of energy generation, conversion, and utilization.

The Institute's precursor was founded in 1941 as the Engineering Research Institute with the objective of pursuing synthetic engineering studies through cooperation with specialists in different fields. Since 1971, the Institute has studied the peaceful application of atomic energy and has performed fundamental research into nuclear engineering. The renaming in 1996 reflects the Institute's recent expansion into new fields such as systems engineering for social and environmental energy systems, advanced energy conversion in quantum engineering, physico-chemistry, and materials science.

In 2002, the Institute joined the Kyoto University 21st Century COE program "Establishment of COE on Sustainable Energy System," with the university's Graduate School of Energy Science and Radio Science Center for Space and Atmosphere. The program was completed successfully in FY 2006. An extension of the program, the International New Energy Cooperative Organization, is in the planning stage. Further changes were also made in response to the FY 2004 structural reforms in the national universities with the aim of introducing various innovative new systems.

The Institute provides research opportunities in advanced energy science, engineering, and related fields. Institute professors lecture in their specialized fields to students of the Graduate School of Energy Science. Graduate students prepare masters or doctoral theses at the Institute under professorial guidance. The educational activities of the staff are described in their respective sections.

The Institute is located on the Uji campus of the university about 20 km south of Kyoto city. Additional facilities for research on advanced materials, advanced chemistry, magnetoplasma, plasma direct energy conversion, plasma physics, and fusion engineering are located in various buildings on the campus.

The Institute publishes the following:

(1) Annual Report of the Institute of Advanced Energy, Kyoto University (in English)

(2) Research Report of the Institute of Advanced Energy, Kyoto University (occasionally in English)

(3) Newsletter of the Institute of Advanced Energy, Kyoto University (three issues a year, in Japanese)

The Institute consists of three main research divisions (listed below), each containing four research sections, an attached laboratory, and two visiting staff research sections. All are encouraged to collaborate with one another to most effectively address the critical energy-related interdisciplinary issues facing us today and in the years to come.

I. ADVANCED ENERGY GENERATION DIVISION

(for the study of advanced, socially acceptable methods for generating energy)

(a) Quantum Radiation Energy Research Section

(b) Advanced Atomic Energy Research Section

(c) Advanced Particle Beam Energy Research Section

(d) Advanced Plasma Energy Research Section

(e) Advanced Energy Research Section (foreign visiting professor and associate professor)

II. ADVANCED ENERGY CONVERSION DIVISION

(for the study of efficient, effective methods for converting energy)

(a) Energy Conversion Processes Research Section

(b) Advanced Laser Science Research Section

(c) Advanced Energy Storage Research Section

(d) Complex Plasma System Research Section

(e) Clean Energy Research Section (domestic visiting professor and associate professor)

III. ADVANCED ENERGY UTILIZATION DIVISION

(for study of high-performance processes for utilizing energy)

(a) Chemical Reaction Complex Processes Research Section

(b) Molecular Assemblies Design Research Section

(c) Biofunctional Science Research Section

(d) Bioenergetics Research Section

IV. LABORATORY FOR COMPLEX ENERGY PROCESSES

(for the promotion of equipment design, software development, and collaboration with domestic and foreign institutions to advance the study of energy generation, conversion, and utilization)

4. RESEARCH ACTIVITIES

4-1. TOPICS

Biofunctional Science Research Section

T. Morii, Professor
K. Tainaka, Assistant Professor

Novel *in vivo* Biosensors for IP_4 Reveal Temporal IP_4 Dynamics Inside Cells

The signaling cascades to link extracellular messengers to intracellular Ca^{2+} mobilization are regulated by the second messenger D-*myo*-inositol-1,4,5-trisphosphate (IP_3). A direct metabolite of IP_3, D-*myo*-inositol-1,3,4,5-tetrakisphosphate (IP_4), is also believed to be a pivotal second messenger in cellular signal transduction due to the close relevance to chromatin remodeling, modulation of IP_3 levels, Ca^{2+} mobilization, and immune cell development. Because conventional ex situ methods such as HPLC have not provided information on intracellular IP_4 mobilization in individual live cells, there is a new demand for a methodology that visualizes the cellular dynamics of the metabolites of IP_3. We developed novel fluorescent biosensors that enable realtime monitoring of IP_4 mobilization in single mammalian cells.

An optical sensor for IP_4 was constructed by utilizing the PH domain of GRP1 that possesses high affinity and selectivity to IP_4. Inspection of the three-dimensional structure of the GRP1 PH domain-IP_4 complex indicated Val15 and Glu82 as possible fluorophore labeling sites (Figure 1A). A unique cystein residue, Cys15 or Cys82, was introduced to the GRP1 mutant followed by labeling with the fluorophore to give **15F-IP_4** and **82F-IP_4**, respectively. The fluorescence intensity of **15F-IP_4** eventually decreased to 0.6-fold of the initial intensity (Figure 1B, left) by the addition of IP_4. In contrast, **82F-IP_4** showed a 1.3-fold enhancement of the fluorescence intensity (Figure 1B, right). Because these two IP_4 sensors exhibited appropriate affinity to

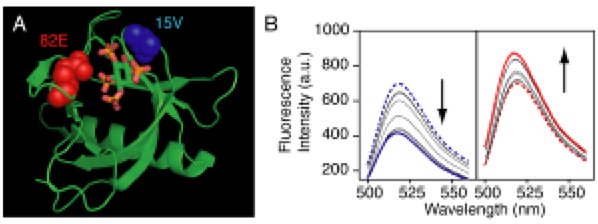

Figure 1. (A) A schematic illustration shows the structure of GRP1 PH domain-IP_4 complex. Positions labeled by fluorescein at 15V and 82E are indicated by CPK representation in blue and red respectively, and IP_4 is shown by a wire-frame model. (B) Emission spectra (initial: dashed, final: solid) show changes in intensity of the fluorophore-labeled PH domains **15F-IP_4** (*left*) and **82F-IP_4** (*right*) in the presence of increasing amount of IP_4.

IP_4 and the remarkable selectivity for IP_4 over other inositol phosphates, the sensors would be quite favorable to specifically detect IP_4 in the cell.

The two IP_4 sensors were next taken into HeLa cells by means of electroporation. The sensor-loaded cells indicated that the sensors would detect the total fluctuation of IP_4 in the whole cell (Figure 2A). In HeLa cells, binding of histamine to H1 receptors activates PLC to produce IP_3, thus inducing Ca^{2+} release from the internal Ca^{2+} store. It is generally accepted that inositol trisphosphate 3-kinase (IP3K) activated by Ca^{2+} ions phosphorylates IP_3 to produce IP_4. To evaluate the potential of **15F-IP_4** and **82F-IP_4** as real-time in vivo IP_4 sensors, we monitored the time courses of their fluorescence changes upon agonist stimulation of HeLa cells. Typical traces observed for single-cell analysis under histamine stimulation (100 μM) by **15F-IP_4** and **82F-IP_4** successfully corresponded to the intracellular IP_4 concentration change (Figure 2B).

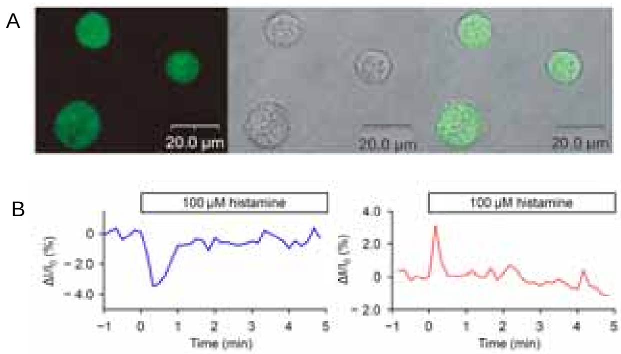

Figure 2. (A) Confocal microscopic observation of 15F-IP_4 in HeLa cells. *Left*, fluorescent images. *Middle*, differential interference contrast (DIC) images of the same cells. *Right*, merged images. (B) Time course of the production of IP_4 observed by temporal changes of **15F-IP_4** (*left*) and **82F-IP_4** (*right*) fluorescence in a single cell under 100 μM histamine stimulation.

In conclusion, fluorescent sensors based on the GRP1 PH domain exhibited appropriate affinity and specificity to IP_4 and distinct fluorescence responses upon target binding in single cells. These IP_4 sensors would serve as a tool to unveil a vital physiological function of IP_4.

This research study was published in *Angew. Chem. Int. Ed.*, which is one of the prime chemistry journals in the world, with an Impact Factor (10.031 in 2007)

Development of a free energy function for discriminating the native fold from misfolded decoys: Demonstration of its highest performance

Laboratory for Complex Energy Processes Section, M. Kinoshita

T. Yoshidome, K. Oda, Y. Harano, R. Roth, Y. Sugita, M. Ikeguchi, and M. Kinoshita, "Free-Energy Function Based on an All-Atom Model for Proteins", Proteins – Structure Function and Bioinformatics, **77**(4), 950-961 (2009).

A protein folds into a unique structure, which is referred to as "the native structure", in aqueous solution under the physiological condition. Predicting the native structure of a protein from its amino-acid sequence is one of the most challenging subjects in molecular biology, biophysics, and biochemistry. According to Anfinsen's principle, the native state lies at the global minimum of the free energy under the physiological condition. Therefore, as the first step toward predicting the native structure, the development of a free-energy (or potential) function which takes the lowest value for the native structure is highly desired. Up to now, there have been many attempts to develop such a function. The function is usually tested as the so-called scoring function for discriminating the native fold from misfolded decoys. If its performance in the discrimination is sufficiently high, it is applied to the prediction of the native structure for a practical purpose. In our opinion, the best function should meet at least the following two requirements. Firstly, the critical roles of water as a molecular ensemble should be taken into consideration. Secondly, since the number of candidate structures is enormous, the calculation of the function is to be accomplished quite rapidly. In this article, we have developed a free-energy function meeting both of these requirements. It is based on physics but quite different from the previously reported physics-based functions.

Our free-energy function, which is based on an all-atom model for proteins, comprises two components, the hydration entropy (HE) and the total dehydration penalty (TDP). Upon a transition to a more compact structure, the number of accessible configurations arising from the translational displacement of water molecules in the system increases, leading to a water-entropy gain. In order to fully account for this effect, the HE is calculated using a statistical-mechanical theory applied to a molecular model for water. The TDP corresponds to the sum of the hydration energy and the protein intramolecular energy when a fully extended structure, which possesses the maximum number of hydrogen bonds with water molecules and no intramolecular hydrogen bonds, is chosen as the standard one. When a donor and an acceptor (e.g., N and O, respectively) are buried in the interior after the break of hydrogen bonds with water molecules, if they form an intramolecular hydrogen bond, no penalty is imposed. When a donor or an acceptor is buried with no intramolecular hydrogen bond formed, an energetic penalty is imposed. We examine all the donors and acceptors for backbone-backbone, backbone-side chain, and side chain-side chain intramolecular hydrogen bonds and calculate the TDP. Our free-energy function has been tested for the 4stare_reduced (PDB code: 1ctf, 1r69, 1sn3, 2cro, 3icb, 4pti, and 4rxn), fisa (1fc2, 1hdd-C, 2cro, and 4icb), and fisa_casp3 (1bg8-A, 1bl0, 1eh2, 1jwe, and smd3) decoy sets maintained at "http://dd.compbio.washington.edu'' as the database "Decoys 'R' Us''. We have demonstrated that ours is better than any other (previously reported) physics-based or knowledge-based potential function in terms of the accuracy in discriminating the native fold from misfolded decoys and the achievement of high *Z*-scores. (Up to now, over fifty proteins have been tested and the native fold has been discriminated with 100% accuracy).

Our free-energy function and its calculation method thus developed are best suited to selecting the most stable structure from among the candidate structures. The number of the candidate structures is allowed to be huge, because the function is calculated with minor computational effort. It may be possible to develop a practical tool for predicting the native structure of a protein from its amino-acid sequence, by combining our free-energy function with the techniques which can generate a variety of candidate structures. The function and its calculation method are capable of handling very large proteins and can also be extended to analyses of protein-protein interaction and protein association. Works in these directions are in progress.

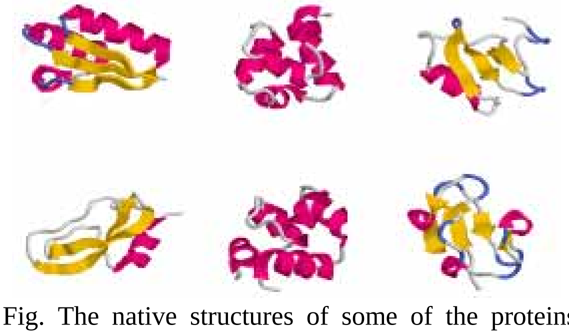

Fig. The native structures of some of the proteins tested.

4-2. RESEARCH ACTIVITIES IN 2009

Quantum Radiation Energy Research Section

H. Ohgaki, Professor
T. Kii, Associate Professor
(R. Kuroda, Lecturer)
(T. Sonobe, GCOE Assistant Professor)
(F. Yamane, 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, energy recovering system, undulator, etc.

2.1 KU-FEL

The KU-FEL is designed to achieve FEL lasing in MIR (Mid infra-red) regime, from 4 to 13 μm. The tunable IR laser will be used for basic research on energy materials and systems, such as high-efficiency solar cells, energy conversion in bio materials. The KU-FEL consists of a 4.5 cell thermionic RF gun, 3 m travelling wave accelerator structure, beam transport system, and a Halbach type undulator of 1.6 m and an optical resonator. Fig. 1 shows a schematic drawing of the system. Optical beam properties of the FEL and the electron beam parameter under the power saturation condition are listed in Table 1 and 2 respectively.

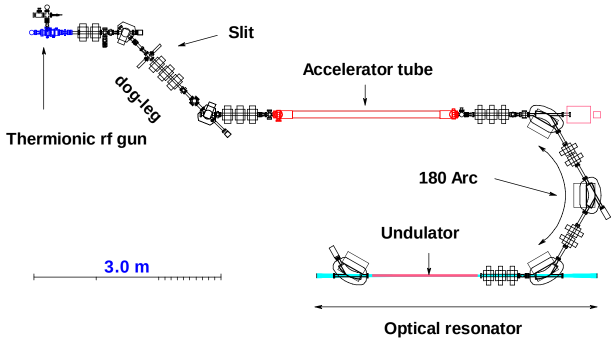

Fig. 1 Schematic drawing of the KU-FEL

Table 1 Optical parameter of the KU-FEL

Wavelength λ	13.2 μm
Bandwidth σ_λ/λ	0.8 %
Average power	4.6 mJ
Peak power *	2.9 MW

*Pulse duration of 650 fs is assumed.

Table 2 Electron beam parameter in the saturation experiment

Energy E_e	24.0 MeV
Energy spread σ_E/E_e	0.8%
Bunch length	2 ps (rms)
Macropulse length	5.5 μs
Average current	115 mA

2.2 MIR-FEL Application in the Energy Science

As for a pilot application of MIR- FEL to eco-energy science, a new approach of material evaluation has been developing. In this study, we focused on the wide gap semiconductors such as SiC, TiO_2, and ZnO since these are widely applied for the eco energy related materials such as next-generation power semiconductor devices, solar cells, and functional materials in the UV region. Since a phonon plays an important role to the photoabsorption, recombination, electric conduction, and band structure of the semiconductor material, we are developing an MIR-FEL assisted photoluminescence(PL) measurement system which consists of He-Cd laser

(Kinmon, IK5451R-E), and monochromator (NOS-Omini-λ3008) as shown in Fig. 2.

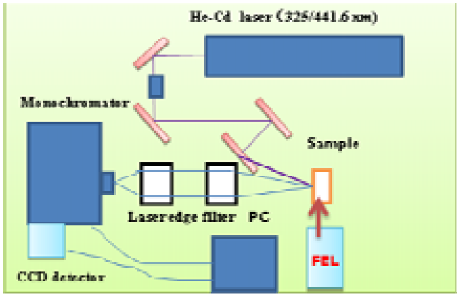

Fig. 2: FEL assisted PL measurement system

3. Bulk HTSC Staggered Array Undulator

Since short period undulator can produce short wavelength radiation at a compact accelerator facility, the development of short period undulator is quite important for future light sources. We proposed a new structure based on bulk HTSC stacked arrays. In the proposal we are aiming at producing strong undulator field by using the property of bulk HTSC magnet where the maximum trapped field reaches 17 T. The bulk HTSC staggered array undulator(SAU) consists of stacked bulk superconductor magnets inserted in a solenoid magnet as shown in fig.3.

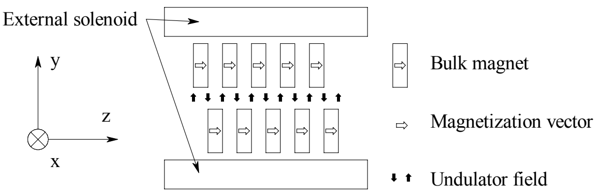

Fig. 3. Conceptual drawing of the bulk HTSC SAU.

We have developed a prototype undulator consisting of a 11 periods of stacked array, a liquid nitrogen cooled vacuum duct, and a normal conducting solenoid, and performed the proof of principle experiment. A periodic magnetic field in the bulk HTSC staggered array undulator is successfully generated and controlled as shown in Fig. 4.

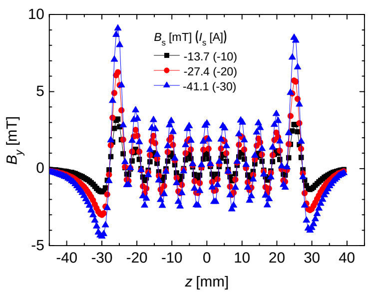

Fig. 4. Undulator field generated by the bulk HTSC SAU.

4. Non-destructive isotope detection using NRF

Nuclear Resonance Fluorescence (NRF) is powerful tool for investigation not only of the nuclear physics, but also of isotope detection for the homeland security such as nondestructive measurement of container at airports or harbors, detection or identification of special nuclear material (SNM). Since especially in the case of the homeland security application, high throughput measurement will be quite important, we have proposed high-flux γ-ray facility utilizing an energy recovery linac (ERL) and laser Compton scattering scheme as shown in fig. 5. The required performances of the detector used in the ERL Compton γ NRF facility are high energy resolution, high full energy efficiency, and high counting rate.

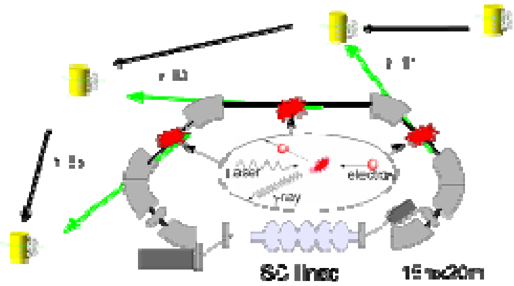

Fig. 5. Conceptual drawing of the ERL Compton-γ NRF facility

We have investigated performance of a $LaBr_3(Ce)$ scintillator for NRF experiment at several MeV gamma ray energy. Good linearity (less than 1 %) in the range of up to 10.7 MeV was confirmed to the NRF signals from ^{208}Pb and ^{24}Mg. Energy resolution was scalable to the square root of the gamma ray energy, and relative resolution was lower than 2 % in FWHM at the energy regime of greater than 5 MeV as shown in Fig. 6. These properties will be suitable for the gamma ray detector in the high throughput NRF measurement facility based on ERL and LCS-γ.

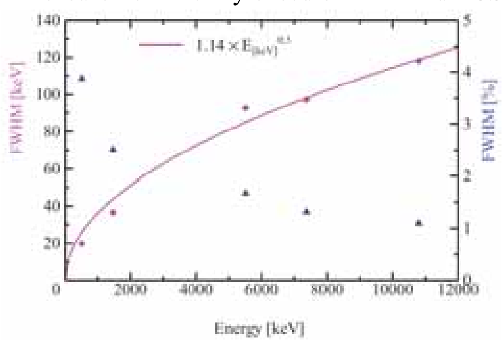

Fig. 6. The absolute and the relative energy resolution in FWHM.

Financial Support

1. Grant-in-Aid for Scientific Research
大垣英明、基盤研究(B)、「逆コンプトンγ線を用いた原子核共鳴蛍光散乱同位体イメージングに関する基礎的研究」

紀井俊輝、基盤研究(B)、「バルク超伝導体を用いた新型超短周期アンジュレータ」

大垣英明、挑戦的萌芽、「干渉効果を用いた共振器型自由電子レーザーの狭帯化」

2. Others
紀井俊輝、共同研究（(財)若狭湾エネルギー研究センター)、「粒子線照射による新型バルク超伝導体アンジュレータの性能向上に関する基礎的研究」

Publications

H. Ohgaki, T. Kii, H. Toyokawa, A New Design for Generation of Tunable Gamma-Ray With a Fixed Energy Electron Beam, IEEE Transactions on Nuclear Science, 56, 1316-1320, 2009

N. Kikuzawa, R. Hajima, N. Nishimori, E. Minehara, T. Hayakawa, T. Shizuma, H. Toyokawa, H. Ohgaki, Nondestructive Detection of Heavily Shielded Materials by Using Nuclear Resonance Fluorescence with a Laser-Compton Scattering γ-ray Source, Applied Physics Express, 2, 36502, 2009

T. Shizuma, T. Hayakawa, H. Ohgaki, H. Toyokawa, T. Komatsubara, N. Kikuzawa, A. Tamii, H. Nakada, Fine structure of the magnetic-dipole-strength distribution in 208Pb, Phys. Rev., C78, 61303, 2009

T. Hayakawa, H.Ohgaki, T. Shizuma, R. Hajima, N. Kikuzawa, E. Minehara, T. Kii, H. Toyokawa, Non-destructive detection of hidden chemical compounds with laser Compton-scattering gamma rays, Rev. of Science Instrum, 80, 045110-1-5, 2009

H. Zen, T. Kii, K. Masuda, R. Kinjo, K. Higashimura, K. Nagasaki, H. Ohgaki, Beam Energy Compensation in a Thermionic RF Gun by Cavity Detuning, IEEE transaction on nuclear science, 56, 3, 1487-1491, 2009

H. Toyokawa, S. Goko, S. Hohara, T. Kaihori, F. Kaneko, R. Kuroda, N. Oshima, M. Tanaka, M. Koike, A. Kinomura, H. Ogawa, N. Sei, R. Suzuki, T. Ohdaira, K. Yamada and H. Ohgaki, K. Masuda, T. Yamazaki, K. Yoshikawa, H. Zen, Recent progress in generation and application of AIST laser-Compton gamma-ray beam, Nuclear Inst. and Methods in Physics Research, A608, S41-S43, 2009

R. Hajima, N. Kikuzawa, N. Nishimori, T. Hayakawa, T. Shizuma, K. Kawase, M. Kando, E. Minehara, H. Toyokawa, H. Ohgaki, Detection of radioactive isotopes by using laser Compton scattered γ-ray beams, Nuclear Instruments and Methods in Physics Research, A608, S57-S61, 2009

N. Terunuma, A. Murata, M. Fukuda, K. Hirano, Y. Kamiya, T. Kii, M. Kuriki, R. Kuroda, H. Ohgaki, K. Sakaue, M. Takano, T. Takatomi, J. Urakawa, M. Washio, Y. Yamazaki, J. Yang, Improvement of an S-band RFgun with a Cs2Te photocathode for the KEK-ATF, Nuclear Instruments and Methods in Physics Research, A613, 1-8, 2010

T. Sonobe, T. Mitani, N. Shinohara, K. Hachiya, S. Yoshikawa, Plasma Emission and Surface Reduction of titanium Dioxides by Microwave Irradiation, Jpn. J. Appl. Phys., 48, 116003, 2009

T. Sonobe, M.A. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, K. Hachiya, T. Kii, K. Masuda, H. Ohgaki, Optical Properties of the Microwave-Treated TiO2 by Quantum Radiation Technology by Use of High-Tc Superconductor Bulk Magnets, Proceedings of WREC, 579-581, 2009

F. Yamane, M. Matsumura, H. Ohgaki, K. Asano, The Effect of Construction of Nuclear Fuel Cycle Facilities on Residual Land Price: The Case of Mutsu-Ogawara Area in Japan**,** Proceedings of WREC, 1233-1238, 2009

M.A. Bakr, H. Zen, K. Higashimura, K. Yoshida, R. Kinjo, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, MIR-FEL Gain Saturation at Kyoto University, Proceedings of WREC, 605-609, 2009

H. Ohgaki, Quantum Beams for Advanced Energy Sciences in Japan, Proceedings of WREC, 765-769, 2009

T. Sonobe, M.A. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, K. Hachiya, T. Kii, K. Masuda, H. Ohgaki, Investigation of the Effects of MIR-FEL Irradiation on the Optical Properties in Titanium Dioxides, Proceedings of the 1st GCOE inter. Sympo. ZERO CARBON ENERGY KYOTO 2009, 2009

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, R. Kinjo, H. Zen, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Comparison between the hexaboride materials as thermionic cathode in the RF guns for a compact MIR-FEL driver, Proceedings of the 1st GCOE inter. Sympo. ZERO CARBON ENERGY KYOTO 2009, 2009

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, R. Kinjo, H. Zen T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, MIR-FEL Tunable Range at Kyoto University, Proceedings of the 6th Annual meeting of Japan accelerator, 2009

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, R. Kinjo, H. Zen T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Numerical simulation of tabletop THz FEL amplifier, Proceedings of the 6th Annual meeting of Japan accelerator, 2009

K. Higashimura, S. Ueda, K. Yoshida, R. Kinjo, M.A.Bakr, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Variation of Undulator Field in Bulk HTSC Staggered Array Undulator, Proceedings of the 6th Annual meeting of Japan accelerator, 2009

M.A. Bakr, K. Higashimura, T. Kii, R. Kinjo, K. Masuda, H. Ohgaki, T. Sonobe, K. Yoshida, H. Zen, Y.U. Jeong, Lasing of MIR-FEL and Construction of User Beamline at Kyoto University, Proc. of PAC09, 2009

T. Kii, M.A. Bakr, K. Higashimura, R. Kinjo, K. Masuda, H. Ohgaki, T. Sonobe, K. Yoshida, H. Zen, Generation of Periodic Magnetic Field Using Bulk High-Tc Superconductor, Proc. of PAC09, 2009

Y. Iwasaki, T. Kaneyasu, S. Koda, Y. Takabayashi, H. Ohgaki, Analysis of the Orbit Response Matrix and Correction of Beta Function at the SAGA Light Source, Proc. of PAC09, 2009

T. Kii, R. Kinjo, M.A. Bakr, T. Sonobe, K. Higashimura, K. Masuda, H. Ohgaki, K. Yoshida, H. Zen, Proposal of a Bulk HTSC staggered array Undulator, Proc. of SRI09, 2009

T. Kii, K. Higashimura, M.A. Bakr, R. Kinjo, K. Yoshida, S. Ueda, T. Sonobe, K. Masuda, H. Ohgaki, Concept of a novel Tabletop THz FEL Amplifier, Proc. of the 34th International Conference on Infrared, Millimeter, and Terahertz Waves, 2009

K. Higashimura, T. Kii, S. Ueda, K. Yoshida, R. Kinjo, M.A. Bakr, T. Sonobe, K. Masuda, H. Ohgaki, Numerical Evaluation of THz Light by using Tabletop FEL Amplifier, Proc. of the 34th International Conference on Infrared, Millimeter, and Terahertz Waves, 2009

H. Ohgaki, T. Kii, K. Masuda, M.A. Bakr, K. Higashimura, R. Kinjo, K. Yoshida, S. Ueda, T. Sonobe, H. Zen , Y.U. Jeong, Status of the MIR-FEL Facility in Kyoto University, Proceedings of FEL2009, 572-575, 2009

K. Masuda, T. Shiiyama, T. Kii, H. Ohgaki, K. Kanno, E. Tanabe, Development of a Thermionic Triode RF Gun, Proceedings of FEL2009, 281-284, 2009

R. Kinjo, T. Kii, M.A. Bakr, K. Higashimura, K. Yoshida, S. Ueda, K. Masuda, K. Nagasaki, H. Ohgaki, T. Sonobe, H. Zen, Yoshida, S. Ueda , T. Sonobe, H. Zen , Y.U. Jeong, Numerical Evaluation of Bulk HTSC Staggered Array Undulator by Bean Mode, Proceedings of FEL2009, 746-749, 2009

T. Kii, K. Higasimura, M.A. Bakr, R. Kinjo, K. Yoshida, S. Ueda, K. Masuda, H. Ohgaki, T. Sonobe, H. Zen, Slippage Effect on the Table-Top THz FEL Amplifier Project in Kyoto University, Proceedings of FEL2009, 390-393, 2009

T. Kii, K. Masuda, H. Ohgaki, H. Harada, F. Kitatani, K. Hayakawa, T. Shizuma, N. Kikuzawa, Nishimori, R. Hajima, H. Toyokawa, Performance of the LaBr3(Ce) Scintillator for Nuclear Resonance Fluorescence Experiment, 2009 IEEE Nuclear Science Symposium Conference Record, 1490-1492, 2009

Presentations

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, M. Takasaki., R. Kinjo, H. Zen T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Lasing of MIR-FEL and Construction of User Beamline at Kyoto University, PAC9, Vancouver, Canada , 2009.5.4

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, M.Takasaki, R. Kinjo, H. Zen T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, MIR-FEL Gain Saturation at Kyoto University, WREC 2009, Bangkok, Thailand, 2009.5.20

T. Sonobe, M. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, K. Hachiya, T. Kii, K. Masuda, H. Ohgaki, Optical Properties of the Microwave-Treated TiO2 by Quantum Radiation Technology, WREC 2009, Bangkok, Thailand, 2009.5.20

T. Sonobe, M. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, K. Hachiya, T. Kii, K. Masuda, H. Ohgaki, Investigation of the Effects of MIR-FEL Irradiation on the Optical Properties in Titanium Dioxides, 1st GCOE inter. Sympo. ZERO CARBON ENERGY KYOTO 2009, Kyoto University, 2009.8.21

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, M. Takasaki, R. Kinjo, H. Zen, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Comparison between the hexaboride materials as thermionic cathode in the RF guns for a compact MIR-FEL driver, 1st GCOE inter.

Sympo. ZERO CARBON ENERGY KYOTO 2009, Kyoto University, 2009.8.21

T. Kii, M.A. Bakr, K. Higashimura, R. Kinjo, K. Masuda, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida, Slippage Effect on the Table-Top THz FEL Amplifier Project in Kyoto University, 31st International Free Electron Laser Conference, BT Convention Centre, Liverpool, UK, 2009.8.23-28

R. Kinjo, M.A. Bakr, K. Higashimura, T. Kii, K. Masuda, K.Nagasaki, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida, H. Zen, Numerical Evaluation of Bulk HTSC Staggered Array Undulator by Bean Mode, 31st International Free Electron Laser Conference, BT Convention Centre, Liverpool, UK, 2009.8.23-28

K. Masuda, M.A. Bakr, K. Higashimura, T. Kii, R. Kinjo, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida, Development of a Thermionic Triode RF Gun, 31st International Free Electron Laser Conference, BT Convention Centre, Liverpool, UK, 2009.8.23-28

H. Ohgaki, M.A. Bakr, K. Higashimura, T. Kii, R. Kinjo, K. Masuda, T. Sonobe, S. Ueda, K. Yoshida, Y.U. Jeong, H. Zen, Status of the MIR-FEL Facility in Kyoto University, 31st International Free Electron Laser Conference, BT Convention Centre, Liverpool, UK, 2009.8.23-28

K. Higashimura, M.A. Bakr, R. Kinjo, K. Yoshida, S. Ueda, T. Sonobe, T. Kii, K. Masuda, H. Zen, H. Ohgaki, Short Bunch Effect on Table-Top THz-FEL Amplification, 2009 International Workshop on Ultrashort Electron & Photon Beams, Xi'an, China, 2009.9.7

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, M.A. Takasaki, R. Kinjo, H. Zen, T. Sonobe, T. Kii, K.Masuda, H. Ohgaki, FEL Beamline for Wide Tunable Range and Sharing System at Kyoto University, 5th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator Based Sources, Banff, Canada, 2009.9.13

T. Sonobe, M. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, K. Hachiya, T. Kii, K. Masuda, H. Ohgaki, Investigation of the Effects of MIR-FEL Irradiation on the Photoluminescence of Titanium Dioxides, 5th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator Based Sources, Banff, Canada, 2009.9.13

H. Ohgaki, Research Activities on MIR-FEL and Table Top THZ Generation in Kyoto University, The 16th International Symposium on Laser Spectroscopy, KAERI, Daejon, Korea, 2009.11.13

T. Sonobe, H. Ohgaki, Preliminary Experiments for the Development of Solid Material Evaluation using Mid-Infrared FREE Electron Laser, 7th Eco-Energy and Materials Science and Engineering Symposium, RMUTT, Chang-Mai, Thailand, 2009.11.19

T. Sonobe, M.A. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, K. Hachiya, T. Kii, K. Masuda, H. Ohgaki, Optical Studies of the Microwave-Treated TiO2 Photocatalyst by MIR-FEL, International Symposium on Sustainable Energy and Environmental Protection (ISSEEP) 2009, 2009.11.24

M.A. Bakr, K. Yoshida, K. Higashimura, S. Ueda, M. Takasaki, R. Kinjo, YW. Choi, H. Zen T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Comparison between Six of the Hexaboride Materials as Thermionic Cathode in the RF Guns, 7th High-frequency high-brightens electron gun Workshop, Tohoku University, Sendai, 2009.11.27

YW. Choi, Ballistic Electron Emitter using Nano-crystallized Poly-Si, 7th High-frequency high-brightens electron gun Workshop, Tohoku University, Sendai, 2009.11.27

H. Ohgaki, Development of MIR-FEL and THz radiation at IAE, Kyoto University, TARLA IMAC meeting, Ankara University, Ankara, Turkey, 2009.12.4

H. Ohgaki, Nuclear Resonance Fluoresence Experiment using LaBr3 Scintillator at AIST-LCS beamline, International and commemorative symposium in establishing the Applied Laser Technology, アクアトム, 2010.2.17

T. Kii, Design study on Table Top THz FEL amplifier in Kyoto University, International and commemorative symposium in establishing the Applied Laser Technology, アクアトム, 2010.2.17

Y.W. Choi, Beam stabilization by using Beam Position Monitor in KU-FEL, International and commemorative symposium in establishing the Applied Laser Technology, アクアトム, 2010.2.17

M.A. Bakr, The Present status and Future upgrade of KU-FEL, International and commemorative symposium in establishing the Applied Laser Technology, アクアトム, 2010.2.17

M.A. Bakr, T. Kii, R. Kinjo, K. Higashimura, K. Masuda, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida, Y.W. Choi, H. Zen, The Present Status and Future Upgrade of KU-FEL, Asian Core mini seminar, Pohang Accelerator Laboratory, 2010.2.17

R. Kinjo, M.A. Bakr, K. Higashimura, T. Kii, K. Masuda, K.Nagasaki, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida, H. Zen, Y.W. Choi, Numerical Simulation of Bulk HTSC Staggered Array Undulator by Bean Model, Asian Core mini seminar, Pohang Accelerator Laboratory, 2010.2.17

T. Kii, R. Kinjo, M.A. Bakr, K. Higashimura, K. Masuda, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida, Y.W. Choi, H. Zen, Research Activities on Generation and Utilization of the Advanced Quantum Radiation in Kyoto University, Asian Core mini seminar, Pohang Accelerator Laboratory, 2010.2.17

園部太郎，Mohmoud A. Bakr，吉田恭平，東村圭祐，金城良太，蜂谷寛，紀井俊輝，増田開，大垣英明，酸化チタン（TiO2）に対する中赤外域波長可変レーザー（KU-FEL）照射効果の検討，第６回日本加速器学会年会，東海村，2009.8.6

園部太郎, 三谷友彦, 篠原真毅, 蜂谷寛, 吉川暹, 大垣英明, マイクロ波照射による二酸化チタンのプラズマ励起現象および非平衡弱還元，第 70 回日本応用物理学会，富山大学，2009.9.10

M.A. Bakr, K. Yoshida, K. Higashimura, R. Kinjo, T. Kii, T. Sonobe, K. Masuda, H. Ohgaki, Characterization of MIR-FEL at Kyoto University User Station, 日本原子力学会 2009 年秋の年会，東北大学，2009.9.16

山根史博，大垣英明，浅野耕太，原子力関連施設の建設が周辺地域の不動産価格に与える影響の分析（2）; 青森県むつ小川原地域を事例に，日本原子力学会 2009 年秋の年会, 東北大学, 2009.9.17

金城良太，紀井俊輝，M.A. Bakr，東村圭祐，吉田恭平, 園部太郎, 増田開, 長崎百伸, 大垣英明, バルク高温超伝導磁石を用いたアンジュレータの 11 周期試作機の実験結果，日本原子力学会 2009 年秋の年会，東北大学，2009.9.18

東村圭祐，上田智史，吉田恭平，金城良太，M.A. Bakr，園部太郎，紀井俊輝，増田開，大垣英明，数値計算によるテーブルトップ THz FEL におけるバンチ長依存性の研究，日本原子力学会 2009 年秋の年会，東北大学，2009.9.18

園部太郎, 篠原真毅, 三谷友彦, 蜂谷寛, 吉川暹, 大垣英明, マイクロ波エネルギー応用による金属酸化物の還元, 第 2 回宇宙環境利用シンポジウム, 京都大学おうばくホール，2009.12.4

東村圭祐, 数値シミュレーションによる THz-FEL 発振に向けた電子ビームの最適化，第 16 回 FEL と High-Power Radiation 研究会，理化学研究所，SPring-8，2010.3.4

吉田恭平, エネルギー材料の中赤外波長可変レーザー照射による物性への影響に関する研究，第 16 回 FEL と High-Power Radiation 研究会，理化学研究所，SPring-8，2010.3.4

金城良太, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータのビーンモデルに基づく数値的検討，第 16 回 FEL と High-Power Radiation 研究会，理化学研究所，SPring-8，2010.3.4

山根史博，大垣英明，浅野耕太，原子力関連施設の建設が周辺地域の不動産価格に与える影響の分析（3）; 青森県むつ小川原地域を事例に，日本原子力学会 2010 年春の年会, 茨城大学, 2010.3.27

M.A. Bakr, K. Higashimura, S. Ueda, K. Yoshida, R. Kinjo, Y.W. Choi, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Wavelength Tunability at KU-FEL，日本原子力学会 2010 年春の年会，茨城大学，2010.3.27

吉田恭平，上田智史，高崎将人，東村圭祐，金城良太，崔龍雲，Mahmoud A. Bakr，園部太郎，紀井俊輝，増田開，大垣英明，半導体材料の中赤外波長可変レーザー照射による物性への影響に関する研究，日本原子力学会 2010 年春の年会，茨城大学，2010.3.27

早川岳人，静間俊行，菊澤信宏，羽島良一，瀬谷道夫，豊川弘之，大垣英明，単色 γ 線ビームを用いた使用済燃料中 Pu, U, MA の非破壊分析の提案；（II）検出器概要及び実証実験，日本原子力学会 2010 年春の年会，茨城大学，2010.3.27

Advanced Atomic Energy Research Section

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Y. Yamamoto, Associate Professor
Y. Takeuchi, Assistant Professor

1. Introduction

The major objective of the study in this section is to pursue advanced energy systems for the sustainable growth under global environmental constraints. The studies described below are featured by not only the innovative technology of energy generation, conversion and utilization systems, but also from the attractiveness in the socio-economic analysis of future society and markets in the global scale and the scope covering 21st century and beyond. Typically, we propose a Zero-emission scenario based on fusion energy for biomass-based recycling system.

The major studies performed in our laboratory this fiscal year were as follows:

(1) Design of small and realistic biomass-fusion hybrid energy system
(2) Development of advanced fusion blanket with liquid LiPb and SiC composite for high temperature heat
(3) Development of Intermediate Heat Exchanger for advanced nuclear energy with SiC composite.
(4) Conversion of waste biomass by endo-thermic reaction to generate hydrogen and liquid fuel
(5) Development of compact neutron beam using newly developed cylindrical discharge device.

This annual report introduces the recent results of (1),(2) and (5) as highlights of the section.

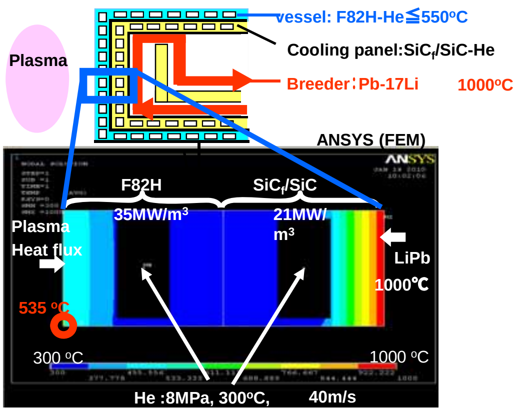

Fig. 1 Future recycling society with fusion-biomass hybrid system.

2. Design of small and realistic biomass-fusion hybrid energy system

We propose the biomass-fusion hybrid concept that enables early fusion energy demonstration with small device and reduced plasma requirements. With the bio-fuel conversion by endo-thermic reaction proved by the previous studies, fusion reactor with the current plasma physics basis can generate net energy production. Design study was focused on the tokamak and blanket system operated at above 900 C with LiPb and SiC combination. Major radius of the tokamak plasma ca. 5m, and Q~5 are expected to be realistic because technical requirements are essentially same level of those for ITER.

Blanket is the key challenge to extract heat. Designed structure and its thermal performance of the cooling panel made of SiC composite, that can actively cool and thus achieves controlled isolation between LiPb and ferritic steel, are shown in the figure 1. The outer vessel is made of ferritic/martensitic steel cooling panel with proven technology. The tritium breeder and multiplier is LiPb eutectic to be slowly circulated to recover the fusion heat.

While temperature of the RAFM is kept below 550 degree, the product LiPb can be obtained at the temperature of 1000 degree C. MHD pressure drop is calculated and found to require insignificant power for circulation.

Figure 2 shows the temperature dependence of the

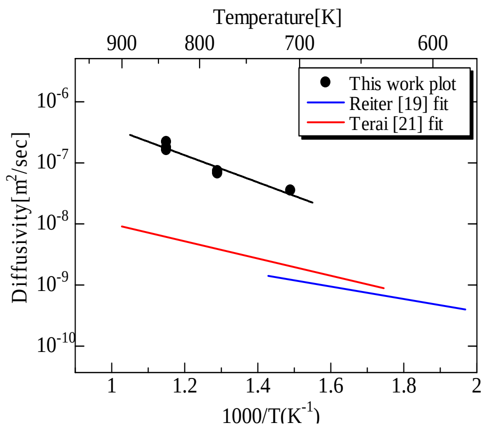

Fig. 2 Temperature dependence of the diffusion coefficient of deuterium in LiPb.

diffusivity of deuterium in LiPb. Based on the data of the diffusivity and solubility of hydrogen isotopes in LiPb obtained in Kyoto and a US-Japan collaboration program, tritium recovery process was studied to utilize the release into vacuum.

Because tritium accompanies with heat transfer media, recovery ratio requirements for the device

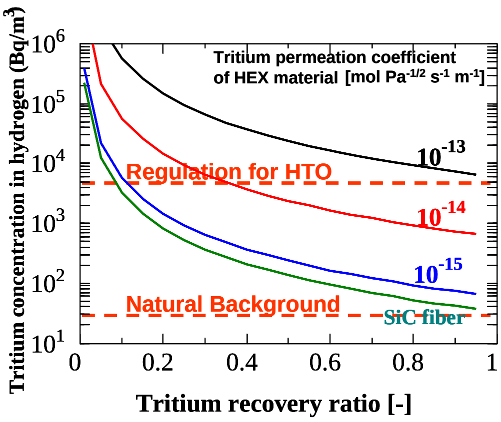

Fig. 3 Required tritium recovery ratio for the vacuum sieve tray as the function of tritium permeability through the SiC used for heat exchanger.

were obtained as the function of tritium permeability through the heat exchanger material. If permeation is small, tritium concentration in the coolant could be larger. We designed a concept of the vacuum sieve tray. Based on the data of the permeability of deuterium through SiC/SiC material obtained by our previous studies, design requirements for this process was well understood as summarized in the fig. 3. Recovery ratio around 40% is sufficient, and the experiments supports the design. Approximately 1mm diameter of the LiPb droplets were made in the experiment, and tritium release was estimated by diffusion data.

The feasibility of the new concept of high temperature SiC-LiPb blanket was verified. The concept of the blanket structure, and analyses on heat transfer, neutronics, MHD, and tritium transfer were made. Feasibility of the concept was confirmed with experimental support, and the concept of this blanket is attractive while technically possible with the current studies in the near future.

3. Generation of Narrow-Shaped and Thermalized Neutron Beam by a Cylindrical Discharge Fusion Device

We have developed a discharge-type tube shaped fusion neutron source that can provide 2.5MeV neutrons by D-D fusion reactions on the surface of the cylindrical electrodes in the device. Concept of this neutron beam source is shown in the fig.4. By surrounding the device with a reflector and a moderator,

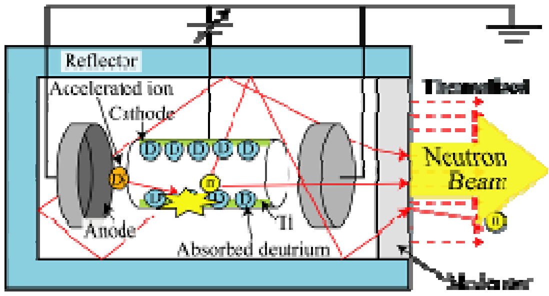

Fig. 4 A schematic view of the cylindrical discharge fusion device.

neutron beams can be generated with the shape and energy spectrum suitable for various applications such as neutron diffraction analysis. This device is compact and economical, and expected to effectively provide small scale neutron beams without fission reactors or large scale accelerator. The work in this year is intended to reveal the effect of the device shape on the discharge and neutron flux. Also, neutronics of the beam was investigated by numerical analysis with the MCNP; three-dimensional particle transport code, to establish the methodology of designing neutron beam to meet the required optics and energy spectrum as shown in the fig.4.. Results of the calculation was verified with experiment that proved the generation of neutron beam.

In the experiment, the device was immersed in the water tank used as a reflector, in order to converge the neutron along one direction. From the result of the experiment and the calculation, narrow-shaped neutron beam was obtained. The effect

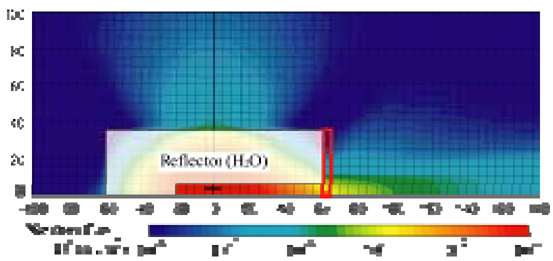

Fig. 4 Simulated neutron beam profile with H2O reflector .

of the geometry of the reflector on the optics of the neutron beam was clarified. Neutron beam was thermalized substantially by the reflector. Energy spectrum of neutron obtained by the calculation was verified by the experiment, From these results, this device is expected as a narrow-shaped and thermalized neutron beam source

Collaboration Works

核融合科学研究所、「原型炉 LiPb-He-Sic 高温発電ブランケットの工学基礎研究」、小西哲之

Financial Support

小西哲之、受託研究（文部科学省）、「先進複合材コンパクト中間熱交換器の技術開発」

小西哲之、受託研究（日本学術振興会）、「平成 21 年度アジア研究教育拠点事業」

山本靖、共同研究（日本原子力研究開発機構）、「イオン及び電子による電動等に及ぼす照射効果の検出法に関する研究」

Publications

K. Noborio, Y. Yamamoto, Y. Takeuchi, T. Hinoki, S. Konishi, Development of High Temperature SiC/SiC Composite Intermediate Heat Exchanger for He and LiPb, Proc. Of he 23rd Symposium of Fusion Engineering (CD ROM), 2009

R. Nadaoka, K. Uriu, Y. Yamamoto, S. Konishi, Diffusion and Solution of Hydrogen Isotopes in Lithium-Lead Blanket, Proc. Of he 23rd Symposium of Fusion Engineering (CD ROM), 2009

M. Ichinose, Y. Yamamoto, K. Noborio Y. Takeuchi, S. Konishi, Preliminary Design of High Temperature Lithium- Lead Blanket with SiC Cooling Panel, Proc. Of he 23rd Symposium of Fusion Engineering (CD ROM), 2009

T. Kanagae, K. Noborio, Y. Yamamoto, S. Konishi, Generation of Neutron Beam by the Cylindrical Discharge Fusion Device, Proc. Of he 23rd Symposium of Fusion Engineering (CD ROM), 2009

Y. Yamamoto, D.H. Kim, C.H. Park, S. Konishi, Development of High Temperature Particle Load Test Equipment by Hydrogen Ion Beam for Divertor, Proc. Of he 23rd Symposium of Fusion Engineering (CD ROM), 2009

T. Shibata, K. Noborio, Y. Yamamoto, S. Konishi, Model of environmental tritium behavior and effect of aquatic system in Japan, Proc. Of he 23rd Symposium of Fusion Engineering (CD ROM), 2009

C. Park, K. Noborio, R. Kasada, Y. Yamamoto, K. Nam, S. Konishi, Compatibility of Materials for Advanced Blanket with Liquid LiPb, Proc. Of The 23rd Symposium of Fusion Engineering (CD ROM), 2009

Presentations

K. Noborio, Y. Yamamoto, Y. Takeuchi, T. Hinoki, S. Konishi, Development of High Temperature SiC/SiC Composite Intermediate Heat Exchanger for He and LiPb, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

R. Nadaoka, K. Uriu, Y. Yamamoto, S. Konishi, Diffusion and Solution of Hydrogen Isotopes in Lithium-Lead Blanket, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

M. Ichinose, Y. Yamamoto, K. Noborio Y. Takeuchi, S. Konishi, Preliminary Design of High Temperature Lithium- Lead Blanket with SiC Cooling Panel, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

T. Kanagae, K. Noborio, Y. Yamamoto, S. Konishi, Generation of Neutron Beam by the Cylindrical Discharge Fusion Device, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

Y. Yamamoto, D.H. Kim, C.H. Park, S. Konishi, Development of High Temperature Particle Load Test Equipment by Hydrogen Ion Beam for Divertor, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

T. Shibata, K. Noborio, Y. Yamamoto, S. Konishi, Model of environmental tritium behavior and effect of aquatic system in Japan, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

C. Park, K. Noborio, R. Kasada, Y. Yamamoto, K. Nam, S. Konishi, Compatibility of Materials for Advanced Blanket with Liquid LiPb, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

S. Konishi, Non-Nuclear Hybrid Concept with Fuel Production, 23rd Symposium of Fusion Engineering, San Diego, California, 2009.6.1-5

S. Konishi, Y. Wu, LiPb blankets for TBM and CEMO, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

S. Konishi, Non-Nuclear Hybrid Concept with Fuel Production, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

S. Konishi, Fuel Production by Fusion and its Implication as Non-Nuclear Hybrid DEMO, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

Y. Takeuchi, C. Park, K. Noborio, Y. Yamamoto, S. Konishi, Heat Transfer in SiC Compact Heat Exchanger, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

K. Noborio, Development of Compact Neutron Beam Generator Using Cylindrical Fusion Device, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

T. Shibata, Model of Environmental Tritium Behavior in Coastal Area and the Effect of the Ocean, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

M. Ichinose, Low Initial Cost Near Term DEMO Reactor for Hydrogen Production, 9th International Symposium on Fusion Nuclear Technology, Furama Hotel, Dalian, 2009.10.11-16

登尾一幸，柴田敏宏，山本靖，森下和功，小西哲之, 渡辺淑之, 原子力施設より放出されるトリチウムを用いた環境中水素・水挙動の解析，日本原子力学会 2009 年秋の大会，東北大学青葉山キャンパス，2009.9.16-18

柴田敏宏，山本靖，小西哲之，登尾一幸，環境中トリチウム移行に対する水環境の及ぼす影響, 日本原子力学会 2009 年秋の大会，東北大学青葉山キャンパス，2009.9.16-18

小西哲之，檜木達也，山本靖，登尾一幸，稲垣嘉之, 先進複合材コンパクト中間熱交換器の技術開発；(12) 開発計画の概要 3, 日本原子力学会 2009 年秋の大会，東北大学青葉山キャンパス，2009.9.16-18

山本靖，竹内右人，小西哲之，登尾一幸，先進複合材コンパクト中間熱交換器の技術開発；（13）複合材と熱交換器要素の特性評価, 日本原子力学会 2009 年秋の大会, 東北大学青葉山キャンパス, 2009.9.16-18

檜木達也，朴二玄，小西哲之，先進複合材コンパクト中間熱交換器の技術開発；（14）スケールモデルのための接合技術開発，日本原子力学会 2009 年秋の大会，東北大学青葉山キャンパス，2009.9.16-18

山本靖，灘岡龍一，瓜生健吾，登尾一幸，小西哲之，LiPb における水素同位体の溶解拡散挙動の評価，第 26 回プラズマ核融合学会，京都市国際交流会館，2009.12.1-4

登尾一幸，金ヶ江剛史，山本靖，小西哲之，円筒放電型核融合装置による中性子ビーム源の開発, 第 26 回プラズマ核融合学会，京都市国際交流会館，2009.12.1-4

柴田敏宏，登尾一幸，山本靖，小西哲之，トリチウムの環境挙動に対する水面の影響，第 26 回プラズマ核融合学会，京都市国際交流会館，2009.12.1-4

一瀬麻衣，登尾一幸，山本靖，小西哲之，小型核融合炉高温ブランケットシステムの概念設計, 第 26 回プラズマ核融合学会，京都市国際交流会館, 2009.12.1-4

伊庭野健造，ビージェイ・スーラ，デービット・ルジック，小西哲之，リチウム蒸着処理によるグラファイトのスパッタリング抑制効果, 日本原子力学会 2010 年春の年会，茨城大学水戸キャンパス，2010.3.26-28

Advanced Particle Beam Energy Research Section

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K. Masuda, Associate Professor

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. Main research subjects are now focused on the following; improvement and understanding of confinement and transport in fusion plasmas, development of heating and current drive systems using high power millimeter waves, development and application of compact and portable neutron/proton sources driven by fusion plasmas and production/diagnostics of highly brilliant relativistic electron beams for advanced light sources such as free electron lasers.

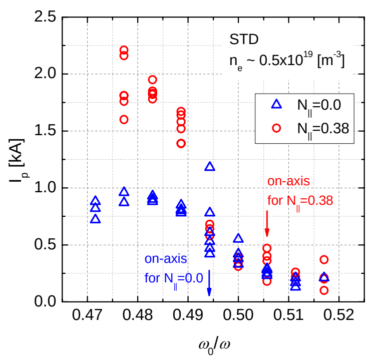
2. ECCD using upgraded launcher in Heliotron J

Non-inductive current has an important role on realization of high performance plasmas and sustainability of steady state plasmas in toroidal fusion devices. In stellarator/heliotron (S/H) systems, no Ohmic current is required for equilibrium since the confinement magnetic field is generated by external coils. However, it is known that non-inductive current flows as well as in tokamaks. Finite plasma pressure drives bootstrap current, and tangential neutral beam injection (NBI) generates so called Ohkawa current, which modifies the rotational transform profile with the result that equilibrium and stability are affected. Electron cyclotron current drive (ECCD) is recognized as a useful scheme for stabilizing magnetohydrodynamic (MHD) instabilities and analyzing heat and particle transport. In S/H systems, ECCD is expected as a useful scheme to avoid dangerous rational surface by cancelling the bootstrap current particularly in low shear devices.

A new EC launching system has been developed in Heliotron J by introducing a focusing mirror and a steerable mirror in order to improve the controllability of power deposition and ECCD. The toroidal injection angle is changed in a range of ±15 degree for the standard configuration, corresponding that the parallel refractive index $N_{||}$ ranges from -0.05 to 0.60. A low power experiment using a Gunn oscillator shows that the $1/e^2$ beam radius is about 30 mm at the magnetic axis. The plasma radius is a=17 cm, so the power can be deposited in more localized area compared to the previous launching system.

ECCD experiments have been conducted in Heliotron J by using this launching system. Figure 1 shows the measured toroidal current as a function of the magnetic field strength at the parallel refractive indices, $N_{||}$=0 and $N_{||}$=0.38. It is noted that the resonance moves to the high field side (the inside of the torus) as B (that is, ω_0/ω) decreases. For $N_{||}$=0.0, it is bootstrap current that mainly contributes to the measured current. The bootstrap current is 0.9 kA at on-axis and high field side heating, and it decreases as the resonance moves to the low field side. For $N_{||}$=0.38, the net current largely increases as the resonance moves to the high field side. Electron cyclotron emission (ECE) signal intensity also increases as the resonance moves to the high field side. Figure 2 shows the relation between a signal intensity of ECE and the toroidal current at $N_{||}$=0.38. High correlation is observed between the toroidal current and the ECE signal intensity. Since the ECE signal intensity reflects both bulk electron temperature and high-energy electron contribution due to grey optical thickness, the high-energy electrons have an important role on the ECCD.

The EC driven current is the order of a few kA, which is relatively lower than that in tokamaks. However, even such a low current has a possibility to change the rotational transform profile because the S/H system has a low poloidal magnetic field. Detailed study on related to magnetic field structure and the effect of ECCD on confinement and stability will be performed in the forthcoming experimental campaign.



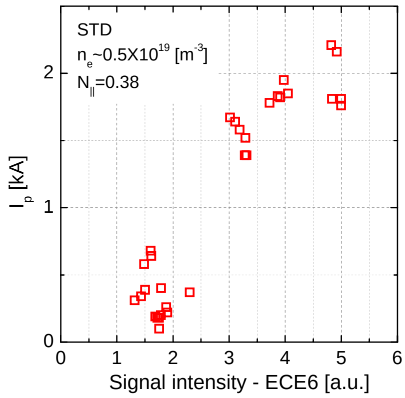


Fig. 2. Relation between toroidal current and ECE signal intensity

3. Enhancement of current-pressure ratio in IECF using a ring-shaped magnetron ion source (RS-MIS)

Inertial Electrostatic Confinement (IEC) aims to produce controlled nuclear fusion reactions by converging ions of a D_2 or D_2-^{3}He glow discharge through concentric spherical electrodes. A discharge is typically produced in a 0.5-1 Pa gas by applying a large negative voltage (50-100 kV) to the central cathode, which is highly transparent to ions. An issue for glow discharge IEC is that the gas itself neutralizes plasma ions limiting their acceleration and confinement. Here the fusion yield increases linearly with the cathode grid current. Moreover there is only a small contribution from energetically favorable 'beam-beam' reactions where the yield is proportional to the current-squared. A crucial goal for IEC is thus to improve the contribution of beam-beam reactions by increasing the ratio of cathode current to gas pressure.

Towards this aim, we have introduced the concept of IECF driven by an internal ring-shaped magnetron ion source (RS-MIS). The glow discharge is replaced by a low pressure (units of mPa) magnetron discharge using perpendicular electric and magnetic field vectors in the vicinity of the anode grid, provided by a ring of small cylinders each containing a permanent magnet and where source ions are extracted using the traditional gridded cathode. This is shown in Figure 3. Unlike external ion sources, RS-MIS prevents the loss of ions to the chamber as ions are created at a potential lower than ground. Proof of concept has been demonstrated using a prototype device featuring an array of 24 Sm-Co magnets with an outer radius of 82 mm. In H_2 gas, an applied magnetron voltage V_m = -1.2 kV yields a magnetron current I_m = 0.3 mA at a gas pressure of just 5 mPa.

This was followed the construction of a new experimental RS-MIS featuring a magnetron array with an outer radius four times as large as for the prototype. For D_2 this provides cathode grid currents as large as 1 mA at 5 mPa, an order-of-magnitude improvement of the current-pressure ratio over the glow driven mode.

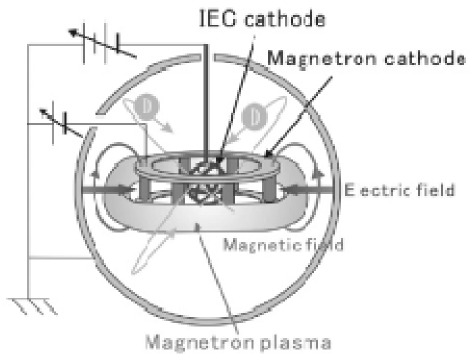


Fig. 3: Schematic for an IECF device driven by a low pressure RS-MIS

4. Double-grid IECF for energy recovery from electron beams

For a single-grid IECF device operating in glow-driven mode, most of the input power (~90%) is lost to electrons striking the vacuum chamber wall. We have proposed the double-grid IEC to reduce the energy of electrons striking the wall, enabling energy recovery for electrons escaping the cathode. The design of Figure 4 incorporates a highly transparent anode grid between the cathode and chamber wall and the cathode, with the discharge inside the anode otherwise unchanged.

Preliminary experiments emphasize the importance of an additional secondary electron suppressing grid to reduce the anode current due to low energy electrons produced near the chamber wall. The combination of double-grid and suppressor does indeed achieve a total input power less than the single-grid IEC under some experimental conditions. However neutron production is only about 30% as efficient and future research will consider efficiency of neutron production in terms of the cathode transparency.

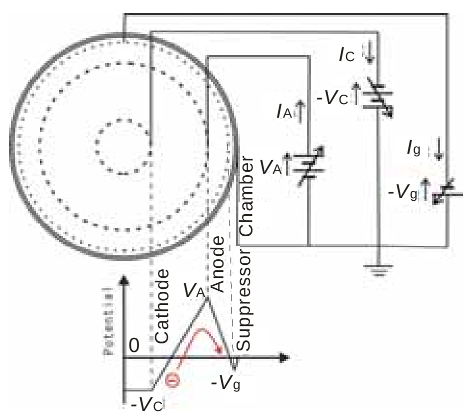


Fig. 4: Schematic for a double-grid IEC with secondary electron suppressing grid.

Collaboration Works

Univ. Wisconsin（米国)、Univ. Wisconsin（米国)、ORNL（米国)、Max Planck Institute（ドイツ)、Provence Univ.（フランス)、CIEMAT（スペイン)、ANU（オーストラリア)、Kharkov Institute（ウクライナ)、SWIP（中華人民共和国)、「先進ヘリカルにおける改善閉じ込めの研究」、佐野史道、水内亨、長崎百伸、岡田浩之、小林進二、山本聡、D. Anderson，F.S.B. Anderson，J.H. Harris，F. Wagner.，S. Benkadda，E. Ascasibar，A. Baciero，C. Hidalgo，B. Zurro，A. Cappa，A. Fernandez，V. Tribaldos，B. Blackwell，H. Punzmann，V. Chechkin，Q. Yang

CIEMAT（スペイン)、IPP（ドイツ)、PPPL（米国)、「3 次元磁場配位における高エネルギー粒子とアルフベン固有モードの相互作用」、佐野史道、水内亨、長崎百伸、小林進二、山本聡、E. Ascasibar(CIEMAT)、C. Hidalgo(CIEMAT)、A. Werner(IPP)、S. Medley(PPPL)、E. Fredrickson(PPPL)

西南物理研究所（中国)、IPP, Greifswald（ドイツ)、「反射計を用いた電子密度分布・揺動解析」、長崎百伸、W.W. Xiao、M. Hirsch

V.G. Khlopin Radium Institute（ロシア)、「Low-background Spectroscopic Position-Sensitive Neutron Detector for Detection of Nuclear Materials in Cargo Containers」、A.V. Kuznetsov（ロシア)、R. Lanza（米国)、増田開、G. Viesti（イタリア)、R. Maykut（カナダ）

IPP, Greifswald（ドイツ)、「電子サイクロトロン電流駆動の理論解析」、長崎百伸、N. Marushchenko

日本原子力研究開発機構、「JT-60U におけるデータマイニングを用いた高速イオン励起 MHD 不安定性の研究」、山本聡、小林進二、長崎百伸

核融合科学研究所、「電子サイクロトロン電流駆動の物理機構に関する研究」、長崎百伸

核融合科学研究所、「低圧力化新方式による中性子計測機器較正用放電型 D-D 中性子源の高性能化」、増田開

核融合科学研究所、「先進ヘリカルによるコンパクト・高ベータ・定常炉の実現に向けた閉じ込め最適化研究」、佐野史道、花谷清、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン J 装置における ICRF 加熱実験」、武藤敬（核融合研)、佐野史道、花谷清、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「高速カメラによる Heliotron J 周辺プラズマの研究」、西野信博（広島大)、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「トロイダル電流が MHD 平衡に与える影響の理論的考察とその実験的検証」、鈴木康浩（核融合研)、佐野史道、花谷清、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「Heliotron J 装置における電極バイアスによる径方向電場制御」、北島純男（東北大)、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「フィルターと AXUV ダイオードアレイを用いた HeliotronJ プラズマのエネルギー閉じ込めにおける炭素不純物の影響に関する実験的研究」、田村直樹（核融合研)、佐野史道、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「方向性プローブを用いた揺動による粒子異常輸送の研究」、竹入康彦（核融合研)、佐野史道、花谷清、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン配位における MHD 平衡・安定性に関する研究」、榊原悟（核融合研)、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「トリムコイルを用いた HeliotronJ プラズマの高エネルギー粒子閉じ込め改善の検討」、中村祐司（京大エネ科)、佐野史道、花谷清、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン J の閉じ込め改善に向けた 3 次元磁場構造からの理論研究」、横山雅之（核融合研)、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「極低磁場での電子バーンシュタイン波加熱のヘリオトロン J プラズマ閉じ込めへの影響」、東井和夫（核融合研)、佐野史道、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン J、CHS,LHD 装置における重水素プラズマの粒子輸送の研究」、田中謙治（核融合研)、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「局所分布構造・長距離相関計測装置の高性能化による乱流揺動の構造解析と HJ-LHD 比較研究」、福田武司（大阪大)、佐野

史道、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリカル系における電子サイクロトロン電流駆動による回転変換制御」、長崎百伸、佐野史道、花谷清、山本聡、水内亨、小林進二、岡田浩之

核融合科学研究所、「磁気計測による磁気島検出器の開発」、岡田浩之、佐野史道、山本聡、水内亨、小林進二、長崎百伸

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1. Grant-in-Aid for Scientific Research
長崎百伸、基盤研究(C)、「非誘導電流駆動を用いた回転変換制御」

2. Others
長崎百伸、共同研究（核融合科学研究所）、「ヘリカル系における電子サイクロトロン電流駆動による回転変換制御」

長崎百伸、共同研究（核融合科学研究所）、「電子サイクロトロン電流駆動の物理機構に関する研究」

増田開、共同研究（核融合科学研究所）、「低圧力化新方式による中性子計測機器較正用放電型D-D中性子源の高性能化」

Publications

K. Yoshikawa, K. Masuda, T. Takamatsu,Y. Yamamoto, H. Toku, T. Fujimoto, E. Hotta, K. Yamauchi, M. Ohnishi, H. Osawa, S. Shiroya, T. Misawa, Y. Takahashi, Y. Kubo, T. Doi, Research and Development of the Humanitarian Landmine Detection System by a Compact Fusion Neutron Source, IEEE Transactions on Nuclear Science, 56, 3, 1193-1202, 2009

K. Masuda, T. Takamatsu, K. Yoshikawa, T. Misawa, S. Shiroya, Y. Takahashi, T. Fujimoto, T. Nakagawa, T. Kajiwara, K. Nagasaki, Research and Development of Compact Neutron Sources based on Inertial Electrostatic Confinement Fusion, AIP Conference Proceedings (20th International Conference on the Application of Accelerators in Research and Industry), 1099, 587-590, 2009

K. Yoshikawa, K. Masuda, T. Takamatsu, Y. Yamamoto, H. Toku, T. Fujimoto, E. Hotta, K. Yamauchi, M. Ohnishi, H. Osawa, S. Shiroya, T. Misawa, Y. Takahashi, Y. Kubo, T. Doi, Results of the Development of the Humanitarian Landmine Detection System by a Compact Fusion Neutron Source and Dual Sensors, AIP Conference Proceedings (20th International Conference on the Application of Accelerators in Research and Industry), 1099, 652-655, 2009

F. Detering, B.D. Blackwell, M. Hegland, D.G. Pretty, K. Nagasaki, S.Yamamoto, Reduction of magnetic confinement fusion data for data mining applications, ANZIAM J., 50C, 729-743, 2009

K. Masuda, T. Kii, H. Ohgaki, H. Zen, T. Yamazaki, Shielding Analysis for a 40 MeV Electron Linac Facility, Nuclear Technology, 168, 467-471, 2009

H. Zen, T. Kii, K. Masuda, R. Kinjo, K. Higashimura, K. Nagasaki, H. Ohgaki, Beam energy compensation in a thermionic RF gun by cavity detuning, IEEE Transactions on Nuclear Science, 56, 3, 1487-1491, 2009

A. Isayama, G. Matsunaga, T. Kobayashi, S. Moriyama, N. Oyama, Y. Sakamoto, T. Suzuki, H. Urano, N. Hayashi, Y. Kamada, T. Ozeki, Y.Hirano, L. Urso, H. Zohm, M. Maraschek, J. Hobirk, K. Nagasaki and the JT-60 team, Neoclassical tearing mode control using electron cyclotron current drive and magnetic island evolution in JT-60, Nucl. Fusion, 49, 5, `055006, 2009

K. Masuda, T. Fujimoto, T. Nakagawa, H. Zen, T. Kajiwara, K. Nagasaki, K. Yoshikawa, Diagnostic System Development for D-D and D-3He Reaction Distributions in an Inertial Electrostatic Confinement Device by Collimated Proton Measurements, Fusion Science and Technology, 56, 1, 528-532, 2009

K. Masuda, T. Nakagawa, T. Kajiwara, H. Zen, K. Yoshikawa, K. Nagasaki, Built-In Ion Source for Inertial Electrostatic Confinement in Low Pressure Regime, Fusion Science and Technology, 56, 1, 523-527, 2009

Y. Nakashima, Y. Higashizono, H. Kawano, N. Nishino, S. Kobayashi, T. Mizuuchi, M. Shoji, K. Nagasaki, H. Okada, F. Sano, K. Kondo, Y. Yoneda, R. Yonenaga, M. Yoshikawa, T. Imai, Recycling studies based on two-dimensional visible light measurements and Monte-Carlo simulation in mirror and helical systems, Journal of Nuclear Materials, 390-391, 15, 511-515, 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, K. Nagasaki, H. Okada, F. Sano, S. Yamamoto, K. Kondo, Measurement of peripheral plasma turbulence using a fast camera in Heliotron J, Journal of Nuclear Materials, 390-391,15, 432-435, 2009

T. Mizuuchi, K. Murai, S. Watanabe, S. Yamamoto, S. Kobayashi, K. Nagasaki, H. Okada, G. Motojima, H. Arimoto, F. Hamagami, D. Katayama, H. Matsuoka, A. Nakajima, H. Takahashi, H. Yasuda, K. Mukai, Y. Kowada, K. Hosaka, S. Mihara, N. Nishino, et al., Comparison of edge plasma behavior at different poloidal positions in Heliotron J, Journal of Nuclear Materials, 390-391, 15, 428-431, 2009

H. Zushi, T. Ryoukai, K. Kikukawa, T. Morisaki, R. Bhattacharyay, T.Yoshinaga, K. Hanada, T. Sakimura, H. Idei, K. Dono, N. Nishino, H.Honma, S. Tashima, T. Mutoh, S. Kubo, K. Nagasaki, M. Sakamoto, Y.Nakashima, Y. Higashizono, K. N. Sato, K. Nakamura, M. Hasegawa, S.Kawasaki, H. Nakashima, A. Higashijima, Two Dimensional DensityFluctuation Measurements During the Non-Inductive Current Ramp-up Phase in the Compact Plasma Wall Interaction Experimental Device CPD, Plasma Sci. Technol, 11, 4, 397-401, 2009

H. Igami, Y. Yoshimura, S. Kubo, T. Shimozuma, H. Takahashi, H. Tanaka, K. Nagasaki, S. Inagaki, T. Mutoh, A. Komori and the LHD experimental group, Electron Bernstein wave heating via the slow X-B mode conversion process with direct launching from the high field side in LHD, Nucl. Fusion, 49, 11, 115005 (11pp), 2009

A. Komori, H. Yamada, S. Sakakibara, O. Kaneko, K. Kawahata, T. Mutoh, N. Ohyabu, S. Imagawa, K. Ida, Y. Nagayama, T. Shimozuma, K.Y. Watanabe,T. Mito, M. Kobayashi, K. Nagaoka, R. Sakamoto, N. Yoshida, S. Ohdachi, N. Ashikawa, Y. Feng, T. Fukuda, H. Igami, S. Inagaki, H. Kasahara, S.Kubo, R. Kumazawa, O. Mitarai, S. Murakami, Yuji Nakamura, M. Nishiura, T. Hino, S. Masuzaki, K. Tanaka, K. Toi, A. Weller, M. Yoshinuma, Y. Narushima, N. Ohno, T. Okamura, N. Tamura, K. Saito, T. Seki, S. Sudo, H. Tanaka, T. Tokuzawa, N. Yanagi, M. Yokoyama, Y. Yoshimura, T. Akiyama, H. Chikaraishi, M. Chowdhuri, M. Emoto, N. Ezumi, H. Funaba, L.Garcia, P. Goncharov, M. Goto, K. Ichiguchi, M. Ichimura, H. Idei, T.Ido, S. Iio, K. Ikeda, M. Irie, A. Isayama, T. Ishigooka, M. Isobe, T. Ito, K. Itoh, A. Iwamae, S. Hamaguchi, T. Hamajima, S. Kitajima, S. Kado, D. Kato, T. Kato, S. Kobayashi, K. Kondo, S. Masamune, Y. Matsumoto, N. Matsunami, T. Minami, C. Michael, H. Miura, J. Miyazawa, N. Mizuguchi, T. Morisaki, S. Morita, G. Motojima, I. Murakami, S. Muto, K. Nagasaki, N. Nakajima, Y. Nakamura, H. Nakanishi, H. Nakano, K. Narihara, A. Nishimura, H. Nishimura, K. Nishimura, S. himura, N.Nishino, T. Notake, T. Obana, K. Ogawa, Y. Oka, T. Ohishi, H. Okada, K. Okuno, K. Ono, M. Osakabe, T. Osako, T. Ozaki, B.J. Peterson, H. Sakaue, M. Sasao, S. Satake, K. Sato, M. Sato, A. Shimizu, M. Shiratani, M. Shoji, H. Sugama, C. Suzuki, Y. Suzuki, K. Takahata, H. Takahashi, Y. Takase, Y. Takeiri, H. Takenaga, S. Toda, Y. Todo, M. Tokitani, H. Tsuchiya, K. Tsumori, H. Urano, E. Veshchev, F. Watanabe, T. Watanabe, T.H. Watanabe, I. Yamada, S. Yamada, O. Yamagishi, S. Yamaguchi, S. Yoshimura, T. Yoshinaga and O. Motojima, Development of net-current free heliotron plasmas in the Large Helical Device, Nucl. Fusion, 49, 10, 104015 (8pp), 2009

N. Oyama and the JT-60 Team, Overview of JT-60U results towards the establishment of advanced tokamak operation, Nucl. Fusion, 49, 10, 104007 (16pp), 2009

T. Mizuuchi, S. Kobayashi, H. Okada, K. Nagasaki, S. Yamamoto, G. Motojima, S. Watanabe, K. Mukai, K. Hosaka, Y. Kowada, S. Mihara, A. Matsuyama, Y. Nakamura, K. Hanatani, Y. Suzuki, M. Yokoyama, A.C. Fernandez, Á.lvaro A. Cappa, S. Konoshima, K. Kondo, F. Sano, Configuration Control Experiments in Heliotron J, Journal of Plasma and Fusion Res. SERIES, 8, 981-986, 2009

S. Nishiumura, Y. Nakamura, G. Motojima, H. Okada, S. Kobayashi, S. Yamamoto, K. Nagasaki, K. Hanatani, K. Kondo, T. Mizuuchi, F. Sano, Effects of Configuration Control on the Neoclassical Viscosity in Heliotron-J, Journal of Plasma and Fusion Res. SERIES, 8, 1003-1009, 2009

G. Motojima, K. Nagasaki, H. Okada, K. Watanabe, T. Mizuuchi, A. Matsuyama, K. Hanatani, S. Yamamoto, S. Kobayashi, Y. Suzuki, K. Kondo, Y. Nakamura, A.C. Fernandez, ÁA. Cappa, Y. Yoshimura, S. Watanabe, K. Mukai, F. Sano, Experimental Study of Non-Inductive Current in Heliotron J, Journal of Plasma and Fusion Res. SERIES, 8, 1010-1014, 2009

K. Nagaoka, S. Kobayashi, K. Hosaka, S. Yamamoto, T. Mizuuchi, M. Osakabe, Y. Takeiri, K. Nagasaki, H. Okada, K. Kondo, K. Hanatani, F. Sano, Observation of Fast Ion Response to MHD Activities in Heliotron J, Journal of Plasma and Fusion Res. SERIES, 8, 1100-1103, 2009

Z. Guoqing, K. Nagasaki, Z. Jun, W. He, H. Mei, C. Gangyu, R. Jun, A Polarizer with Sinusoidal Grooves in the Electron Cyclotron Resonance Heating System of the HL-2A Tokamak, Plasma Sci. Technol., 11, 619-624, 2009

H. Igami, R. Ikeda, H. Takahashi, Y. Yoshimura, T. Shimozuma, S. Kubo, H. Tanaka, K. Nagasaki, T. Mutoh, Investigation of Experimental Configuration for Electron Bernstein Wave Heating on LHD, Plasma Sci. Technol., 11, 430-438, 2009

K. Nagasaki, G. Motojima, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, K. Hanatani, S. Konoshima, K. Masuda, Y. Nakamura, S. Watanabe, K. Mukai, K. Hosaka, K. Kowada, S. Mihara, Y. Yoshimura, Y. Suzuki, A. Fernández, A. Cappa, F. Sano, Effect of magnetic field ripple on electron cyclotron current drive in Heliotron J, Nucl. Fusion, 50, 025003 (7pp), 2010

下妻隆, 長崎百伸, 小特集　核融合プラズマにおける電子サイクロトロン加熱・電流駆動の進展 3.3 ヘリカル装置における ECH・ECCD の進展, プラズマ・核融合学会誌，85，6，368-373，2009

金城良太，紀井俊輝，Mahmoud A. Bakr，東村圭祐，吉田恭平，上田智史，園部太郎，増田開，長崎百伸, 大垣英明, バルク高温超伝導磁石を用いたアンジュレータの 11 周期試作機の実験結果, 原子力学会 2009 年秋の大会，H40，2009

東村圭祐，上田智史，吉田恭平，金城良太，Mahmoud A. Bakr, 園部太郎, 紀井俊輝, 増田開, 大垣英明，数値計算によるテーブルトップ THz FEL におけるバンチ長依存性の研究，原子力学会 2009 年秋の大会，H40，2009

K. Yoshikawa, K. Masuda, T. Takamatsu, Y. Yamamoto, H. Toku, T. Fujimoto, E. Hotta, K. Yamauchi, M. Ohnishi, H. Osawa, S. Shiroya, T. Misawa, Y. Takahashi, Development of a High-performance Landmine Detection System through Gamma-ray Detection by Using a Compact Fusion Neutron Source and Dual-sensors, Anti-personnel Landmine Detection for Humanitarian Demining, K. Furuta and J. Ishikawa, Editors, Springer, ISBN978-1-84882-345-7, 157-173, 2009

Presentations

K. Nagasaki, G. Motojima, K. Minami, K. Sakamoto, S. Kobayashi, S.Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima,K. Masuda, K. Kondo, Y.Nakamura, S. Watanabe, K. Mukai, K. Hosaka, Y.Kowada, S. Mihara, Y. Yoshimura, Y. Suzuki, A. Ferna'ndez, A'. Cappa, F. Sano, Recent Results on ECCD Experiment in Heliotron J, The 3rd Japan-Korea Workshop on Plasma Heating and Current Drive Systems, National Institute for Fusion Science, 2009.8.5-7

R. Kinjo, T. Kii, H. Zen, M. A. Bakr, K. Higashimura, K. Yoshida, S. Ueda, K. Masuda, K. Nagasaki, H. Ohgaki, Numerical Evaluation of Bulk HTSC Staggered Array Undulator with Bean Model, Free Electron Laser Conference 2009, BT Conventional Centre Liverpool, UK, 2009.8.23-28

K. Nagasaki, K. Minami, K. Sakamoto, H. Yoshino, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, G. Motojima, K. Masuda, Y. Nakamura, K. Mukai, H. Lee, Y. Yoshimura, Y. Suzuki, A. Fernandez, A. Cappa, F. Sano, ECCD Experiments Using Upgraded Launcher in Heliotron J, US-EU-Japan RF Workshop, Kyushu National Musium, Dazaifu, Japan, 2009.9.16-18

K. Masuda, T. Nakagawa, T. Kajiwara, K. Yoshikawa, K. Nagasaki, An Inertial Electrostatic Confinement Fusion Device Driven by a Built-In Ring-Shaped Ion Source in Low Pressure Regime, ICMAP2009, BEXCO Conventional Center, Busan, Korea, 2009.9.23-25

T. Kajiwara, K. Masuda, K. Yoshikawa, K. Nagasaki, Double-grid IEC for Energy Recovery from Escaping Electron Beams, ICMAP2009, BEXCO Conventional Center, Busan, Korea, 2009.9.23-25

K. Nagasaki, K. Sakamoto, K. Minami, H. Yoshino, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S.Konoshima, Y. Nakamura, S.Ohshima, K. Mukai, S. Kishi, H. Y. Lee, Y. Takabatake, G. Motojima, Y. Yoshimura, A. Fernandez, A. Cappa, B.Blackwell, F. Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, Proc. 17th International Stellarator/Heliotron Workshop, Princeton Plasma Physics Laboratory, 2009.10.12-16

H. Okada, S. Kobayashi, S. Kishia, S. Miharaa, T. Mutohb, T. Mizuuchi, K. Nagasaki, Y. Nakamuraa, T. Minami, S. Yamamoto, S. Konoshima, H.Y. Leea, Y. Takabatakea, K. Hanatani, F. Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, Proc. 17th International Stellarator/Heliotron Workshop, Princeton Plasma Physics Laboratory, 2009.10.12-16

T. Mizuuchi, F. Sano, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, K. Mukai, S. Kishi, H. Lee, K. Minami, Y. Takabatake, N. Nishino, Y Nakashima, Y. Suzuki, M. Yokoyama, Study of Improved Confinement Modes in Heliotron J, Proc. 17th International Stellarator/Heliotron Workshop, Princeton Plasma Physics Laboratory, 2009.10.12-16

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Watanabe, K. Mukai, S. Kishi, H. Leea, K. Minami, Y. Takabatake, H. Yashiroa, N. Nishinob, Y Nakashimac, Y. Nakamuraa, K. Hanatani, S. Konoshima, F. Sano, Effects of gas-fueling control on plasma performance in Heliotron J, Proc. 17th International Stellarator/Heliotron

Workshop, Princeton Plasma Physics Laboratory, 2009.10.12-16

S. Kobayashi, K. Nagaoka, S. Yamamoto, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H. Y. Lee, Y. Suzuki, Y. Nakamura, Y. Takeiri, M. Yokoyama, K. Hanatani, K. Hosaka, S. Konoshim, S. Ohshim, K. Toushi, F. Sano, Energetic particle transport in NBI plasmas of Heliotron J, Proc. 17th International Stellarator/Heliotron Workshop, Princeton Plasma Physics Laboratory, 2009.10.12-16

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, D. Nishi, K. Minami, H. Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, Proc. 17th International Stellarator/Heliotron Workshop, Princeton Plasma Physics Laboratory, 2009.10.12-16

K. Masuda, Overview of Kyoto University Research and Considerations for an IEC Device Driven by a Built-In Ring-Shaped Ion Source, 11th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, FLUNO Center, Madison, Wisconsin, 2009.10.12-13

J. Kipritidis, Optical diagnostics and numerical modeling of a gaseous discharge Inertial Electrostatic Confinement device, 11th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, FLUNO Center, Madison, Wisconsin, 2009.10.12-13

T. Kajiwara, Double-grid IEC for Recovery of Energy from Escaping Electron Beams, 11th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, FLUNO Center, Madison, Wisconsin, 2009.10.12-13

K. Nagasaki, G. Motojima, K. Sakamoto, K. Minami, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, Study of Non-Inductive Current in Heliotron J, The 7th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA2009) and the Asia-Pacific Plasma Theory Conference (APPTC2009), Aomori, Japan, 2009.10.27-30

S. Kobayashi, H. Y. Lee, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, Y. Suzuki, Y. Nakamura, K. Hanatani, S. Konoshima, K. Toushi, F. Sano, Development of High Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, The 7th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA2009) and the Asia-Pacific Plasma Theory Conference (APPTC2009), Aomori, Japan, 2009.10.27-30

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, D. Nishi, K. Minami, H. Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, The 7th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA2009) and the Asia-Pacific Plasma Theory Conference (APPTC2009), Aomori, Japan, 2009.10.27-30

F. Sano, T. Mizuuchi, K. Nagasaki, K. Hanatani, H. Okada, Y. Nakamura, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, S.Ohshima, M.Takeuchi, Y. Ijiri, K. Yaguchi, T. Senju, M. Shibano, K. Tohshi, K. Sakamoto, A. Matsuyama, K. Mukai, K. Minami, S. Kishi, H. Lee, Y. Takabatake, H. Yashiro, K. Yamamoto, K. Nomura, K. Suwa, H. oshino, S. Murakami, T.Mutoh, Y. Takeiri, K. Nagaoka, S. Okamura, K. Y. Watanabe, M.Yokoyama, Y. Suzuki, Y.Yoshimura, S. Nishimura, N. Tamura, S.Sakakibara, G. Motojima, N.Nishino, T.Fukuda, Y.Nakashima, Z. Feng, Q. Yang, A. Fernández, A. Cappa, V. Tribaldos, B.Blackwell, V.V. Chechkin, Physics Research on the Heliotron J Confinement, International Toki Conference 19, セラトピア土岐, 2009.12.8-11

N. Nishino, T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, F. Sano, Peripheral plasma measurement in Heliotron J using fast cameras, International Toki Conference 19, セラトピア土岐, 2009.12.8-11

M. Sugihara, K. Oki, R. Ikezoe, T. Onchi, A. Sanpei, H. Himura, S. Masamune, T. Akiyama, A. Ejiri, Y. Sakamoto, K. Nagasaki, V. Zhuravlev, Density regime of low-aspect-ratio RFP plasmas in RELAX, International Toki Conference 19, セラトピア土岐, 2009.12.8-11

K. Nagasaki, et al., Experimental Study of L-H Transition in Heliotron J, China-Japan Workshop on Plasma Science and Nuclear Fusion, SWIP, Chengdu, China, 2010.1.25-26

K. Nagasaki, et al., ECCD Experiment Using Upgraded Launcher in Heliotron J, Korea-Japan Joint Workshop on RF Heating Physics in Fusion Plasmas, National Fusion Research Institute, Daejeon, Korea, 2010.3.8-9

長崎百伸, 南桂史, 坂本欣三, 本島厳, 小林進二, 山本聡，水内亨，岡田浩之，南貴司，花谷清，木

島滋，増田開，中村祐司，向井清史，李炫庸，吉村泰夫，鈴木康浩，A. Ferna'ndez，A'. Cappa，佐野史道，ヘリオトロン J における ECCD 実験，平成 21 年度「ミリ波・サブミリ波応用の新展開ための調査研究」作業会，核融合科学研究所，2009.8.5

金城良太，紀井俊輝，Mahmoud A. Bakr，東村圭祐，吉田恭平，上田智史，園部太郎，増田開，長崎百伸，大垣英明，バルク高温超伝導磁石を用いたアンジュレータの 11 周期試作機の実験結果，日本原子力学会 2009 年秋の大会，東北大学青葉山キャンパス，2009.9.16-18

東村圭祐，上田智史，吉田恭平，金城良太，Mahmoud A. Bakr，園部太郎，紀井俊輝，増田開，大垣英明，数値計算によるテーブルトップ THz FEL におけるバンチ長依存性の研究，日本原子力学会 2009 年秋の大会，東北大学青葉山キャンパス，2009.9.16-18

梶原泰樹，増田開，John Kipritidis，長崎百伸，慣性静電閉じ込め核融合装置における電子エネルギー回収実験，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

水内亨，小林進二，山本聡，岡田浩之，長崎百伸，南貴司，向井清史，岸真太朗，李庸，南桂史，高畠優，大島慎介，西野信博，中嶋洋輔，中村祐司，花谷清，佐野史道，ヘリオトロン J における超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ･核融合学会年会，京都市国際交流会館，2009.12.1-4

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡，木島滋，西大輔，南桂史，李庸，高畠優，岸真太郎，八代浩彰，佐野史道，マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測，第 26 回プラズマ･核融合学会年会，京都市国際交流会館，2009.12.1-4

南貴司，八代浩彰，小林進二，水内亨，岡田浩之，長崎百伸，中村祐司，花谷清，山本聡，木島滋，大島慎介，佐野史道，Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

J. Kipritidis, Optical diagnostics and numerical modeling of a gaseous discharge Inertial Electrostatic Confinement device，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

高橋裕己，北島純男，宇藤裕康，田中豊，横山雅之，磯部光孝，竹内正樹，池田亮介，東井和夫，岡村昇一，笹尾真実子，石井啓一，佐藤惇弥，小林進二，山本聡，岡田浩之，水内亨，長崎百伸，南貴司，佐野史道，増崎貴，庄司主，芦川直子，時谷政行，CHS グループ，LHD 実験グループ，ヘリカルプラズマにおける電極バイアスによる閉じ込め遷移に対するリップル構造依存性，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

西野信博，高畠優，水内亨，長崎百伸，岡田浩之，南貴司，山本聡，小林進二，佐野史道，ヘリオトロン J における加熱時の周辺揺動観測，第 26 回プラズマ･核融合学会年会，京都市国際交流会館，2009.12.1-4

大島慎介，藤澤彰英，清水昭博，中野治久，長崎百伸，HIBP による CHS フィッシュボーン現象時の電場構造変化の観測，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

山本聡，中村佑司，岡村昇一，田部井優，西岡賢二，佐野史道，水内亨，長崎百伸，花谷清，岡田浩之，南貴司，小林進二，木島滋，大島慎介，ヘリカル軸ヘリオトロン磁場配位の最適化研究，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

杉原正記，江尻晶，倉品博樹，秋山毅志，坂本慶司，高橋幸司，長崎百伸，向井清史，Vladimir Zhuravlev，大木健輔，池添竜也，恩地拓己，三瓶明希夫，比村治彦，政宗貞男，球状 RFP 装置 RELAX におけるミリ波干渉計を用いた電子密度測定，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

伊神弘恵，池田亮介，久保伸，下妻隆，吉村泰夫，高橋裕己，長崎百伸，田中仁，武藤敬，LHD における電子バーンシュタイン波加熱用アンテナの検討，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

南桂史，長崎百伸，坂本欣三，水内亨，岡田浩之，南貴司，小林進二，山本聡，木島滋，向井清史，李庸，岸真太郎，高畠優，佐野史道，ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

岡田浩之，山本聡，榊原悟，鈴木康浩，小林進二，長崎百伸，中村祐司，南貴司，水内亨，木島滋，渡邊清政，成嶋吉郎，向井清史，岸真太郎，李康，高畠優，南桂史，佐野史道，磁気計測による磁気島検出器の開発，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

高畠優，水内亨，西野信博，長崎百伸，岡田浩之，南貴司，小林進二，山本聡，木島滋，中嶋洋輔，井尻芳行，千住徹，矢口啓二，坂本欣三，東使潔，芝野匡志，向井清史，李庸，岸真太郎，南桂史，

佐野史道, 静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

岸真太郎, 岡田浩之, 水内亨, 長崎百伸, 花谷清, 南貴司，小林進二，山本聡，木島滋，武藤敬，松山顕之，向井清史，李庸，高畠優，南桂史，佐野史道，ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

Lee Hyunyong，小林進二，南貴之，門信一郎，水内亨，長崎百伸，岡田浩之，南貴司，山本聡，村上定義，鈴木康浩，中村祐司，花谷清，木島滋，向井清史，岸真太郎，高畠優，南桂史，香川輔，東使潔，佐野史道，ヘリオトロン J における荷電交換再結合分光計測，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

Advanced Plasma Energy Research Section

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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 institute and also groups of other universities/institutes under the auspices of the Collaboration Program of the Lab. Complex Energy Processes, IAE, the Collaborative Research Program of NIFS (National Institute for Fusion Science), etc.

In this report, some results obtained in the Heliotron J experimental study in FY2009 are reported focusing on (1) the fast ion response to the energetic-ion-driven MHD activities and (2) the design of new high repetition rate Nd:YAG Thomson scattering system.

2. Fast ion response to the energetic-ion-driven MHD activities [a]

Study of anomalous transport of fast ions induced by the interactions with energetic-ion-driven MHD instabilities such as Alfvén eigenmodes is important subject since it affects alpha heating efficiency and causes damage on the first wall in burning plasmas. Some models of the anomalous fast-ion transport due to the energetic-ion-driven MHD activities in toroidal plasmas have been reviewed from the viewpoint of the fast ion response to the amplitude of the magnetic fluctuation. In Heliotron J, having a low-magnetic-shear configuration with an L/M = 1/4 helical coil, the energetic-ion-driven MHD instabilities identified as global Alfvén eigenmodes (GAE) have been observed in ECH+NBI plasmas. The fast ion response to the energetic-ion-driven MHD activities is investigated using a hybrid directional Langmuir probe (HDLP) installed in Heliotron J.

A synchronization of the observed ion fluxes into the probe tip (δI_{IS}) measured by the co-directed probe of HDLP with the bursts of the magnetic fluctuation (δB) measured by the magnetic probe mounted on the inner surface of the vacuum vessel has been found during the chirping-down mode in the frequency range of 40-70kHz in the co-NBI plasmas. In this case, the beam velocity normalized by Alfvén velocity $v_{b\|}/v_A$ was around 0.4 under the assumption of 5% of the carbon ion density. A small response of the ion flux detected by the counter-directed probe was also observed in the growth phase of the mode amplitude of each burst and disappeared after the peak of the burst, which indicates that this phenomenon might occur under the condition where the fast ion pressure was fairly high before the re-distribution of fast ion due to the bursts.

Figure 1 shows the relation between δI_{IS} and δB, where the co-directed probe was located at r/a=0.87. Almost linear correlation of δI_{IS} with δB indicates that the fast ion response is probably due to a resonant convective oscillation. In this model, it is expected that the fast ion is oscillated in radial

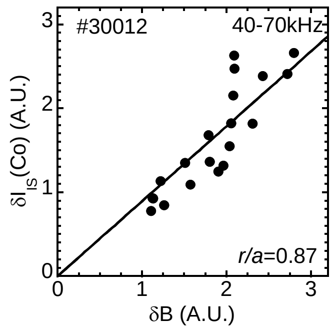

Fig. 1. Ion flux response measured by HDLP as a function of mode amplitude.

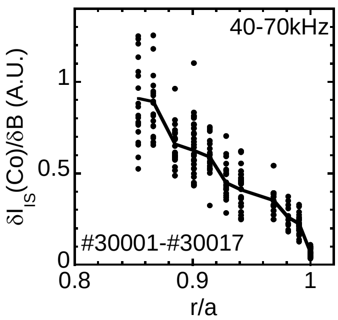

Fig. 2. Radial profile of δI_{IS} with co-directed

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direction by the bursting mode where the gradient of the fast ion density profile is significant high. The displacement of the fast ion would be proportional to the amplitude of the magnetic fluctuation. Then the oscillation of the fast ion flux should be proportional to the local gradient of the fast ion density profile and the mode amplitude. This description is supported by the radial profile of δI_{IS} normalized by δB as shown in Fig. 2. The normalized fast ion flux decreases with the minor radius, indicating the radial profile of the fast ion response may reflect the gradient of the fast ion density profile and eigenfunction of the bursting mode. Note that the fast ion response was small outside LCFS, suggesting that the amount of the fast ions lost outside LCFS due to the bursts was small.

3. Design of a new high repetition rate Nd:YAG Thomson scattering system for Heliotron J

3.1. Introduction

Investigation of improved confinement phenomena observed in torus plasma is important to enhance the performance of magnetic confinement fusion devices. Various experimental results in tokamak and helical devices, such as an internal transport barrier formation and an edge transport barrier formation (H-mode), show that the improved confinement phenomena are closely related to plasma profile, and the plasma profile control can enhance the plasma confinement. Meanwhile, the helical-axis heliotron device has a merit in a realization of a compact and high beta steady-state reactor. Accordingly, the confinement improvement of the Heliotron J plasma by the plasma profile control is an important issue to realize the fusion reactor of the heliotron configuration.

3.2. Design Policy of High Repetition Rate Nd:YAG Thomson Scattering System

A new Nd:YAG Thomson scattering system installed on the Heliotron J device is required to measure the time evolution of the plasma profile. The popular techniques of the multipoint Thomson scattering system for the profile measurement are the LIDER method, TV Thomson method and the high repetition rate Nd:YAG laser method. Among these three methods, however, the time evolution measurement is difficult by the LIDER and the TV Thomson methods, because these two methods normally use a high power ruby laser, which is not suitable for the high repetition operation. Therefore, the Nd:YAG Thomson method is most suitable for our purpose.

Because the duration of the discharge of Heliotron J experiment is 100ms-200ms, the profile measurement is required to be performed by at least 10 ms time interval. The required performances of the Nd:YAG laser are (a) the repetition rate is greater than 100Hz, and (b) the required laser power of the one pulse is greater than 550mJ. For achieving these requests by commercial lasers, we choose a two 50 Hz Nd:YAG lasers (made by Continuum) system, where the 100 Hz repetition rate is achieved by the two laser beam combination technique. It is noted that we have a next-step plan to improve time interval to ~5ms by increasing the number of the lasers to four lasers.

3.3. Design goal of the new Nd:YAG Thomson scattering system

The design goal of the new Nd:YAG Thomson scattering system is determined as follows by taking into account the required performance for the time evolution profile measurement on Heliotron J plasma

1) Spatial resolution: ~1cm
2) Spatial channels: 25
3) Time interval of measurement:
   ~10ms (Period of discharge ~200ms)
4) Range of Te: 10eV-10keV
5) Range of ne: $>0.5\times10^{19}\mathrm{m}^{-3}$

3.4. Configuration of the new Nd:YAG Thomson scattering system

When the Thomson scattering system is installed a helical device, a large helical coil, which winds around the vacuum vessel, severely limits the configuration of the components. To measure the profile of the whole poloidal plasma cross-section, the scattered light form the laser beam through the plasma cross-section is required not to be blocked by any objects as less as possible. In Heliotron J, two large basement structures that support vertical coils are located above and below the vacuum vessel. Moreover, the inner vertical coil is mounted around the central axis of the torus. Accordingly, the enough space for the Thomson scattering system construction only exists in the outside of the vessel.

Consequently, the laser beam is decides to inject from obliquely downward to upward, and obliquely back scattered light is detected (Scattering angle is 160°). And we also decide to add new ports for the Nd:YAG Thomson scattering system, because no appropriate port is available in the present Heliotron J device. The scattered light is collected with a large concave mirror (D=800mm, f/2.25) with a solid angle of ~100 mstr. The collected scattered light is transferred to the 25 polychromators by optical fibers that are lined up on the image of the scattered light, then the plasma profile is measured at the 25 spatial points with ~10mm resolution.

Input-output vacuum windows of the laser beam are designed to be located far from the plasma, because the vacuum widows generate the stray light that causes the reduction of the S/N ratio. The results of these study show the new design accomplish the above mentioned performance goal.

Collaboration Works

ハリコフ研究所（ウクライナ）、マックスプランク・プラズマ物理研究所（ドイツ）、CIEMAT（スペイン）、「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、小林進二、山本聡、V.V. Chechkin, M. Hirsch 他, F. Tabares 他

Univ. Wisconsin（米国）、Univ. Wisconsin（米国）、ORNL（米国）、Max Planck Institute（ドイツ）、Provence Univ.（フランス）、CIEMAT（スペイン）、ANU（オーストラリア）、Kharkov Institute（ウクライナ）、SWIP（中華人民共和国）、「先進ヘリカルにおける改善閉じ込めの研究」、佐野史道、水内亨、長崎百伸、岡田浩之、小林進二、山本聡、D. Anderson, F.S.B. Anderson, J.H. Harris, F. Wagner., S. Benkadda, E. Ascasibar, A. Baciero, C. Hidalgo, B. Zurro, A. Cappa, A. Fernandez, V. Tribaldos, B. Blackwell, H. Punzmann, V. Chechkin, Q. Yang

CIEMAT（スペイン）、IPP（ドイツ）、PPPL（米国）、「3 次元磁場配位における高エネルギー粒子とアルフベン固有モードの相互作用」、佐野史道、水内亨、長崎百伸、小林進二、山本聡、E. Ascasibar(CIEMAT)、C. Hidalgo(CIEMAT)、A. Werner(IPP)、S. Medley(PPPL)、E. Fredrickson(PPPL)

日本原子力研究開発機構、「JT-60U におけるデータマイニングを用いた高速イオン励起 MHD 不安定性の研究」、山本聡、小林進二、長崎百伸

核融合科学研究所、「強磁場側 ECH 入射によるイオンテール生成の実験的検証」、小林進二

核融合科学研究所、「高性能ヘリカルプラズマに向けた先進ヘリカル研究の進展」、水内亨

核融合科学研究所、「ヘリオトロン型プラズマ実験装置開発に関する歴史的資料収集・整理」、水内亨

核融合科学研究所、「先進ヘリカルによるコンパクト・高ベータ・定常炉の実現に向けた閉じ込め最適化研究」、佐野史道、花谷清、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン J 装置における ICRF 加熱実験」、武藤敬（核融合研）、佐野史道、花谷清、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「高速カメラによる Heliotron J 周辺プラズマの研究」、西野信博（広島大）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「トロイダル電流が MHD 平衡に与える影響の理論的考察とその実験的検証」、鈴木康浩（核融合研）、佐野史道、花谷清、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「Heliotron J 装置における電極バイアスによる径方向電場制御」、北島純男（東北大）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「フィルターと AXUV ダイオードアレイを用いた HeliotronJ プラズマのエネルギー閉じ込めにおける炭素不純物の影響に関する実験的研究」、田村直樹（核融合研）、佐野史道、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「方向性プローブを用いた揺動による粒子異常輸送の研究」、竹入康彦（核融合研）、佐野史道、花谷清、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン配位における MHD 平衡・安定性に関する研究」、榊原悟（核融合研）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「補助コイルを用いたヘリオトロン J 磁場配位最適化設計」、岡村昇一（核融合研）、佐野史道、山本聡、水内亨、岡田浩之

核融合科学研究所、「ヘリオトロン J 装置を用いた非中性プラズマのヘリカル磁気面閉じ込め実験」、比村治彦（京都工芸繊維大）、佐野史道、水内亨、岡田浩之

核融合科学研究所、「トリムコイルを用いた HeliotronJ プラズマの高エネルギー粒子閉じ込め改善の検討」、中村祐司（京大エネ科）、佐野史道、花谷清、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「サーマルプローブを用いたヘリオトロン J の周辺熱流束計測」、松浦寛人（大阪府立大）、水内亨、岡田浩之

核融合科学研究所、「ヘリオトロン J における多チャンネル Hα線放射計測器を用いた中性粒子輸送解析」、中嶋洋輔（筑波大）、水内亨、小林進二、岡田浩之

核融合科学研究所、「ヘリオトロン J の閉じ込め改善に向けた 3 次元磁場構造からの理論研究」、横山雅之（核融合研）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロンJにおけるビーム放射分光法を用いた密度揺動計測」、門信一郎（東京大）、水内亨、小林進二、岡田浩之

核融合科学研究所、「ヘリオトロンJにおける高効率燃料供給に向けたペレット入射の検討」、本島厳（核融合研）、佐野史道、水内亨、岡田浩之

核融合科学研究所、「極低磁場での電子バーンシュタイン波加熱のヘリオトロン J プラズマ閉じ込めへの影響」、東井和夫（核融合研）、佐野史道、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン J、CHS,LHD 装置における重水素プラズマの粒子輸送の研究」、田中謙治（核融合研）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「局所分布構造・長距離相関計測装置の高性能化による乱流揺動の構造解析と HJ-LHD 比較研究」、福田武司（大阪大）、佐野史道、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリカル系における電子サイクロトロン電流駆動による回転変換制御」、長崎百伸、佐野史道、花谷清、山本聡、水内亨、小林進二、岡田浩之

核融合科学研究所、「磁気計測による磁気島検出器の開発」、岡田浩之、佐野史道、山本聡、水内亨、小林進二、長崎百伸

Financial Support

1. Grant-in-Aid for Scientific Research
水内亨、基盤研究(C)、「プラズマ生成に伴うヘリカル磁場構造の変化」

小林進二、若手研究(A)、「荷電交換再結合分光装置の高速・高精度化と粘性の高いプラズマでの径電場微細構造」

向井清史、特別研究員奨励費、「ヘリオトロンJにおけるプラズマ粒子輸送特性の解明とその制御に関する研究」

2. Others
水内亨、共同研究（核融合科学研究所）、「ヘリオトロン型プラズマ実験装置開発に関する歴史的資料収集・整理」

水内亨、共同研究（核融合科学研究所）、「高性能ヘリカルプラズマに向けた先進ヘリカル研究の進展」

小林進二、共同研究（核融合科学研究所）、「強磁場側 ECH 入射によるイオンテール生成の実験的検証」

Publications

T. Mizuuchi, K. Murai, S. Watanabe, S. Yamamoto, S. Kobayashi, K. Nagasaki, H. Okada, G. Motojima, H. Arimoto, F. Hamagami, D. Katayama, H. Matsuoka, A. Nakajima, H. Takahashi, H. Yasuda, K. Mukai, Y. Kowada, K. Hosaka, S. Mihara, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, K. Kondo, F. Sano, Comparison of edge plasma behavior at different poloidal positions in Heliotron J, Journal of Nuclear Materials, 390-391, 428-431, 2009

Y. Nakashima, Y. Higashizono, H. Kawano, N. Nishino, S. Kobayashi, T. Mizuuchi, M. Shoji, K. Nagasaki, H. Okada, F. Sano, K. Kondo, Y. Yoneda, R. Yonenaga, T. Imai, Recycling studies based on two-dimensional visible light measurements and Monte-Carlo simulation in mirror and helical systems, Journal of Nuclear Materials, 390-391, 511-515, 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, K. Nagasaki, H. Okada, F. Sano, S. Yamamoto, K. Kondo, Measuremnt of peripheral plasma turbulence using a fast camera in Heliotron J, Journal of Nuclear Materials, 390-391, 511-515, 2009

T. Minami, S. Okamura, C. Suzuki, K. Matsuo, T. Oishi, T. Akiyama, M. Isobe, K. Ida, H. Nakano, A. Fujisawa, K. Nagaoka, M. Yoshinuma, Y. Yoshimura, K. Toi, S. Ohshima, M. Takeuchi, H. Iguchi, S. Nishimura, A. Shimizu, K. Matsuoka, C. Takahashi, Simultaneous realization of a high density edge transport barrier and an improved L-mode on CHS, Nuclear Fushion, 49, 8, 85018, 2009

N. Oyama and JT-60 Team, Overview of JT-60U results towards the establishment of advanced tokamak operation, Nuclear Fusion, 49, 104007, 2009

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, G. Motojima, S. Watanabe, A. Matsuyama, Y. Nakamura, K. Hanatani, K. Kondo, F. Sano and Heliotron J Group, Configuration control experiments in Heliotron J, Journal of Plasma Fusion Research, SERIES, Vol. 8, 981-986, 2009

S. Nishimura, Y. Nakamura, G. Motojima, H. Okada,

S. Kobayashi, S. Yamamoto, K. Nagasaki, K. Hanatani, K. Kondo, T. Mizuuchi, F. Sano, Effects of Configuration Control on the Neoclassical Viscosity in Heliotron-J, Journal of Plasma Fusion Research, SERIES, Vol. 8, 1003-1009, 2009

G. Motojima, K. Nagasaki, H. Okada, K. Watanabe, T. Mizuuchi, A. Matsuyama, K. Hanatani, S. Yamamoto, S. Kobayashi, Y. Suzuki, K. Kondo, Y. Nakamura, A.C.Fernández, Á.A. Cappa, Y. Yoshimura, S. Watanabe, K. Mukai, F. Sano, Experimental Study of Non-Inductive Current in Heliotron J., Journal of Plasma Fusion Research, SERIES, Vol. 8, 1010-1014, 2009

K. Nagaoka, S. Kobayashi, K. Hosaka, S. Yamamoto, T. Mizuuchi, M. Osakabe, Y. Takeiri, K. Nagasaki, H. Okada, K. Kondo, K. Hanatani, F. Sano, Observation of Fast Ion Response to MHD Activities in Heliotron J, Journal of Plasma Fusion Research, SERIES, Vol. 8, 1100-1103, 2009

K. Nagasaki, G. Motojima, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, K. Hanatani, S. Konoshima, K. Masuda, Y. Nakamura, S. Watanabe, K. Mukai, K. Hosaka, K. Kowada, S. Mihara, Y. Yoshimura, Y. Suzuki, A. Fernández, A. Cappa, F. Sano, Effect of magnetic field ripple on electron cyclotron current drive in Heliotron J, Nuclear Fusion, 50, 2, 25003, 2010

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Watanabe, K. Mukai, S. Kishi, H.Y. Lee, K. Minami, Y. Takabatake, H. Yashiro, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Effects of gas-fueling control on plasma performance in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

H. Okada, S. Kobayashi, S. Kishi, S. Mihara, T. Mutoh, T. Mizuuchi, K. Nagasaki, Y. Nakamura, T. Minami, S. Yamamoto, S. Ohshima, S. Konoshima, K. Mukai, H.Y. Lee, Y. Takabatake, K. Hanatani, F. Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

S. Kobayashi, K. Nagaoka, S. Yamamoto, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, Y. Suzuki, Y. Nakamura, Y. Takeiri, M. Yokoyama, K. Hanatani, K. Hosaka, S. Konoshima, S. Ohshima, K. Toushi, F. Sano, nergetic particle transport in NBI plasmas of Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

K. Nagasaki, K. Sakamoto, K. Minami, H. Yoshino, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, S. Ohshima, K. Mukai, S. Kishi, H.Y. Lee, Y. Takabatake, G. Motojima, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

K. Mukaia, K. Nagasaki, V. Zhuravlevd, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, D. Nishi, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, 17th International Stellarator Workshop/Heliotron Workshop, 2009

S. Kobayashi, H.Y. Lee, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, S. Yamamoto, H. Okada, T. Minami, S. Murakami, Y. Suzuki, Y. Nakamura, K. Hanatani, S. Konoshima, K. Toushi, F. Sano, Development of Highly Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, D. Nishino, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

K. Nagasaki, G. Motojima, K. Sakamoto, K. Minami, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, K. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernandes, A. Cappa, B. Blackwell, F. Sano, Study of Non-Inductive Current in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

F. Sano, T. Mizuuchi, K. Nagasaki, K. Hanatani, H. Okada, Y. Nakamura, T. Minami, S. Kobayashi, S. Yamamoto, S. Ohshima, S. Watanabe, K. Mukai, K. Minami, S. Kishi, A. Matsuyama, H. Lee, Y. Takabatake, H. Yashiroa H. Yoshino, S. Konoshima, B. Blackwell, Physics Research on the Heliotron J Confinement, 19th International Toki onference (ITC19), 2009

S. Yamamoto, H. Okada, S. Sakakibara, Y. Suzuki,

S. Kobayashi, T. Minami, T. Mizuuchi, K. Mukai, K. Nagasaki, Y. Nakamura, Y. Narushima, F. Sano, K.Y. Watanabe, Development of magnetic island detector by magnetic measurement in helical plasmas, 19th International Toki onference (ITC19), 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, F. Sano, Peripheral plasma measurement in Heliotron J using fast cameras, 19th International Toki onference (ITC19), 2009

M. Osakabe, S. Murakami, T. Itoh, M. Isobe, S. Kobayashi, T. Tokuzawa, K. Nagaoka, H. Nakano, K. Tsumori, K. Ikeda, Y. Takeiri, O. Kaneko and LHD-group, Evaluation of fast-ion confinement using radially injected neutral beam on LHD, 19th International Toki onference (ITC19), 2009

Lee Hyunyong（李炫庸）, 小林進二, 村上定義, 水内亨, 長崎百伸, 南貴司, 岡田浩之, 山本聡, 木島滋, 向井清史, 高畠優, 岸真太郎, 南桂史, 佐野史道, ヘリオトロン J における NBI プラズマ中の CX-NPA 解析, 日本物理学会 2009 年秋季大会，2009

水内亨，小林進二，山本聡，岡田浩之、長崎百伸，南貴司，向井清史，岸真太朗，李炫庸，南桂史, 高畠優, 大島慎介, 竹内正樹, 西野信博, 中嶋洋輔，中村祐司，花谷清，木島滋，佐野史道，ヘリオトロン J における 超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ・核融合学会年会，2009

小林進二，山本聡，岡田浩之，長崎百伸，南貴司，向井清史，岸真太朗，李炫庸，南桂史，高畠優，大島慎介，西野信博，中嶋洋輔，中村祐司，花谷清，佐野史道，ヘリオトロン J における超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ・核融合学会年会，2009

岡田浩之，山本聡，榊原悟，鈴木康浩，小林進二，長崎百伸，中村祐司，南貴司，水内亨，木島滋，渡邊清政，成嶋吉郎，向井清史，岸真太郎，李炫庸，高畠優，南桂史，佐野史道，磁気計測による磁気島検出器の開発, 第 26 回プラズマ・核融合学会年会，2009

高畠優，水内亨，西野信博，長崎百伸，岡田浩之，南貴司，小林進二，山本聡，木島滋，中嶋洋輔, 井尻芳行, 千住徹, 矢口啓二, 坂本欣三, 東使潔，芝野匡志，向井清史，李炫庸，岸真太郎，南桂史，佐野史道，静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析，第 26 回プラズマ・核融合学会年会，2009

岸真太郎，岡田浩之，水内亨，長崎百伸，花谷清，南貴司，小林進二，山本聡，木島滋，武藤敬，松山顕之，向井清史，李炫庸，高畠優，南桂史，佐野史道，ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率，第 26 回プラズマ・核融合学会年会，2009

Lee Hyunyong，小林進二，南貴之，門信一郎，水内亨, 長崎百伸, 岡田浩之，南貴司，山本聡，村上定義，鈴木康浩，中村祐司，花谷清，木島滋，向井清史，岸真太郎，高畠優，南桂史，香川輔，東使潔，佐野史道，ヘリオトロン J における荷電交換再結合分光計測，第 26 回プラズマ・核融合学会年会，2009

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡，木島滋，西大輔，南桂史，李炫庸，高畠優，岸真太郎，八代浩彰，佐野史道，マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測，第 26 回プラズマ・核融合学会年会，2009

南貴司，八代浩彰，小林進二，水内亨，岡田浩之，長崎百伸，中村祐司，花谷清，山本聡，木島滋，大島慎介，佐野史道，Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画, 第 26 回プラズマ･核融合学会年会, 2009

山本聡，中村佑司，岡村昇一，田部井優，西岡賢二，佐野史道，水内亨，長崎百伸，花谷清，岡田浩之，南貴司，小林進二，木島滋，大島慎介，ヘリカル軸ヘリオトロン磁場配位の最適化研究，第 26 回プラズマ・核融合学会年会，2009

南桂史，長崎百伸，坂本欣三，水内亨，岡田浩之，南貴司，小林進二，山本聡，木島滋，向井清史，李炫庸，岸真太郎，高畠優，佐野史道，ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験，第 26 回プラズマ・核融合学会年会，2009

杉本大地，比村治彦，平松秀朗，三瓶明希夫，政宗貞男，岡田浩之，山本聡，小林進二，水内亨，佐野史道，平行電場検証のための立体磁気軸ヘリオトロン J における非中性プラズマ閉じ込め実験，第 26 回プラズマ・核融合学会年会，2009

中野賢，松浦寛人，水内亨，岡田浩之，永岡賢一，ヘリオトロン J 実験グループ，ヘリオトロン J における周辺プラズマ熱流束に関する研究，第 26 回プラズマ・核融合学会年会，2009

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡, 花谷清, 木島滋, 大島慎介, 竹内正樹，西大輔，南桂史，Lee Hyunyong，高畠優，岸真

太郎，八代浩彰，佐野史道，ヘリオトロン J プラズマにおける電子密度分布の加熱特性依存性，日本物理学会第 65 回年次大会，2010

長崎百伸，南桂史，吉野隼生，坂本欣三，小林進二，山本聡，水内亨，岡田浩之，南貴司，増田開，花谷清，木島滋，大島慎介，竹内正樹，向井清史，Lee Hyunyong，岸真太郎，高畠優，吉村泰夫，本島厳，A. Cappa，佐野史道，先進ヘリカル配位における電子サイクロトロン電流駆動実験，日本物理学会第 65 回年次大会，2010

大島慎介，長崎百伸，山本聡，竹内正樹，水内亨，岡田浩之，小林進二，南貴司，花谷清，木島滋，佐野史道，ヘリオトロン J における周辺乱流計測のための静電プローブ，日本物理学会第 65 回年次大会，2010

竹内正樹，南貴司，田中謙治，水内亨，長崎百伸，岡田浩之，山本聡，小林進二，大島慎介，木島滋，花谷清，中村祐司，佐野史道，ヘリオトロン J における FIR レーザー干渉計の開発，日本物理学会第 65 回年次大会，2010

Presentations

K. Nagasaki, K. Sakamoto, K. Minami, G. Motojima, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, ECCD Experiment Using Upgraded Launcher in Heliotron J, Workshop on RF Heating Technology of Fusion Plasmas 2009, 九州国立博物館, 2009.9.16-18

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Watanabe, K. Mukai, S. Kishi, K. Minami, Y. Takabatake, H. Yashiro, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Effects of gas-fueling control on plasma performance in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

H. Okada, S. Kobayashi, S. Kishi, S. Mihara, T. Mutoh, T. Mizuuchi, K. Nagasaki, Y. Nakamura, T. Minami, S. Yamamoto, S. Ohshima, S. Konoshima, K. Mukai, H.Y. Lee, Y. Takabatake, K. Hanatani, F. Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

S. Kobayashi, K. Nagaoka, S. Yamamoto, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, Y. Suzuki, Y. Nakamura, Y. Takeiri, M. Yokoyama, K. Hanatani, K. Hosaka, S. Konoshima, S. Ohshima, K. Toushi, F. Sano, Energetic particle transport in NBI plasmas of Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

K. Nagasaki, K. Sakamoto, K. Minami, H. Yoshino, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, S. Ohshima, K. Mukai, S. Kishi, H.Y. Lee, Y. Takabatake, G. Motojima, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

K. Mukaia, K. Nagasaki, V. Zhuravlevd, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, D. Nishi, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

S. Kobayashi, H.Y. Lee, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, S. Yamamoto, H. Okada, T. Minami, S. Murakami, Y. Suzuki, Y. Nakamura, K. Hanatani, S. Konoshima, K. Toushi, F. Sano, Development of Highly Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

K. Nagasaki, G. Motojima, K. Sakamoto, K. Minami, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, K. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernandes, A. Cappa, B. Blackwell, F. Sano, Study of Non-Inductive Current in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, D. Nishino, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

F. Sano, T. Mizuuchi, K. Nagasaki, K. Hanatani, H. Okada, Y. Nakamura, T. Minami, S. Kobayashi, S. Yamamoto, S. Ohshima, S. Watanabe, K. Mukai, K. Minami, S. Kishi, A. Matsuyama, H. Lee, Y. Takabatake, H. Yashiro H. Yoshino, S. Konoshima, B. Blackwell, Physics Research on the Heliotron J Confinement, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

S. Yamamoto, H. Okada, S. Sakakibara, Y. Suzuki, S. Kobayashi, T. Minami, T. Mizuuchi, K. Mukai, K. Nagasaki, Y. Nakamura, Y. Narushima, F. Sano, K.Y. Watanabe, Development of magnetic island detector by magnetic measurement in helical plasmas, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

N. Nishino, T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, F. Sano, Peripheral plasma measurement in Heliotron J using fast cameras, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

M. Osakabe, S. Murakami, T. Itoh, M. Isobe, S. Kobayashi, T. Tokuzawa, K. Nagaoka, H. Nakano, K. Tsumori, K. Ikeda, Y. Takeiri, O. Kaneko and LHD-group, Evaluation of fast-ion confinement using radially injected neutral beam on LHD, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

T. Minami, Plan for new high repetition rate Nd:YAG Thomson scattering system on Heliotron J, Japan-Korea Workshop on Advanced Technology of Lasers for Understanding of Plasma Physics, Institute of Laser Engineering, Osaka University, 2010.1.28-29

Lee Hyunyong（李炫庸）, 小林進二, 村上定義, 水内亨, 長崎百伸, 南貴司, 岡田浩之, 山本聡, 木島滋, 向井清史, 高畠優, 岸真太郎, 南桂史, 佐野史道, ヘリオトロン J における NBI プラズマ中の CX-NPA 解析, 日本物理学会 2009 年秋季大会, 熊本大学黒髪キャンパス, 2009.9.25-28

水内亨, 小林進二, 山本聡, 岡田浩之, 長崎百伸, 南貴司, 向井清史, 岸真太朗, 李炫庸, 南桂史, 高畠優, 大島慎介, 西野信博, 中嶋洋輔, 中村祐司, 花谷清, 佐野史道, ヘリオトロン J における超音速分子ビーム入射法の適用とその効果, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

岡田浩之, 山本聡, 榊原悟, 鈴木康浩, 小林進二, 長崎百伸, 中村祐司, 南貴司, 水内亨, 木島滋, 渡邊清政, 成嶋吉郎, 向井清史, 岸真太郎, 李炫庸, 高畠優, 南桂史, 佐野史道, 磁気計測による磁気島検出器の開発, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

高畠優, 水内亨, 西野信博, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 中嶋洋輔, 井尻芳行, 千住徹, 矢口啓二, 坂本欣三, 東使潔, 芝野匡志, 向井清史, 李炫庸, 岸真太郎, 南桂史, 佐野史道, 静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

岸真太郎, 岡田浩之, 水内亨, 長崎百伸, 花谷清, 南貴司, 小林進二, 山本聡, 木島滋, 武藤敬, 松山顕之, 向井清史, 李炫庸, 高畠優, 南桂史, 佐野史道, ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

Lee Hyunyong, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 鈴木康浩, 中村祐司, 花谷清, 木島滋, 向井清史, 岸真太郎, 高畠優, 南桂史, 香川輔, 東使潔, 佐野史道, ヘリオトロン J における荷電交換再結合分光計測, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

向井清史, 長崎百伸, Vladimir Zhuravlev, 福田武司, 水内亨, 南貴司, 岡田浩之, 小林進二, 山本聡, 木島滋, 西大輔, 南桂史, 李炫庸, 高畠優, 岸真太郎, 八代浩彰, 佐野史道, マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

南貴司, 八代浩彰, 小林進二, 水内亨, 岡田浩之, 長崎百伸, 中村祐司, 花谷清, 山本聡, 木島滋, 大島慎介, 佐野史道, Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

山本聡, 中村佑司, 岡村昇一, 田部井優, 西岡賢二, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 木島滋, 大島慎介, ヘリカル軸ヘリオトロン磁場配位の最適化研究, 第 26 回プラズマ・核融合学会年会, 京都国際交流会館, 2009.12.1-4

南桂史, 長崎百伸, 坂本欣三, 水内亨, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 向井清史, 李炫庸, 岸真太郎, 高畠優, 佐野史道, ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験,

第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

杉本大地，比村治彦，平松秀朗，三瓶明希夫，政宗貞男，岡田浩之，山本聡，小林進二，水内亨，佐野史道，平行電場検証のための立体磁気軸ヘリオトロン J における非中性プラズマ閉じ込め実験，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

中野賢，松浦寛人，水内亨，岡田浩之，永岡賢一，ヘリオトロン J 実験グループ，ヘリオトロン J における周辺プラズマ熱流束に関する研究，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡，花谷清，木島滋，大島慎介，竹内正樹，西大輔，南桂史，Lee Hyunyong，高畠優，岸真太郎，八代浩彰，佐野史道，ヘリオトロン J プラズマにおける電子密度分布の加熱特性依存性，日本物理学会第 65 回年次大会，岡山大学，2010.3.20-23

長崎百伸，南桂史，吉野隼生，坂本欣三，小林進二，山本聡，水内亨，岡田浩之，南貴司，増田開，花谷清，木島滋，大島慎介，竹内正樹，向井清史，Lee Hyunyong，岸真太郎，高畠優，吉村泰夫，本島厳，A. Cappa，佐野史道，先進ヘリカル配位における電子サイクロトロン電流駆動実験，日本物理学会第 65 回年次大会，岡山大学，2010.3.20-23

大島慎介，長崎百伸，山本聡，竹内正樹，水内亨，岡田浩之，小林進二，南貴司，花谷清，木島滋，佐野史道，ヘリオトロン J における周辺乱流計測のための静電プローブ，日本物理学会第 65 回年次大会，岡山大学，2010.3.20-23

竹内正樹，南貴司，田中謙治，水内亨，長崎百伸，岡田浩之，山本聡，小林進二，大島慎介，木島滋，花谷清，中村祐司，佐野史道，ヘリオトロン J における FIR レーザー干渉計の開発，日本物理学会第 65 回年次大会，岡山大学，2010.3.20-23

Advanced Energy Research Section

David S. Gelles, Foreign Visiting Professor
(Staff Engineer, retired, Energy and Environment Directorate,
Engineering Mechanics and Structural Materials Group II,
Pacific Northwest National Laboratory, of America)

1. Summary

The author will present a personal perspective on materials development for fast breeder reactor cladding and for the fusion reactor first wall.

2. Introduction

Opportunities for well-funded materials development programs are rare. The author has been fortunate to have spent most of his career working on two such programs. Starting in 1974 and continuing for about 15 years, an effort was made to find an improved material for fast breeder reactor fuel cladding. As that program approached its end, an effort was established to provide a material for a fusion reactor first wall, a program sharing similar objectives. The fusion program continues. This paper is intended to provide a personal history of both programs.

3. LMFBR

The US Department of Energy liquid metal fast breeder reactor (LMFBR) materials development program was established in 1974 in order to find an improvement over 316CW for fuel cladding. It had been found that in the course of irradiation in a fast reactor, 316 stainless steel develops cavities, or voids, that can lead to large dimensional changes. Cold working provided some improvements over annealed 316. After reactor components reach a critical size, they must be removed, and use of a more stable material was expected to improve fuel lifetimes. The program considered several options, developmental stainless steels, with, for example, titanium additions, precipitation strengthened iron and nickel based superalloys, such as Nimonic PE16 and Inconel 706, and super 12% Cr martensitic steels such as HT-9. However, refractory alloys such as vanadium and lower chrome ferritic steels were not considered due to poor corrosion resistance in liquid sodium, although some tests on molybdenum alloy TZM and Nb-1Zr were included. This program considered both commercial alloy options as well as unique alloys developed by the program to give further improvements.

Re-irradiation experiments were attempted, using neutron irradiated specimens for follow-on electron irradiations in order to quickly reach goal fluences. However, comparison of neutron irradiation and electron irradiation results demonstrated that although electron irradiations were generally successful at predicting neutron response, occasional misleading results were obtained, and if neutron testing was required to find the misleading examples, electron irradiation was not necessary. Also, electron irradiation of neutron irradiated samples sometimes gave misleading results, due to what might be termed temperature change problems. For example, if neutron irradiation produced a fine structure and the subsequent electron irradiation a coarser one, then the electron irradiation response was at least initially controlled by the finer microstructure, and therefore re-irradiation experiments were often very difficult to interpret.

As the program evolved, the following conclusions were reached. Stainless steels could indeed be improved by the addition of titanium and similar elements. The onset of swelling could be delayed considerably, but not prevented, and the peak swelling temperature was shifted to lower temperatures, so that high temperature response could be very good. Precipitation strengthened superalloys showed great promise until it was discovered that post-irradiation elongation values could be reduced to zero for tensile testing 110°C above the irradiation temperature, considered an important property in a loss-of-coolant situation. The problem was traced to a solute segregation effect. As point defects created during irradiation seek lower energy sites, they drag precipitation strengthening solutes such as aluminum and titanium to sinks such as grain boundaries, resulting in precipitation coated boundaries that lead to premature failure. Refractory alloys produced some unusual responses; for example, TZM developed a void lattice as well as dislocation loop arrays in rafts. The alloy class with the most interesting properties was the super 12% Cr steels. HT-9 was found to be very resistant to swelling, in the worst case producing about 2% swelling after 200 dpa. Use of HT-9 for reactor cladding required lowering the reactor operating temperature by about 50°C, but savings in fuel lifetime made up for the reduction in efficiency. Also, post irradiation embrittlement was observed in Charpy impact and fracture toughness testing, requiring special care during fuel handling.

When it became apparent that the LMFBR materials development program was not going to use Nimonic PE16 for fuel cladding, the International Nickel Company shared with us a patent for a fuel cladding material made by mechanical alloying: MA957. MA957, an yttrium oxide dispersion strengthened (ODS) alloy appeared to offer the advantages of low swelling gained from HT-9, but with much high operating temperatures possible. As a result, in reactor testing was begun, a purchase was made of sufficient MA957 bar stock for fuel testing, and efforts were initiated to have reactor fuel cladding made to tight tolerances. Given the hardness of this material and the tendency for loss of properties due to secondary recrystallization, tubing production by qualified vendors turned out to be a challenging problem. Eventually, tubing was successfully made by two vendors, but cracking was found in many of the tubes. At that point in time, politics took over, the US government decided not to pursue further LMFBR development and the program ended.

4. Fusion

In 1978, a program was begun in the US to develop a material for a fusion first wall. The requirements for such a material were similar to those for LMFBR fuel cladding. The operating temperatures were expected to be similar by design, with higher energy neutrons involved and goals to similar doses (40 MWyr/m2). The program began with a program similar to the LMFBR cladding/duct program, involving four classes of materials of interest: Austenitic Alloys, Fe-Ni-Cr Superalloys, Reactive and Refractory Metals and Alloys, and New Concepts. In 1979, ferritic steels, such as HT-9, were added to the New Concepts class, based on successes in the LMFBR program.

This program differed from the LMFBR program in a number of ways. Whereas fast reactors produced neutrons as high as 1 MeV in energy, the fusion reaction produced 14 MeV neutrons, with significant consequences regarding resulting transmutation production of helium and hydrogen. Furthermore, no convenient source of 14 MeV neutrons existed for testing to high dose so only simulation environments were possible, and efforts were made to use fission reactors and to study the physical differences with low dose 14 MeV experiments, instead. Therefore, two parallel efforts resulted, one to find a first wall material, and the second to understand the physics and the physical differences between fission and fusion environments.

In 1983, radioactive waste conditions were defined by the US Atomic Energy Commission for shallow waste burial and the program redefined objectives to include materials development for shallow waste burial, called “low activation” materials. In effect, this meant removing Nb, Mo, and Ni from first wall materials because these elements produced long-lived isotopes in fusion environments. As a result, stainless steels and precipitation strengthened superalloys needed to be redesigned without Ni, perhaps by substituting Mn, and Nb and Mo needed to be replaced as strengthening agents, perhaps by Ta, V and W. Therefore, a spent fusion reactor made from low activation materials could be disposed of by shallow land burial, and would become benign after about 100 years, making it more environmentally friendly than a fission reactor, which required 10,000 years to become benign.

The fusion materials development program evolved similarly to the LMFBR program. Austenitic steels had disadvantages from swelling and thermal conductivity issues, and Mn replacement for Ni offered no advantages. Precipitation strengthened superalloys were out of consideration due to embrittlement arising from solute segregation, but martensitic steels showed promise, with W working effectively as a substitute for Mo and with improvements to irradiation embrittlement, but still with high temperature limitations. Vanadium alloys remained a viable choice provided compatibility with lithium could be established, but in this case compatibility required development of an insulating layer, to avoid magneto-strictive issues. A third alternative emerged, consider long term but with advantages if problems of fracture toughness and compatibility could be solved, silicon carbide-silicon / carbide composites. The effort also became international, with joint programs established with Japan, Europe and Russia.

Most recently, the US fusion program has shifted to emphasize an ODS ferritic alloy option in order to improve reactor efficiency by operating at higher temperatures. The program continues with greater emphasis on computer simulation, less available neutron irradiation facilities and still no source of high energy neutrons.

Figure 1 FFTF in Richland, WA

Advanced Energy Research Section

Sadruddin Benkadda, Foreign Visiting Professor
(Professor at Centre National de la Recherche Scientifique (CNRS) / Universite de Provence, France)

1. Introduction

From 1st December 2009 until the end of March 2010, I was hosted at the Institute of Advanced Energy. This continues collaboration with Heliotron J group on theoretical fusion plasma physics. I also gave some Institute seminars to the graduate students as shown below.

2. Research

Advances in understanding the complex nature of turbulent transport in magnetized fusion plasmas have been produced recently. From this point of view, buoyancy-driven flows such as thermal convection are of great importance for a wide range of phenomena in geophysical, astrophysical and fusion plasmas [1,2,3]. We consider here intermittent aspects of convective turbulence and transport in magnetized plasma of magnetic fusion machines such as tokamaks or stellarators. These investigations use Direct Numerical Simulation (DNS) of Ion Temperature Gradient instability (ITG) which is identical to the Rayleigh–Bénard thermal convection problem in neutral fluids [4,5,6]. Rayleigh–Bénard convection in particular is a fundamental paradigm for nonlinear dynamics including instabilities and bifurcations, pattern formation, chaotic dynamics and developed turbulence. Using a weakly non-linear analysis, we show that the back-reaction on the mean profile is the natural mechanism for saturation and suggest that it will stay the main non-linear coupling mechanism in the turbulent state. We also will review some basic aspects of the interaction between convective cells and a mean flow [7,8]. In particular and still along the line of the "defreezing" assumption we study the behavior of a model for shear flow instability: transient bursts of vorticity flux are generated in this model. We briefly discuss the advantage of this kind of formulation compared to the "non-normal" operator approach where the mean velocity is also assumed frozen. An extension of Herring model is derived. It takes into account the self-consistent generation of a mean flow. It is shown that our model has substantially richer dynamics than the one of Herring. In particular the interaction between the convective modes and the mean flow leads in the turbulent state to a transition in the statistical properties of the transport. This bifurcation is analogous the so-called soft to hard turbulence transition in convection. In the strongly turbulent state, intermittent bursts of thermal transport are observed in both cases. For the latter regime, the reduced model as well as DNS show that the Nusselt number Nu (normalized heat flux) scales with the normalized ion pressure gradient K_i as Nu ~ $K_i^{1/3}$[6]. Since the Rayleigh number for ITG turbulence is proportional to K_i, the Nusselt number scaling for ITG turbulence is thus similar to the classical Globe & Dropkin scaling for Rayleigh–Bénard convection in neutral fluids.

3. Seminars

- December 21st (Mon) 2009 : 15:30-17:30
  Advances in Understanding the Complex Nature of Turbulent Transport in Magnetized Fusion Plasmas.
- January 18th (Mon) 2010 : 15:30-17:30
  Signal Processing Techniques for Characterizing Nonlinear Processes in Turbulent Plasmas.
- February 8th (Mon) 2010 : 15:30-17:30
  Multiscale Physics in Magnetic Fusion Plasmas.
- February 22nd (Mon) 2010 : 15:30-17:30
  Characterization and Control of Relaxation Oscillations in Fusion Devices.

References

[1] S. Benkadda, P. Beyer, N. Bian *et al*, Nuclear Fusion **41**, 997 (2001) [2] H. Sugama and S. Nishimura, Phys. Plasmas **9**, 4637 (2002); **15**, 042502 (2008)
[2] P. Beyer, S. Benkadda, X. Garbet and P.H. Diamond, Phys. Rev Letters **85**, 4892 (2000).
[3] Amita Das, Abhijit Sen, and Predhiman Kaw, S. Benkadda and Peter Beyer, Physics of Plasmas 12, 032302 (2005).
[4] K. Takeda, S. Benkadda, S. Hamaguchi and M. Wakatani, Physics of Plasmas **11**, 3561-3571 (2004).
[5] K. Takeda, S. Benkadda, S. Hamaguchi and M. Wakatani, J. Plasma Fusion Res **6** 570 (2004).
[6] K. Takeda, S. Benkadda, S. Hamaguchi, M. Wakatani, Physics of Plasmas 12, 052309 (2005).
[7] N. Bian, S. Benkadda, X. Garbet, O. Garcia, J. Paulsen, Physics of Plasmas, **10**, 1382, (2003).
[8] O. Garcia, N. Bian, J. Paulsen , S. Benkadda and K. Rypdal, Plasma Physics and Controlled Fusion **45**, 919-932, (2003)

Advanced Energy Research Section

Jürgen Reif, Foreign Visiting Professor
(Professor, Chair of Experimental Physics / Materials Science, Brandenburgische Technische Universität Cottbus, Cottbus, Germany)

1. Introduction

I had the pleasure of spending three months from mid December 2009 to mid March 2010 as a Visiting Professor at the Institute of Advanced Energy (IAE), Kyoto University, upon invitation by Professor Kenzo MIYAZAKI. During the last almost ten years both of us have been working on the fascinating topic of nano-structure formation on solid surface, induced by laser ablation with femtosecond pulses. Independently, we observed very similar structures on quite different materials as well as a similar influence of different experimental parameters on the nano-structure properties. The microscopic, atomic-level physical processes underlying this structure formation being, however, by far not understood, the visit was intended to exchange and join our mutual experience and to devise new strategies for a route to elucidate the phenomenon.

2. Seminars and lectures

Since, as a professor, I am not only a scientist but also a teacher, during my stay I did not only present our recent work and the status of our ideas about the fundamental processes, but also enjoyed to give a series of lectures on the basic phenomena of laser ablation, which was attended not only by members of the Miyazaki group but also by other graduate students and researchers.

Once being in Japan, I also accepted an invitation by Dr Koji SUGIOKA, Laser Technology Laboratory at RIKEN, to visit the laboratory and to present our latest research at RIKEN. Again, the seminar was attended by an impressive number of researchers.

3. Scientific

The laser generation of sub-wavelength nano-structures on solid surfaces bears, in principle, a very high potential for technological applications, from nano-lithography to processing of functional surfaces (manipulation of tribological properties, "black silicon", point-emitter arrays, marking …). Though empirically applied already in several reports, the experiments lack, so far, from a realistic possibility of fully controlling the structures.

Both, my group at BTU Cottbus and Professor MIYASAKI's group at IAE, have achieved similar but also complementary knowledge about the empirical influence of several parameters on the structuring. We both also have developed already different approaches for the basic physical interactions. During my visit we had the opportunity to exchange our ideas and to define a possible route to combine our findings and ideas to develop a promising model for the basic processes underlying the nano-structure formation.

4. Future

The main outcome of my visit is the strong incentive to start a collaboration joining our complementary experience and ideas. An excellent way will be a joined German-Japanese proposal in the framework of the DFG-JSPS "Memorandum of Understanding (MOU) on Scientific Cooperation", complemented by the MOU on "German-Japanese Graduate Externship – International Research Training Groups".
The combination of both programmes will allow the funding of graduate students and research as well as regular joint seminars bringing together both partner groups to share and exchange latest results. This will not only promote the knowledge about and thus the controllability of the laser-induced structure formation, but also the bi-national scientific exchange.

Advanced Energy Research Section

C.H.Zhang, Foreign Visiting Associate Professor
(Associate Professor, Institute of Modern Physics, Chinese Academy of Sciences)

1. Introduction

Because of inferior creep strength of conventional ferritic steels at elevated temperatures, oxide-dispersion-strengthened (ODS) ferritic steels were developed, by introducing nano-sized oxide particles (usually oxides of yttrium) in the ferrite matrix via a mechanical alloying (MA) procedure and subsequent hot static press (HIP) or hot extrusion procedures [1]. Previous studies show that ODS ferritic steels have significantly improved creep rupture strength [2], higher resistance to neutron irradiation [3,4] and to helium accumulation [5,6,7]. These merits make the ODS ferritic steels highly applicable to the cladding materials of fuel pins in fast reactors, or to structure materials of the blanket vessel in fusion reactors. Recent study showed that the increase of Cr concentration up to 16wt% significantly increased the corrosion resistance of the ODS ferritic steels to super critical pressurized water, meanwhile still keep the thermal stability against the thermal aging embrittlement which has been a concern for high-Cr ferritic steels used at elevated temperatures [8]. And the addition of Al to a percentage of about 4 wt.% makes the ODS alloy show good corrosion resistance to Pb-Bi eutectic coolant. Since the properties of ODS ferritic steel are strongly dependent on the structure of the finely distributed oxide particles, a understanding about the chemical and crystalline features of the oxide particles is of fundamental importance for the optimization of properties of the ODS steels.

In the present work microstructures of dispersoids in two high-Cr Al-added ODS ferritic steels (commercial MA956 and an ODS ferritic steel recently developed in Kyoto University) were studied.

2. Results and Discussion

Typical morphologies of the dispersoids in the specimens of the two ODS steels under TEM are shown in Fig.1 (a) and (b). Good contrast is obtained when observed with the incident electron beam close to some low-index axis like [110], [111] or [113]. Dislocation segments generally along the extrusion direction were observed in some two-beam conditions. There is a high concentration of dispersoids (with sizes ranging from a few nanometers up to more than 100 nm) in the grains. By combining bright-field images and an estimation of the foil thickness with converged-beam electron diffraction (CBED) [10], the number density and size-distribution of the dispersoids in the specimens can be obtained. The effective diameter with the highest frequency occurs at about 10 nm and 6 nm while the number densities are around 5x1015 cm-3 and 3x1016 cm-3 in the MA956 and the 16Cr-3.5Al ODS steel, respectively, as shown in Fig.1(c).

More details about the crystalline structure and chemical composition of the nano-sized dispersoids can be obtained by using the extraction replica technique, which supplies an enhanced image contrast and a reduced background absorption. A typical morphology of the dispersoids retrieved in a carbon film from the MA956 is shown in Fig.2 (a). We found that the fine dispersoids in the ODS steels can be efficiently retrieved in the thin carbon films. A size-distribution of the dispersoids retrieved in the carbon films from each of the two ODS steels was found to be close to that from the thin foils as shown in Fig.1 (c).

Selected area diffraction (SAD) patterns of individual particles in the carbon replica showed that they are in perovskite structure (of orthorhombic YAP with a proposed chemical formula YAlO3 [11]), or in tetragonal or BCC structures of garnets (YAT or YAG with a proposed chemical formula Y2Al3O5). Since the investigation of individual oxides with SAD patterns usually tend to make use of relatively larger particles with a zone axis close to the electron-beam direction, the results do not ensure a good statistics especially over fine oxide particles in specimens. We thus tried to make use of the polycrystalline rings from SAD over a large number of fine particles in a region of the replica specimens. The SAD patterns exhibit three relatively intensive rings. The radii of the rings (under an acceleration voltage of 200kV and a camera length of 60 cm). It can be seen that the three strong rings of the SAD pattern can be readily ascribed to some low-index reflections like (020), (031), (320) respectively of YAP, which has a structure of perovskite (space group: Pbnm, a=5.179Å, b=5.329Å, c=7.370Å). From the

SAD pattern with shorter exposure time the ring proposed from the (110) of YAP, close to the direct beam, can also be seen. On the other hand, rings corresponding to proposed strong lower-index reflections of other structures like tetragonal or cubic (of garnets or pure Y2O3) were not obvious. Another proposed hexagonal structure of YAH, which was proven to be the main species among oxides in a Ni-based ODS alloy MA6000 [11]) was not found to be the main species in the present ODS steels.

With the fine probe (1 nm in beam-size) in the STEM mode, the energy-dispersion spectrometry (EDS) point measurement supplied relative atomic concentrations of the main elements in individual fine particles. Most of the observed fine particles were found to be complex oxides contains Y, Al and O, as reported in a similar Al-added 20Cr ODS ferritic steel of PM2000 [12]. The ratios between the measured atomic concentrations of the main elements were given as a function of the effective diameter of the oxide particles. The ratio between Al and Y falls around 1 for different sizes of the oxides. The oscillation of the ratios of Y-C, Al-C, O-C with oxide size is ascribed to the variation of thickness of the local carbon film, which tended to overlap in some area and thus increase the local thickness. The carbon film of the replica contains oxygen (due to O absorption during exposure in air), and results in a high concentration of oxygen from EDS spectra of the small oxides. With the increase of the oxide size, the volume fraction of the oxides in the local region of the specimen increases, so that the measured O-Y atomic ratio approaches to the ratio of O-Y in the oxide. The ratio of Y-O is close to 3:1 in an oxide with a large effective diameter of about 50 nm. It is thus suggested that the oxides tend to have a chemical formula of YAlO3, which is in good agreement with a proposed structure of perovskite of YAP from the SAD patterns. The ratio of Ti-Y is generally much lower than the ratio of Al-Y, indicating the Ti is not a major constitute in the oxides in the present ODS steels. The presence of Ti in the EDS spectra is attributed to contribution from the nearby large titanium carbonitride (Ti(CN)) particles in the replica specimen.

From the point EDS analysis, there is also a small portion of large particles in both the ODS steels, which generally have sizes over 100 nm and were in polygonal shapes, do not contain the element of yttrium. An investigation by combining SAD analysis showed that these fewer large particles are mainly pure alumina (Al2O3) and titanium carbonitrides (Ti(CN)).

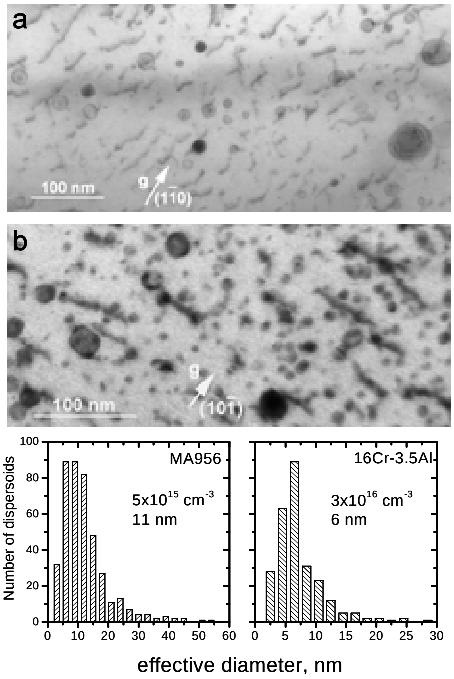

Fig.1 Typical morphologies of the dispersoids in the specimens of the two ODS steels.

3. Conclusions

The microstructural investigation of the commercial ODS steel MA956 and a 16Cr-3.5Al ODS ferritic steel showed that the nano-sized oxides in the alloys consist mainly of a complex Y-Al-O compound (YAlO3) in a perovskite structure (of YAP), together with other compounds in tetragonal or cubic structure of garnet in smaller percentage. The comparison between the two ODS steels shows that the size distribution and the number density of the oxide particles depends significantly on the conditions of fabrication.

References

[1] J.S.Benjamin, Metall Trans 1 (1970) 2943—2951.

[2] S.Ukai, T.Nishida, H.Okada, M. Fujiwara, J. Nucl. Sci. Technol. 34 (1997) 256-263.

[3] A. Alamo, J.L. Bertin, V.K. Shamardin, P. Wident, J.Nucl.Mater. 367-370 (2007) 54-59.

[4] T.Yoshitake, T.Ohmori, S.Miyakawa, J.Nucl.Mater. 307-311 (2002) 788-792.

[5] E.A.Little, D.J.Mazey, W.Hanks, Scripta Metall. Mater. 25 (1991) 1115-1118.

[6] I.S. Kim, J.D. Hunn, N. Nashimoto, D.L. Larson, P.J. Maziasz, K. Miyahara, E.H. Lee, J. Nucl. Mater.,280 (2000) 264-274.

[7] K. Yutani, H. Kishimoto, R. Kasada, A. Kimura, J.Nucl.Mater. 367-370 (2007) 423-427.

[8] A. Kimura, et al., J. Nucl. Sci. & Technol. 44 (2007) 323-328.

Advanced Energy Materials Research Section

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1. Introduction

The importance of materials development for future energy systems has been growing more rapidly in this decade. Gas cooled fast reactor (GFR), very high temperature reactor (VHTR), and fusion reactor are the potential candidates, where the materials are responsible to keep the plant performance under very severe environment including high-temperature, high energy neutron bombardment, and stress and thermal fatigue. The mission of our research section is to develop the ceramic based composites to improve the plant efficiency owing to the excellent high temperature properties. The research field may be divided into two main topics of studies on 1) radiation effects and the underlying mechanisms, and 2) material development. Both are playing important roles in national and international programs for R & D of energy materials such as TITAN (Japan-US joint project) and ITER project and so on.

2. Development of advanced SiC/SiC composites

In comparison to the best high-temperature alloys, silicon carbide fiber-reinforced silicon carbide matrix (SiC/SiC) composites have excellent high temperature properties such as chemical stability and mechanical properties in both neutron irradiation and non-irradiation conditions. In addition to the inherent superior heat and irradiation resistance of SiC/SiC, the very light and low activation features are attractive. Nano Infiltration and Transient Eutectic phase (NITE) process, which was developed in our research group, is the first successful application of liquid phase sintering (LPS) for matrix densification of SiC/SiC in the world. The matrix in NITE SiC/SiC consists of well-crystallized SiC grains with small remnants of the metal oxide sintering additives. Such the pure polycrystalline SiC matrix provides excellent radiation resistance of the NITE SiC/SiC composites similar to that of Chemical Vapor Infiltration (CVI) SiC/SiC. The differences in properties between NITE and CVI SiC/SiC, if any, may be mainly caused by the difference in the populations of open and closed pores. The highly dense feature of NITE SiC/SiC improved many material properties as stated follows for some examples. A heat flux capacity of NITE SiC/SiC is superior comparing to other candidate of plasma facing materials, so that it is expected that NITE composite has an excellent figure of merit against the thermal stresses. Satisfactory results for reducing the leakage of helium gas as a coolant gas in the reactor were also confirmed.

3. Development of evaluation methods for Advanced SiC/SiC

Since the multiple phases of fiber/interface/matrix make the mechanical properties even more complex, various testing methods for different fracture mode should be employed. Our research group has made efforts to develop and improve the testing methods so far such as monotonic tensile, in-plane tensile strength, transthickness tensile strength, and diametral compression test. Note that, all tests were successfully conducted using small specimens aiming to reduce the volume of radioactivated samples at post irradiation experiments. The validity of diametral compression test was confirmed at ambient temperature by comparing trans-thickness tensile test standardized in ASTM C1468. Inter-laminar shear/tensile strengths was confirmed to be increased at 1573K, due to the relaxation of residual stress caused by the coefficient of thermal expansion (CTE) mismatch between interface and matrix/fiber. At an elevated temperature in $Ar+O_2$, PyC interface was deteriorated and inter-laminar shear/tensile strengths were decreased. Double-notched shear (DNS) test and diametral compression tests were conducted in the temperature range of 298-1573K, in air, Ar or $Ar+O_2$ atmospheres. Our recent testing method of hoop strength is very unique, where the stress is applied through the compression of polyurethane preliminarily embedded in the tubular specimen. Based on the comparison with the results of the standardized testing following ASTM D2290, the validity was confirmed at ambient temperature. The alternative deformable metals or ceramics planned to be embedded in the tubular for testing at high temperature.

4. Engineering research on joining of materials for nuclear energy systems

One of the key issues to use SiC/SiC in neutron environment is the development of joining and coating techniques. In the case of joining of SiC and/or SiC/SiC each other, our joint technique using the same joint material of SiC has an advantage especially under the high heat flux due to the lack of CTE mismatch. Indeed, the advanced NITE process allows the SiC and SiC/SiC to be joined smoothly and stiffly with complicated shapes comparing to other conventional joining process. Particularly, the techniques of processing and joining were developed for application of the compact intermediate heat exchanger (IHX) using the NITE SiC/SiC. Grooving on plate for channel in the IHX and screwing on tube for joining to IHX were succeeded without chipping. The joining technique to form SiC as joining layer was developed using hot press. The scale model with 10 cm square was developed using the joining technique (Fig.1).

Fig.1 The scale model with 10cm square for compact intermediate heat exchanger (IHX) using the NITE-SiC/SiC composites with channel.

Fundamental study of interface of dissimilar joints or metal coated SiC materials are ongoing in parallel with the engineering developments. For example, tungsten coated SiC is attractive for fusion application, and the diffusion bonding process has been developed. The joint's interfacial microstructure, mechanical properties, and joining mechanism were evaluated. A tough SiC/W joint has been obtained, indicating the applicability to the plasma facing components in the fusion reactors.

The techniques to bond SiC and SiC/SiC to general purpose construction materials, *i.e.* stainless steel, has been also developed for broadening the practical applications of SiC. Two step joining method has been developed for SiC/steel joints. The first step is joining of SiC to W or W alloy by diffusion bonding. The second step is joining of SiC/W to steel with the intermediate layer of Ni or Cu which is inserted to reduce the residual stress at the joint interface. The excellent strength of the joints was demonstrated by various shaped SiC/steel components.

5. Modeling of microstructural evolution in β-SiC under irradiation

Crystal lattice defects produced by neutron bombardments cause the microstructural changes and resulting material property change. In order to evaluate the atomistic behavior and to understand the kinetics of defects, some energetic parameters such as defect formation energies and migration energies are essential.

Formation energies and stable configurations of self-interstitial atom (SIA) clusters in β-SiC are calculated using a classical molecular dynamics (MD) method using Gao-Weber potential based on the Brenner potential formalism in our theoretical research group. The properties of SIA clusters with various sizes and composition of silicon (Si) and carbon (C) interstitials are studied in the MD simulations of 1000 unit cells. Temperature condition is started at elevated temperature and reduced to 0 K during the calculation to obtain the total energy.

From these formation energies of SIA-clusters, binding energy of an SIA to SIA-clusters can be obtained. Defect energies such as binding energies are very important to investigate formation kinetics of defect clusters. Some of microstructural defects in SiC were experimentally observed by TEM following irradiation at DuET facility, Kyoto University, where the size and populations are consistent with our theoretical results.

6. Irradiation effects on tensile and interfacial properties of advanced SiC/SiC

In order to clarify the radiation effects on tensile and interfacial properties of SiC/SiC, cyclic tensile tests were conducted and the hysteresis loop analysis method was applied for the investigation. Neutron irradiation was performed at JOYO (Oarai, Ibaraki). Nominal fluence and irradiation temperature were 3.1×10^{25} n/m^2 at 740^{o}C and 1.2×10^{26} n/m^2 at 750^{o}C. The ultimate tensile strength and proportional limit stress of composites in both conditions showed excellent irradiation resistance. The hysteresis loop analysis indicated that the sliding stress at fiber/matrix interfaces was not changed after irradiation to 3.1×10^{25} n/m^2 at 740^{o}C, whereas it was significantly reduced by 1.2×10^{26} n/m^2 at 750 ^{o}C for both composites.

7. Development of Nondestructive test method for NITE SiC and SiC/SiC

To apply the SiC and SiC/SiC as structural components for advanced energy systems, evaluation method has to be developed to insure structural soundness and reliability under in-service or pre-service. The defects detection capability of Ultrasonic Test (UT) methods (C-Scan method and Pulse-echo reflection method) on SiC and SiC/SiC has been investigated. Particularly, the examination sensitivity limit of UT method based on C-Scan method was performed by inserting an artificial defect in SiC ceramics. The UT inspection was performed in axial and planar direction to detect the measurement limit of width and depth. The type and frequency of transducer was used focused-immersion type and 50 MHz, respectively. The detection limit by UT method was decided to be 70 μm.

Collaboration Works

東義大学（大韓民国）、「新プロセスによる先進 SiC/SiC 複合材料の開発と耐環境特性評価」、檜木達也、Han-Ki Yoon

Oak Ridge National Laboratory（米国）、「TAITAN (Tritium,Irradiation and Thermofluid for America and Nippon) Task2-2 接合・被覆システムの健全性」、檜木達也、T.Yamamoto (UCSB)、Y.Katoh (ORNL)

Oak Ridge National Laboratory（米国）、「TAITAN (Tritium,Irradiation and Thermofluid for America and Nippon) Task2-3 動的変形挙動」、檜木達也、Y. Katoh

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、M. Ferraris、Y. Katoh

核融合科学研究所、「SiC/SiC 複合材料の熱・電気伝導特性に及ぼす構成要素の影響」、檜木達也

核融合科学研究所、「低放射化構造材料の W 被覆プロセス技術開発研究」、木村晃彦、檜木達也、笠田竜太

東北大学金属材料研究所附属量子エネルギー材料科学国際研究センター、「次世代原子力エネルギー用 SiC/SiC 複合材料及び SiC の中性子照射効果」、檜木達也

Financial Support

檜木達也、共同研究（日本原子力研究開発機構）、「加速器を用いた SiC セラミックスの照射損傷組織及びスウェリングに関する研究」

檜木達也、共同研究（日本原子力研究開発機構）、「SiC/SiC 複合材料の破損挙動に関する研究」

Publications

K. Shimoda, T. Hinoki, Y. Katoh, A. Kohyama, Development of the tailored SiC/SiC composites by the combined fabrication process of ICVI and NITE methods, Journal of Nuclear Materials, 384, 2, 103-108, 2009

T. Nozawa, T. Hinoki, A. Hasegawa, A. Kohyama, Y. Katoh, L.L. Snead, J.C.H. Henager, J.B.J. Hegeman, Recent advances and issues in development of silicon carbide composites for fusion applications, Journal of Nuclear Materials, 386-388, 622-627, 2009

H.C. Jung, Y.H. Park, J.S. Park, T. Hinoki, A. Kohyama, R&D of joining technology for SiC components with channel, Journal of Nuclear Materials (C), 386-388, 847-851, 2009

Y.H. Park, T. Hinoki, A. Kohyama, Development of multi-functional NITE-porous SiC for ceramic insulators, Journal of Nuclear Materials, 386-388, 1014-1017, 2009

K. Shimoda, J.S. Park, T. Hinoki, A. Kohyama, Microstructural optimization of high-temperature SiC/SiC composites by NITE process, Journal of Nuclear Materials, 386-388, 634-638, 2009

Y.H. Park, T. Hinoki, A. Kohyama, Process development for porous Si-based ceramics by a decarburization method, Journal of Ceramic Processing Research, 10, 3, 286-289, 2009

K. Shimoda, A. Kohyama, T. Hinoki, High mechanical performance SiC/SiC composites by NITE process with tailoring of appropriate fabrication temperature to fiber volume fraction, Composites Science and Technology 69, 10, 1623-1628, 2009

J.J. Sha, T. Hinoki, A. Kohyama, Microstructure and mechanical properties of Hi-Nicalon™ Type S fibers annealed and crept in various oxygen partial pressures, Materials Characterization, 60, 8, 796-802, 2009

Z. Zhong, T. Hinoki, A. Kohyama, Effect of holding time on the microstructure and strength of tungsten/ferritic steel joints diffusion bonded with a nickel interlayer, Materials Science and Engineering, A518, 1-2, 167-173, 2009

K. Shimoda, T. Hinoki, A. Kohyama, Effect of carbon nanofibers (CNFs) content on thermal and mechanical properties of CNFs/SiC nanocomposites, Composites Science and Technology, 70, 2, 387-392, 2009

T. Nishitani, H. Tanigawa, S. Jitsukawa, T. Nozawa, K. Hayashi, T. Yamanishi, K. Tsuchiya, A. Möslang,

N. Baluc, A. Pizzuto, E.R. Hodgson, R. Laesser, M. Gasparotto, A. Kohyama, R. Kasada, T. Shikama, H. Takatsu, M. Araki, Fusion materials development program in the broader approach activities, Journal of Nuclear Materials, 386-388, C30, 405-410, 2009

Y. Watanabe, K. Morishita, A. Kohyama, Capture efficiency for clustering reaction between charged defects in β-SiC, Journal of Nuclear Materials, 386-388, 199-202, 2009

J.K. Lee, S.P. Lee, K.S. Cho, J.H. Lee, A. Kohyama, Characteristic evaluation of liquid phase-sintered SiC materials by a nondestructive technique, Journal of Nuclear Materials, 386-388, 487-490, 2009

S.P. Lee, M.H. Lee, J.K. Lee, A. Kohyama, J.H. Lee, High temperature characterization of LPS-SiC based materials with oxide additives, Journal of Nuclear Materials, 386-388, 433-486, 2009

T. Kato, S.I. Komazaki, Y. Kohno, H. Tanigawa, A. Kohyama, High-temperature strength analysis of welded joint of RAFs by small punch test, Journal of Nuclear Materials, 386-388, 520-524, 2009

K. Morishita, Y. Watanabe, A. Kohyama, H.L. Heinisch, F. Gao, Nucleation and growth of vacancy clusters in β-SiC during irradiation, Journal of Nuclear Materials, 386-388, 30-32, 2009

Y. Watanabe, K. Morishita, A. Kohyama, H.L. Heinisch, F. Gao, Defect properties in β-SiC under irradiation formation energy of interstitial clusters, Fusion Science and Technology, 56, 1, 328-330, 2009

Y. Watanabe, K. Morishita, A. Kohyama, H.L. Heinisch, F. Gao, Energetics of defects in β-SiC under irradiation, Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms, 267, 18, 3223-3226, 2009

Y. Katoh, S. Kondo, L.L. Snead, DC electrical conductivity of silicon carbide ceramics and composites for flow channel insert applications, Journal of Nuclear Materials, 386-388, 639-642, 2009

S. Kondo, Y. Katoh, L.L. Snead, Cavity swelling and dislocation evolution in SiC at very high temperatures, Journal of Nuclear Materials, 386-388, 222-226, 2009

N.Y. Iwata, R. Kasada, A. Kimura, T. Okuda, M. Inoue, F. Abe, S. Ukai, S. Ohnuki, T. Fujisawa, Characterization of mechanically-alloyed powders for high-Cr oxide dispersion strengthened ferritic steel, ISIJ International, 49, 12, 1914-1919, 2009

Z. Zhong, T. Hinoki, T. Nozawa, Y.H. Park, A. Kohyama, Microstructure and mechanical properties of diffusion bonded joints between tungsten and F82H steel using a titanium interlayer, Journal of Alloys and Compounds, 489, 2, 545-551, 2009

J.P. Bonal, A. Kohyama, J.V.D. Laan, L.L. Snead, Graphite, ceramics, and ceramic composites for high-temperature nuclear power systems, MRS Bulletin, 34, 1, 28-34, 2009

Z. Zhong, T. Hinoki, H.C. Jung, Y.H. Park, A. Kohyama, Microstructure and mechanical properties of diffusion bonded SiC/steel joint using W/Ni interlayer, Materials & Design, 31, 3, 1070-1076, 2010

阿部勝憲，香山晃，田中知，難波忠清，プロジェクトレビュー（日米科学技術協力事業 JUPITER-Ⅱプロジェクト）１．プロジェクトのねらいと進め方，プラズマ・核融合学会誌，85，5，247-257，2009

長谷川晃，檜木達也，清水昭比古，柴山環樹，横峰健彦，野上修平，プロジェクトレビュー（日米科学技術協力事業 JUPITER-Ⅱプロジェクト）２．SiC/SiC 複合材料・ヘリウム冷却システムの研究，プラズマ・核融合学会誌，85，5，267-275，2009

大野直子，檜木達也，笠田竜太，近藤創介，松井秀樹，木村晃彦，施設共用によるエネルギー材料のイノベーション創出に向けた取り組み，まてりあ，48，10，522，2009

K. Noborio, Y. Yamamoto, Y. Takeuchi, T. Hinoki, S. Konishi, Development of high temperature SiC/SiC composite intermediate heat exchanger for He and LiPb, Proceedings - Symposium on Fusion Engineering , art., 5226504, 2009

M. Kim, T. Hinoki, A. Kohyama, J. Park, H. Kishimoto, Process optimization for high performance SiC fibers from polymer-driven pre-ceramics, Proceedings - Symposium on Fusion Engineering , art, 5226455, 2009

A. Kimura, R. Kasada, N.Y. Iwata, H. Kishimoto, C. Zhang, P. Dou, J. Isselin, N. Muthukumar, J.H. Lee, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS steels R&D for fuel cladding of next generation nuclear systems: introduction and alloy design, Proc. 2009 International Congress on Advances in Nuclear Power Plants (ICAPP '09), 922, 2009

A. Kimura, J.H. Lee, R. Kasada, N.Y. Iwata, H. Kishimoto, C. Zhang, J. Isselin, P. Dou, N. Muthukumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS steels R&D for fuel cladding of next generation nuclear systems: corrosion behavior in SCPW, Proc. 2009 International Congress on Advances in Nuclear Power Plants (ICAPP '09), 9223, 2009

M.S. Suh, T. Hinoki, A. Kohyama, Erosion Wear Mechanism of SiCf/SiC Composites by Solid Particles, Proceedings of WTC 2009, 909, 2009

M.S. Suh, A. Kohyama, T. Hinoki, Special Issues on "in-situ" Crystallized SiCf/SiC Composites, Proceedings of ISAE2009, 439-442, 2009

Presentations

T. Hinoki, Y.H. Park, S. Konishi, Development of NITE-SiC/SiC Composite Compact Intermediate Heat Exchanger, IMAPS/ACerS 5th International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies (CICMT 2009), The Curtis Hotel Denver, Colorado – USA, 2009.4.21-23

A. Kimura, R. Kasada, N.Y. Iwata, H. Kishimoto, C. Zhang, P. Dou, J. Isselin, N. Muthukumar, J.H. Lee, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP '09), Super ODS steels R&D for fuel cladding of next generation nuclear systems 1) introduction and alloy design, Keio Plaza Hotel Tokyo, Tokyo, Japan, 2009.5.10-14

A. Kimura, J.H. Lee, R. Kasada, N.Y. Iwata, H. Kishimoto, C. Zhang, J. Isselin, P. Dou, N. Muthukumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS steels R&D for fuel cladding of next generation nuclear systems 6) corrosion behavior in SCPW, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP '09), Super ODS steels R&D for fuel cladding of next generation nuclear systems 1) introduction and alloy design, Keio Plaza Hotel Tokyo, Tokyo, Japan, 2009.5.10-14

M.S. Suh, T. Hinoki, A. Kohyama, Mechanical Properties and Microstructure of SiC/SiC Composites Fabricated for Erosion Component, The 1st International Symposium Kyoto University Global COE Program Energy Science in the Age of Global Warming Toward CO2 Zero-emission-, Kyoto University, Kyoto City, Japan, 2009.8.20-21

Z. Zhong, T. Hinoki, A. Kohyama, Diffusion Bonding of Tungsten to Reduced Activation Ferritic/Martensitic Steel F82H using a Titanium Interlayer, The 1st International Symposium Kyoto University Global COE Program Energy Science in the Age of Global Warming Toward CO2 Zero-emission-, Kyoto University, Kyoto City, Japan, 2009.8.20-21

Y.S. Shin, Y.H. Park, T. Hinoki, Nondestructive Testing of NITE-SiC Ceramics for Fusion Reactor Application, The 1st International Symposium Kyoto University Global COE Program Energy Science in the Age of Global Warming Toward CO2 Zero-emission-, Kyoto University, Kyoto City, Japan, 2009.8.20-21

N.Y. Iwata, T. Liu, P. Dou, R. Kasada, A. Kimura, T. Okuda, M. Inoue, F. Abe, S. Ukai, S. Ohnuki, T. Fujisawa, Effects of MA environment on the mechanical and microstructural properties of ODS ferritic steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

T. Nagasaka, T. Muroga, H. Watanabe, R. Kasada, N.Y. Iwata, A. Kimura, Mechanical property of V-4Cr-4Ti alloy after first wall coating with tungsten, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

T. Hinoki, Irradiation Effect on Tensile Properties of NITE-SiC/SiC Composites, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

N. Iwata, Effects of MA environment on the mechanical and microstructural properties of ODS ferritic, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

N. Oono, Liquid phase diffusion bonding between ODS steel and W, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

Z. Zhong, Diffusion Bonding of SiC to F82H using W/Cu Interlayer, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

Y.H. Park, Development of SiCf/porous-SiC Composites for Functional and Structural Materials, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

T. Koyanagi, The Influence of Sintering Additives on Irradiation Resistance of NITE-SiC, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

M.K. Kim, Effect of Multiple Heat Treatments on Crystallization of SiC Fiber, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

M.S. Suh, Fabrication of SiC/SiC by means of In-situ Crystallization of SiC Fibers, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

Y.S. Shin, Development of NDE Technique in SiC Ceramics for Fusion Reactor Application, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

H.C. Jung, Development of the testing method of shear stress for NITE-SiC joining material, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

S. Kondo, Fracture Strength of SiC Neutron Irradiated at Very High Temperatures, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

S. Kondo, Microstructure Evolution in High Purity 3C-SiC during Neutron Irradiation, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, Sapporo, Japan, 2009.9.6-11

M.S. Suh, A. Kohyama, Erosion Wear Mechanism of SiCf/SiC Composites by Solid Particles, World Tribology Congress(WTC), Kyoto, 2009.9.6-11

T. Hinoki, Development of Joining Technique for SiC/SiC Composite Component Utilizing NITE Process, 10ｔｈ International Nuclear Graphite specialist meeting, West Yellowstone, Montana, 2009.9.27-30

Z. Zhong, T. Hinoki, Y.H. Park, A. Kohyama, Interfacial reaction and diffusion control between SiC and F82H steel, The Ninth International Symposium on Fusion Nuclear Technology, Dalian, China, 2009.10.11-16

Y. Katoh, L. Snead, A. Hasegawa, S. Kondo, Effects of Helium Production on Silicon Carbide Ceramics and Composites for Fusion and Nuclear Services, 34th InternatIonal ConferenCe and exposItIon on AdvAnced cerAmics And composites organized by the american Ceramic society and the american Ceramic society's engineering Ceramics division(34th ICCAC), Hilton Daytona Beach Resort & Oce, 2010.1.24-29

T. Koyanagi, S. Kondo, T.Hinoki, Swelling of SiC Containing Sintering Additives under Ion Irradiation, 34th InternatIonal ConferenCe and exposItIon on AdvAnced cerAmics And composites organized by the american Ceramic society and the american Ceramic society's engineering Ceramics division(34th ICCAC), Hilton Daytona Beach Resort & Oce, 2010.1.24-29

M. Suh, S. Oh, W. Jeong, A. Kohyama, T. Hinoki, C. Suh, Threshold of Ring Crack Initiation on Ceramic Materials under Particle Impact, 34th InternatIonal ConferenCe and exposItIon on AdvAnced cerAmics And composites organized by the american Ceramic society and the american Ceramic society's engineering Ceramics division(34th ICCAC), Hilton Daytona Beach Resort & Oce, 2010.1.24-29

T. Hinoki, Y. Park, S. Konishi, Assembly Technique for SiC/SiC Composite Compact Intermediate Heat Exchanger Utilizing NITE Process, 34th InternatIonal ConferenCe and exposItIon on AdvAnced cerAmics And composites organized by the american Ceramic society and the american Ceramic society's engineering Ceramics division(34th ICCAC), Hilton Daytona Beach Resort & Oce, 2010.1.24-29

M. Suh, S. Oh, A. Kohyama, T. Hinoki, C. Suh, Particle Erosion Wear Mechanism of New Conceptive SiC/SiC Composites, 34th InternatIonal ConferenCe and exposItIon on AdvAnced cerAmics And composites organized by the american Ceramic society and the american Ceramic society's engineering Ceramics division(34th ICCAC), Hilton Daytona Beach Resort & Oce, 2010.1.24-29

檜木達也，SiC/SiC 複合材料の現状と応用，Electronic Journal 第 343 回 Technical Seminar（主催：電子ジャーナル），総評会館（東京・お茶の水），2009.5.20

檜木達也, 次世代原子力エネルギー用 SiC/SiC 複合材料及び SiC の中性子照射効果，平成 21 年度東北大学金属材料研究所大洗研究会，東北大学東京分室（東京都千代田），2009.6.26

檜木達也，SiC/SiC 複合材料の破損挙動に関する研究，平成 21 年度第 1 回核融合原型炉構造材料技術検討会，日本原子力研究開発機構国際核融合エネルギー研究センター（青森県六ヶ所村），2009.7.22-23

檜木達也，加速器を用いた SiC セラミックスの照射損傷組織及びスウェリングに関する研究，平成 21 年度第 1 回核融合原型炉構造材料技術検討会，日本原子力研究開発機構国際核融合エネルギー研究センター（青森県六ヶ所村），2009.7.22-23

近藤創介，SiC の照射効果研究の現状と課題，平成 21 年度第 1 回核融合原型炉構造材料技術検討会，日本原子力研究開発機構国際核融合エネルギー研究センター（青森県六ヶ所村），2009.7.22-23

檜木達也, DuET 施設と核融合炉材料粒子線照射研究，第 2 回核融合/原子力国際ビジネスフォーラム，<IBF-FE09>，札幌コンベンションセンター，2009.9.7-9

大野直子，笠田竜太，松井秀樹，木村晃彦，今成文郎，佐川眞人，Dy 改質処理を施したネオジム磁石の微細構造の研究，日本金属学会 2009 年秋期(第 145 回)，京都大学吉田キャンパス，2009.9.15-17

岩田憲幸，笠田竜太，木村晃彦，奥田隆成，井上賢紀，阿部冨士雄，鵜飼重治，大貫惣明，藤澤敏治，酸化物分散強化鋼における組織と強度特性に及ぼす MA 雰囲気の影響，日本金属学会 2009 年秋期(第 145 回)，京都大学吉田キャンパス，2009.9.15-17

盧相熏，笠田竜太，大野直子，岩田憲幸，木村晃彦，液相拡散接合した ODS 鋼の微細組織及び強度特性, 日本金属学会 2009 年秋期(第 145 回)，京都大学吉田キャンパス，2009.9.15-17

小西哲之，檜木達也，山本靖，登尾一幸，先進複合材コンパクト中間熱交換器の技術開発；（12）開発計画の概要 3，日本原子力学会「2009 年秋の大会」，東北大学青葉山キャンパス，2009.9.16-18

檜木達也，朴二玄，小西哲之，先進複合材コンパクト中間熱交換器の技術開発；スケールモデルのための接合技術開発, 日本原子力学会「2009 年秋の大会」，東北大学青葉山キャンパス，2009.9.16-18

鄭憲採，檜木達也，加藤雄大，高強度セラミックス接合材のねじりせん断強度評価に及ぼすサイズとグリップ形状の影響，日本原子力学会「2009 年秋の大会」，東北大学青葉山キャンパス，2009.9.16-18

小柳孝彰，近藤創介，檜木達也，NITE-SiC と CVD-SiC のスウェリング特性に及ぼす微細組織変化の影響, 日本原子力学会「2009 年秋の大会」，東北大学青葉山キャンパス，2009.9.16-18

近藤創介，加藤雄大，Lance Snead，中性子照射による SiC の微細組織発達，日本原子力学会「2009 年秋の大会」，東北大学青葉山キャンパス，2009.9.16-18

辛侖錫，朴二玄，檜木達也，超音波 Cースキャン法による SiC セラミックスの内部欠陥検出，日本セラミックス協会第 22 回秋季シンポジウム，愛媛大学，2009.9.16-18

李泳柱，朴二玄，檜木達也，マトリックス焼結条件の制御による NITE-SiC/SiC 複合材料の熱伝導度制御，日本セラミックス協会第 22 回秋季シンポジウム，愛媛大学，2009.9.16-18

朴二玄，檜木達也，香山晃，マイクロオーダーの円柱状貫通孔を有するポーラス SiC セラミックスの開発，日本セラミックス協会第 22 回秋季シンポジウム，愛媛大学，2009.9.16-18

檜木達也，坂公恭，大学の先端実験装置利用を企業へ無償提供-京都大学 ADMIRE 計画と名古屋大学ナノ･バイオサイエンス支援事業の連携-，びわ湖環境ビジネスメッセ 2009，滋賀県立長浜ドーム，2009.10.21-23

近藤創介，ADMIRE 計画において共用可能な装置の紹介ーイオン加速器と電子顕微鏡を はじめとする材料特性評価装置群ー，グローバル COE「地球温暖化時代のエネルギー科学拠点」産学連携シンポジウム，京都テルサ，2009.12.14

檜木達也，ADMIRE 計画への参加方法ー大学の保有する装置の無償利用のためにー，グローバル COE「地球温暖化時代のエネルギー科学拠点」産学連携シンポジウム，京都テルサ，2009.12.14

近藤創介，小柳孝彰，檜木達也，応力負荷下イオン照射法による SiC の照射クリープ評価，日本原子力学会 2010 年春の年会，茨城大学水戸キャンパス，2010.3.26-28

大野直子，長谷川晃子，岩田憲幸，近藤創介，橋冨興宣，笠田竜太，松井秀樹，木村晃彦，樋口徹，坂本寛，中司雅文，ジルコニウム水素化物に及ぼすイオン照射影響評価～(2)微細組織変化～，日本原子力学会 2010 年春の年会，茨城大学水戸キャンパス，2010.3.26-28

豊島和沖，檜木達也，樋口真一，鹿野文寿，軽水炉燃料被覆管材料のフープ強度評価法開発，

日本原子力学会 2010 年春の年会，茨城大学水戸キャンパス，2010.3.26-28

小柳孝彰，近藤創介，檜木達也，SiC 粒界上第 2 相に形成された照射欠陥の TEM 評価，日本原子力学会 2010 年春の年会，茨城大学水戸キャンパス，2010.3.26-28

岩田憲幸，笠田竜太，木村晃彦，奥田隆成，井上賢紀，阿部冨士雄，鵜飼重治，大貫惣明，藤澤敏治，水素雰囲気中 MA 処理の適用による高クロム ODS 鋼の引張特性向上，日本金属学会 2010 年春期(第 146 回)大会，筑波大学筑波キャンパス，2010.3.28-30

大野直子，笠田竜太，松井秀樹，木村晃彦，佐川眞人，ネオジム磁石の Cu 粒界拡散処理による保磁力低下，日本金属学会 2010 年春期(第 146 回)大会，筑波大学筑波キャンパス，2010.3.28-30

Advanced Laser Science Research Section

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1. Introduction

Our research interest is focused on the development of advanced lasers and the application of their unique functions and abilities to study of new fields of science and technology. The laser development is aiming at the generation of high-intensity, femtosecond (fs) laser pulses and coherent extreme- ultraviolet fs pulses. The intense fs laser pulses are applied to the experimental study of ultrafast strong-field interactions with matte and advanced materials control and processing. The goal is to demonstrate potential abilities of coherent radiation sources in new scientific regimes and to contribute to the development of new fields.

2. High-intensity ultrashort pulse lasers

A high-intensity fs Ti:sapphire laser system is one of the principal experimental apparatus of our group, which employs the chirped-pulse amplification (CPA) technique and produces a peak power of 1 TW (40 mJ in 40 fs) at 800 nm. This laser system is used for the study of strong field interactions with atoms and molecules. Another fs Ti:sapphire CPA laser system was developed for the purposes of material processing, which produces 50-100 fs, 800-nm pulses with a well-defined intensity distribution.

Recently, a new fs laser oscillator-amplifier system is introduced for advanced study of attosecond (as) science and engineering, which is shown in Fig.1. This laser system consists of a mode- locked fs Ti:sapphire laser oscillator producing 6.8 fs pulses at 80 MHz, a pulse stretcher, a CEP locking apparatus, a pulse selector, a multi-pass Ti:sapphire laser amplifier, and a grating compressor. The output is more than 1.6 W at 1 kHz with 25 fs pulses of which carrier envelope phase can be stabilized. The 25-fs pulses are compressed to few cycles (7 fs in duration) with a pulse compressor consisting of a long gas-filled hollow fiber and chirped mirrors for dispersion compensation.

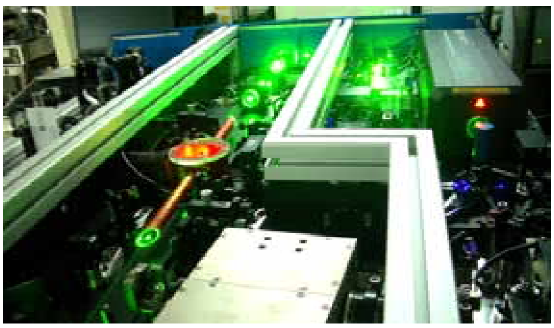

Fig.1. CEP stabilized Ti:sapphire CPA laser that produces intense few-cycle pulses of less than 7 fs.

The few-cycle pulse laser system will be used for the high-order harmonic generation (HHG) in a gaseous medium to produce attosecond extreme ultraviolet (EUV) pulses. The experimental apparatus for the EUV pulse generation is under development.

3. High-order harmonic generation from coherently rotating molecules

Ultrafast strong field interactions with atoms and molecules have been one of our major subjects to be studied with intense fs laser pulses. Using the high-order harmonic generation (HHG) process, we have first developed a new method to study nonadiabatically aligned molecules and succeeded to develop a theoretical model to fully understand the HHG process from coherently rotating molecules.

We applied the results of HHG from aligned molecules to the sensitive measurement of molecular rotational temperature T_{rot} in a thin supersonic gas

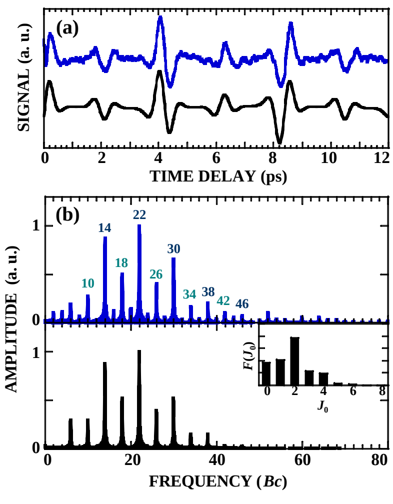

Fig.2. (a) Time-dependent 19th harmonic signals observed (upper) and calculated (lower) for T_{rot} = 20 K, and (b) their frequency spectra for N_2. The inset indicates the rotational state distribution at T_{rot} = 20 K.

beam. The method uses nonresonant pump and probe fs laser pulses to align molecules and to generate the harmonic radiation from coherently rotating molecules. The rotational temperature of molecules could accurately be derived with high spatial and temporal resolutions from the Fourier spectrum of time-dependent signals. The validity of method was tested for an expanding supersonic flow of N_2 with a rapid temperature decrease. The results show the versatile applicability of this method.

In our physical model of HHG from coherently rotating molecules, the frequency spectrum of time-dependent harmonic signal depends on only T_{rot}, when the pump and probe intensities are fixed for a molecular species. Figure 2 shows examples of (a) the observed (upper) and calculated (lower) time-dependent harmonic signals and (b) their frequency spectra, where the best agreement between theory and experiment is obtained for T_{rot} = 20 K.

We measured T_{rot} as a function of the distance from the nozzle for different pressures of gas source. The results demonstrate that the present technique provides a versatile way to measure T_{rot}.

4. Nanoprocessing with fs laser pulses

Despite the diffraction limit of light, several years ago we have found that fs laser pulses are able to form periodic nanostructures on hard thin films such diamond-like carbon (DLC) and TiN. The properties of nanostructuring have been studied extensively for dielectric and semiconductor materials.

In a series of experimental studies for DLC, we have shown that nanoscale local field is enhanced with *nearfield* on the surface having high curvatures to initiate nanoscale ablation, and then nanoperiodicity observed in ablation traces could be attributed to the excitation of *surface plasmon polaritons* (SPPs) in the surface layer. This nearfield-SPP model has been shown to reconcile with the observed properties of nanostructuring.

The validity of the physical picture consisting of nearfield and SPPs has been studied by applying the model to semiconductor materials such as Si, InP, and GaAs. The results are consistent with the proposed model.

On the basis of our model of nanostructuring, we expect to control and/or shape the nanostructured surface. This should be done by means of changing the distribution of local field on the surface. We have shown that nanostructured surface of DLC can certainly be inclined to have a sawlike shape, when fs laser pulses are obliquely incident on the target. Figure 3 shows the SEM images and their lateral scans of DLC target surfaces irradiated at the incident angle θ = 0˚, 20˚, 40˚ and 60° with N = 100 of p-polarized laser pulses at laser fluence F = 120 mJ/cm^2. It is noted that, with an increase in θ, the surface slope increases to have the height h ~ 110 nm.

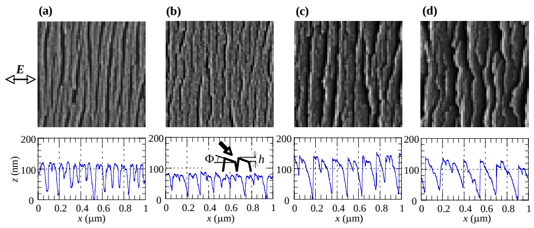

Fig.3. SEM images and their lateral (x-z) scans of DLC surface irradiated at (a) θ = 0°, (b) θ = 20°, (c) θ = 40°, and (d) θ = 60° with N = 100 of p-polarized laser pulses at F = 120 mJ/cm^2.

We confirmed that h and F increased monotonously with increasing θ at fixed values of F and N. These results demonstrate that the obliquely incident E-field produces the periodically enhanced non-uniform local field to form the sawlike ablation trace.

The inclined surface could be formed with only p-polarization of fs laser pulses, and never with s-polarization. This polarization-dependent surface shapes observed provide the experimental evidence that the *local field* enhanced on the surface initiates the nanoscale ablation with high curvature.

To see the generation of non-uniform local-fields with obliquely incident laser pulses, we calculated nearfield distributions on nanostructured surfaces, using a finite-difference time-domain method. The results have shown that the obliquely incident p-polarized 800-nm laser field produces non-uniform local field to produce the slope of nanostructured surface in ablation. The calculation has represented that s-polarized pulses never produces such non-uniform field distribution.

5. Theoretical study of ultrafast laser-matter interactions

We have proposed a new scheme to characterize as pulses. Our theoretical study shows that the fidelity of the as pulse reconstruction by our scheme is very high down to the pulse duration of 100 as even if the as pulse is linearly or nonlinearly chirped. We have also shown that the fs pulse propagation is very sensitive to the transverse mode of the incident pulse. Among others the Bessel mode turns out to show the best performance due to the presence of the energy reservoir in the outer part of the pulse.

6. Study of heat transfer

Numerical study has been made of twisted-tape-induced swirl flow heat transfer in a short circular tube of 6 mm in inner diameter and 636 mm in length with a 70 mm heated length. The results are compared with our experimental data and those calculated so far.

Collaboration Works

Johns Hopkins University（米国)、「フェムト秒レーザーによる表面ナノ構造生成過程のモデル構築」、宮崎健創、A.E. Kaplan

University of Brawijaya（インドネシア)、「超短パルス高強度レーザーによる分子配向と高次高調波発生」、宮崎健創、Abdurrouf

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、G. Buica

北京大学(中華人民共和国)、「フェムト秒フィラメントの横モード依存性」、中嶋隆、Z. Zhang

天津工業大学(中華人民共和国)、「フェムト秒フィラメントの空間伝搬特性」、中嶋隆、Z. Song

中国計量学院(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、J. Chen

核融合科学研究所、「短いスワール管内水の強制対流サブクール沸騰限界熱流束」、畑幸一

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1. Grant-in-Aid for Scientific Research
中嶋隆、基盤研究(A)、「超短パルスレーザーを用いた超高速核スピン偏極の実現」

宮地悟代、若手研究(B)、「サイクルパルスによる表面ナノ構造の制御に関する研究」

2. Others
中嶋隆、受託研究「ベッセルモードのレーザーパルスによるリモートセンシング技術の開発」

Publications

K. Yoshii, G. Miyaji, K. Miyazaki, Measurement of molecular rotational temperature in a supersonic gas jet with high-order harmonic generation, Opt. Lett., 34, 11, 1651-1653, 2009

G. Miyaji, K. Miyazaki, Control of surface shape in nanostructure formed with femtosecond laser pules, Proceeding of LAMP 2009 - the 5th International Congress on Laser Advanced Materials Processing, 94, 1-4, 2009

K. Yoshii, K. Miyazaki, G. Miyaji, Measurement of rotational temperature in a molecular beam with femtosecond laser pules, Proceeding of LAMP 2009 - the 5th International Congress on Laser Advanced Materials Processing, 240, 1-4, 2009

N. Yasumaru, K. Miyazaki, J. Kiuchi, Surface nanostructure and modified layer formed on hard coatting eith femtosecond kaser oules, J.Japan Soc. Heat Treament, 49, 396-399, 2009

S.N. Volkov, A.E. Kaplan, K. Miyazaki, Evanescent field at nanocorrugated dielectric surface, Appllied Physics Letters, 94, 41104, 2009

G. Miyaji, K. Miyazaki, Shape control of nanostructured thin film surface in femtosecond laser ablation, Applied Physics A Materials Science & Processing, 98, 927-930, 2010

T. Nakajima, Ultrafast nuclear spin polarization for isotopes with large nuclear spin, J. Opt. Soc. Am. B, 26, 572-580, 2009

T. Nakajima, Effects of the carrier-envelope phase on atomic ionization by the pulse train in the multiphoton ionization regime, Phys. Rev. A, 79, 43414, 2009

Z. Song, Z. Zhang, T. Nakajima, Transverse-mode dependence of femtosecond filamentation, Optics Express, 17, 12217-12229, 2009

J. Chen, T. Nakajima, Characterization of attosecond XUV pulses from photoelectron spectra of atoms, Laser Physics, 19, 1586-1590, 2009

K. Hata, S. Masuzaki, Subcooled Boiling Heat Transfer in a Short Vertical SUS304-tube at Liquid Reynolds Number Range 5.19×104 to 7.43×105, Nuclear Engineering and Design, 239, 2885-2907, 2009

K. Hata, S. Masuzaki, Subcooled Boiling Heat Transfer for Turbulent Flow of Water in a Short Vertical Tube, Journal of Heat Transfer, 132, 011501-1-11, 2010

K. Hata, S. Masuzaki, Influence of Heat Input Waveform on Transient Critical Heat Flux of Subcooled Water Flow Boiling in a Short Vertical Tube, Nuclear Engineering and Design, 240, 440-452, 2010

T. Nakajima, Y. Matsuo, T. Kobayashi, First Step Toward Ultrafast Nuclear-Spin Polarization: All-optical Control and Direct Detection of Ultrafast Electron-Spin Polarization Using Femtosecond Laser Pulses, AIP Conference Proceedings, 1149, 876-879, 2009

K. Hata, S. Masuzaki, Subcooled Boiling Heat Transfer in a Short Vertical SUS304-Tube at High Liquid Reynolds Number, Proceedings of 17th International Conference on Nuclear Engineering, Brus-

sels, ICONE17, 75818, 1-15, 2009

Y. Shirai, H. Tatsumoto, K. Hata, M. Shiotsu, H. Kobayashi, Y. Naruo, Y. Inatani, Preliminary Study on Heat Transfer Characteristics of Liquid Hydrogen for Coolant of HTC Superconductors, Proceedings of EUCAS 2009, 1-8, 2009

K. Hata, S. Masuzaki, Twisted-Tape-Induced Swirl Flow Heat Transfer and Pressure Drop in a Short Circular Tube under Velocities Controlled, Proceedings of 13th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, NURETH13, N13P1114, 1-15, 2009

安丸尚樹，宮崎健創，木内淳介，硬質薄膜のナノ構造形成とトライボロジョー特性制御への応用，レーザー研究，37，7，504-508，2009

Presentations

K. Miyazaki, Nanostructuring of solid surfaces with periodiucally enhanced local fields in femtosecond laser ablation, 9th Mediterial Workshop and Topical Meeting "Novel Optical Materials and Applications"(NOMA2009), Grand Hotel San Michele, Cetraro, Italy, 2009.6.9

K. Yoshii, Abdurrouf, G. Miyaji, K. Miyazaki, Probing Molecular Structure with Alignment-Dependent High-Order Harmonic Generation, CLEO/EUROPE 2009, International Congress Center Munich, Munich, 2009.6.15

K. Miyazaki, G. Miyaji, Nanostructuring of solid surfaces ablated with femtosecond laser pules, 19th International Conference, Laser in Manufacturing (LiM 2009), International Congress Center Munich, Munich, 2009.6.17

G. Miyaji, K. Miyazaki, Control of surface shape in nanostructure formed with femtosecond laser pulses, The 5th International Congress on Laser Advanced Materials Processing (LAMP 2009), Kobe Convention Center, Kobe, 2009.7.1

K. Yoshii, K. Miyazaki, G. Miyaji, Measurement of rotational temperature in a molecular beam with femtosecond laser pules, The 5th International Congress on Laser Advanced Materials Processing (LAMP 2009), Kobe Convention Center, Kobe, 2009.7.1

Z. Song, Z. Zhang, T. Nakajima, Transverse-mode-dependence of Femtosecond Filamentation, 18th International Laser Physics Workshop, World Trade Center Barcelona, Spain, 2009.7.13-17

K. Yoshii, G. Miyaji, K. Miyazaki, Estimation of Rotational Tempreratūre in a Molecular Beam with High-Order Harmonic Generation, The 1st International Symposium Kyoto University Global COE Profram, Kyoto University, 2009.8.20

T. Nakajima, Y. Matsuo, T. Kobayashi, Change of ultrafast nuclear-spin polarization upon photoionization by short laser pulses, XIIIth International Workshop on Polarized Sources and Targets (PST09), Camera di Commercio, 2009.9.7-11

K. Yoshii, G. Miyaji, K. Miyazaki, High-order harmonic generation from coherently rotating molecules with high-intensity ultrashort laser pulses, 2010 Kyoto-Ajou Graduate Student Joint Symposium on Energy Science, Kyoto University, 2010.2.2

張開鋒, 宮地悟代, 宮崎健創, フェムト秒レーザーによるシリコン表面のナノ構造生成, 第 56 回応用物理学関係連合講演会, 筑波大学, 2009.4.1

畑幸一, 増崎貴, 短い垂直円管内水の強制対流サブクール沸騰熱伝達, 第 46 回日本伝熱シンポジウム講演論文集, 京都市、国立京都国際会議場, 2009.6.2-4

宮地悟代, Ravi Bhushan, 張開鋒, 宮崎健創, 水中でのフェムト秒レーザー照射によるシリコン表面のナノ構造生, 第 70 回応用物理学会学術講演会, 富山大学, 2009.9.8

吉井一倫, 宮地悟代, 宮崎健創, 単一分子の高次高調波発生角度分布の再構成, 第 70 回応用物理学会学術講演会, 富山大学, 2009.9.8

白井康之, 塩津正博, 畑幸一, 達本衡輝, 小林弘明, 成尾芳博, 稲谷芳文, 高温超電導材冷却を目的とした液体水素熱流動特性試験装置ー概要ー, 2009 年度秋季低温工学･超電導学会講演概要集, 岡山大学, 2009.11.18-20

達本衡輝, 白井康之, 塩津正博, 畑幸一, 小林弘明, 成尾芳博, 稲谷芳文, 高温超電導材冷却を目的とした液体水素熱流動特性試験装置ー設計･試験方法ー, 2009 年度秋季低温工学･超電導学会講演概要集, 岡山大学, 2009.11.18-20

吉川浩太郎, 小林啓人, 白井康之, 畑幸一, 塩津正博, 達本衡輝, 小林弘明, 成尾芳博, 稲谷芳文, 液体水素のプール冷却における熱伝達, 2009 年度秋季低温工学･超電導学会講演概要集, 岡山大学, 2009.11.18-20

塩津正博, 吉川浩太郎, 小林啓人, 白井康之, 畑幸一, 達本衡輝, 小林弘明, 成尾芳博, 稲谷芳文, 木下勝弘, 液体水素の強制対流沸騰熱伝達, 2009

年度秋季低温工学･超電導学会講演概要集, 岡山大学, 2009.11.18-20

吉井一倫, 宮地悟代, 宮崎健創, 高強度フェムト秒レーザーによる配向分子の非線形光学過程, 京都大学グローバル COE プログラム平成 1 年度年次報告会, 京都大学, 2010.2.3

吉井一倫, 宮地悟代, 宮崎健創, 単一分子からの高次高調波発生分布と回転量子状態の再構成, レーザー学会学術講演会第 30 回年次大会, 千里ライフサイエンスセンター, 2010.2.3

宮地悟代, Ravi Bhushan, 張開鋒, 宮崎健創, 水中におけるシリコン表面のフェムト秒レーザー誘起ナノ構造生成, レーザー学会学術講演会第 30 回年次大会, 千里ライフサイエンスセンター, 2010.2.4

畑幸一, 増崎貴, 捻りテープ挿入短円管内スワール流れによる熱伝達と圧力損失, 日本原子力学会 2010 年「春の年会」要旨集, 茨城大学水戸キャンパス, 2010.3.26-28

Advanced Energy Storage Research Section

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1. Introduction

Efficient energy conversion and storage are great concerns for sound human life in the near future. This section takes up a mission of materials R & D for advanced nuclear energy conversion and storage, such as development of fusion blanket structural materials and fuel clad materials for high burn-up operation of light water reactors. The main issues are as follows:

(1) ODS steels for the advanced nuclear energy systems: Cladding material development is essential for realization of highly efficient high burn-up operation of next generation nuclear systems, where high performance is required for the materials, that is, high strength at elevated temperature, high resistance to corrosion and high resistance to irradiation. Oxide dispersion strengthening (ODS) ferritic steels are considered to be most adequate for the cladding material because of their high strength at elevated temperature. From fiscal year 2005, our re-search group has begun a research project "R&D of Su-per ODS steels for the Advanced Nuclear Energy Systems" in MEXT Innovative Nuclear Research and Development Program.

(2) Multiscale modeling of fusion blanket structural materials: Reduced activation ferritic steels (RAFS) and SiC/SiC composite are the promising candidates for fusion structural materials for future fusion reactors where structural materials are expected to suffer sever high-energy particle irradiation. The multiscale modeling approach is very useful to understand and predict the degradation.

(3) Lifetime evaluation 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. From fiscal year 2007, our research group has begun a METI project concerning "program".

2. Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems

Cladding material development is essential for realization of highly efficient high burn-up operation of next generation nuclear systems, where high performance is required for the materials, that is, high strength at elevated temperature, high resistance to corrosion and high resistance to irradiation. Oxide dispersion strengthening (ODS) ferritic steels are considered to be most adequate for the cladding material because of their high strength at elevated temperature. In this work, "Super ODS steel" that has better corrosion resistance than 9Cr-ODS steel, has been developed for application to cladding of a variety of next generation nuclear systems.

The alloy design of "Super ODS steel" has been determined during this five years project. Corrosion issue requires As shown in Fig. 1, Cr concentration more than 14wt.%, but aging embrittlement issue requires less than 16wt.%. An addition of 4wt.%Al is effective to improve corrosion resistance of 16wt.%Cr-ODS steel in SCW and LBE, while it is detrimental to high-temperature strength. Additions of 2wt.%W and 0.1wt.%Ti are necessary to keep high strength at elevated temperatures. An addition of small amount of Zr or Hf results in a significant increase in creep strength at 700 ºC in Al added ODS steels. Tube manufacturing was successfully done for the super ODS steel candidates.

The "Super ODS steel" is promising for the fuel cladding material of next generation nuclear systems, and the R&D is now ready to proceed to the next stage of empirical verification.

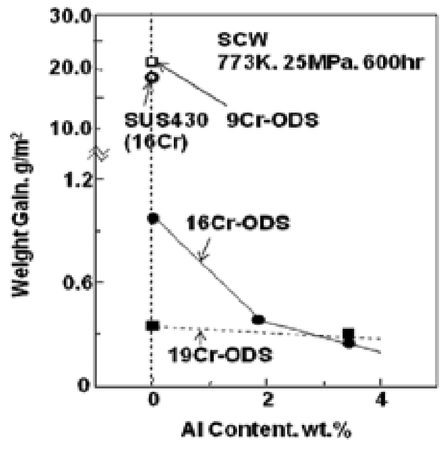

Fig. 1 The dependence of the weight gain on the Cr and Al contents in 16 and 19Cr-ODS steels.

3. Precise evaluation of formation energy of lattice defects in β-SiC

Cubic silicon carbide (β-SiC) has the zinc-blend structure, and is the base element of SiC/SiC composite that is a promising candidate for blanket structural materials of nuclear fusion reactor, because of good mechanical strength and low activation properties. Point defects and defect clusters are generally produced and accumulated in a material under irradiation, which changes the material microstructure, leading to the degradation of material properties such as mechanical properties, thermal properties and dimensional stabilities. Therefore, the defect behavior in an irradiated material should be accurately predicted and controlled to suppress the degradation of the materials' properties. Energetics of defects in a material is one of the parameters required for the evaluation of the kinetics of defect behavior under irradiation; however, for β-SiC, even the defect energetics is not yet understood enough. In the present work, atomistic calculations were performed to investigate formation energies and migration energies of the point defects, vacancies, self-interstitial atoms (interstitials) and antisites in β-SiC.

Molecular dynamics (MD) and molecular statics MS) calculations were performed to evaluate the defect energies in β-SiC. The empirical interatomic potential employed here was the Gao–Weber potential which was developed to provide a good description of interstitials' properties in β-SiC. So far, a variety of atomistic calculations have been performed to investigate defect energies in materials, in which two types of relaxation methods are used to obtain relaxed configurations of a defect in a system. One is a simple static relaxation method using MS technique, where the initial temperature of the computational system is generally set up at around 0 K, the system is then quenched to 0 K to obtain the converged value of the total potential energy of the system. The other relaxation method is a dynamic relaxation method using MD&MS combined technique, where the computational system is relaxed at finite temperature before quench. In the present work, the defect energies in β-SiC were separately evaluated using the two types of relaxation methods.

Our results showed that the most relaxed configurations of silicon- and carbon interstitials are Si_{TC}- and $CC_{<1\ 0\ 0>}$ configurations, respectively, with the lowest formation energies of 3.17 eV and 3.24 eV. The lowest formation energies of vacancies and antisites are 2.56 eV for silicon vacancies, 3.49 eV for carbon vacancies, 7.37 eV for silicon antisites and 2.08 eV for carbon antisites, respectively. Moreover, the results showed that the dynamic relaxation method always provide more relaxed defect configuration than the simple static relaxation method.

4. Lifetime evaluation of fission nuclear structural materials

Manganese is a major alloying element of typical reactor pressure vessel (RPV) steels. However roles of Mn in irradiation hardening and embrittlement of RPV steels has been not cleared yet, although there are a few studies on irradiation effects on Fe-Mn binary alloys. It was reported that the precipitation of other alloying elements, such as Mn, Ni and so on, occurs at the late stage of the irradiation, which is called manganese nickel precipitates (MNP) or late blooming phase (LBP). Irradiation hardening and embrittlement of low Cu RPV steels are considered to be due to the formation of MNP and radiation induced defect clusters which are called matrix defects. Microstructural development of the MNP in irradiated RPV steels and model alloys was begun investigating by three-dimensional atom probe (3DAP) and small angle neutron scattering (SANS). On the other hand, nature of matrix defects has not been clarified yet. In order to clarify the role of Mn in matrix defects, irradiation hardening and microstructural evolution of Fe-Mn binary alloys were examined and compared with those of commercial grade pure Fe and Fe-Cu binary alloy.

Fig. 3 shows Δσy as a function of square root of dpa for Pure-Fe, Fe-1Mn and Fe-1Cu with the results reported by Alexander et. al. The Δσy of Fe-1Cu exhibits a typical irradiation hardening at lower irradiation dose and a tendency of saturation as reported in literatures. The Δσy of Pure-Fe has a liner dependence of $(dpa)^{1/2}$ under about 2.5×10^{-3} dpa, at which the irradiation hardening saturates. The Δσy of Fe-1Mn also shows a liner dependence of (dpa)1/2 under about 1.6×10^{-2} dpa and it might have no dependence at more irradiation. However some Fe-1Mn alloys show significant irradiation hardening in the range of displacement damage more than 0.06 dpa. The mechanism of significant irradiation hardening in Fe-Mn will be investigated using DuET facility.

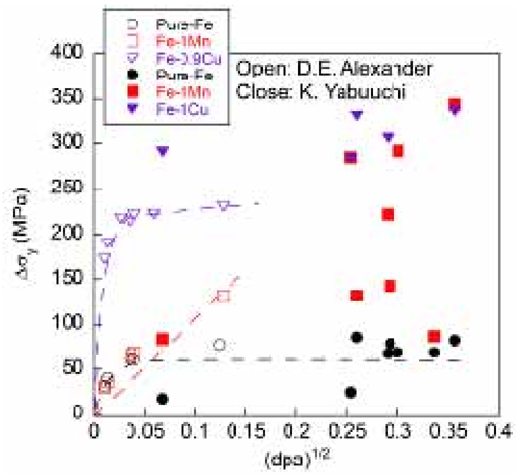

Fig. 3 The dose dependence of irradiation hardening in Fe, Fe-Mn and Fe-Cu model alloys.

Collaboration Works

韓国原子力研究所（大韓民国）、「Effects of neutron irradiation on ODS ferritic steels（先進鉄鋼材料の照射効果研究）」、木村晃彦、Jun-Wo Hong

Illinois 大学（米国）、「ODS steels R&D for next generation nuclear systems」、木村晃彦、J.A. Stubbins

Russian Research Center, Kurchatov Institute（ロシア）、「Irradiation effects on high Cr ODS steels」、木村晃彦、A. Ryazanov

UCSB（米国）、「Advanced ferritic stels R&D」、木村晃彦、G.R. Odette

PSI（スイス）、「In-situ creep behavior of ODS steels under ion irradiations」、木村晃彦、M. Pouchon

PNNL（米国）、「Multiscale modeling ofradiation damage in materials」、森下和功、H.L. Heinisch、F. Gao

Pacific Northwest国立研究所（米国）、「Resistance to neutron irradiation in ODS ferritic steels」、木村晃彦、R.M. Kurtz

KAIST（大韓民国）、「Corrosion Properties of Nuclear Materials」、木村晃彦、C.H. Jang

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、C. Zhang

核融合科学研究所、「核融合材料のマルチスケールモデリング」、森下和功

東北大学金属材料研究所所属量子エネルギー材料科学国際研究センター、「高耐食性酸化物分散強化鋼の開発」、木村晃彦、笠田竜太、J. Lee、S. Noh、B. Kim、濃野真広、山本泰功、高山嘉幸、鳴井実

東北大学金属材料研究所所属量子エネルギー材料科学国際研究センター、「ITER-TBMの作製に向けた低放射化フェライト鋼における照射影響評価」、木村晃彦、笠田竜太、J. Lee、S. Noh、B. Kim

東北大学金属材料研究所所属量子エネルギー材料科学国際研究センター、「軽水炉寿命延長時における照射脆化支配因子の検討」、木村晃彦、笠田竜太、藪内聖皓、鳴井実

京都大学原子炉実験所、「酸化物分散強化鋼のナノ構造に及ぼす熱時効効果及び照射効果」、木村晃彦、笠田竜太

Financial Support

1. Grant-in-Aid for Scientific Research
森下和功、基盤研究(C)、「照射下材料内の非平衡欠陥集合体核生成の機構論的解明と体系化」

藪内聖皓、特別研究員奨励費、「高経年化原子炉圧力容器鋼の照射脆化に及ぼすMn影響の解明」

2. Others
木村晃彦、経産省補助金、「革新的実用原子力技術開発費補助金」

木村晃彦、受託研究（文部科学省)、「原子力システム高効率化に向けた高耐食性スーパーODS鋼の開発の研究」

木村晃彦、共同研究（日本原子力研究開発機構)、「低放射化フェライト鋼の破壊靭性および照射下挙動評価に関する研究」

森下和功、共同研究（日本原子力研究開発機構)、「核融合材料の照射下挙動のモデル化に関する研究」

木村晃彦、共同研究（日本原子力研究開発機構)、「疲労特性、破壊靭性、及びき裂成長速度に関する微小試験片の試験技術開発」

木村晃彦、笠田竜太、共同研究（株式会社原子力安全システム研究所)、「原子炉容器鋼の照射脆化におよぼす応力の影響」

Publications

T. Nagasaka, R. Kasada, A. Kimura, Y. Ueda, T. Muroga, Thermophysical properties and microstructure of plasma-sprayed tungsten coating on low activation materials, Fusion Science and Technology, 56, 2, 1053-1057, 2009

N.Y. Iwata, R. Kasada, A. Kimura, T. Okuda, M. Inoue, F. Abe, S. Ukai, S. Ohnuki, T. Fujisawa, Characterization of mechanically-alloyed powders for high-Cr oxide dispersion strengthened ferritic steel, ISIJ International, 49, 12, 1914-1919, 2009

S. Takaya, T. Furukawa, K. Aoto, G. Müller, A. Weisenburger, A. Heinzel, M. Inoue, T. Okuda, F. Abe, S. Ohnuki, T. Fujisawa, A. Kimura, Corrosion behavior of Al-alloying high Cr-ODS steels in lead-bismuth eutectic, J. Nucl. Mater, 386-388, 507-510, 2009

A. Hasegawa, M. Ejiri, S. Nogami, M. Ishiga, R. Kasada, A. Kimura, K. Abe, S. Jitsukawa, Effects of helium on ductile-brittle transition behavior of reduced-activation ferritic steels after high-concentration helium implantation at high temperature, J. Nucl. Mater, 386-388, 241-244, 2009

T. Nishitani, H. Tanigawa, S. Jitsukawa, T. Nozawa, K. Hayashi, T. Yamanishi, K. Tsuchiya, A. Möslang, N. Baluc, A. Pizzuto, E.R. Hodgson, R. Laesser, M. Gasparotto, A. Kohyama, R. Kasada, T. Shikama, H. Takatsu, M. Araki, Fusion materials development program in the broader approach activities, J. Nucl. Mater, 386-388, 405-410, 2009

J. Chen, M.A. Pouchon, A. Kimura, P. Jung, W. Hoffelner, Irradiation creep and microstructural changes in an advanced ODS ferritic steel during helium implantation under stress, J. Nucl. Mater, 386-388, 143-146, 2009

S. Oh, J.S. Lee, C. Jang, A. Kimura, Irradiation hardening and embrittlement in high-Cr oxide dispersion strengthened steels, J. Nucl. Mater, 386-388, 503-506, 2009

R.J. Kurtz, A. Alamo, E. Lucon, Q. Huang, S. Jitsukawa, A. Kimura, R.L. Klueh, G.R. Odette, C. Petersen, M.A. Sokolov, P. Spätig, J.-W. Rensman, Recent progress toward development of reduced activation ferritic/martensitic steels for fusion structural applications, J. Nucl. Mater, 386-388, 411-417, 2009

H. Kishimoto, R. Kasada, O. Hashitomi, A. Kimura, Stability of Y-Ti complex oxides in Fe-16Cr-0.1Ti ODS ferritic steel before and after heavy-ion irradiation, J. Nucl. Mater, 386-388, 533-536, 2009

N. Okuda, R. Kasada, A. Kimura, Statistical evaluation of anisotropic fracture behavior of ODS ferritic steels by using small push tests, J. Nucl. Mater, 386-388, 974-978, 2009

N. Muthukumar, A. Ilangovan, S. Maruthamuthu, N. Palaniswamy, A. Kimura, 1-Aminoanthraquinone derivatives as a novel corrosion inhibitor for carbon steel APL 5L-X60 in white petrol-water mixtures, Materials Chemistry and Physics, 115, 444-452, 2009

S. Takaya, T. Furukawa, M. Inoue, T. Fujisawa, T. Okuda, F. Abe, S. Ohnuki, A. Kimura, Corrosion resistance of Al-alloying high Cr-ODS steels in stagnant lead-bismuth, J. Nucl. Mater, 398, 132-138, 2010

K. Morishita, Y. Watanabe, A. Kohyama, H.L. Heinisch, F. Gao, Nucleation and growth of vacancy clusters in β-SiC during irradiation, J. Nucl. Mater, 386-388, 30-32, 2009

Y. Watanabe, K. Morishita, A. Kohyama, Capture Efficiency for Clustering Reaction between Charged Defects in β-SiC under irradiation, J. Nucl. Mater, 386-388, 199-202, 2009

Y. Watanabe, K. Morishita, A. Kohyama, H. Heinisch, F. Gao, R.J. Kurtz, Defect Properties in β-SiC under Irradiation –Formation Energy of Interstitial Clusters–, Fusion Science and Technology, 56, 328-330, 2009

Y. Watanabe, K. Morishita, A. Kohyama, H.L. Heinisch, F. Gao, R.J. Kurtz, Energetics of defects in β-SiC under irradiation, Nuclear Instruments and Methods in Physics Research, B267, 3223-3226, 2009

D. Kato, H. Iwakiri, K. Morishita, First-principle Study on Binding Energy of Vacancy-Hydrogen Cluster in Tungsten, Journal of Plasma and Fusion Research, SERIES 8, 404-407, 2009

A. Kimura, R. Kasada, N. Iwata, H. Kishimoto, C.H. Zhang, J. Isselin, P. Dou, J.H. Lee, N. Muthukumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, T.F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 7th Eco-Energy and materials Science and Engineering Symposium, 2009

C.C. Fu, A. Kimura, M. Samaras, M. Serrano de Caro, R.E. Stoller, Materials for Future Fusion and Fission Technologies, MRS Symposium Proceedings, 1125, 1-141, 2009

C. Park, K. Noborio, R. Kasada, Y. Yamamoto, K. Nam, S. Konishi, Compatibility of materials for advanced blanket with liquid LiPb, Proceedings - Symposium on Fusion Engineering, art, 5226459, 2009

A. Kimura ,R. Kasada, N. Iwata, H. Kishimoto, C. Zhang, P. Dou, J. Isselin, N. Muthkumar, J. Lee, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 1) Introduction and alloy design, Proceedings of ICAPP'09, 9220, 1-8, 2009

S. Ohnuki, N. Hashimoto, S. Ukai, A. Kimura, M. Inoue, T. Kaito, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 2) Effect of Minor Alloying Elements, Proceedings of ICAPP'09, 9306, 1-5, 2009

T. Okuda, M. Fujiwara, T. Nakai, K. Shibata, A. Kimura, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 3) Development of high-performance attrition type ball mill, Proceedings of ICAPP'09, 9229, 1-4, 2009

T. Furukawa, S. Ohtsuka, M. Inoue, T. Okuda, F. Abe, S. Ohnuki, T. Fujisawa, A. Kimura, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 4) Mechanical Properties at Elevated Temperatures, Proceedings of ICAPP'09, 9221, 1-7, 2009

R. Kasada, C. Zhang, P. Dou, J. Isselin, S. Lee, A. Kimura, M.Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 5) Mechanical properties and microstructure, Proceedings of ICAPP'09, 9072, 1-4, 2009

A. Kimura, J. Lee, R. Kasada, N. Iwata, H. Kishimoto, C. Zhang, J. Isselin, P. Dou, N. Muthkumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 6) Corrosion Behavior in SCPW, Proceedings of ICAPP'09, 9223, 1-6, 2009

H. Sano, T. Fujisawa, A. Kimura, M. Inoue, S. Ukai, S. Ohnuki, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 7) Corrosion Behavior and Mechanism in LBE, Proceedings of ICAPP'09, 9308, 1-5, 2009

H. Kishimoto, R. Kasada, A. Kimura, M. Inoue, T. Okuda, F. Abe, S. Ohnuki, T. Fujisawa, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 8) Ion Irradiation Effects at Elevated Temperatures, Proceedings of ICAPP'09, 9219, 1-8, 2009

S. Ohnuki, N. Hashimoto, S. Ukai, A. Kimura, M. Inoue, T. Kaito, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 9) Damage Structure Evolution under Electron-Irradiation, Proceedings of ICAPP'09, 9307, 1-5, 2009

S. Ukai, A. Kimura, M. Inoue, T. Kaito, S. Ohnuki, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 10) Cladding tube manufacturing and summary, Proceedings of ICAPP'09, 9232, 1-7, 2009

B.J. Kim, R. Kasada, A. Kimura, Development of small specimen technique to evaluate ductile-brittle transition behavior of welded reactor pressure vessel steels, Zero-Carbon Energy Kyoto 2009, 306-309, 2009

S.H. Noh, R. Kasada, N. Oono, N. Iwata, A. Kimura, Relationship between Microstructure and Mechanical Property of Transient Liquid Phase Bonded ODS steels, Zero-Carbon Energy Kyoto 2009, 339-345, 2009

木村晃彦, ニュークリア・マテリアル　産業基盤技術，日本原子力誌，51，4，82，2009

相良明夫，関村直人，橋爪秀利，深田智，森下和功，田中照也，プロジェクトレビュー：日米科学技術協力事業JUPITER-IIプロジェクト（分担執筆）5．統合モデル，プラズマ・核融合学会誌，85，5，276-280，2009

大野直子，檜木達也，笠田竜太，近藤創介，松井秀樹，木村晃彦，施設共用によるエネルギー材料のイノベーション創出に向けた取り組み，まてりあ (Materia Japan)，48，10，2009

Presentations

A. Kimura, R. Kasada, N. Iwata, H. Kishimoto, C. Zhang, P. Dou, J. Isselin, N. Muthukumar, J.H. Lee, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 1) Introduction and alloy design, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

S. Ohnuki, N. Hashimoto, S. Ukai, A. Kimura, M. Inoue, T. Kaito, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 2) Effect of Minor Alloying Elements, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

T. Okuda, M. Fujiwara, T. Nakai, K. Shibata, A. Kimura, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 3) Development of high-performance attrition type ball mill, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

T. Furukawa, S. Ohtsuka, M. Inoue, T. Okuda, F. Abe, S. Ohnuki, T. Fujisawa, A. Kimura, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 4) Mechanical Properties at Elevated Temperatures, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東

京新宿，京王プラザホテル, 2009.5.10-14

R. Kasada, C. Zhang, P. Dou, J. Isselin, S. Lee, A. Kimura, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 5) Mechanical properties and microstructure, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

A. Kimura, J. Lee, R. Kasada, N. Iwata, H. Kishimoto, C. Zhang, J. Isselin, P. Dou, N. Muthkumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 6) Corrosion Behavior in SCPW, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

H. Sano, T. Fujisawa, A. Kimura, M. Inoue, S. Ukai, S. Ohnuki, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 7) Corrosion Behavior and Mechanism in LBE, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

H. Kishimoto, R. Kasada, A. Kimura, M. Inoue, T. Okuda, F. Abe, S. Ohnuki, T. Fujisawa, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 8) Ion Irradiation Effects at Elevated Temperatures, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-14

S. Ohnuki, N. Hashimoto, S. Ukai, A. Kimura, M. Inoue, T. Kaito, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 9) Damage Structure Evolution under Electron-Irradiation, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-1

S. Ukai, A. Kimura, M. Inoue, T. Kaito, S. Ohnuki, T. Fujisawa, T. Okuda, F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 10) Cladding tube manufacturing and summary, 2009 International Congress on Advances in Nuclear Power Plants (ICAPP2009), 東京新宿，京王プラザホテル, 2009.5.10-1

A. Kimura, R. Kasada, N. Iwata, H. Kishimoto, C.H. Zhang, J. Isselin, P. Dou, N. Muthukumar, H.S. Cho, J.H. Lee, N. Toda, T. Shinohara, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, T. Okuda, F. Abe, Current Status of Fuel Claddings R&D for Next Generation Nuclear Systems, AESJ/KNS Joint Workshop 2009 on Nuclear Fuel and Materials and Fusion in conjunction with the Korea Nuclear Society the 40th year Anniversary Meeting, Crystal hall C, Haevichi Hotel, Jeju, Korea, 2009.5.20

K. Morishita, Modeling of hydrogen and helium in fusion materials, Second Meeting of IEA Working Group on Irradiation Facilities and Testing (IEA W-GIFT-2), JAEA Tokyo Office, Ueno, Taito-ku, Tokyo, 2009.5.22-23

A. Kimura, Advanced Fuel Cladding Materials, Frédéric Joliot / Otto Hahn Summer School on Nuclear Reactors, Kirlsruhe Institute of Technology, Paul Scherrer Institute, 2009.8.27-9.3

J. Yoshimatsu, K. Morishita et al., Formation energy of lattice defects in W for fusion application, 14th International Conference on Fusion Reactor Materials, Young Scientist Program (ICFRM-14 YSP), APA Hotel & Resort Sapporo, Japan, 2009.9.5

A. Kimura, R. Kasada, N. Iwata, H. Kishimoto, C.H. Zhang, J. Isselin, P. Dou, J.H. Lee, N. Muthukumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Development of Al added high-Cr ODS steels for fuel cladding of next generation nuclear systems, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

R. Kasada, S.G. Lee, T. Omura, A. Kimura, Facture Toughness and Ductile-Brittle Transition Behavior of ODS Ferritic Steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

P. Dou, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Effects of Extrusion Temperature on the Nano-mesoscopic Structure and Hardness of High-Cr ODS Ferritic Steel, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

J. Isselin, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujiwara, T. F. Abe, Evaluation of Fracture Behavior of Recrystallized and Aged High-Cr ODS Ferritic Steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

N. Muthukumar, J.H. Lee, A. Kimura, SCC behavior of austenitic and martensitic steels in supercritical pressurized water, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo

Convention Center, 2009.9.6-11

J.H. Lee, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Influence of alloy composition and temperature on corrosion behavior of ODS ferritic steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

B.J. Kim, R. Kasada, A. Kimura, H. Tanigawa, Effects of Cold Work and Phosphorous on the Ductile to Brittle Transition Behavior of F82H steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

S.H. Noh, R. Kasada, A. Kimura, Seung Hwan C. Park, S. Hirano, Microstructure and Mechanical Properties of Friction Stir Processed ODS ferritic steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

M. Nono, T. Nakajima, M. Iwama, R. Kasada, A. Kimura, SCC Behavior of SUS316L in the High Temperature Pressurized Water Environment, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

K. Yabuuchi, H. Yano, R. Kasada, H. Kishimoto, A. Kimura, Dose dependence of irradiation hardening of binary ferritic alloys irradiated with Fe3+ ions, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

J. Yoshimatsu, Y. Kaneta, K. Morishita Y. Watanabe, D. Kato, H. Iwakiri, Formation energy of lattice defects in W for fusion application, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

N.Y. Iwata, T. Liu, R. Kasada, A. Kimura, T. Okuda, M. Inoue, F. Abe, S. Ukai, S. Ohnuki, T. Fujisawa, Effects of MA environment on the mechanical and microstructural properties of ODS ferritic steels, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

N. Oono, R. Kasada, N.Y. Iwata, A. Kimura, Liquid phase diffusion bonding between ODS steel and W, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

T. Nagasaka, T. Muroga, H. Watanabe, R. Kasada, N.Y. Iwata, A. Kimura, Mechanical property of V-4Cr-4Ti alloy after first wall coating with tungsten, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

D. Kato, H. Iwakiri, K. Morishita, Formation of vacancy clusters in tungsten crystals under hydrogen-rich condition, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

Y. Watanabe, K. Morishita, A. Kohyama, Composition dependence of formation energy of self-interstitial atom clusters in β-SiC, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

K. Morishita, J. Yoshimatsu, Y. Watanabe, H. Iwakiri, D. Kato, Y. Kaneta, M. Miyamoto, Computational modeling of microstructural evolution in fusion materials during irradiation, 14th International Conference on Fusion Reactor Materials (ICFRM-14), Sapporo Convention Center, 2009.9.6-11

K. Morishita, Y. Watanabe, K. Noborio, S. Konishi, T. Shibata, J. Yoshimatsu, Y. Yamamoto, 放射性物質の自然環境漏洩の予測・制御に必要な物質移行モデルの開発研究, International Business Forum for Fusion/Fission Energｙ 2009, Sapporo Convention Center (SCC), Sapporo, Japan, 2009.9.7-9

K. Yabuuchi, R. Kasada, A. Kimura, The Mn-effects: Are the defects unstable?, The 15th Meeting of the International Group on Radiation Damage Mechanism (IGRDM15), Congress Center, Budapest, 2009.10.10-16

S.H. Noh, R. Kasada, N. Oono, N. Iwata, A. Kimura, Evaluation of microstructure and mechanical properties of liquid phase diffusion bonded ODS steels, 9th International Symposium on Fusion Nuclear Technology (ISFNT-9), Dalian, China, 2009.10.12

R. Kasada, B. J. Kim, A. Kimura, M. Ando, H. Tanigawa, Evaluation of mechanical properties in weld-joint of F82H by using small specimens, 9th International Symposium on Fusion Nuclear Technology (ISFNT-9), Dalian, China, 2009.10.12

A. Kimura, R. Kasada, N. Iwata, H. Kishimoto, C.H. Zhang, J. Isselin, P. Dou, J.H. Lee, N. Muthukumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, T.F. Abe, Super ODS Steels R&D for Fuel Cladding of Next Generation Nuclear Systems, 7th Eco-Energy and Material Science and Engineering Symposium

(EMSES), Chiang Mai, Thailand, 2009.11.19-22

K. Morishita, Multiscale modeling for radiation damage in blanket materials, Asian CORE Winter School Technical Program on Advanced Energy Science, APA Hotel & Resort, Sapporo, Japan, 2010.2.22-23

A. Kimura, Materials Innovation for Next Generation Nuclear Systems, Nuclear Energy Materials, IMP-CAS, China, 2010.3.16

A. Kimura, Current Status of Fuel Cladding Materials R&D for Next Generation Nuclear Systems, Discussion of "Fushion Materials R&D for joininf and welding"and "Ion irradiation experiments", Institute of Modern Physics, Chinese Academy of Sciences, 2010.3.16

A. Kimura, Super ODS Steels R&D for Fuel Cladding of Advanced Nuclear Systems, Nuclear Energy Materials, Beijing University of Aeronautics & Astronautics (BUAA), China, 2010.3.17

A. Kimura, Current Status of Fuel Cladding Materials R&D for Next Generation Nuclear Systems, Discussion of "Fushion Materials R&D for joininf and welding" and "ODS steel application for DEMO blankets", 2010.3.17

森下和功, 核融合材料の照射下挙動のモデル化に関する研究，BA-DEMO R&D原型炉ブランケットに向けた材料工学研究開発　平成20年度成果検討会, 日本原子力研究開発機構システム計算機科学センター，2009.4.9-10

金田保則，森下和功，渡辺淑之，濱口大，材料モデリングの視点から, 核融合エネルギーフォーラムモデリングシミュレーションサブクラスター平成21年度第1回会合，日本原子力研究開発機構システム計算機科学センター，2009.5.29

森下和功, 核融合炉材料のガス不純物挙動に関するモデリング研究，九州大学応用力学研究所RIAMフォーラム2009，九州大学筑紫地区総合研究棟，2009.6.12

森下和功, 分子動力学計算による欠陥エネルギーの評価とマルチスケールモデリング，「マルチスケールのモデリングとプラズマ・壁相互作用」合同研究会（核融合BA会合，プラズマ・核融合学会専門委員会, 九大応研共同研究キックオフミーティング，九州大学応用力学研究所，2009.6.25

森下和功，PWIによる材料損傷プロセスのマルチスケールモデリング，「マルチスケールのモデリングとプラズマ・壁相互作用」合同研究会（核融合BA会合，プラズマ・核融合学会専門委員会，九大応研共同研究キックオフミーティング，2009.6.26

笠田竜太，Effects of neutron irradiations on various kinds of ferritic steels for advanced and current nuclear power generation system components –BR2 irradiation experiments on ODS and PPV, 平成21年度東北大学金属材料研究所大洗研究会, 東北大学東京分室，2009.6.26

木村晃彦，次世代原子力システム燃料被覆管，2009年度　軽水炉燃料・材料・水化学　夏期セミナー，ホテル玉泉，2009.7.2-4

盧相熏，笠田竜太，木村晃彦，朴勝煥，平野聡，摩擦撹拌処理したODS鋼の微細組織及び強度特性, 2009年度　軽水炉燃料・材料・水化学　夏期セミナー，ホテル玉泉，2009.7.2-4

B.J. Kim, R. Kasada, A. Kimura, Effects of specimen size on the impact properties of welded A533B steels, 2009年度　軽水炉燃料・材料・水化学　夏期セミナー，ホテル玉泉，2009.7.2-4

渡辺淑之，森下和功，14MeV中性子照射効果予測技術開発, 平成21年度BA共同研究第2回研究会, 青森県六ケ所村, 国際核融合エネルギー研究センター，2009.7.21-23

森下和功，吉松潤一，山本泰功，渡辺淑之，照射による材料劣化現象のマルチスケール的なものの見方と原子炉の保全，日本保全学会第6回学術講演会，ホテルニューオータニ札幌，2009.8.3-5

森下和功, 原子炉材料の照射損傷挙動に関するミクロ・マクロモデルの構築，第4回先進原子力科学技術に関する連携重点研究討論会, 茨城県東海村テクノ交流館リコッティ，2009.8.24-25

岩田憲幸，笠田竜太，木村晃彦，奥田隆成，井上賢紀，阿部冨士雄，鵜飼重治，大貫惣明，藤澤敏治, 酸化物分散強化鋼における組織と強度特性に及ぼすMA雰囲気の影響，日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

盧相熏，笠田竜太，大野直子，岩田憲幸，木村晃彦, 液相拡散接合したODS鋼の微細組織及び強度特性, 日本金属学会2009年秋期（第145回）大会, 京都大学，2009.9.15-17

藪内聖皓，笠田竜太，木村晃彦，イオン照射したFe-Mn二元系合金の照射硬化挙動，日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

濃野真広，木村晃彦，低炭素ステンレス鋼のSCC感受性に及ぼす腐食電位の影響，日本金属学会2009年秋期（第145回）大会，京都大学，

2009.9.15-17

戸田佳明，原徹，阿部冨士雄，木村晃彦，笠田竜太，井上賢紀，奥田隆成，大貫惣明，鵜飼重治，藤澤敏治，高耐食性ODS鋼のクリープ変形挙動，日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

藤井克彦，福谷耕司，笠田竜太，木村晃彦，低合金鋼の照射硬化に対する応力下照射の影響, 日本金属学会2009年秋期（第145回）大会, 京都大学, 2009.9.15-17

J.H. Lee, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Corrosion behavior of ODS ferritic steels made from elemental and pre-alloyed powders, 日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

金秉俊，笠田竜太，木村晃彦，安堂正巳，谷川博康，Development of small specimen testing technologies for evaluation of irradiation embrittlement of F82H, (1) Mechanical properties, 日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

P. Dou, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Effects of Zirconium on the Microstructure and Mechanical Properties of High Cr ODS Ferritic Steels，日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

J. Isselin, G. Vogt, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Zirconium Effect on the Microstructure with 14% Cr-4%Al ODS Ferritic steels，日本金属学会2009年秋期（第145回）大会，京都大学，2009.9.15-17

森下和功, 計算材料科学の炉材料へのアプローチ「核融合炉材料開発への計算科学の応用」，日本原子力学会2009年秋の大会, 東北大学青葉山キャンパス，2009.9.16-18

登尾一幸，柴田敏宏，渡辺淑之，山本靖，森下和功, 小西哲之, 原子力施設より放出されるトリチウムを用いた環境中水素・水挙動の解析，日本原子力学会2009年秋の大会, 東北大学青葉山キャンパス，2009.9.16-18

渡辺淑之，森下和功，吉松潤一，香山晃，SiC材料におけるSIA集合体形成エネルギーのサイズ・組成依存性, 日本原子力学会2009年秋の大会, 東北大学青葉山キャンパス，2009.9.16-18

吉松潤一，森下和功，渡辺淑之，金田保則，加藤太治，岩切宏友，核融合炉用BCC金属におけるボイドの形成条件, 日本原子力学会2009年秋の大会, 東北大学青葉山キャンパス，2009.9.16-18

森下和功, 材料照射損傷マルチスケールモデリング概要, 材料照射損傷マルチスケールモデリング研究会，東京大学工学部，2009.9.30

森下和功, 材料照射損傷マルチスケールモデリング概要（ミクロ構造変化），材料照射損傷マルチスケールモデリング研究会, 京都大学エネルギー理工学研究所，2009.11.4

坂本瑞樹，時谷政行，吉田直亮，芦川直子，森下和功, 矢木雅敏，マルチスケールのプラズマ・壁相互作用，プラズマ・核融合学会第26回年会，京都市国際交流会館，2009.12.1-4

吉松潤一，森下和功，山本泰功，渡辺淑之，核融合炉材料の照射下ミクロ構造変化, プラズマ・核融合学会第26回年会，京都市国際交流会館，2009.12.1-4

森下和功，シンポジウムVI「核融合炉材料照射下挙動のマルチスケールモデリング」趣旨説明, プラズマ・核融合学会第26回年会, 京都市国際交流会館，2009.12.1-4

渡辺淑之，宮本光貴，森下和功，シンポジウムVI「核融合炉材料照射下挙動のマルチスケールモデリング」ミクロ構造変化の計算と実験(1), プラズマ・核融合学会第26回年会, 京都市国際交流会館，2009.12.1-4

宮本光貴，渡辺淑之，森下和功，シンポジウムVI「核融合炉材料照射下挙動のマルチスケールモデリング」ミクロ構造変化の計算と実験(2), プラズマ・核融合学会第26回年会, 京都市国際交流会館，2009.12.1-4

森下和功，吉松潤一，山本泰功，渡辺淑之，核融合材料の照射下ミクロ構造変化の損傷速度依存性のモデル化, 第10回核破砕中性子源用材料技術の研究会，いばらき量子ビーム研究センター，2009.12.14-15

森下和功, 核融合炉における照射効果のモデリングの現状とこれからの課題, 物質・材料に対する照射効果のモデル構築研究会，東京大学工学部，2009.12.15

吉松潤一，森下和功，渡辺淑之，山本泰功，照射材料における欠陥集合体核生成の損傷速度依存性の評価, 物質・材料に対する照射効果のモデル構築研究会，東京大学工学部，2009.12.15

山本泰功，吉松潤一，渡辺淑之，森下和功，照射場の評価, 物質・材料に対する照射効果のモデル構築研究会，東京大学工学部，2009.12.15

加藤太治, 岩切宏友, 森下和功, タングステン格子中のdi-vacancy形成における水素効果の第一原理計算, 京都大学原子炉実験所ワークショップ「材料照射効果と応用」, 京都大学原子炉実験所, 2009.12.21-22

渡辺淑之, 森下和功, 吉松潤一, 山本泰功, β-SiCにおけるSIA集合体形成エネルギーのサイズ・組成依存性, 京都大学原子炉実験所ワークショップ「材料照射効果と応用」, 京都大学原子炉実験所, 2009.12.21-22

吉松潤一, 森下和功, 渡辺淑之, 山本泰功, 照射材料における欠陥集合体核生成の照射速度依存性の評価, 京都大学原子炉実験所ワークショップ「材料照射効果と応用」, 京都大学原子炉実験所, 2009.12.21-22

森下和功, 核融合材料の照射下挙動のモデル化に関する研究, 平成21年度日本原子力研究開発機構第2回BA原型炉R&D共同企画専門部会, 日本原子力研究開発機構システム計算科学センター, 2010.1.28-29

S.H. Noh, 笠田竜太, 木村晃彦, 先進原子力システム用のODS鋼の接合技術開発及び特性評価, 日本原子力学会　若手研究者発表会, 大阪大学中之島センター, 2010.3.12

樋口徹, 坂本寛, 中司雅文, 木村晃彦, 松井秀樹, 笠田竜太, 近藤創介, 大野直子, 橋冨興宣, ジルコニウム水素化物に及ぼすイオン照射影響評価；(1) 硬度変化, 日本原子力学会2010年春の年会, 茨城大学水戸キャンパス, 2010.3.26-28

大野直子, 笠田竜太, 長谷川晃子, 近藤創介, 橋冨興宣, 岩田憲幸, 松井秀樹, 木村晃彦, 中司雅文, 坂本寛, 樋口徹, ジルコニウム水素化物に及ぼすイオン照射影響評価；(2) 微細組織変化, 日本原子力学会2010年春の年会, 茨城大学水戸キャンパス, 2010.3.26-28

藤井克彦, 福谷耕司, 笠田竜太, 木村晃彦, 大久保忠勝, 低合金鋼の照射硬化とミクロ組織変化に対する応力下照射の影響, 日本原子力学会2010年春の年会, 茨城大学水戸キャンパス, 2010.3.26-28

岩田憲幸, 笠田竜太, 木村晃彦, 奥田隆成, 井上賢紀, 阿部冨士雄, 鵜飼重治, 大貫惣明, 藤澤敏治, 水素雰囲気中MA処理の適用による高クロムODS鋼の引張特性向上, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

藪内聖皓, 笠田竜太, 木村晃彦, イオン照射したFe-Mn 二元系合金の照射硬化回復挙動, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

盧相熏, 笠田竜太, 木村晃彦, 長坂琢也, Mechanical Property on Joints of ODS steel and Tungsten for Fusion Applications, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

金秉俊, 笠田竜太, 木村晃彦, 安堂正巳, 谷川博康, Fracture Toughness and Charpy Impact Properties of Cold Worked F82H Steels, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

高山嘉幸, 笠田竜太, 木村晃彦, 安堂正巳, 濱口大, 谷川博康, 超微小押し込み硬さ試験によるイオン照射した F82H の硬化特性評価, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

中川雄仁, 濃野真広, 木村晃彦, EBSDを用いたステンレス鋼の SCC 発生時における破壊様式の検討, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

藤井克彦, 福谷耕司, 大久保忠勝, 笠田竜太, 木村晃彦, 曲げ応力下で照射した低合金鋼の照射硬化とミクロ組織変化, 日本金属学会2010年春期（第146回）大会, 筑波大学, 2010.3.28-30

Complex Plasma Systems Research Section

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1. Introduction

This research section seeks to investigate the confinement optimization of high-temperature plasma in the helical-axis heliotron line. For the experimental and theoretical investigation of this theme, the plasma device of Heliotron J has been operated at the Laboratory for Complex Energy Processes since FY2000. Measurements for electron cyclotron resonance (ECR)/neutral beam injection (NBI)/ion cyclotron range of frequencies (ICRF) heating plasmas have been made of the global energy confinement in connection with the international stellarator scaling law (ISS04), the spontaneous confinement improvement (L-H transition), the confinement improvement based on the supersonic molecular beam injection (SMBI), the MHD activities, the edge plasma characteristics including the rotation of a filamentary turbulence structure, the plasma current control including the electron cyclotron current drive (ECCD), the energetic-particle driven Alfvén eigenmodes and relating fast ion dynamics, etc. The results are discussed in terms of the rotational transform $\iota/2\pi$ and the bumpiness ε_b (or the effective helical ripple ε_{eff}). Their controls were experimentally demonstrated to be the key issues to determine the optimum performance of Heliotron J. It has been ascertained that the helical-axis heliotron provides a unique and high potential for exploiting an alternative and advanced path to the future helical systems.

2. Studies of turbulence at plasma edge

In the magnetically confined plasmas aiming at a nuclear fusion reactor, the performance of plasma confinement is characterized by both particle and energy transports from the plasma core toward the edge. The transport is divided into two classes, neoclassical and anomalous transport caused by (macro) MHD instabilities and/or micro instabilities such as drift wave. The spontaneous transition of plasma confinement from low mode (L-mode) to high mode (H-mode) is observed in Heliotron J plasmas. This phenomenon seems to be related to the degradation of the turbulence and the formation of structure of plasmas.

We applied the bicoherence technique to the signal of Langmuir probe array in order to analysis the behavior of turbulence caused by micro instabilities in the period of spontaneous L-H transition. Bicoherence is a squared normalized value of the bispectra which are third order function of Fourier transform. It can be evaluated the quantifying the extent of phase coupling between three waves in a signal, that is, formation of new structure in a turbulence and the energy transfer from the turbulence to newly formed structure in a plasma. If the bicoherence of appeared structure is high, turbulence would take its energy to structure and stabilized. The time evolution of power spectrum of poloidal electric field obtained from Langmuir probe array at plasma edge in the period of spontaneous L-H transition is shown in Fig. 1. Here we applied not fast Fourier transform but wavelet transform which is non-stationary decomposition to get high time and frequency resolutions around L-H transition. When the spontaneous L-H transition occurs at t=276 (ms) because of the sudden change of Hα signals and plasma stored energy, the decreasing of fluctuation power in electric field with all frequencies are simultaneously observed. Figure 2 shows the bicoherence of poloidal electric field $E\theta$. We observed new mode with the frequency of 20 kHz with high coherence although statistics precision may not be enough. This might indicate that new structure are formed by the nonlinear mode coupling

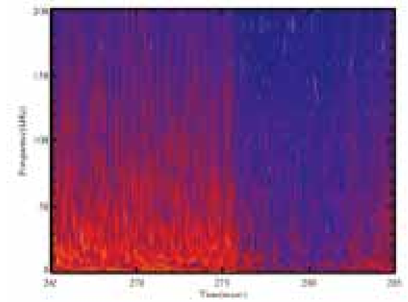

Fig. 1. Time evolution of amplitude of poloidal electric field fluctuation around L-H

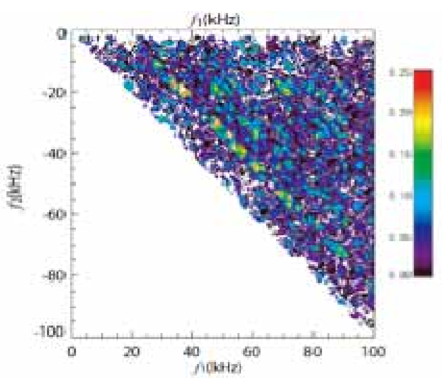

Fig. 2. Bicoherence in the H-mode phase for poloidal electric field.

between each turbulences and its disturb the vertical transport by the turbulence.

3. Calculation of neoclassical diffusion and viscosity coefficients for stellarator/heliotron devices by the Green-Kubo approach [1]

Neoclassical transport theory is addressed by a guiding-center particle simulation based on the Green-Kubo formalism. With the assumption of the neoclassical ordering $\varepsilon = \rho_p / L << 1$, the transport problem is described by the *linear* non-equilibrium statistical mechanics, where ρ_p is the poloidal gyroradius and L is the radial scale length. Following the procedure used in the nonequilibrium molecular dynamics (NEMD), the transport coefficients are evaluated from the time integration of the auto- and cross-correlation functions of fluxes carried by the test particles. We here choose a practically important example for stellarator/heliotron devices. The neoclassical diffusion and viscosity coefficients are calculated on the basis of the pitch-angle scattering approximation. The present calculation works in the framework of the moment-equation approach [2,3], which constitutes a useful method to calculate the neoclassical diffusion and flow with taking into account the full linearized Fokker-Planck collision operators. The stochastic motion of test particles are simulated by the guiding-center Langevin equations [4].

The stochastic integration of the auto and cross-correlation functions with respect to the microscopic fluxes $\sigma_{Xa} \equiv -v^2 P_2(\xi)\hat{b}\bullet\nabla(B\tilde{U})/(2\Omega_a)$ and $\sigma_{Ua} \equiv -m_a v^2 P_2(\xi)\vec{B}\bullet\nabla \ln B$ yields the energy-dependent diffusion and viscosity coefficients L, M, and N. Here, $P_2(\xi)$ is the second-order Legendre polynomial of the pitch variable ξ, $\Omega_a = e_a B / m_a$ is the gyrofrequency, and is related to the generating function of the Hamada coordinates. In the simulation, the auto and cross-correlation function $R_{XX}(t)$, $R_{XU}(t)$, and $R_{UU}(t)$ have decayed in about an effective collision time ν_{eff}. The stochastic integrations of these functions have converged to the finite asymptotic values.

References

[1] A. Matsuyama and K. Hanatani, in *Proceedings of 36th EPS Conference on Plasma Physics(Sofia, Bulgaria, 29June- 3 July,2009) edited by M.Mateev and E.Benova (European Physical Society, 2009), ECAVol. 33E, P-4.126 (2009)*

[2] H. Sugama and S. Nishimura, Phys. Plasmas **9**, 4637 (2002); **15**, 042502 (2008)

[3] M. Taguchi, Phys. Fluids B **4**, 3638 (1992)

[4] A. Matsuyama and K. Hanatani, in *Proceedings of 18th International Toki Conference* (National Institute for Fusion Science, Toki, 2008, December 9-12), P1-212

4. Development of magnetic island detector by magnetic measurement for helical plasmas.

A magnetic island which disturbs the structure of nested magnetic flux surface would lead to degradation of plasma confinement. High performance plasmas are achieved by the shrinkage of low-*n* magnetic islands using a resonant magnetic perturbation (RMP) or electron cyclotron current drive (ECCD) in tokamak and/or helical plasmas. However, the physics of magnetic islands and its effect on plasma confinement is little understood. The aim of our study is to develop a magnetic island detector using saddle coils with high spatial and time resolution and to clarify the physics and effect of magnetic island in helical plasmas. We are developing the island detector in Heliotron J where the magnetic island is expected to be large because of low magnetic shear.

In order to optimize the location and the shape of magnetics, and the RMP coil to externally control m=2/n=1 magnetic island, we developed a numerical scheme combined with HINT2 MHD equilibrium solver and JDIA external magnetic field solver where three-dimensional magnetic configuration, finite beta effect and plasma current can be taken into account. Fig.1 shows Poincare plots of magnetic surface where RMPs have maximum coil current. We experimentally investigated magnetic field by the RMP coil using a toroidal array of magnetic probe. The result indicates that the perturbation magnetic field with m=2/n=1 is successfully produced in vacuum chamber of Heliotron J. Moreover, the penetration time of magnetic field τ~5 (ms), is short enough in comparison with Heliotron J plasma discharge duration τ > 100 (ms). Moreover, We designed new saddle coils, as shown in Fig.2, using the numerical scheme mentioned above and RMP experimental result. Optimized new magnetics consist of two coil sets locating a different toroidal section in order to measure the asymmetry of magnetic field by Pfirsch-Schlüter current caused by existence of m=2/n=1 magnetic island. We applied the m=2/n=1 RMP to plasma experiment in the configuration with rotational transform of 0.5. The response of the plasma was detected by new saddle coils. The detected field component is order of 10^{-4}T and this result is consistent with the numerical simulation result.

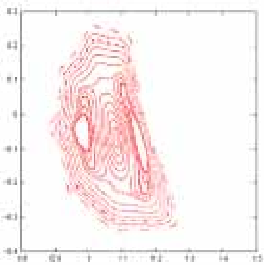

Fig.3. magnetic surface with m=2/n=1 magnetic is-

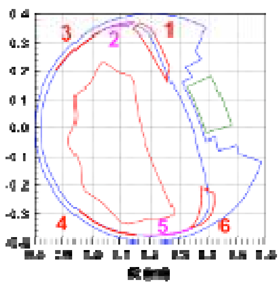

Fig.4. new saddle coil system.

Collaboration Works

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核融合科学研究所、「ヘリカルプラズマにおける新古典電流に対する径電場・配位制御の効果」、西村伸（核融合研）、花谷清、山本聡、岡田浩之

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核融合科学研究所、「補助コイルを用いたヘリオトロン J 磁場配位最適化設計」、岡村昇一（核融合研）、佐野史道、山本聡、水内亨、岡田浩之

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核融合科学研究所、「ヘリオトロン J における高効率燃料供給に向けたペレット入射の検討」、本島厳（核融合研）、佐野史道、水内亨、岡田浩之

核融合科学研究所、「極低磁場での電子バーンシュタイン波加熱のヘリオトロン J プラズマ閉じ込めへの影響」、東井和夫（核融合研）、佐野史道、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

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亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「局所分布構造・長距離相関計測装置の高性能化による乱流揺動の構造解析と HJ-LHD 比較研究」、福田武司（大阪大）、佐野史道、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリカル系における電子サイクロトロン電流駆動による回転変換制御」、長崎百伸、佐野史道、花谷清、山本聡、水内亨、小林進二、岡田浩之

核融合科学研究所、「磁気計測による磁気島検出器の開発」、岡田浩之、佐野史道、山本聡、水内亨、小林進二、長崎百伸

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佐野史道、受託研究（関西電力株式会社）、「大電力高周波・マイクロ波の発生・伝送技術の開発と応用に関する調査研究」

佐野史道、双方向型共同研究（核融合科学研究所）、「先進ヘリカルによるコンパクト・高ベータ・定常炉の実現に向けた閉じ込め最適化研究」

佐野史道、奨学寄付金（株式会社日立製作所）、「京都大学エネルギー理工学研究所における核融合研究に対する助成」

山本聡、共同研究（核融合科学研究所）、「データマイニングを用いた LHD プラズマの MHD 安定性解析」

Publications

A. Matsuyama, M.Y. Isaev, K.Y. Watanabe, K. Hanatani, Y. Suzuki, N. Nakajima, W.A. Cooper, T.M. Tran, Moment approach to the bootstrap current in nonaxisymmetric toroidal plasmas using δf Monte Carlo methods, Physics of Plasmas, 16, 52501, 2009

T. Mizuuchi, K. Murai, S. Watanabe, S. Yamamoto, S. Kobayashi, K. Nagasaki, H. Okada, G. Motojima, H. Arimoto, F. Hamagami, D. Katayama, H. Matsuoka, A. Nakajima, H. Takahashi, H. Yasuda, K. Mukai, Y. Kowada, K. Hosaka, S. Mihara, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, K. Kondo, F. Sano, Comparison of edge plasma behavior at different poloidal positions in Heliotron J, Journal of Nuclear Materials, 390-391, 428-431, 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, K. Nagasaki, H. Okada, F. Sano, S. Yamamoto, K. Kondo, Measurement of peripheral plasma turbulence using a fast camera in Heliotron J, Journal of Nuclear Materials, 390-391, 432-435, 2009

Y. Nakashima, Y. Higashizono, H. Kawano, N. Nishino, S. Kobayashi, T. Mizuuchi, M. Shoji, K. Nagasaki, H. Okada, F. Sano, K. Kondo, Y. Yoneda, R. Yonenaga, M. Yoshikawa, T. Imai, Recycling studies based on two-dimensional visible light measurements and Monte-Carlo simulation in mirror and helical systems, Journal of Nuclear Materials, 390-391, 511-515, 2009

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, G. Motojima, S. Watanabe, A. Matsuyama, Y. Nakamura, K. Hanatani, K. Kondo, F. Sano and Heliotron J Group, Configuration control experiments in Heliotron J, Journal of Plasma Fusion Research, 8, 981-986, 2009

S. Nishimura, Y. Nakamura, G. Motojima, H. Okada, S. Kobayashi, S. Yamamoto, K. Nagasaki, K. Hanatani, K. Kondo, T. Mizuuchi, F. Sano, Effects of Configuration Control on the Neoclassical Viscosity in Heliotron-J, Journal of Plasma Fusion Research, 8, 1003-1009, 2009

G. Motojima, K. Nagasaki, H. Okada, K. Watanabe, T. Mizuuchi, A. Matsuyama, K. Hanatani, S. Yamamoto, S. Kobayashi, Y. Suzuki, K. Kondo, Y. Nakamura, A.C.Fernadez, ÁA. Cappa, Y. Yoshimura, S. Watanabe, K. Mukai, F. Sano, Experimental Study of Non-Inductive Current in Heliotron J, Journal of Plasma Fusion Research, 8, 1010-1014, 2009

K. Nagaoka, S. Kobayashi, K. Hosaka, S. Yamamoto, T. Mizuuchi, M. Osakabe, Y. Takeiri, K. Nagasaki, H. Okada, K. Kondo, K. Hanatani, F. Sano, Observation of Fast Ion Response to MHD Activities in Heliotron J, Journal of Plasma Fusion Research, 8, 1100-1103, 2009

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Watanabe, K. Mukai, S. Kishi, H.Y. Lee, K. Minami, Y. Takabatake, H. Yashiro, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Effects of gas-fueling control on plasma performance in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

H. Okada, S. Kobayashi, S. Kishi, S. Mihara, T. Mutoh, T. Mizuuchi, K. Nagasaki, Y. Nakamura, T. Minami, S. Yamamoto, S. Ohshima, S. Konoshima, K. Mukai, H.Y. Lee, Y. Takabatake, K. Hanatani, F. Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

S. Kobayashi, K. Nagaoka, S. Yamamoto, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, Y. Suzuki, Y. Nakamura, Y. Takeiri, M. Yokoyama, K. Hanatani, K. Hosaka, S. Konoshima, S. Ohshima, K. Toushi, F. Sano, Energetic particle transport in NBI plasmas of Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

K. Nagasaki, K. Sakamoto, K. Minami, H. Yoshino, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, S. Ohshima, K. Mukai, S. Kishi, H.Y. Lee, Y. Takabatake, G. Motojima, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

K. Mukaia, K. Nagasaki, V. Zhuravlevd, T. Fukuda, T. Mizuuchi, T. Minami , H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, D. Nishi, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, 17th International Stellarator Workshop/Heliotron Workshop, 2009

S. Kobayashi, H.Y. Lee, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, S. Yamamoto, H. Okada, T. Minami, S. Murakami, Y. Suzuki, Y. Nakamura, K. Hanatani, S. Konoshima, K. Toushi, F. Sano, Development of Highly Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, D. Nishino, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

K. Nagasaki, G. Motojima, K. Sakamoto, K. Minami, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, K. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernandes, A. Cappa, B. Blackwell, F. Sano, Study of Non-Inductive Current in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

F. Sano, T. Mizuuchi, K. Nagasaki, K. Hanatani, H. Okada, Y. Nakamura, T. Minami, S. Kobayashi, S. Yamamoto, S. Ohshima, S. Watanabe, K. Mukai, K. Minami, S. Kishi, A. Matsuyama, H. Lee, Y. Takabatake, H. Yashiroa, H. Yoshino, S. Konoshima, B. Blackwell, Physics Research on the Heliotron J Confinement, 19th International Toki onference (ITC19), 2009

S. Yamamoto, H. Okada, S. Sakakibara, Y. Suzuki, S. Kobayashi, T. Minami, T. Mizuuchi, K. Mukai, K. Nagasaki, Y. Nakamura, Y. Narushima, F. Sano, K.Y. Watanabe, Development of magnetic island detector by magnetic measurement in helical plasmas, 19th International Toki onference (ITC19), 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, F. Sano, Peripheral plasma measurement in Heliotron J using fast cameras, 19th International Toki onference (ITC19), 2009

Lee Hyunyong（李炫庸），小林進二，村上定義，水内亨，長崎百伸，南貴司、岡田浩之，山本聡，木島滋，向井清史，高畠優，岸真太郎，南桂史，佐野史道，ヘリオトロン J における NBI プラズマ中の CX-NPA 解析，日本物理学会 2009 年秋季大会，2009

小林進二, 山本聡, 岡田浩之, 長崎百伸, 南貴司, 向井清史，岸真太朗，李炫庸，南桂史，高畠優，大島慎介，西野信博，中嶋洋輔，中村祐司，花谷清，佐野史道，ヘリオトロン J における超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ・核融合学会年会，2009

岡田浩之, 山本聡, 榊原悟, 鈴木康浩, 小林進二, 長崎百伸，中村祐司，南貴司，水内亨，木島滋，渡邊清政，成嶋吉郎，向井清史，岸真太郎，李炫庸，高畠優，南桂史，佐野史道，磁気計測による磁気島検出器の開発，第 26 回プラズマ・核融合学会年会，2009

高畠優, 水内亨, 西野信博, 長崎百伸, 岡田浩之, 南貴司，小林進二，山本聡，木島滋，中嶋洋輔，井尻芳行, 千住徹, 矢口啓二, 坂本欣三, 東使潔, 芝野匡志, 向井清史, 李炫庸, 岸真太郎, 南桂史, 佐野史道, 静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析，第 26 回プラズマ・核融合学会年会，2009

岸真太郎, 岡田浩之, 水内亨, 長崎百伸, 花谷清, 南貴司，小林進二，山本聡，木島滋，武藤敬，松山顕之，向井清史，李炫庸，高畠優，南桂史，佐野史道，ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率，第 26 回プラズマ・核融合学会年会，2009

Lee Hyunyong，小林進二，南貴之，門信一郎，水内亨，長崎百伸，岡田浩之，南貴司，山本聡，村上定義，鈴木康浩，中村祐司，花谷清，木島滋，向井清史，岸真太郎，高畠優，南桂史，香川輔，東使潔，佐野史道，ヘリオトロン J における荷電交換再結合分光計測，第 26 回プラズマ・核融合学会年会，2009

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡，木島滋，西大輔，南桂史，李炫庸，高畠優，岸真太郎，八代浩彰，佐野史道，マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測, 第 26 回プラズマ･核融合学会年会, 2009

南貴司, 八代浩彰, 小林進二, 水内亨, 岡田浩之, 長崎百伸，中村祐司，花谷清，山本聡，木島滋，大島慎介，佐野史道，Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画, 第 26 回プラズマ・核融合学会年会，2009

山本聡，中村佑司，岡村昇一，田部井優，西岡賢二，佐野史道，水内亨，長崎百伸，花谷清，岡田浩之，南貴司，小林進二，木島滋，大島慎介，ヘリカル軸ヘリオトロン磁場配位の最適化研究, 第 26 回プラズマ・核融合学会年会，2009

南桂史, 長崎百伸, 坂本欣三, 水内亨, 岡田浩之, 南貴司，小林進二，山本聡，木島滋，向井清史，李炫庸，岸真太郎，高畠優，佐野史道，ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験，第 26 回プラズマ・核融合学会年会，2009

杉本大地，比村治彦，平松秀朗，三瓶明希夫，政宗貞男，岡田浩之，山本聡，小林進二，水内亨，佐野史道, 平衡電場検証のための立体磁気軸ヘリオトロン J における非中性プラズマ閉じ込め実験，第 26 回プラズマ・核融合学会年会，2009

中野賢, 松浦寛人, 水内亨, 岡田浩之, 永岡賢一, ヘリオトロン J 実験グループ，ヘリオトロン J における周辺プラズマ熱流束に関する研究，第 26 回プラズマ・核融合学会年会，2009

Presentations

A. Matsuyama, K. Hanatani, Calculation of neoclassical diffusion and viscosity coefficients for stellarator/heliotron devices by the Green-Kubo approach, 36th European Physical Society Conference on Plasma Physics, Sofia, Bulgaria, 2009.6.29-7.3

A. Matsuyama, K. Hanatani, K.Y. Watanabe, A Monte-Carlo-based calculation of neoclassical viscosity and flows for nonaxisymmetric toroidal plasmas, 17th International Stellarator Heliotron Workshop, Princeton, USA, 2009.10.12-16

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Watanabe, K. Mukai, S. Kishi, K. Minami, Y. Takabatake, H. Yashiro, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Effects of gas-fueling control on plasma performance in Heliotron J, 17th International Stellarator Heliotron Workshop, Princeton, USA, 2009.10.12-16

H. Okada, S. Kobayashi, S. Kishi, S. Mihara, T. Mutoh, T. Mizuuchi, K. Nagasaki, Y. Nakamura, T. Minami, S. Yamamoto, S. Ohshima, S. Konoshima, K. Mukai, H.Y. Lee, Y. Takabatake, K.Hanatani, F.Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, 17th International Stellarator Heliotron Workshop, Princeton, USA, 2009.10.12-16

S. Kobayashi, K. Nagaoka, S. Yamamoto, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, Y. Suzuki, Y. Nakamura, Y. Takeiri, M. Yokoyama, K. Hanatani, K. Hosaka, S. Konoshima, S. Ohshima, K. Toushi, F. Sano, Energetic particle transport in NBI plasmas of Heliotron J, 17th International Stellarator Heliotron Workshop, Princeton, USA, 2009.10.12-16

K. Nagasaki, K. Sakamoto, K. Minami, H. Yoshino, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, S. Ohshima, K. Mukai, S. Kishi, H.Y. Lee, Y. Takabatake, G. Motojima, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, 17th International Stellarator Heliotron Workshop, Princeton, USA, 2009.10.12-16

K. Mukaia, K. Nagasaki, V. Zhuravlevd, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, D. Nishi, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, 17th International Stellarator Heliotron Workshop, Princeton, USA, 2009.10.12-16

K. Nagasaki, G. Motojima, K. Sakamoto, K. Minami, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, K. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernandes, A. Cappa, B. Blackwell, F. Sano, Study of Non-Inductive Current in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan,

2009.10.27-30

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, D. Nishino, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

S. Kobayashi, H.Y. Lee, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, S. Yamamoto, H. Okada, T. Minami, S. Murakami, Y. Suzuki, Y. Nakamura, K. Hanatani, S. Konoshima, K. Toushi, F. Sano, Development of Highly Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

A. Matsuyama, K. Hanatani, Monte Carlo computation of neoclassical poloidal and toroidal viscosity coefficients in helical-axis heliotrons, 19th International Toki onference (ITC19), Ceratopia Toki, 2010.12.8-11

F. Sano, T. Mizuuchi, K. Nagasaki, K. Hanatani, H. Okada, Y. Nakamura, T. Minami, S. Kobayashi, S. Yamamoto, S. Ohshima, S. Watanabe, K. Mukai, K. Minami, S. Kishi, A. Matsuyama, H. Lee, Y. Takabatake, H. Yashiro H. Yoshino, S. Konoshima, B. Blackwell, Physics Research on the Heliotron J Confinement, 19th International Toki onference (ITC19), Ceratopia Toki, 2010.12.8-11

S. Yamamoto, H. Okada, S. Sakakibara, Y. Suzuki, S. Kobayashi, T. Minami, T. Mizuuchi, K. Mukai, K. Nagasaki, Y. Nakamura, Y. Narushima, F. Sano, K.Y. Watanabe, Development of magnetic island detector by magnetic measurement in helical plasmas, 19th International Toki onference (ITC19), Ceratopia Toki, 2010.12.8-11

N. Nishino, T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, F. Sano, Peripheral plasma measurement in Heliotron J using fast cameras, 19th International Toki onference (ITC19), Ceratopia Toki, 2010.12.8-11

Lee Hyunyong（李炫庸），小林進二，村上定義，水内亨，長崎百伸，南貴司，岡田浩之，山本聡，木島滋，向井清史，高畠優，岸真太郎，南桂史，佐野史道，ヘリオトロン J における NBI プラズマ中の CX-NPA 解析，日本物理学会 2009 年秋季大会，熊本大学黒髪キャンパス，2009.9.25-28

松山顕之，花谷清，渡邊清政，モンテカルロ法に基づくヘリカルプラズマの新古典粘性およびフローの数値計算，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

小林進二, 山本聡, 岡田浩之, 長崎百伸, 南貴司，向井清史，岸真太朗，李炫庸，南桂史，高畠優，大島慎介，西野信博，中嶋洋輔，中村祐司，花谷清，佐野史道，ヘリオトロン J における超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

岡田浩之, 山本聡, 榊原悟, 鈴木康浩, 小林進二，長崎百伸，中村祐司，南貴司，水内亨，木島滋，渡邊清政，成嶋吉郎，向井清史，岸真太郎，李炫庸，高畠優，南桂史，佐野史道，磁気計測による磁気島検出器の開発，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

高畠優, 水内亨, 西野信博, 長崎百伸, 岡田浩之，南貴司，小林進二，山本聡，木島滋，中嶋洋輔，井尻芳行, 千住徹, 矢口啓二, 坂本欣三, 東使潔，芝野匡志, 向井清史, 李炫庸, 岸真太郎, 南桂史，佐野史道, 静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

岸真太郎, 岡田浩之, 水内亨, 長崎百伸, 花谷清，南貴司，小林進二，山本聡，木島滋，武藤敬，松山顕之，向井清史，李炫庸，高畠優，南桂史，佐野史道，ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

Lee Hyunyong，小林進二，南貴之，門信一郎，水内亨，長崎百伸，岡田浩之，南貴司，山本聡，村上定義，鈴木康浩，中村祐司，花谷清，木島滋，向井清史，岸真太郎，高畠優，南桂史，香川輔，東使潔，佐野史道，ヘリオトロン J における荷電交換再結合分光計測，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡，木島滋，西大輔、南桂史，李炫庸，高畠優，岸真太郎，八代浩彰，佐野史道，マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測, 第 26 回プラズマ･核融合学会年会，京都市国際交流会館，2009.12.1-4

南貴司, 八代浩彰, 小林進二, 水内亨, 岡田浩之，長崎百伸，中村祐司，花谷清，山本聡，木島滋，大島慎介，佐野史道，Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画，第 26 回プラズマ・核融合学会年会，京都市国際

交流会館，2009.12.1-4

山本聡，中村佑司，岡村昇一，田部井優，西岡賢二，佐野史道，水内亨，長崎百伸，花谷清，岡田浩之，南貴司，小林進二，木島滋，大島慎介，ヘリカル軸ヘリオトロン磁場配位の最適化研究, 第26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

南桂史, 長崎百伸, 坂本欣三, 水内亨, 岡田浩之, 南貴司，小林進二，山本聡，木島滋，向井清史，李炫庸，岸真太郎，高畠優，佐野史道，ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験，第 26 回プラズマ・核融合学会年会，京都市国際交流会館, 2009.12.1-4

杉本大地，比村治彦，平松秀朗，三瓶明希夫，政宗貞男，岡田浩之，山本聡，小林進二，水内亨，佐野史道, 平行電場検証のための立体磁気軸ヘリオトロン J における非中性プラズマ閉じ込め実験，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

松浦寛人，中野賢，山本聡，KMAGN/KMAG-II コードを用いたヘリオトロン J 周辺磁場構造の研究，第 26 回プラズマ・核融合学会年会，京都市国際交流会館，2009.12.1-4

中野賢, 松浦寛人, 水内亨, 岡田浩之, 永岡賢一, ヘリオトロン J 実験グループ, ヘリオトロン J における周辺プラズマ熱流束に関する研究，第 26 回プラズマ・核融合学会年会, 京都市国際交流会館，2009.12.1-4

Clean Energy Conversion Research Section

Hideo Sugama, Visiting Professor
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1. Introduction

In magnetically confined toroidal plasmas, transport of particles and heat across magnetic flux surfaces occurs due to binary Coulomb collisions between charged particles and due to electrostatic or electromagnetic turbulent fluctuations driven by various plasma instabilities. Since the latter process, plasma turbulence, generally dominates plasma transport, a great number of researches have been conducted so far to understand its physical mechanisms and devise efficient methods for reducing turbulent transport toward realization of controlled fusion energy. Gyrokinetic theory and simulation are powerful tools to investigate turbulent transport with accurate descriptions of important kinetic effects such as Landau damping, finite gyroradii, and gyrocenter drift motion in complex magnetic configurations. In recent years, we have been doing gyrokinetic stuides on ion temperature gradient (ITG) turbulence and zonal flows in helical systems [1-7]. Figure 1 shows structures of the electrostatic potential obtained by the gyrokinetic Vlasov (GKV) simulation of ITG turbulence in the Large Helical Device (LHD). Poloidal *ExB* zonal flows are found to be generated by the ITG turbulence in Fig.1 corresponding to the case of the inward-shifted LHD configuration. Zonal flows are now widely recognized as an attractive mechanism for regulation of turbulent transport [8].

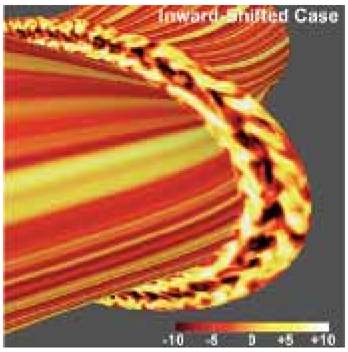

Fig. 1 Color contours of the electrostatic potential in the ITG turbulence obtained by the GKV simulation for the inward-shifted LHD configuration. Zonal-flow structures are seen to be generated.

2. Zonal Flows in Helical Systems

Theoretical studies on collisionless time evolution of zonal flows in tokamaks [9] and helical systems [1-7] such as heliotrons and stellarators elucidated how the zonal-flow response to a given turbulence source depends on the toroidal magnetic geometry that determines particle orbits. Our previous studies [1,2] predicted that the zonal-flow response can be increased in helical systems by reducing the radial drift velocities of helical-ripple-trapped particles. This implies that the helical configurations optimized for reducing neoclassical ripple transport can simultaneously reduce the turbulent transport by enhancing the zonal-flow generation. In fact, the theoretical prediction was confirmed by the ITG turbulence simulation using the GKV code [3-5] as shown in Fig.2 where the regulation of the turbulent ion thermal diffusivity by zonal flows is clearly seen in the inward-shifted (neoclassically-optimized) LHD configuration. The simulation results agree with the confinement improvement that was observed experimentally in the inward-shifted plasma of the LHD. The reduction of anomalous transport by neoclassical optimization also provides an attractive scenario for improving plasma confinement in advanced helical configurations.

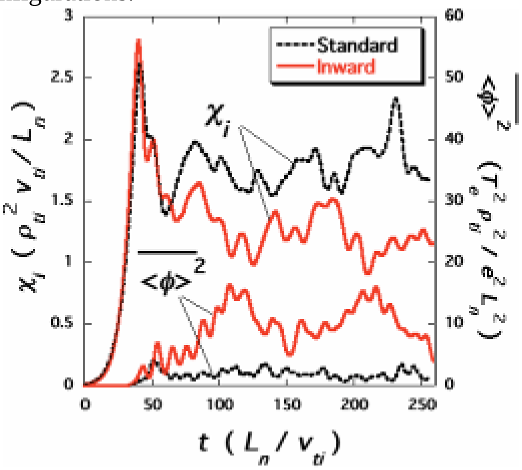

Fig. 2 The turbulent ion thermal diffusivity χ and the radial average of the squared zonal-flow potential ϕ as functions of time t obtained by the ITG turbulence simulations for the standard and inward-shifted LHD configurations.

In helical systems, the radial electric field *Er* is produced from ambipolar particle fluxes and it generates the macroscopic *E*x*B* rotation, which is distinguished from the microscopic sheared *E*x*B* zonal flows. The *E*x*B* rotation driven by *Er*, which was not taken into account in our original theory [1,2] is expected to reduce both neoclassical ripple transport and turbulent transport by improving the zonal-flow response. In our new works [5-7], the collisionless response of the zonal-flow potential to the initial particle distribution and turbulence source is theoretically described for helical systems with equilibrium radial electric fields driving the poloidal *E*x*B* rotation of helical-ripple-trapped particles. Theoretically predicted enhancement of the residual zonal-flow potential due to the *E*x*B* rotation is verified by the linear gyrokinetic Vlasov simulation using the poloidally global domain for a model magnetic geometry corresponding to the inward-shifted LHD configuration [7].

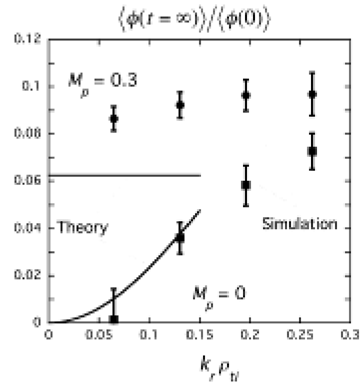

Fig. 3 The normalized residual zonal-flow potential as a function of the normalized radial wave number for Mp = 0 and Mp = 0.3. Symbols with error bars and solid lines represent simulation results and theoretical predictions, respectively.

In Fig.3, the normalized residual zonal-flow potential obtained by the simulation is plotted by symbols with error bars as a function of the normalized radial wave number $k\rho$ for $Mp = 0$ and $Mp = 0.3$, where *Mp* represents the poloidal Mach number of the background *E*x*B* drift velocity. Different radial-wave-number dependences of the residual zonal-flow potential in the small $k\rho$ limit for $Mp = 0$ and $Mp = 0.3$ are confirmed in Fig.3 as theoretically predicted. In the presence of the radial electric field which significantly reduces the radial displacement of the helical-ripple-trapped particles, enhancement of the zonal-flow generation due to the turbulence is expected. Since the *Er* effects appear through the poloidal Mach number *Mp*, higher zonal-flow responses are predicted by using ions with a heavier mass, which increases *Mp*, and accordingly the resultant turbulent transport is expected to show a more favorable ion-mass dependence than the conventional gyro-Bohm scaling.

3. Linearized model collision operators and gyrokinetic entropy balance equations

In magnetically-confined toroidal plasmas, Coulomb collisions are a main cause of the neoclassical ransport, which is investigated by using the drift kinetic equations. On the other hand, the turbulent transport is described by the gyrokinetic equation, which still needs a collision term for the steady turbulent state to be realized. Therefore, it is desirable to use a good collision model in the kinetic equations, which is easy to treat analytically or numerically but satisfies physically correct constraints such as conservation laws of particles, momentum, and energy.

In our recent study [10], novel linearized model collision operators for multiple ion species plasmas are presented, which conserve particles, momentum, and energy, and satisfy adjointness relations and Boltzmann's H-theorem even for collisions between different particle species with unequal temperatures. The model collision operators are also written in the gyrophase-averaged form that can be applied to the gyrokinetic equation. Balance equations for the turbulent entropy density, the energy of electromagnetic fluctuations, the turbulent transport fluxes of particle and heat, and the collisional dissipation are derived from the gyrokinetic equation including the collision term and the Maxwell equations. It is shown that, in the steady turbulence, part of the entropy produced by the turbulent transport fluxes produced in the unstable nonzonal-mode region is nonlinearly transferred into the stable zonal-mode region where the collisional dissipation occurs.

References

[1] H. Sugama and T.-H. Watanabe, Phys. Rev. Lett. **94**, 115001 (2005).
[2] H. Sugama and T.-H. Watanabe, Phys. Plasmas **13**, 012501 (2006).
[3] T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet, Nucl. Fusion **47**, 1380 (2007).
[4] T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet, Phys. Rev. Lett. **100**, 195002 (2008).
[5] H. Sugama, T.-H. Watanabe, and S. Ferrando-Margalet, Plasma Fusion Res. **3**, 041 (2008).
[6] H. Sugama and T.-H. Watanabe, Phys. Plasmas **16**, 056101 (2009).
[7] H. Sugama and T.-H. Watanabe, to be published in Contrib. Plasma Phys.
[8] P. H. Diamond, S.-I. Itoh, K. Itoh, and T. S. Hahm, Plasma Phys. Controlled Fusion **47**, R35 (2005).
[9] M. N. Rosenbluth and F. L. Hinton, Phys. Rev. Lett. **80**, 724 (1998).
[10] H. Sugama and T.-H. Watanabe, Phys. Plasmas **16**, 112503 (2009)

Clean Energy Conversion Research Section

Takeshi Yamauchi, Visiting Associate Professor
(Niigata University)

1. Introduction

There has been much research work to focusing on biopolymers as green sustainable materials [1], [2], [3]. Alginic acid, one of the biopolymers extracted from seaweed, is a polysaccharide of the electrolytes that has the carboxyl group and it can be easily prepared the polymer gel by the ionic bond with the Ca^{2+}. For high-grade green composite materials, the polymer gel fabricated on a micro-scale is expected to be a useful material to prepare smart soft materials which show properties by external stimuli such as pH, temperature, and electric field [4], [5], [6].

From the biomimetic aspect, brush like structure produces high grade functions. For example, lotus leaves which have nano-fibers show super hydrophobility, self-cleaning function and low frictional properties. Gecko's feet, which have nano-rods, can touched and detached on the ceiling by nano-space interaction. Starfish move across the sea bed using tube feet which are extended hydraulically and retracted using muscles. The movement of the tube feet is coordinated by the central nerve system.

Recently, materials which have arrayed micro rods on the surface have been actively researched. These materials are known for their high adsorptive properties, self-cleaning function and low frictional properties. However, it is difficult to fabricate surface of soft materials by conventional methods. We focused on the silicon plate which has arrayed micro pits fabricated by electro chemical method [7]. It is expected that micro rods on the soft material would be prepared from solution filled in micro pits. Calcium alginate easily gelled and has high formability in addition to biocompatibility.

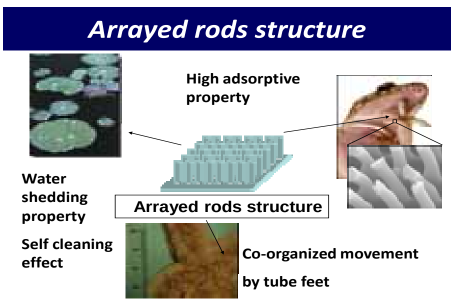

Figure 1 Effect of arrayed rods structure in nature

It has also been reported that such ionic gels are swollen and release solvent by electric stimulation or pH as intelligent material. [8], [9].

In this research work, a new method to prepare calcium alginate gel with micro rods was developed. The surface structure of the gel was observed by optical microscopy and optical properties of the gel were investigated. The micro rod gel is expected to work as novel smart micro bio-devices.

2. Preparation and surface structure of micro-rods gel

The micro pits on the surface of the silicon plate were filled up with 1 wt% sodium alginate aqueous solution mixed with surfactant by application of pressure. The silicon plate was dipped in 200 mM calcium chloride aqueous solution to form the gel.

No micro rod was observed onto the plain gel and it had smooth surface. By contrast, micro rods were regularly arrayed on the surface of the gel. The size of micro rods increased with the diameter of micro pits. High aspect ratio of micro rods on the surface of the gel was formed using template of silicon plates.

The surface structure of the gel was observed with micro scope. Optical transparency of the gels was investigated from patterns of transmitted light through the gel membrane with a laser pointer. The laser light was irradiated to surface of the gel and the pattern of transmitted light was observed at a screen. Patterns of transmitted light through micro rod gels were compared with the pattern of the light through a plain gel. Laser light through the micro rod gel showed arrayed dots pattern.

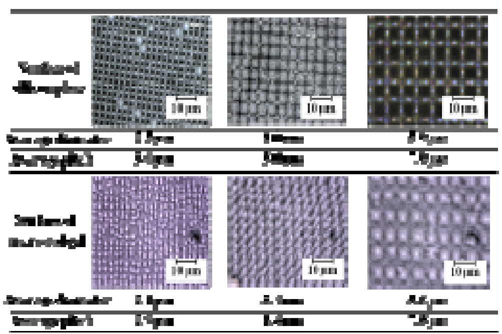

Figure 2 Surface images of the gels and silicon plates

The calculated theoretical values of diffractive intervals corresponded with actual measurement intervals of dots patterns. These results indicated that the surface structure of silicon plates and gels were complementary to each other. The micro rod gels had much larger surface area as same as a lotus leaf which has self-cleaning function and low frictional properties.

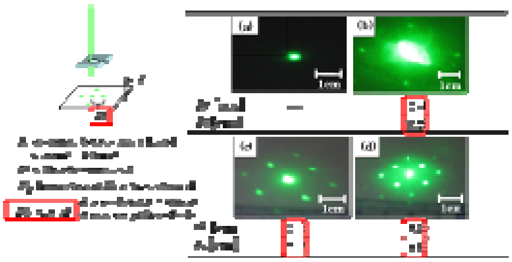

Figure 3 Photographs of diffractive patterns of the micro-rods gel (a) Pain gel, (b) average diameter 2.2 μm, (c) average diameter 3.4 μm, (d) average diameter 5.6 μm

3. Application to smart bio-devices

The micro-rod arrayed gel was evaluated its biomimetic properties concerning micro bio-devices such as actuator and bioreactor. The mico-rod alginate gel decreased in volume in an acidic solution of pH 2, and increased in volume in the alkaline solution of pH 10. Diameter of micro rods was decreased to about 70 %. Conversely, in NaOH, the diameter of micro rods was increased to about 110 %. Micro rod gels were shrunk and swollen by pH with size alteration of micro rods. In acidic solution, COO^- ion and H^+ ion were bonded by presence of a large quantity of H^+ ion, and the gel was contracted by neutralized electrostatic repulsion [10]. In alkaline solution, COO^- ion and H^+ ion were dissociated, and the gel was swelled due to electrostatic repulsion of carboxylate anion in the hydro gels. It was revealed that swelling and shrinking of the composite gels were controlled by external stimuli of pH.

Biomaterials such as enzyme, antibody, and microorganism were easily dissolved in biopolymer solution and entrapped into the gel by the ionic bond with the Ca^{2+}. Glucose oxidase was immobilized in micro-rod gel and evaluated its properties as a bio-reactor. The activity of immobilized enzyme was measured by colorimetric method to detect D-glucono-d-lactone as products by biochemical reaction. It was appeared that D-glucono-d-lactone was effectively produced through the enzyme immobilized micro-rods.

The micro rod gel is expected to be used in new types of smart micro bio-devices such as sensors, actuators, as well as bioreactors utilized in many research fields including chemical engineering, biomedical science, and electronics.

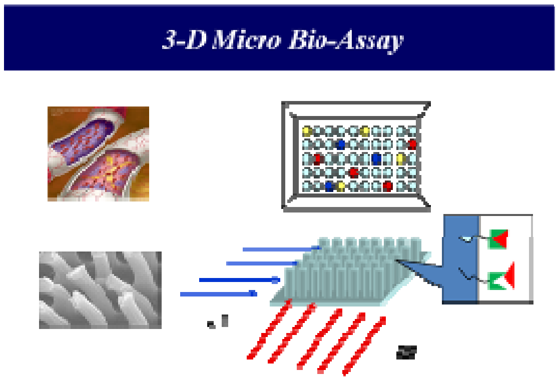

Figure 4 Application of micro-rods gel for bio-devices

References

[1] P. Sierpinski, J. Garrett, J. Ma, P. Apel, D. Klorig, T. Smith, L. Andrew Koman, A. Atala and M. Van Dyke, Biomaterials, 29, 1, 118-128 (2008)

[2] J.Glowacki, and S. Mizuno, Biopolymers, 89, 5, 338-344 (2008)

[3] Y. Furuhashi, Y. Kumura, N. Yoshie, Polymer Journal 38, 10, 1061-1067 (2006)

[4] Y. Osada, H. Okuzaki, And H. Hori, Nature, 355, 242-244 (1992)

[5] M. Shahinpoor, Int. J. Intelligent Material Systems, 6(3), 307-314 (1995).

[6] T. Yamauchi, S. Tansuriyavong, K. Doi, S. Masato, N. Tsubokawa, S. Miyauchi, and J. F. V. Vinent, Synthetic Metals, 152, 45—48 (2005)

[7] K. Fukami, F. A. Harraz, T. Yamauchi, T. Sakka, Y. Ogata, Electrochemistry Communications, 10, 1, 56-60 (2008)

[8] S.Obara, T. Yamauchi, N. Tsubokawa, Journal of Technology and Education, 16, 2, 69-76 (2009)

[9] S.Obara, T. Yamauchi, N. Tsubokawa, Polymer Journal , 42, 1, 1-6 (2010)

[10]Y. Qiu, K. Park, *Advanced Drug Delivery Reviews*, **53**, 321 (2001)

Chemical Reaction Complex Processes Research Section

Y. H. Ogata, Professor
T. Sakka, Associate Professor
K. Fukami, Assistant Professor

1. Introduction

Surface and interface phenomena play an important role in many light energy conversion processes. In this research section fabrication and characterization of various surface structures are investigated. We utilize electrochemical processes and laser spectroscopic techniques to approach this subject.

In this academic year we have performed research work on the mechanism of metal-assisted etching of p-type silicon, gold filling into macro- and mesoporous silicon, laser diffraction of particle monolayers, and application of laser ablation emission spectroscopy to *in situ* underwater elemental analysis. Some details are given below.

2. Metal-assisted etching of p-type silicon under anodic polarization

Porous silicon is formed by anodization of silicon in HF solution. If silicon surface is modified with silver nanoparticles, the etching results in the formation of pores due to the intrusion of the nanoparticles. In this year, we studied the mechanism of the pore formation due to the intrusion of metal nanoparticles under anodization.

The intrusion was observed not with platinum and palladium but with silver. The intrusion behavior is explained by considering both the electrochemical microporous layer formation and the metal-catalyzed chemical dissolution of the microporous layer. The microporous layer formation is affected by the local band modulation at the metal/silicon junction. If a p-type silicon surface is modified with silver nanoparticles, a local Shottky-barrier is formed, leading to the slow and thin microporous layer formation. On the other hand, with platinum or palladium nanoparticles, an ohmic-contact is achieved at the metal nanoparticles, which leads to the fast and thick microporous layer formation. Due to the slow and thin microporous layer formation, silver nanoparticles can sink into the silicon by metal-catalyzed chemical etching of the microprous layer.

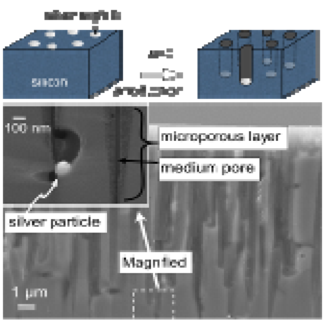

Fig. 2-1 Schematic illustrations of the metal-assisted etching of silicon, together with the cross-sectional images of the substrate after the etching.

3. Filling of porous silicon with gold

The filling of nano-sized pores or trenches by electrodeposition is an important issue for the development of nanotechnology. The utilization of porous silicon as template for electrodeposition is one of the promising approaches for understanding the deposition behavior within porous semiconducting templates.

In the present work, the filling of p-type macropores with ~5 μm in diameter and mesopores having the diameter of ~30 nm were carried out by electrodeposition of gold. The experimental results indicated that the deposition from chloro-complex of Au ions resulted in the discontinuous filling of macro- and mesoporous silicon. On the other hand, when the deposition was performed in a solution containing thiosulfate/surfite complex, macropores were continuously filled as gold tube under illumination, and mesopores were filled continuously from the bottom to the opening as rod.

The discontinuous filling within porous silicon is often caused by displacement deposition of metals on the porous silicon wall, which is driven by the oxidation of pore wall. The displacement deposition is suppressed by the negative shift of the potential of gold deposition due to the stabilization of Au thiosulfate/surfite complex. In p-type macropore filling, illumination is necessary because the potential of gold deposition is too negative to induce hole-injection to the valence band of silicon. Thereby gold deposition in p-type macropores proceeds by electron transfer via the conduction band. In mesopore filling, the deposition from the bottom to the opening can be explained by considering the resistance of the porous layer. The resistivity of the sil-

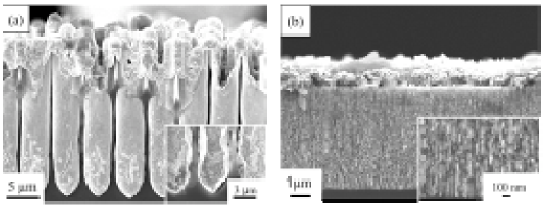

Fig. 3-1 Cross-sectional SEM images of a p-type macroporous silicon (a) and a mesoporous silicon (b) after the electrodeposition of gold in an aqueous solution with thiosulfate/surfite Au complex. The inserts show the magnified images.

icon substrate is very low like 0.01 Ωcm. However, the resistivity might be important to induce the asymmetry of the nucleation of gold between the bottom and the opening even if the resistivity is quite low.

4. Laser diffraction of arrayed particle layers

Self-assembled monodisperse spherical particles on solid surfaces can be used as a template for various ordered surface structures. Two-dimensional (2D) arrays of monodisperse spherical particles can be formed by using capillary force during the evaporation of the solvent from a concave-meniscus surface. Such a technique based on self-assembly has an advantage that it provides a simple method for the formation of an arrayed structure with a large area. In practice, however, we often encounter a difficulty in fabricating large area with a single domain structure. *In situ* monitoring of the surface structure is expected to greatly accelerate the optimization of the process parameters. We have shown that the laser diffraction technique is a powerful tool for *in situ* monitoring of the hexagonally-packed structure.

In this year we have examined laser diffraction patterns different from the hexagonally ordered one. The results were obtained from the disordered portions of the monolayer, and analyzed by comparing with the theoretical simulation based on the Laue function, analogous to the X-ray diffraction theory. The instrumentation has been improved by replacing a screen with a CCD detector to obtain diffraction intensity, which enables quantitative comparison with the simulation. Three examples of the diffraction patterns are shown in Fig. 5-1. The results suggest that a square lattice can be formed in a disordered portion of the self-assembled monolayer of polystylene spheres.

5. Emission spectroscopy of laser ablation plume: composition analysis of a target in water

Previously, we have shown that the emission spectra of the laser ablation plume in water do not necessarily reflect the composition ratio of the target material. This has been attributed to the melting and evaporation processes at a relatively low temperature

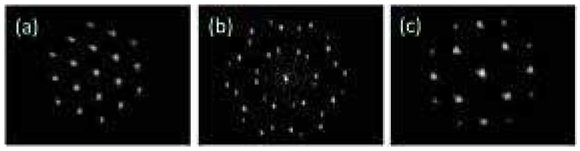

Fig. 5-1 Laser diffraction patterns obtained for various structures formed on a glass plate with monodisperse polystylene colloid spheres with the diameter of 3.21 µm. (a) represents a well-ordered hexagonal array, (b) two domains of hexagonal array in the laser spot, (c) tetragonal structure as a result of deformation of the hexagonal packing structure.

where the difference of the melting points of the target components takes effects. According to this mechanism solute elements in the solution should preserve their composition ratio in the plume, since they do not experience the melting and evaporation processes in the course of the incorporation into the plume. Aqueous solution of 0.1 M $BaCl_2$+0.1 M $CaCl_2$ was examined as an example. As a result, all the lines were reproduced and fitted very well to the theoretical calculations which assume atomic ratio of Ba/Ca to be the same as the concentration ratio of Ba^{2+}/Ca^{2+} in the solution. This is in contrast to the analysis of the elements originated from the solid target, and suggests that the calibration-free analysis of the elements in solution is possible.

6. Underwater LIBS measurement in a micrometer resolution

Previously we have shown that the laser-induced breakdown spectroscopy (LIBS) in water can be successful by using a long ns pulse as an excitation laser. In this year we have extended this technique to micrometer resolution by using a microscope objective lens for focusing the laser pulse to the surface to be irradiated. As in the case using 60-mm focal-length lens for the laser focusing onto the Cu target in water, clear Cu atomic emission lines were observed by using 40x microscope objective lens (f=4.5 mm) as a focusing lens. The irradiation damage left on the target was observed by SEM and a laser confocal microscope. By taking into account the deformation mechanism of the surface by melting, pressurizing, and flowing out from the central part, it is concluded that the ablation occurs in the area characterized by the relatively deep hole observed in the central part of the damage. In other words, the size of this hole is regarded as a spatial resolution of the LIBS measurement in the case of the tightly focused irradiation. In the present experiment the size of this ablation zone was typically 10 to 20 µm in diameter. The use of the microscope objective lens gives a greatly improved spatial resolution of the measurement, as well as the clear emission spectral lines.

Collaboration Works

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Publications

T. Matsumoto, K. Kobayashi, K. Fukami, T. Sakka, Y.H. Ogata, Electrodeposition behavior of noble metals in ordered macroporous silicon, Phys. Status Solidi, C6, 7, 1561-1565, 2009

K. Fukami, T. Sakka, Y. H. Ogata, T. Yamauchi, N. Tsubokawa, Multistep filling of porous silicon with conductive polymer by electropolymerization, Phys. Status Solidi, A206, 6, 1259-1263, 2009

M.S. Salem, M.J. Sailor, K. Fukami, T. Sakka, Y.H. Ogata, Preparation and optical properties of porous silicon rugate-type multilayers with different pore sizes, Phys. Status Solidi, C6, 7, 1620-1623, 2009

T. Sakka, H. Yamagata, H. Oguchi, K. Fukami, Y.H. Ogata, Emission Spectroscopy of Laser Ablation Plume: Composition Analysis of a Target in Water, Appl. Surf. Sci., 255, 24, 9576-9580, 2009

T. Sakka, S. Masai, K. Fukami, Y.H. Ogata, Spectral profile of atomic emission lines and effects of pluse duration on laser ablation in liquid, Spectrochim. Acta, B64, 10, 981-985, 2009

M.L. Chourou, K. Fukami, T. Sakka, S. Virtanen, Y.H. Ogata, Metal-assisted etching of p-type silicon under anodic polarization in HF solution with and without H2O2, Electrochim. Acta, 55, 3, 903-912, 2010

H. Okayama, K. Fukami, R. Plugaru, T. Sakka, Y.H. Ogata, Ordering and disordering of macropores formed in pre-patterned p-type silicon, J. Electrochem. Soc., 157, 1, D54-D59, 2010

Presentations

K. Fukami, Y. Tanaka, M.L. Chourou, T. Sakka, Y.H. Ogata, Filling of mesoporous silicon with copper by electrodeposition from an aqueous solution, 5th Kurt Schwabe Symposium, エアランゲン大学, 2009.5.24-28

M.L. Chourou, K. Fukami, T. Sakka, S. Virtanenn, Y.H. Ogata, Metal-assited electrochemical pore formation of Si deposited with Ag, Pt and Pd, 5th Kurt Schwabe Symposium, エアランゲン大学, 2009.5.24-28

M.S. Salem, M.J. Sailor, K. Fukami, T. Sakka, Y.H. Ogata, Preparation of rugate-type multilayered porous silicon and its application to sensing, The 3rd Kyoto-Erlangen Symposium, エアランゲン大学, 2009.9.3-4

M.L. Chourou, K. Fukami, T. Sakka, S. Virtanen, Y.H. Ogata, Metal-assisted etching of p-Si under anodic polarization with and without H2O2, The 3rd Kyoto-Erlangen Symposium, エアランゲン大学, 2009.9.3-4

K. Fukami, H. Okayama, R. Plugaru, T. Sakka, Y.H. Ogata, Ordering and disordering of macropores formed in pre-patterned p-Si, The 3rd Kyoto-Erlangen Symposium, エアランゲン大学, 2009.9.3-4

Y. Uematsu, T. Sakka, K. Fukami, Y.H. Ogata, Laser-induced breakdown spectroscopy of a solid target in water with micrometer resolution, The 3rd Kyoto-Erlangen Symposium, エアランゲン大学, 2009.9.3-4

H. Yamagata, T. Sakka, K. Fukami, Y.H. Ogata, In situ elemental composition analysis by emission spectroscopy of laser ablated species, The 3rd Kyoto-Erlangen Symposium, エアランゲン大学, 2009.9.3-4

T. Sakka, M. Kubo, T. Shigenobu, K. Fukami, Y.H. Ogata, Fabrication and characterization of solid surfaces with array structure of micrometer-scale, The 3rd Kyoto-Erlangen Symposium, エアランゲン大学, 2009.9.3-4

T. Sakka, T. Nishi, M. Sakata, K. Fukami, Y.H. Ogata, In situ elemental analysis of electrodeposited films by laser induced breakdown spectroscopy, The 4th KIFEE Symposium on Environment, Energy, Materials and Education, NTNU, Trondheim, Norway, 2009.9.6-9

K. Fukami, M.L. Chourou, T. Sakka, S. Virtanen, Y.H.

Ogata, Metal-assisted etching of p-Si under anodic polarization, The 4th KIFEE Symposium on Environment, Energy, Materials and Education, NTNU, Trondheim, Norway, 2009.9.6-9

H. Yamagata, T. Sakka, K. Fukami, Y.H. Ogata, In situ elemental composition analysis by emission spectroscopy of laser ablated species in water, The 4th KIFEE Symposium on Environment, Energy, Materials and Education, NTNU, Trondheim, Norway, 2009.9.6-9

Y. Uematsu, T. Sakka, K. Fukami, Y.H. Ogata, Laser-induced breakdown spectroscopy of a solid target in water with micrometer resolution, The 4th KIFEE Symposium on Environment, Energy, Materials and Education, NTNU, Trondheim, Norway, 2009.9.6-9

M. Kubo, T. Sakka, K. Fukami, Y.H. Ogata, Structural analysis of colloidal monolayer by laser diffraction, The 4th KIFEE Symposium on Environment, Energy, Materials and Education, NTNU, Trondheim, Norway, 2009.9.6-9

山内健，高橋論史，小原佐智子，坪川紀夫，深見一弘，作花哲夫，尾形幸生，Material design using TRIZ problem solving techniques for sustainable engineering，International Symposium on Engineering Neo-Biomimetics，産業技術総合研究所，2009.10.1-2

山内健，高橋論史，小原佐智子，坪川紀夫，深見一弘，作花哲夫，尾形幸生，Preparation and evaluation of the gel with arrayed micro rods for biomimetic actuator，5th World Congress on Biomimetics, Artificial Muscles and Nano-Bio，千里ライフサイエンスセンター，2009.11.25-27

高橋論史，小原佐智子，山内健，坪川紀夫，深見一弘，作花哲夫，尾形幸生，Preparation of the gel with arrayed micro rods and investigation of its surface structure, The 11th Pacific Polymer Conference, ケアンズ国際会議場，2009.12.6-11

高橋論史，小原佐智子，山内健，坪川紀夫，深見一弘，作花哲夫，尾形幸生，マイクロロッド配列構造を有するソフトマテリアルの開発，第 58 回高分子学会北陸支部研究発表会, 新潟大学五十嵐キャンパス，2009.8.27-28

高橋論史，小原佐智子，山内健，坪川紀夫，深見一弘，作花哲夫，尾形幸生，マイクロロッド配列構造を有するソフトマテリアルの作製及び表面構造評価，58 回高分子討論会，熊本大学黒髪キャンパス，2009.9.16-18

M.L. Chourou, K. Fukami, T. Sakka, S. Virtanen, Y.H. Ogata, Metal-assisted etching of p-type silicon under anodic polarization in HF solution with and without hydrogen peroxide, 表面技術協会第 120 回講演大会，幕張メッセ，2009.9.17-18

深見一弘，多孔質シリコンの形態制御と機能化，兵庫県立大学工学部セミナー, 兵庫県立大学姫路書写キャンパス，2009.11.19

山形肇，作花哲夫，深見一弘，尾形幸生，レーザーアブレーションによる溶液成分の元素組成分析，平成 21 年度第 3 回関西電気化学研究会，神戸大学六甲台キャンパス，2009.11.28

上松義孝，作花哲夫，深見一弘，尾形幸生，水中固体試料表面のレーザー誘起ブレイクダウン分光法における空間分解能，平成 21 年度第 3 回関西電気化学研究会，神戸大学六甲台キャンパス，2009.11.28

宮川竜平，深見一弘，作花哲夫，尾形幸生，シリコンに形成したメソ孔への金の置換析出，平成 21 年度第 3 回関西電気化学研究会，神戸大学六甲台キャンパス，2009.11.28

上松義孝，作花哲夫，深見一弘，尾形幸生，水中固体試料表面のレーザー誘起ブレイクダウン分光法における空間分解能，第 11 回表面技術フォーラム，甲南大学ポートアイランドキャンパス，2009.12.1-2

宮川竜平，深見一弘，作花哲夫，尾形幸生，シリコンに形成したメソ孔への貴金属置換析出，第 11 回表面技術フォーラム，甲南大学ポートアイランドキャンパス，2009.12.1-2

山形肇，作花哲夫，深見一弘，尾形幸生，レーザーアブレーションによる溶液成分の元素組成分析，第 11 回表面技術フォーラム，甲南大学ポートアイランドキャンパス，2009.12.1-2

Molecular Assemblies Design Research Section

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Y. Kobuke, Visiting Professor

1. Introduction

Nanostructred inorganic/organic materials have been expected as key components of molecular electronic devices, catalysts, separators, and so on both in terms of bottom-up and top-down fabrications. In this context, utilization of self-organized molecular assembly and preparation of novel nanomaterials of metal oxides or conductive polymers, such as nanotubes, nanowires, nanosheets, or porous ones are studied in this research section. Particularly, we are developing highly efficient organic solar cells, photocatalysts, and filters. Followings are main research achievements in the year of 2009.

2. One-dimensional nanostructured semiconducting materials for organic photovoltaics

Recently, solar cells have attracted much attention relevant to global environmental issues. In particular, organic photovoltaics (OPVs) such as dye-sensitized solar cells (DSSCs) and organic thin-film solar cells have made remarkable progress in terms of power conversion efficiency (PCE) and durability. The maximum PCEs of DSSCs (11%) and organic thin-film solar cells (7%) are still lower than those of silicon-based solar cell. Nevertheless, such organic materials are superior to silicon in the light of lightness, flexibility, color tunability, and facile processability and thus highly promising for ubiquitous utilization. The external quantum efficiency (EQE) of a OPV based on exciton dissociation at a donor-acceptor (D-A) interface is represented as follows: $\eta_{EQE} = \eta_A \times \eta_{ED} \times \eta_{CT} \times \eta_{CC}$

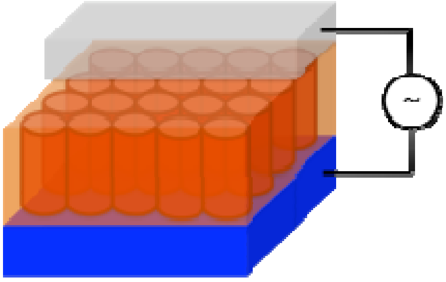

Fig. 1 One-dimensional vertical and bicontinuous arrays of D-A. (T. S., S. Y. *et. al.*, *J. Phys. Chem. Lett.* **2010**, *1*, 1020-1025).

where η_A is the optical absorption efficiency, η_{ED} is the exciton diffusion efficiency, η_{CT} is the charge transfer efficiency, and η_{CC} is the carrier collection efficiency, respectively. In OPVs, the short exciton diffusion length of donors (less than 10 nm), which is much shorter than the optical absorption length (*ca* 100 nm) for sufficiently high η_A, has limited the EQE and a large fraction of the photogenerated excitons remains unused for photocurrent generation. Therefore, it is crucial to control the morphology and mixing state of D-A heterojunction, which would influence on the efficiencies of η_{ED}, η_{CT}, and η_{CC}. Even though morphology control of bulk heterojunction by treatments of solvents, annealing, and/or additives attained high EQE over 70%, overall PCEs reported are still low, due to the inferior charge-transport properties and limited spectral absorption range of the devices. In this context, we tried to construct an improved semiconductor device consisting of arrays of "one-dimensional vertical and bicontinuous arrays of D-A" of densely packed nanorods (Fig. 1), which would enable good optical absorption and carrier collection into orthogonal spatial directions (*viz*. parallel to the incident light direction). We coated ZnO nanorod arrays with TiO_2 to fabricate a poly(3-hexylthiophene) (P3HT) and fullerene derivative of [6,6]-phenyl-C_{61}-butyric acid methyl ester (PCBM) devices resulting in a PCE of 0.7% because of the low crystallinity and small surface area of TiO_2 nanotubes. Further improvement of the hybrid electron-transporting layers would be required for enhancing charge separation and preventing charge recombination. For instance, the cell performance of DSSC can be improved by treating the TiO_2 nanotube arrays with $TiCl_4$. After $TiCl_4$–treatment the TiO_2 nanotubes were covered with a small amount of TiO_2 crystals. Both the short circuit current (J_{sc}) and the PCE were *ca*. 2 times larger than those without the TiO_2 treatment.

Newly prepared oligo-Zn-porphyrin showed excellent absorption characteristics of visible light and was or ganized into a porphyrin-fullerene composite by pyridyl to Zn coordination (by Y. K.).

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Organization (NEDO) from the Ministry of Economy, Trade and Industry (METI) as R&D for Next Generation PV System: Research and development of high-efficient organic thin-film solar cell with supra-hierarchical nano-structure (FY2006-FY2009) to S.Y., T.S., and Y.K.

3. Design and photovoltaic properties of bulk heterojunction polymer solar cells

Highly ordered bulk heterojunction solar cells using semiconducting conjugated polymer of P3HT and fullerene derivative of PCBM were prepared as shown in Fig. 2 and evaluated their photovoltaic properties with respect to the higher device performance. Active layer of D-A in 100 nm thicknesses was prepared by spin-coating using chlorobenzene (*viz*. good solvent) solution with several types of poor solvent such as 1,8-octanedithiol, *N*-methyl 2-pyrrolidone, or benzonitrile. The additives improved the crystallinity of P3HT and suitable segregation of PCBM and resulted effective suppression of the recombination as compared with simple heat treatment. Thickness of the hole transporting layer of poly (3, 4-ethylenedioxythiophene)- poly (styrenesulfonate) (PEDOT:PSS) and the active layer of P3HT-PCBM in polymer based solar cells is crucial to determine the device performance. For instance, thickness can affect the photo absorption of the active layer, which ultimately limits the current density of solar cells. On the other hand, probability of the recombination of excitons becomes higher along with the increase of the thickness. Since photon is electromagnetic wave, the absorbance is affected by the magnitude of magnetic field and the direction of the irradiated photons, which are determined by the reflective index and thickness of each layer. In this context, the optimal thicknesses of the hole transporting layer and the active layer of the polymer based solar cells were theoretically predicted in terms of higher PCE by using a program, semiconducting thin film optics simulator (SETFOS), which is well corresponding to the experimental results. The charge carrier mobility and bimolecular recombination rate coefficient of the cells have also been measured by photo-induced charge extraction by linearly increasing voltage (Photo-CELIV) technique and resulted good correspondence with the above predictions.

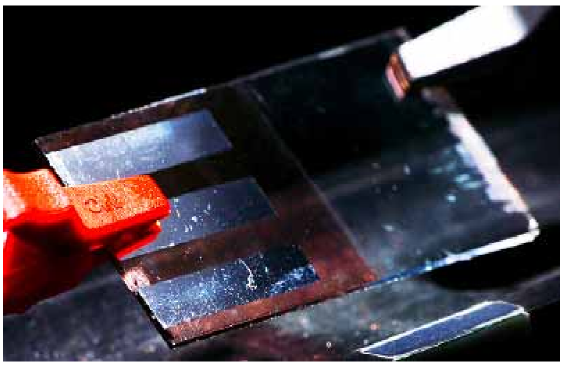

Fig. 2 Bulk heterojunction solar cell composed of glass-ITO/PEDOT:PSS/P3HT-PCBM/TiO_x/Al.

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4. Porous $MgTi_2O_5$ with Pseudobrookite-type Structure Toward Third Generation Diesel Particulate Filter (DPF) Material

Double-oxide-based porous ceramics are promising for third-generation DPF materials. As a candidate material, porous $MgTi_2O_5$ ceramics with pseudobrookite-type crystal structure have been successfully prepared by *in situ* processing (*viz.* reactive sintering). The porous $MgTi_2O_5$ sintered at 1100ºC exhibited very narrow pore-size distribution at 1.0 μm. Thinking about the *in situ* reaction relating to CO_2, porous $MgTi_2O_5$-based materials might absorb CO_2 gas at high temperatures. Intelligent DPF with "self-healing function" for microcracks is expected in the future. Furthermore, due to its well-controlled microstructure, porous $MgTi_2O_5$ is now tested as a new standard material for porosimetry in a US company. This work was supported by MEXT, Japan (Grant-in-Aid for Science Research No. 19685020 For Young Scientist: Category A).

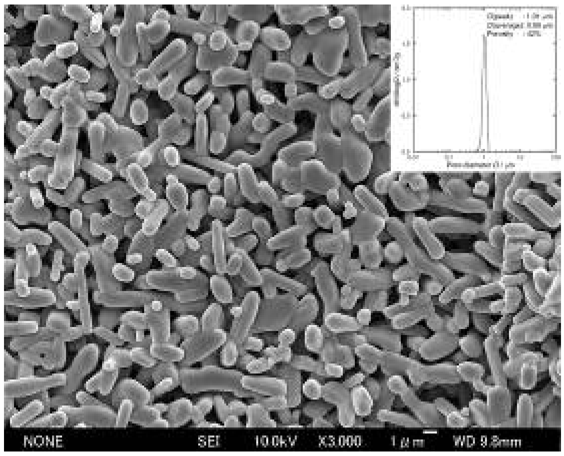

Fig. 3 Microstructure and pore-size distribution (insert) of porous $MgTi_2O_5$ (sintered at 1100ºC for 2h). (Y. Suzuki, *Proc. ICACC* **2010**, Daytona Beach, USA, i*n press*.)

Collaboration Works

インペリアルカレッジロンドン（連合王国）、「機能性高分子の合成」、佐川尚、Joachim H. G. Steinke

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1. Grant-in-Aid for Scientific Research
佐川尚、基盤研究(C)、「高度に結晶化した有機無機ナノ構造体の構築と太陽光発電用透明導電膜への展開」

鈴木義和、若手研究(A)、「三次元ネットワーク型多孔質複合セラミックスのディーゼル粒子除去フィルターへの応用」

2. Others
佐川尚、受託研究（日本学術振興会）、「太陽光発電及び蓄電用機能性有機薄膜の開発」

吉川暹、受託研究（新エネルギー産業技術総合開発機構）、「太陽光発電システム未来技術開発／超階層ナノ構造を有する高効率有機薄膜太陽電池の研究開発」

吉川暹、受託研究（科学技術振興機構）、「高分子ハイブリッドセルの開発」

吉川暹、奨学寄付金（積水化学工業株式会社）、「有機薄膜太陽電池の研究助成」

Publications

S. Chuangchote, J. Jitputti, T. Sagawa, S. Yoshikawa, Photocatalytic Activity for Hydrogen Evolution of Electrospun TiO2 Nanofibers, ACS Applied Materials & Interfaces, 1, 5, 1140-1143, 2009

H. Jintoku, T. Sagawa, M. Takafuji, H. Ihara, Chirally Self-Assembled Porphyrin Nanowires Assisted by L-Glutamide-Derived Lipid for Excitation Energy Transfer, Organic & Biomolecular Chemistry, 7, 11, 2430-2434, 2009

T. Umeyama, T. Takamatsu, N. Tezuka, Y. Matano, Y. Araki, T. Wada, O. Yoshikawa, T. Sagawa, S. Yoshikawa, H. Imahori, Synthesis and Photophysical and Photovoltaic Properties of Porphyrin-Furan and –Thiophene Alternating Copolymers, The Journal of Physical Chemistry, C113, 24, 10798-10806, 2009

H. Hayashi, A. Kira, T. Umeyama, Y. Matano, P. Charoensirithavorn, T. Sagawa, S. Yoshikawa, N.V. Tkachenko, H. Lemmetyinen, H. Imahori, Effects of Electrode Structure on Photoelectrochemical Properties of ZnO Electrodes Modified with Porphyrin-Fullerene Composite Layers with an Intervening Fullerene Monolayer, The Journal of Physical Chemistry, C113, 24, 10819-10828, 2009

T. Tanaka, H. Takishita, T. Sagawa, S. Yoshikawa, S. Hayase, Electrochemiluminescence Devices Consisting of ZnO Nanorods Vertically Grown on Substrate, Chemistry Letters, 38, 7, 742-743, 2009

Y. Suzuki, P.E.D. Morgan, Meso- and Macroporous Ceramics by Phase Separation and Reactive Sintering Methods, MRS Bull., 34, 8, 587-591, 2009

Y. Suzuki, B.P. Pichon, M. Grandcolas, N. Keller, V. Keller-Spitzer, S. Yoshikawa, Preparation and Microstructure of Titanate Nanotube Thin Films by Spray Layer-by-Layer Assembly Method: 1. Agglomerate Problem of Titanate Nanotubes for Thin-Film Processing, Trans. MRS-J, 34 3, 545-549, 2009

P. Charoensirithavorn, Y. Ogomi, T. Sagawa, S. Hayase, S. Yoshikawa, Effect of Heat-Treatment on Electron Transport Process in TiO2 Nanotube Arrays Prepared Through Liquid Phase Deposition for Dye-Sensitized Solar Cells, Journal of the Electrochemical Society, 156, 11, H803-H807, 2009

B.P. Pichon, Y. Suzuki, M.H. Berger, Seeded Growth of Iron Oxide onto Titanate Nanowires, J. Jpn. Soc. Powd. Powd. Metall., 56, 10, 640-644, 2009

T. Puangpetch, T. Sreethawong, S. Yoshikawa, S. Chavadej, Hydrogen production from photocatalytic water splitting over mesoporous-assembled SrTiO3 nanocrystal-based photocatalysts, J. Molecular Catal. A: Chem., 312, 1-2, 97-106, 2009

S. Chuangchote, T. Sagawa, S. Yoshikawa, Electrospinning of Poly(vinyl pyrrolidone): Solvent Effects on Electrospinnability for Fabrication of Poly(p-phenylene vinylene) and TiO2 Nanofibers, Journal of Applied Polymer Science, 114, 5, 2777-2791, 2009

P. Charoensirithavorn, Y. Ogomi, T. Sagawa, S. Yoshikawa, Improvement of Dye-Sensitized Solar Cell through TiCl4 Treated TiO2 Nanotube Arrays, Journal of the Electrochemical Society, 157, 3, B354-B356, 2010

P. Charoensirithavorn, Y. Ogumi, T. Sagawa, S. Hayase, S. Yoshikawa, A Ficile Route to TiO2 Nanotube Arrays for Dye-Sensitized Solar Cells, Journal of Crystal Growth, 311, 757-759, 2009

T. Rattanavoravipa, P. Charoensirithavorn, T. Sagawa, S. Yoshikawa, Efficient Electron Transfers in ZnO Nanorod Arrays with N719 Dye for Hybrid Solar Cells, Solid-State Electronics, 53, 2, 176-180, 2009

S. Chuangchote, T. Sagawa, S. Yoshikawa, Fine-Tuning of TiO2 Nanofibers-Mixed Nanoparticles-Photoelectrode for High Efficient Dye-Sensitized Solar Cells, ECS Transactions, 16, 33, 21-26, 2009

T. Rattanavoravipa, T. Sagawa, S. Yoshikawa, Hybrid Bulk Heterojunction Solar Cells with Anatase Titanium Dioxide Nanotubes Arrays from Liquid Phase Deposition Using ZnO Template, ECS Transactions, 16, 33, 21-26, 2009

N. Watanabe, H. Jintoku, T. Sagawa, M. Takafuji, T. Sawada, H. Ihara, Self-Assembling Fullerene Derivatives for Energy Transfer in Molecular Gel System, Journal of Physics: Conference Series, 159, 12016, 2009

O. Yoshikawa, T. Sonobe, T. Sagawa, S. Yoshikawa, Single Mode Microwave Irradiation to Improve the Efficiency of Polymer Solar Cell Based on Poly(3-hexylthiophene) and Fullerene Derivative, Applied Physics Letters, 94, 083301-1-3, 2009

T. Sagawa, S. Yoshikawa, H. Imahori, One-Dimensional Nanostructured Semiconducting Materials for Organic Photovoltaic Cell, The Journal of Physical Chemistry Letters, 1, 1020-1025, 2010

Y. Hayami, Y. Suzuki, T. Sagawa, S. Yoshikawa, TiO2 Rutile Nanorod Arrays Grown on FTO Substrate Using Amino Acid at a Low Temperature, Journal of Nanoscience and Nanotechnology, 10, 2284-2291, 2010

H. Jintoku, T. Sagawa, T. Sawada, M. Takafuji, H. Ihara, Versatile Chiroptics of Peptide-Induced Assemblies of Metalloporphyrins, Organic & Biomolecular Chemistry, 8, 6, 1344-1350, 2010

Y. Suzuki, Morphology Control of TiO2-Based Nanomaterials for Sustainable Energy Applications, Zero-Carbon Energy Kyoto 2009, 39-45, 2010

吉川暹, 有機薄膜太陽電池の現状と将来展望, 電気評論 11 月号，18，11，1-4，2009

鈴木義和, 次世代フィルター, ナノ空間材料の創製と応用、フロンティア出版，232-238，2009

吉川暹, 有機薄膜型太陽電池, 図解　最新太陽光発電のすべて，1534-1549，2009

吉川暹, 薄膜太陽電池の高効率化と材料開発, 太陽電池 革新的技術全集 2009 版，370-375，2009

Presentations

P. Charoensirithavorn, T. Sagawa, S. Hayase, S. Yoshikawa, Improvement of cell performance by using ZnO nanorod arrays as the electrode for dye-sensitized solar cell, World Renewable Energy Congress 2009 –Asia (WREC 2009 –Asia) & Sustainable Energy and Environment (SEE 2009), Bangkok, Thailand, 2009.5.19-22

T. Rattanavoravipa, T. Sagawa, S. Yoshikawa, Improvement of cell performance of inorganic/organic hybrid solar cells through the surface modification of TiO2 and ZnO nanoarrays by using low molecular organic dyes, World Renewable Energy Congress 2009 –Asia (WREC 2009 –Asia) & Sustainable Energy and Environment (SEE 2009), Bangkok, Thailand, 2009.5.19-22

N. Adulsirisawad, T. Sagawa, S. Yoshikawa, Optimization of photovoltaic performance of bulk heterojunction of organic solar cell by slowgrowth treatment, World Renewable Energy Congress 2009 –Asia (WREC 2009 –Asia) & Sustainable Energy and Environment (SEE 2009), Bangkok, Thailand, 2009.5.19-22

P. Ruankham, T. Sagawa, S. Yoshikawa, Improvement of photovoltaic property of bulk heterojunction organic thin film solar cell based on poly(3-hexylthiophene) and fullerene derivative, World Renewable Energy Congress 2009 –Asia (WREC 2009 –Asia) & Sustainable Energy and Environment (SEE 2009), Bangkok, Thailand, 2009.5.19-22

H. Jintoku, T. Sawada, M. Takafuji, T. Sagawa, S.

Yoshikawa, H. Ihara, Molecular Design of Self-Assembling Donor-Acceptor Complex for Organic Photovoltaics, World Renewable Energy Congress 2009 –Asia (WREC 2009 –Asia) & Sustainable Energy and Environment (SEE 2009), Bangkok, Thailand, 2009.5.19-22

P. Charoensirithavorn, T. Sagawa, S. Hayase, S. Yoshikawa, Enhanced efficiency of dye-sensitized solar cells based on TiO2 nanotube arrays by TiCl4 treatment, The 4th East Asia Symposium on Functional Dyes and Advanced Materials, International House, Osaka, 2009.6.2-5

T. Rattanavoravipa, T. Sagawa, S. Yoshikawa, Fabrication and Optical Properties of Electrospun Organic Semiconductor Nanofibers from Blended Polymer Solution, The 4th East Asia Symposium on Functional Dyes and Advanced Materials, International House, Osaka, 2009.6.2-5

T. Sagawa, Self-Organization of Organic Molecules on the Nanostructured Semiconducting Electrode for Organic Solar Cells, 4th East Asia Symposium on Functional Dyes and Advanced Materials, International House, Osaka, 2009.6.5

Y Suzuki, B.P. Pichon, Preparation and Microstructure of Nanostructured 1-D Titanate Thin Films by Spray Layer-by-Layer Assembly Method, E-MRS 2009, ストラスブール国際会議場, 2009.6.9

T. Sagawa, R. Tange, K. Inai, J.H.G. Steinke, S. Yoshikawa, Functional Organic Thin-Films for Photovoltaic Devices, International Conference on Sustainable Energy & Environmental Protection (SEEP2009), Dublin City University, Dublin, Ireland, 2009.8.12-15

T. Sagawa, Functional Organic Thin Films for Photovoltaic Devices, Chemical Biology Section Summer Lecture, Imperial College London, 2009.8.19

Y. Suzuki, Morphology Control of TiO2-Based Nanomaterials for Sustainable Energy Applications - A Short Review, Zero-Carbon Energy Kyoto 2009, 京都大学百周年記念会館, 2009.8.21

Y Suzuki, B.P. Pichon, Titanate Nanowire Thin Films by Spray Layer-by-Layer Assembly Method, Rocam 2009, ブラショフ大学, 2009.8.27

P. Ruankham, T. Rattanavoravipa, T. Sagawa, S. Yoshikawa, Preparation of Nanostructured TiO2 Thin Film Coated with Bulk Heterojunction of Polythiophene and Fullerene Derivative for Hybrid Organic-Inorganic Solar Cells, 7th Eco-Energy and Materials Science and Engineering Symposium (EMSES), Chiangmai, Thailand, 2009.11.19-22

S. Chuangchote, T. Sagawa, S. Yoshikawa, TiO2 Nanofibers for High Efficient Dye-Sensitized Solar Cells, 7th Eco-Energy and Materials Science and Engineering Symposium (EMSES), Chiangmai, Thailand, 2009.11.19-22

H. Jintoku, T. Sagawa, M. Takafuji, H. Ihara, Self-Assembled Porphyrin-Fullerene Complex for Energy Transfer, 11th Pacific Polymer Conference, Cairns, Australia, 2009.12.6-11

K. Miyamoto, H. Jintoku, T. Sagawa, T. Sawada, M. Takafuji, H. Ihara, Non-Covalent High Conjugation System by Self-Assembled Molecular Gels with L-Glutamide-Functionalized Thiophene Derivative, 第 3 回学生国際会議（ICAST 2009 Seoul）, Seoul, Korea, 2009.12.11-12

Y. Suzuki, In Situ Processing of Porous Ceramics with Pseudobrookite-type Structure Toward Third Generation Diesel Particulate Filter Materials, 34th International Conference and Exposition on Advanced Ceramics and Composites (ICACC '10), Hilton Daytona Beach Resort & Ocean Center, 2010.1.26

Y. Suzuki, Porous Ceramics with Pseudobrookite-type Structure Toward Third Generation Diesel Particulate Filter Materials, International Symposium on Multifunctional Ceramic Materials Based on Nanotechnology (ISMCN2010), Tokyo Big Site, 2010.3.6-7

H. Jintoku, T. Sagawa, M. Takafuji, H. Ihara, Peptide-Functionalized Zinc Porphyrin Assembly with Multi-Responsiveness Based on Selective Axial Coordination, American Chemical Society Spring 2010 National Meeting & Exposition, San Francisco, USA, 2010.3.21-25

H. Jintoku, T. Sagawa, K. Miyamoto, S. Shimoda, C. Ushijima, N. Watanabe, T. Sawada, M. Takafuji, H. Ihara, Formation of Novel Porphyrin-Fullerene Assemblies Assisted by Functionality with Peptide-Lipid, American Chemical Society Spring 2010 National Meeting & Exposition, San Francisco, USA, 2010.3.21-25

K. Miyamoto, H. Jintoku, T. Sagawa, T. Sawada, M. Takafuji, H. Ihara, Design of High-Conjugate Nanostructure from Self-Assembled Molecular Gel with L-Glutamide-Functionalized Thiophene-Derivatives, American Chemical Society Spring 2010 National Meeting & Exposition, San

Francisco, USA, 2010.3.21-25

佐川尚, 有機太陽電池の高効率化に向けて～新しい素子構造の設計と材料開発, 有機薄膜太陽電池サテライトミーティング, 産業技術総合研究所つくば研究センター，2009.4.2

佐川尚, バルクヘテロ接合有機薄膜太陽電池のキャリア輸送特性, 有機太陽電池研究会, 京都大学宇治キャンパス，2009.4.28

鈴木義和, Benoît P. Pichon, Marie-Hélène Berger, スプレー交互吸着法を用いたチタネートナノワイヤー薄膜の作製と評価, 粉体粉末冶金協会平成21 年度春季大会，京都工芸繊維大学，2009.6.4

月ヶ瀬弘樹，鈴木義和，佐川尚，吉川暹，硫化スズナノ粒子増感型太陽電池の作製と評価, 粉体粉末冶金協会平成 21 年度春季大会，京都工芸繊維大学，2009.6.4

佐川尚, 有機薄膜太陽電池の高効率化に向けて～新しい素子構造の設計と材料開発，PV Japan 2009，幕張メッセ展示会場，2009.6.24

佐川尚, 吉川暹, 種々の条件で成膜したバルクヘテロ接合有機薄膜太陽電池の特性評価，第 6 回「次世代の太陽光発電システム」−エネルギー産業クラスターの形成を見据えた産学連携：新潟−, 新潟コンベンションセンター，2009.7.2-3

神徳啓邦，宮本皓史，高藤誠，澤田剛，佐川尚, 伊原博隆, 有機金属錯体の集積化による機能性分子ゲルの開発，第 46 回化学関連支部合同九州大会，北九州国際会議場，2009.7.11

阿部真，丹下龍，吉川整，稲井公二，佐川尚，吉川暹, 光合成色素分子集合体を利用した機能性薄膜の光電変換特性, 第 55 回高分子研究発表会（神戸）55 周年記念講演会, 兵庫県民会館, 2009.7.17

藤澤直樹，吉川整，佐川尚，吉川暹，バルクヘテロ接合型有機薄膜太陽電池の作製と高性能化, 第55 回高分子研究発表会（神戸）55 周年記念講演会，兵庫県民会館，2009.7.17

鈴木義和, 水溶液プロセスを用いた酸化チタン系１次元ナノ材料の創製と高次構造制御, 日本セラミックス協会第 22 回秋季シンポジウム，愛媛大学，2009.9.16

月ヶ瀬弘樹，鈴木義和，佐川尚，吉川暹，硫化スズ増感型太陽電池の作製, 日本セラミックス協会第 22 回秋季シンポジウム，愛媛大学，2009.9.16

宮本皓史，神徳啓邦，佐川尚，澤田剛，高藤誠，伊原博隆, 自己集合性チオフェン誘導脂質を用いた長共役分子ゲルシステムの構築，第 58 回高分子討論会，熊本大学，2009.9.16-18

瀧下いずみ，佐川尚，阿部真，丹下龍，吉川整，稲井公二，神徳啓邦，伊原博隆，吉川暹，集光機能性色素を用いた有機薄膜太陽電池の開発，第58 回高分子討論会，熊本大学，2009.9.16-18

下田俊二，神徳啓邦，高藤誠，澤田剛，佐川尚，伊原博隆, 複合グルタミド誘導分子ゲルによるポルフィリン集積構造の制御，第 58 回高分子討論会，熊本大学，2009.9.16-18

神徳啓邦，佐川尚，澤田剛，高藤誠，伊原博隆，二次元キラリティーを有するポルフィリン集積体の形成：配位子による集積構造の制御，第 58 回高分子討論会，熊本大学，2009.9.16-18

梅山有和，高松毅，手塚記庸，俣野善博，荒木保幸, 和田健彦, 吉川整, 佐川尚, 吉川暹, 今堀博, ポルフィリンを主鎖に有する共役系高分子の光物性，2009 年光化学討論会，群馬県桐生市市民文化会館，2009.9.16-18

佐川尚, ナノ材料・分子集合体が拓く次世代太陽電池の研究開発, 第７回超分子・超構造科学シンポジウム，熊本大学工学部百周年記念館，2009.9.19

佐川尚, 有機太陽電池の開発動向：材料開発とデバイス設計および評価方法の検討，平成 21 年度応用物理学会関西シンポジウム「材料・デバイスが拓く創エネルギー技術の新展開」, (株)島津製作所，関西支社マルチホール，2009.11.26

佐川尚, サイエンスカフェ～新しい太陽電池が未来を拓く～，2009（平成 21）年度公開研究会, 奈良女子大学附属中等教育学校，2009.11.21

佐川尚, 太陽電池の現状と有機太陽電池の可能性, 材料学会関西支部　第４回若手シンポジウム～環境を創造する材料科学～，アーブしが，2009.12.4

鈴木義和, 鈴木達, 高等学校におけるセラミックス教育の現場から，日本セラミックス協会 2010 年年会，東京農工大学，2010.3.23

鈴木義和，第３世代 DPF 材料に向けた MgTi2O5 および MgTi2O5/MgTiO3 多孔体の作製，日本セラミックス協会 2010 年年会，東京農工大学，2010.3.23

藤澤直樹，吉川整，佐川尚，吉川暹，付加物を添加して成膜したポリマー／フラーレンバルクヘテロ接合太陽電池の電荷輸送特性評価，2010 年春季第 57 回応用物理学関係連合講演会，東海大学湘南キャンパス，2010.3.17-20

大土井正昭，梅山有和，俣野善博，吉川整，佐川尚，吉川暹，今堀博，イミド縮環チオフェンを主鎖に含む新規共役系高分子を用いたバルクヘテロ接合型太陽電池，日本化学会第 90 春季年会，近畿大学本部キャンパス，2010.3.26-29

佐川尚，吉川暹，高分子太陽電池のバルクヘテロ接合の設計と光電流特性，日本化学会第 90 春季年会，近畿大学本部キャンパス，2010.3.26-29

Biofunctional Science Research Section

T. Morii, Professor
K. Tainaka, Assistant Professor

1. Introduction

The work in our research group takes synthetic, organic chemical, biochemical and biophysical approaches to understand the biological molecular recognition and chemical reactions. Design and application of miniature proteins and functional protein/nucleic acids assemblies are explored to target and to chemically transform biologically important molecules in water, the solvent of life. Followings are main research achievements in the year of 2009.

2. Novel *in vivo* Biosensors for IP_4 Reveal Temporal IP_4 Dynamics Inside Cells

The signaling cascades to link extracellular messengers to intracellular Ca^{2+} mobilization are regulated by the second messenger D-*myo*-inositol-1,4,5-trisphosphate (IP_3). A direct metabolite of IP_3, D-*myo*-inositol-1,3,4,5-tetrakisphosphate (IP_4), is also believed to be a pivotal second messenger in cellular signal transduction due to the close relevance to chromatin remodeling, modulation of IP_3 levels, Ca^{2+} mobilization, and immune cell development though the physiological function for IP_4 remains unclear. Conventional *ex situ* methods such as HPLC are not suitable to visualize a detailed picture of intracellular IP_4 mobilization in the individual live cells. The real time detection of temporal and spatial dynamics of Ca^{2+} influx and IP_3 has accelerated understanding of their function in cellular signaling events. We constructed novel fluorescent biosensors for IP_4 that enable a real-time monitoring of IP_4 mobilization in mammalian cells. Optimally designed fluorescent sensors based on GRP1 PH domain exhibited appropriate affinities to IP_4 and detectable fluorescence responses upon target binding, in addition to the remarkable selectivity for IP_4 over other inositol phosphates. Expression of the genetically-encoded biosensors sometimes perturbs the intracellular dynamics of target ligands. The IP_4 sensors were homogeneously introduced into cytosol without greatly affecting the molecular geography of inositol phosphates in intact cells by controlling the loading conditions. The *in vivo* IP_4 sensors in combination of other biosensors would realize simultaneous monitoring of the *bona fide* behavior of multiple cellular second messengers in the single-cell, which is currently underway in our laboratory.

3. A Genetically Encoded Fluorescent Biosensor for IP_4 Based on a Split PH Domain

A rational design of fluorescent biosensors for biologically relevant molecules in the cell would accelerate the ubiquitous application of the real-time fluorescent monitoring in the field of diagnosis and pharmacology. In order to visualize the *bona fide* behavior of target molecules, the genetically encoded biosensors based on green fluorescent protein (GFP) represent the attractive and practical strategy. A single circularly permuted (cp) GFP is one of the promising strategies for the development of versatile fluorescent biosensors that enable transducing the conformational change of the receptor associated with the ligand binding event to a significant fluorescent response.

We have demonstrated the functional

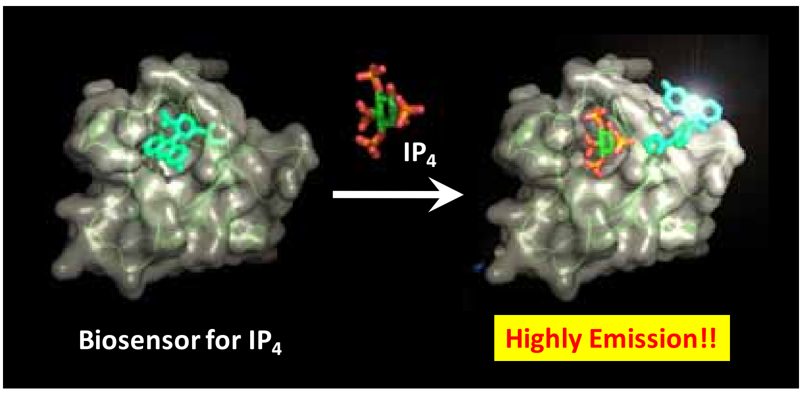

Figure 1. A schematic illustration shows the structure of biosensor for IP_4 based on GRP1 PH domain and biosensor-IP_4 complex. This biosensor exhibits a highly fluorescent emission in response to IP_4 binding.

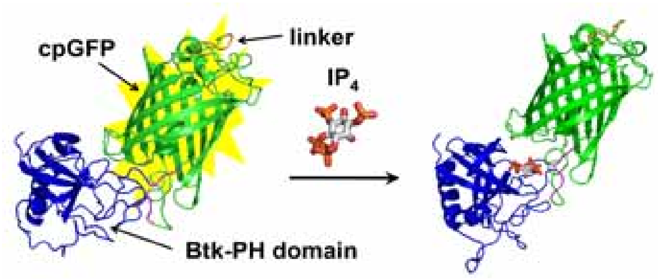

Figure 2. Schematic illustration shows a fluorescent biosensor for IP_4 based on the split Btk PH domain-cpGFP conjugate. The original N and C termini are linked with a short peptide linker (orange), and the novel terminal of cpGFP (purple) is fused to the split Btk PH domain (blue).

reconstitution strategy based on a split pleckstrin homology (PH) domain by dissecting the PH domain and tethering a coiled coil module to each subunit. The reassembled split PH domain maintains binding selectively for IP_3, similar to that of the native PLCδ_1 PH domain. It is possible that the dissection strategy of the split PH domain would permit the target binding region of the PH domain to be contiguously fused to the essential residue for the fluorescence behavior of the cpGFP chromophore without sacrificing the intrinsic function of parent cpGFP and PH domain. We designed and constructed a fluorescent sensor for an intracellular signal messenger IP_4, from a split PH domain of Bruton's tyrosine kinase (Btk) and a single cpGFP. The resulting split PH domain-cpGFP conjugate, Btk-cpGFP, exhibited bimodal absorption spectra corresponding to the protonated and deprotonated state of the chromophore in GFP. Addition of IP_4 to Btk-cpGFP was accompanied by the decrease of 508 nm emission band by the excitation at 470 nm and the increase of the emission band by the excitation at 396 nm. As a result, the Btk-cpGFP realized the ratiometric fluorescence detection of IP_4, and retained the ligand affinity and the selectivity of the original PH domain.

4. Development of Fluorescent Ribonucleopeptide Sensors for Histamine

Biologically active amines, such as dopamine, histamine, and serotonin, are pivotal molecules in the central nervous system. These amines play major roles in the regulation of movement and are implicated in the pathophysiology of Parkinson's and Huntington's diseases, psychosis, and drug addiction. Pharmacotherapy of some major disorders of the central nervous system is based on targeting these biologically active amines. Fluorescent biosensors based on the biological macromolecule receptor would serve as useful tools for investigating the function of biologically active amines in the living cell. However, fluorescent biosensors synthesized by the chemical modification of the ligand binding protein domains with fluorophores are not always guaranteed to execute the expected optical signals.

We have reported a strategy that enables isolation of fluorescent ribonucleopeptide (RNP) sensors with a variety of binding and signal-transducing characteristics, i.e., a high signal-to-noise ratio, various wavelengths and concentration ranges for the ligand detection. The strategy would provide ideal fluorescent RNP sensors for sensing biologically active amines. We developed fluorescent RNP sensors for histamine with a variety of binding and signal-transducing characteristics. Combination of RNA subunits of histamine-binding RNP receptors obtained by *in vitro* selection and a Rev peptide modified with 7-methoxycoumarin-3-carboxylic acid afforded a fluorescent RNP sensor with distinct signaling characteristics in the changes of fluorescence emission intensity upon binding to histamine. The fluorescent histamine sensor showed distinct selectivity for histamine over structurally related histamine analogs, such as imidazole, ethylamine and L-histidine.

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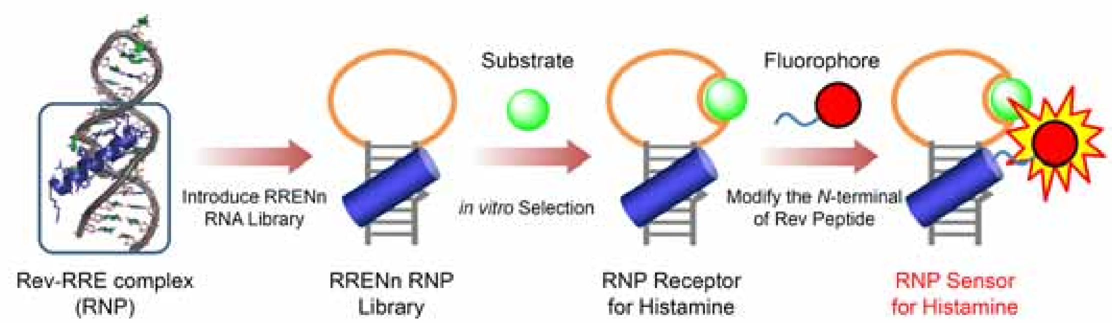

Figure 3. A strategy to obtain RNP fluorescent sensors specific for histamine. Combination of the RNA subunits of the histamine-binding RNP receptor and a fluorophore-modified Rev peptide provided a histamine RNP fluorescent sensor.

Collaboration Works

ウェイン州立大学（米国)、「機能性 RNA 素子の開発」、森井孝、C.S. Chow

医科大学(米国)、「リンパ球内イノシトールの可視・定量」、森井孝、B.D. Freedman

New York 大学（米国)、「イノシトール誘導体の生理活性評価」、森井孝、Y.T. Chang

デュッセルドルフ大学(ドイツ)、「イノシトール三リン酸の白血病への役割」、森井孝、M. Müschen

ロチェスター大学(米国)、「カルシウムイオンによるアラキドン酸産出機構」、森井孝、T. Shuttleworth

Financial Support

1. Grant-in-Aid for Scientific Research
森井孝、基盤研究(A)、「モジュール設計による機能性 RNAータンパク質複合体創製原理の確立」

仲野瞬、特別研究員奨励費、「RNAーペプチド複合体を用いた加水分解酵素の創製」

林宏典、特別研究員奨励費、「熱安定性の高い RNA とタンパク質の複合体の創製」

松本佳彦、特別研究員奨励費、「画期的なフォトクロミック核酸塩基の開発」

2. Others
森井孝、受託研究（科学技術振興機構)、「高機能 RNP ナノデバイスの開発」

田井中一貴、奨学寄付金（国際科学技術財団)、「「太陽光駆動型人工酵素の作製」についての研究活動に対する助成」

Publications

R. Sakaguchi, T. Endoh, S. Yamamoto, K. Tainaka, K. Sugimoto, N. Fujieda, S. Kiyonaka, Y. Mori, T. Morii, A Single Circularly Permuted GFP Sensor for Inositol-1,3,4,5-tetrakisphosphate Based on a Split PH Domain, Bioorg. Med. Chem., 17, 7381-7386, 2009

S. Kiyonaka, K. Kato, M. Nishida, K. Mio, T. Numaga, Y. Sawaguchi, T. Yoshida, M. Wakamori, E. Mori, T. Numata, M. Ishii, H. Takemoto, A. Ojida, K. Watanabe, A. Uemura, H. Kurose, T. Morii, T. Kobayashi, Y. Sato, C. Sato, I. Hamachi, Y. Mori, Selective and direct inhibition of TRPC3 channels underlies biological activities of a pyrazole compound, Proc Natl Acad Sci U S A, 106, 5400-5405, 2009

K. Matsumoto, Y. Shinohara, S. S. Bag, Y. Takeuchi, T. Morii, Y. Saito, I. Saito, Pyrene-labeled Deoxyguanosine as a Fluorescence Sensor to Discriminate Single and Double Stranded DNA Structures: Design of Ends Free Molecular Beacons, Bioorg. med. Chem. Lett., 19, 6392-6395, 2009

M. Inoue, K. Tainaka, A. Hirata, T. Konno, T. Morii, The Amyloid Fibrillization of Phosphorylated Human Tau Core Peptides, Trans. Mat. Res. Soc. Jpn., 34, 517-520, 2009

M. Fukuda, H. Hayashi, T. Hasegawa, T. Morii, Development of A Fluorescent Ribonucleopeptide Sensor for Histamine, Trans. Mat. Res. Soc. Jpn., 34, 525-527, 2009

R. Sakaguchi, K. Tainaka, N. Shimada, S. Nakano, M. Inoue, S. Kiyonaka, Y. Mori, T. Morii, An In Vivo Fluorescent Sensor Reveals Intracellular Ins(1,3,4,5)P4 Dynamics in Single Cells, Angew. Chem. Int. Ed., 49, 2010

K. Matsumoto, Y. Shinohara, K. Numajiri, S. Ishioroshi, T. Morii, Y. Saito, I. Saito, Design of Extremely Facile 3'- and 5'- ends Free Molecular Beacons Using C8 Alkylamino Substituted 2'-Deoxyguanosine, Nucleic Acids Symp. Ser., 53, 141-142, 2009

M. Fukuda, F-F. Liew, T. Morii, Covalently linked fluorescent ribonucreopeptide sensors, Nucleic Acids Symp. Ser., 53, 257-258, 2009

S. Nakano, M. Fukuda, M. T. Mashima, M. Katahira, T. Morii, Structural aspects for the function of ATP-binding ribonucleopeptide receptors, Nucleic Acids Symp. Ser., 53, 259-260, 2009

T. Mashima, A. Matsugami, S. Nakano, M. Inoue, M. Fukuda, T. Morii, M. Katahira, Structural analysis of ribonucleopeptide aptamer against ATP, Nucleic Acids Symp. Ser., 53, 267-268, 2009

Presentations

T. Morii, A Modular Strategy for Tailoring Functional Ribonucleopeptide Complexes, 2nd Swiss-Japan Biomolecular Chemistry Symposium 2009, 東京大学駒場リサーチパークコンベンションホール, 2009.9.11-12

T. Morii, A Modular Strategy for Tailoring Fluorescent Sensors From Ribonucleopeptides, 3rd Asia-Pacific International Peptide Symposium, Shineville Luxury Resort, Jeju Island, Republic of Korea, 2009.11.8-11

T. Morii, Chemical approaches untangling dynamics of cellular signaling molecules, Kyoto-Oxford University Collaborative Forum, Oxford University, 2009.2.5

仲野瞬，福田将虎，真嶋司，片平正人，森井孝，ATP 結合性リボヌクレオペプチドリセプターの機能と構造，第 24 回生体機能関連化学シンポジウム・第 12 回バイオテクノロジー部会シンポジウム，九州大学医系キャンパス，2009.9.13-15

松本桂彦，篠原雄太，竹内辰樹，齋藤義雄，齋藤烈, 森井孝, 遺伝子検出の為のための画期的なモレキュラービーコンの開発，第 24 回生体機能関連化学シンポジウム・第 12 回バイオテクノロジー部会シンポジウム，九州大学医系キャンパス，2009.9.13-15

森井孝, リボヌクレオペプチド複合体による蛍光センサーの設計，第 58 回高分子討論会，熊本大学黒髪南キャンパス，2009.9.16-18

T. Konno, M. Inoue, K. Tainaka, T. Morii，Positional Effects of Phospholylation upon Fibrillation of Tau Derived Peptide，日本生物物理学会第 47 回年会，徳島文理大学徳島キャンパス，2009.10.30-11.1

T. Morii，細胞内シグナル分子を標的とした蛍光センサーの構築, 第 5 回ケミカルバイオロジー・第 2 回センシングバイオロジーシンポジウム, 東京医科歯科大学医学部，2010.2.23

Bioenergy Research Section

M. Katahira, Professor
T. Kodaki, Associate Professor

1. Introduction

Our research section is developing environmentally clean and efficient reaction systems by means of chemically or biologically manipulated systems suitable for energy production. For the development of such a process by learning from biological systems, it is essential to understand complex network of biological signal transductions and mechanism of chemical transformations in the system. Following aspects have been investigated to establish the fundamental basis that would emerge a new technology for the energy-efficient utilization of ubiquitous environmental resources.

2. Protein Engineering of Enzymes Involved in Efficient Xylose Fermentation

Xylose is the second most abundant pentose sugar constituting the lignocellulosic renewable biomass after glucose, and its complete fermentation is economically valuable for producing biofuel from biomass. Many yeast, fungi, and bacteria can ferment xylose into ethanol. *Saccharomyces cerevisiae* is one of the most important microorganisms for ethanol fermentation. Although native *S. cerevisiae* cannot ferment xylose, many studies have shown that recombinant *S. cerevisiae* can acquire the ability to ferment xylose but with some efficiency limitations.

Recombinant *S. cerevisiae* can ferment xylose through a fungal pathway involving two heterologous oxidoreductase genes. In this pathway, *Pichia stipitis* xylose reductase (PsXR) (XR; EC 1.1.1.21), which prefers NADPH, reduces xylose to xylitol followed by xylitol dehydrogenase (PsXDH), which exclusively requires NAD^+ (XDH; EC 1.1.1.9), oxidizes xylitol into xylulose. *S. cerevisiae* xylulokinase (XK) (EC 2.7.1.17) naturally phosphorylates xylulose to xylulose-5-phosphate, which is then metabolized by the glycolytic pathway via the pentose phosphate pathway. XK overexpression improves the efficiency of xylose fermentation. Although this fungal pathway is highly expressed in *S. cerevisiae*, the efficiency of ethanol production is somewhat obstructed by the unfavorable accumulation of xylitol due to the imbalance of coenzyme specificities between XR and XDH. Protein engineering has been widely used to address this issue. Since PsXDH accepts only NAD^+, many researchers have changed the preference of XR to NADH in order to achieve effective recycling of NAD^+/NADH. Converting the cofactor usage of XDH to $NADP^+$ from NAD^+ is another alternative trend.

In this fiscal year, site-directed mutagenesis of PsXR was performed to construct a strictly NADPH-dependent XR. The mutations were designed based on combinations of the sequence alignment of analogous enzymes in the aldo-ketoreductase (AKR) family, crystal structure of *Candida tenuis* XR (CtXR), and 3D structure modeling of *P. stipitis* XR with the binding interactions of NAD^+ and $NADP^+$. Although the differences between the two binding sites of NADH and NADPH are very subtle and unclear, residues that can potentially increase NADPH dependency were selected. The first residue was Glu223, which is located at the end of the short rigid helix β7 of the CtXR crystal structure and has a critical effect on the contact of hydrogen bonds with both 2′- and 3′-hydroxyl groups of the adenosine ribose. Three mutants (E223A, E223D, and E223G) were constructed and the enzyme activities with NADH and NADPH were determined. XR activity with NADH was nearly abolished after the first round of mutations in E223A, E223D, and E223G. These results are in agreement with those of a previous study on other AKR enzymes in which analogous interactions were observed and there were no obvious potential contacts that precluded the absence of a 2′ phosphate allowing for NADH binding. Furthermore, this residue was subjected to a mutation trial and the result revealed that alteration of this site might further inhibit NADH binding. In addition, from the 3D structure model of PsXR, it has been reported that Glu223 and Phe236 can form 3 and 2 hydrogen bonds with NAD^+, respectively. As shown in Fig. 1, the specific activities of E223A, E223D, and E223G XR mutants with NADPH were 52%, 44%, and 39%, respectively, compared to WT; catalytic efficiencies were 26%, 15%, and 12%, respectively, compared to WT. Although there was a decrease in the specific activity compared to WT, two mutants E223A and E223G showed strict NADPH dependency, and the third mutant E223D showed a 2.54-fold improvement in the NADPH/NADH ratio and a 3.9-fold improvement in k_{cat}/K_m . The second selected residue for single mutation, which was not tested previously by mutation trials, was Glu237. This residue was selected from the 3D structure modeling and has 1 hydrogen bond that interacts with NAD^+ but not with $NADP^+$. Glu237 was replaced by alanine or aspartic acid in the amino acid sequence alignments of several related enzymes. Although mutation of this residue did not show any positive results for NADPH preference, E237A showed positive results in terms of improved NADH preference as its catalytic efficiency increased by 2.26-fold with NADH and decreased by 4.14-fold with NADPH compared to WT. Mutation in E237D did not show any significant differences in activity compared to WT. Mutation of this residue to glycine did not show any positive results but produced an approximate 50% decrease in activity compared to WT (data not shown).

For the second round of mutations, investigation of the binding sites of PsXR with NAD(P)H based on the crystal structure of CtXR showed that mutation of the residues Lys270 and Arg276 of PsXR improve the preference for NADH, while that of Ser271 increases the preference for NADPH. An increase in preference for NADH and NADPH was observed in the N272D mutant with stronger preference for NADH. Based on these results, a combination of Ser271 or Asn272 mutants with Glu223 mutants is expected to increase the activity of XR with NADPH. Double N272D/Glu223 mutants did not produce the expected results where both preferences for NADPH and NADH were increased (data not shown). The S271A mutant had greater NADPH preference as shown in Fig. 1, and the specific activities with NADPH and NADH were 125% and 85% compared to WT, respectively. On the other hand, the activity of S271T mutant with NAD(P)H was nearly abolished, although this choice of NAD(P)H was selected by sequence alignment based on the sequence of XR in *Hypocrea jecorina*, which has a strong preference for NADPH. These data suggest the importance of this residue for NADPH preference and enzyme activity, and encouraged us to perform further investigations by combining S271A and Glu223 mutants. A combination of site-directed mutations of the residues Glu223 and S271A produced unique results. The double mutants E223A/S271A (AA), E223D/S271A (DA), and E223G/S271A (GA) showed improvement in activity with NADPH compared to single Glu223 mutant. Figure 1 shows the specific activity of the double mutants AA and GA in which their activities were 106% and 90% compared to WT, respectively.

We previously succeeded in improving xylose fermentation and ethanol production by combining PsXR WT with the mutated PsXDH which accepts only $NADP^+$ (i.e., quadruple ARSdR mutant), and overexpression of XK. It may provide further clues for understanding of importance of coenzyme specificities of XR and XDH, using the strictly NADPH-dependent PsXR of this study with the strictly $NADP^+$-dependent PsXDH. It could be expected that more efficient xylose fermentation is achieved by an effective recycling of coenzymes of NADPH between XR and XDH.

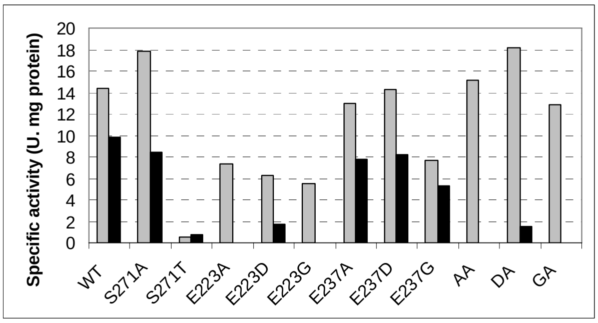

Fig. 1. The specific activities of PsXR WT and XR mutants with NADPH (gray bars) and NADH (black bars).

3. Efficient Bioethanol Production from Algae in Lake Biwa by Yeast Transformed with Protein Engineered Enzyme

Highly efficient bioethanol production from algae in Lake Biwa is developed using genetic recombinant yeast. At first, the best conditions for saccharification of algae were investigated, according to the results of analysis of sugar components. Then, bioethanol was produced from the sugar solution using a genetic recombinant yeast (*S. cerevisiae*) which ferments not only hexose but also pentose. It has a beneficial effect on keeping clean environment in Lake Biwa to use algae as resource for bioethanol production, since the algae is thought to be a major environmental pollutant in Lake Biwa.

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渡邉誠也、若手研究(B)、「代謝工学的手法による木質系バイオマス由来六炭糖･五炭糖同時発酵性酵母の育種」

2. Others
小瀧努、受託研究（関西ティー・エル・オー株式会社)、「琵琶湖産水草を原料としたバイオエタノールの生産実証プロセスの開発」

小瀧努、受託研究（産業技術総合研究所)、「キシロース発酵酵素改変の研究」

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Publications

N.K. Kamisetty, S.P. Pack, A. Doi, M. Nonogawa, K. Yamada, Y. Yoshida, T. Kodaki, K. Makino, Stabilization of the immobilized linkers and DNA probes for DNA microarray fabrication by end-capping of the remaining unreacted silanol on the glass, J. Biotechnol., 140, 242-245, 2009

A. Doi, S.P. Pack, T. Kodaki, K. Makino, Reinvestigation of the molecular influence of hypoxanthine on the DNA cleavage efficiency of restriction endonucleases BglII, EcoRI and BamHI, J. Biochem, 146, 201-208, 2009

T. Kodaki, Development of Highly Efficient Bioethanol Production Yeast Using Protein Engineering, The 1st International Symposium Kyoto University Global COE Program "Energy Science in the Age of Global Warming -Toward CO2 Zero-emission Energy System-", 2009

松鹿昭則, 井上宏, 渡邊誠也, 小瀧努, 牧野圭祐, 澤山茂樹, 改変型酵素を導入したキシロース発酵性実用酵母によるエタノール生産，第 61 回日本生物工学会大会，2009

A. Matsushika, H. Inoue, T. Kodaki, S. Sawayama, Ethanol production from xylose in engineered yeasts: current state and perspectives, Appl. Microbiol. Biotechnol., 84, 37-53, 2009

Presentations

T. Kodaki, Development of Highly Efficient Bioethanol Production Yeast Using Protein Engineering, The 1st International Symposium Kyoto University Global COE Program "Energy Science in the Age of Global Warming -Toward CO2 Zero-emission Energy System-",京都, 2009.8.20-21

松鹿昭則, 井上宏, 渡邊誠也, 小瀧努, 牧野圭祐, 澤山茂樹, 改変型酵素を導入したキシロース発酵性実用酵母によるエタノール生産，第 61 回日本生物工学会大会，名古屋，2009.9.23-25

Laboratory for Complex Energy Processes 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 investigations on the hydrophobic and hydrophilic hydrations, anomalous behavior of confined liquids, folding/unfolding mechanisms of proteins, receptor-ligand binding, prediction of the native structure of a protein, and mechanism of the 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. The interactions between fast-ions and materials cause the impurity problem for the plasma confinement and the damage for the vessel or the first wall materials.

Fast-ion velocity distribution is 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'). Optimization of the ICRF heating is important for the three-dimensional magnetic configuration. One condition is investigated by changing ion cyclotron resonance layer, and then it is found that there is a difference between the fast-ion formation and bulk ion heating.

(A-1) Entropic insertion of a big solute into a vessel [1]

We consider the insertion of a big body into an even bigger vessel in small spheres forming the solvent. Such an insertion is a basic process in biological systems. Typical examples are the introduction of a polypeptide into the chaperonin GroEL and that of an antibiotic molecule or a toxic protein into a cell-membrane protein. They form elementary steps in the facilitation of protein folding and in the export of unfavorable molecules to the outside, respectively. We calculate the potential of mean force between a big sphere and a cylindrical vessel using the three-dimensional integral equation theory. We find that due to the entropic effect by solvent particles, a big sphere whose diameter lies in a fairly wide range is spontaneously inserted into the vessel and strongly confined within a small space almost in the center of the vessel cavity.

(A-2) Pressure effect on helix-coil transition of an alanine-based peptide [2]

It has been shown in a recent experimental study for an alanine-based peptide that the transition from the coil state to the helix state occurs at high pressures. We show that this result can be elucidated by our method wherein the solvent entropy, which is calculated using an elaborate statistical-mechanical theory, is treated as an essential factor. The structural stability is described by the competition between the solvent-entropy gain and the conformational-entropy loss of the polypeptide upon the transition. Though the former is smaller at low pressures, it prevails over the latter at high pressures.

(A-3) Characteristics of protein structures induced by cold denaturation [3]

We study the entropy change upon denaturation of yeast frataxin. The minimum and maximum values of the conformational-entropy gain are estimated via two routes. The range of the water-entropy loss is then determined from the entropy change experimentally obtained. We calculate the water-entropy loss upon the transition from the native structure to a variety of unfolded structures. The hybrid of the angle-dependent integral equation theory combined with the multipolar water model and the morphometric approach is employed. We then select the unfolded structures for which the water-entropy loss falls within the determined range. The selection is performed at cold and heat denaturation temperatures. It is found that the average values of the radius of gyration, excluded volume, and water-accessible surface area for the cold-denatured structures are almost the same as those for the heat-denatured ones. We estimate the cold denaturation temperature from the experimental data for the enthalpy, entropy, and heat-capacity changes upon denaturation: It is considerably higher than 273 K. These results are in qualitatively good accord with the experimental observations.

(A-4) Effects of side-chain packing on the formation of secondary structures in protein folding [4]

For some proteins we calculate the hydration entropies of a number of structures including the native structure with or without side chains. Major findings are as follows. For the structures without side chains, there is an apparent tendency that the water entropy becomes higher as the α-helix or β-sheet content increases. For the structures with side chains, however, a higher content of α-helices or β-sheets does not necessarily lead to larger entropy of water due to the effect of the side-chain packing. The thorough, overall packing of side chains, which gives little space in the interior, is unique to the native structure. To accomplish such specific packing, the α-helix and β-sheet contents are prudently adjusted in protein folding.

(B-1) Dependence of the fast-ion formation and ion heating efficiency on the position of the ion cyclotron resonance layer [5]

Fast ion velocity distribution is investigated using fast protons generated by ICRF minority heating in Heliotron J, a low-shear helical-axis heliotron (R_0 = 1.2 m, a = 0.1-0.2 m, $B_0 \leq$ 1.5 T). The fast ions are measured by a charge-exchange neutral particle energy analyzer (CX-NPA) installed at the opposite position in the toroidal angle to the ICRF antennas. By changing resonance layer position, the CX flux was measured, and then fast-ion energy spectrum and ion heating efficiency were investigated. The majority species of plasma is deuteron and the minor is proton. The minority ratio is about 10%.

The heating position is changed by ICRF frequency in the medium bumpy case. The frequency of 19 MHz is used for the on-axis heating and 23.2 MHz is for the inner-side off-axis heating. The ICRF power is about 280 kW and minority ratio is 0.1. The fundamental cyclotron resonance layers for protons. In this configuration, the resonance layer for 19 MHz is located on-axis for all toroidal angles, whereas the resonance layer for 23.2 MHz inside the plasma disappears for about 40% in the toroidal angles. The energy spectra for both cases in the function of the pitch angle of the measured protons by the CX-NPA are observed. The pitch angle was changed by moving toroidal and poloidal angles of CX-NPA in the condition that the line of sight of the detector crosses the magnetic axis. The measured flux at a fixed energy of the on-axis resonance case is larger than that in the inner-side case. The amount of flux and the slope of the energy spectrum are different for each pitch angle. The effective temperature is estimated from the measured energy spectra in the range from 0.8 keV to 7 keV. It is larger in the on-axis case than in the inner-side case. For both cases, the effective temperature is largest near 120 deg of pitch angle, and the effective temperature decreases towards either side.

The increase of majority ion temperature, however, has different tendency from the fast ion energy spectra. The increase of ion temperature in the inside heating case is larger than that in the on-axis heating case. The heating efficiency in the power scan experiment for both cases is estimated from the CX-NPA measurement. In the minority heating scheme, the bulk ions mainly heated due to Coulomb collisions with fast ions accelerated by ICRF heating. This result cannot be explained only be the heating of minority fast ions.

It is possible that fast ions are localized in some part of the poloidal or toroidal location, the loss cone structure in velocity space for complex Heliotron J field affects the energy spectra, or the energy deposition for three species is different among two cases. The poloidal angle scan of the CX-NPA is performed to investigate the fast-ion vertical profile in the cross section for a fixed toroidal angle. Pitch angle does not change in the poloidal scan. In the off-axis heating condition, where the proton cyclotron resonance is located on the high-field side of the torus, the effective temperature at the toroidal angle of 0 deg decreases as the poloidal angle. On the contrary, the change along poloidal angle in the plasma core region is little in the on-axis heating. It is considered that the fast ions are localized along the vertical position and the localizatin depends on the heating position.

For analyzing wave structure in the Heliotron J plasma, three-dimensional code is required because of the structure of the magnetic field and the flux surface. The TASK/WM code [6] can treat the fully three-dimensional plasma, where the Fourier series expansion is used for the toroidal and poloidal directions. In the analysis of Heliotron J plasmas, the magnetic coordinates of VMEC code [7] are used. The preliminary analysis has been started.

[1] K. Amano and M. Kinoshita, Chem. Phys. Lett., **488**, 1 (2010).
[2] T. Yoshidome and M. Kinoshita, Chem. Phys. Lett., **477**, 211 (2009).
[3] H. Oshima, T. Yoshidome, K. Amano, and M. Kinoshita, J. Chem. Phys., **131**, 205102 (2009).
[4] S. Yasuda, T. Yoshidome, H. Oshima, R. Kodama, Y. Harano, and M. Kinoshita, J. Chem. Phys., **132**, 065105 (2010).
[5] H. Okada et al., Proc. 17th ISHW (2009), Princeton, USA, P03-18.
[6] A. Fukuyama et al., Proc. 19th IAEA Fusion Energy Conference (2002) IAEA-CN-94/TH/P3-14.
[7] S. P. Hirshman and O. Betancourt, J. Comput. Phys. **96**, 99 (1991).

Collaboration Works

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核融合科学研究所、「高速カメラによる Heliotron J 周辺プラズマの研究」、西野信博（広島大）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリカルプラズマにおける新古典電流に対する径電場・配位制御の効果」、西村伸（核融合研）、花谷清、山本聡、岡田浩之

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核融合科学研究所、「フィルターと AXUV ダイオードアレイを用いた HeliotronJ プラズマのエネルギー閉じ込めにおける炭素不純物の影響に関する実験的研究」、田村直樹（核融合研）、佐野史道、水内亨、小林進二、長崎百伸、岡田浩之

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核融合科学研究所、「ヘリオトロン J 装置を用いた非中性プラズマのヘリカル磁気面閉じ込め実験」、比村治彦（京都工芸繊維大）、佐野史道、水内亨、岡田浩之

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核融合科学研究所、「ヘリオトロン J における高効率燃料供給に向けたペレット入射の検討」、本島厳（核融合研）、佐野史道、水内亨、岡田浩之

核融合科学研究所、「極低磁場での電子バーンシュタイン波加熱のヘリオトロン J プラズマ閉じ込めへの影響」、東井和夫（核融合研）、佐野史道、山本聡、水内亨、南貴司、小林進二、長崎百伸、岡田浩之

核融合科学研究所、「ヘリオトロン J、CHS,LHD 装置における重水素プラズマの粒子輸送の研究」、田中謙治（核融合研）、佐野史道、山本聡、水内亨、小林進二、長崎百伸、岡田浩之

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核融合科学研究所、「ヘリカル系における電子サイクロトロン電流駆動による回転変換制御」、長

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核融合科学研究所、「磁気計測による磁気島検出器の開発」、岡田浩之、佐野史道、山本聡、水内亨、小林進二、長崎百伸

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木下正弘、新学術領域研究、「ATP 駆動蛋白質の機能発現における水の役割：統計力学理論解析」

2. Others

岡田浩之、共同研究（核融合科学研究所)、「磁気計測による磁気島検出器の開発」

Publications

T. Yoshidome, M. Kinoshita, Pressure Effect on Helix-Coil Transition of an Alanine-Based Peptide: Theoretical Analysis, Chemical Physics Letters, 477, 211-215, 2009

T. Yoshidome, K. Oda, Y. Harano, R. Roth, Y. Sugita, M. Ikeguchi, M. Kinoshita, Free-Energy Function Based on an All-Atom Model for Proteins, Proteins – Structure Function and Bioinformatics, 77, 950-961, 2009

H. Oshima, T. Yoshidome, K. Amano, M. Kinoshita, A Theoretical Analysis on Characteristics of Protein Structures Induced by Cold Denaturation, Journal of Chemical Physics, 131, 205102-1-11, 2009

S. Yasuda, T. Yoshidome, H. Oshima, R. Kodama, Y. Harano, M. Kinoshita, Effects of Side-Chain Packing on the Formation of Secondary Structures in Protein Folding, Journal of Chemical Physics, 132, 065105-1-10, 2010

K. Amano, M. Kinoshita, Entropic Insertion of a Big Sphere into a Cylindrical Vessel, Chemical Physics Letters, 488, 1-6, 2010

T. Mizuuchi, K. Murai, S. Watanabe, S. Yamamoto, S. Kobayashi, K. Nagasaki, H. Okada, G. Motojima, H. Arimoto, F. Hamagami, D. Katayama, H. Matsuoka, A. Nakajima, H. Takahashi, H. Yasuda, K. Mukai, Y. Kowada, K. Hosaka, S. Mihara, N. Nishino Y. Nakashima, Y. Nakamura, K. Hanatani, K. Kondob, F. Sano, Comparison of edge plasma behavior at different poloidal positions in Heliotron J, Journal of Nuclear Materials, 390-391, 428-431, 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, K. Nagasaki, H. Okada, F. Sano, S. Yamamoto, K. Kondo, Recycling studies based on two-dimensional visible light measurements and Monte-Carlo simulation in mirror and helical systems, Journal of Nuclear Materials, 390-391, 511-515, 2009

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, G. Motojima, S. Watanabe, A. Matsuyama, Y. Nakamura, K. Hanatani, K. Kondo, F. Sano, Heliotron J Group, Configuration control experiments in Heliotron J, Journal of Plasma Fusion Research, SERIES, 8, 981-986, 2009

S. Nishimura, Y. Nakamura, G. Motojima, H. Okada, S. Kobayashi, S. Yamamoto, K. Nagasaki, K. Hanatani, K. Kondo, T. Mizuuchi, F. Sano, Effects of Configuration Control on the Neoclassical Viscosity in Heliotron-J, Journal of Plasma Fusion Research, SERIES, 8, 1003-1009, 2009

G. Motojima, K. Nagasaki, H. Okada, K. Watanabe, T. Mizuuchi, A. Matsuyama, K. Hanatani, S. Yamamoto, S. Kobayashi, Y. Suzuki, K. Kondo, Y. Nakamura, A.C.Fernandez, Á. lvaro A. Cappa, Y. Yoshimura, S. Watanabe, K. Mukai, F. Sano, Experimental Study of Non-Inductive Current in Heliotron J, Journal of Plasma Fusion Research, SERIES, 8, 1010-1014, 2009

K. Nagaoka, S. Kobayashi, K. Hosaka, S. Yamamoto, T. Mizuuchi, M. Osakabe, Y. Takeiri, K. Nagasaki, H. Okada, K. Kondo, K. Hanatani, F. Sano, Observation of Fast Ion Response to MHD Activities in Heliotron J, Journal of Plasma Fusion Research, SERIES, 8, 1100-1103, 2009

Y. Karino, R. Akiyama, M. Kinoshita, A Simple Theory for Entropic Interaction Induced between Large Spheres in a Binary Mixture of Small and Medium Spheres, Journal of the Physical Society of Japan, in press.

吉留崇，アポプラストシアニン折り畳みの熱力学：理論と実験との定量的比較，生物物理，トピックス（新進気鋭シリーズ)，50，90-91，2010

木下正弘，固体表面近傍における液体の構造，トライボロジスト，特集「固液界面の物理」，55，229-235，2010

木下正弘，表面の水和の統計力学理論，日本化学会・コロイドおよび界面化学部会 35 周年記念出版，丸善，「現代界面コロイド科学の事典ーシャンプーから宇宙までー」，10 章 6 節，pp. 244-245.

T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Watanabe, K. Mukai, S.

Kishi, H.Y. Lee, K. Minami, Y. Takabatake, H. Yashiro, N. Nishino, Y. Nakashima, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Effects of gas-fueling control on plasma performance in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

H. Okada, S. Kobayashi, S. Kishi, S. Mihara, T. Mutoh, T. Mizuuchi, K. Nagasaki, Y. Nakamura, T. Minami, S. Yamamoto, S. Ohshima, S. Konoshima, K. Mukai, H.Y. Lee, Y. Takabatake, K. Hanatani, F. Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

S. Kobayashi, K. Nagaoka, S. Yamamoto, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, Y. Suzuki, Y. Nakamura, Y. Takeiri, M. Yokoyama, K. Hanatani, K. Hosaka, S. Konoshima, S. Ohshima, K. Toushi, F. Sano, Energetic particle transport in NBI plasmas of Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

K. Nagasaki, K. Sakamoto, K. Minami, H. Yoshino, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, Y. Nakamura, S. Ohshima, K. Mukai, S. Kishi, H.Y. Lee, Y. Takabatake, G. Motojima, Y. Yoshimura, A. Fernández, Á. Cappa, B. Blackwell, F. Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, 2009

K. Mukaia, K. Nagasaki, V. Zhuravlevd, T. Fukuda, T. Mizuuchi, T. Minami , H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, D. Nishi, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, 17th International Stellarator Workshop/Heliotron Workshop, 2009

S. Kobayashi, H.Y. Lee, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, S. Yamamoto, H. Okada, T. Minami, S. Murakami, Y. Suzuki, Y. Nakamura, K. Hanatani, S. Konoshima, K. Toushi, F. Sano, Development of Highly Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

K. Mukai, K. Nagasaki, V. Zhuravlev, T. Fukuda, T. Mizuuchi, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, S. Konoshima, D. Nishino, K. Minami, H.Y. Lee, Y. Takabatake, S. Kishi, H. Yashiro, F. Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

K. Nagasaki, G. Motojima, K. Sakamoto, K. Minami, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Yamamoto, K. Konoshima, Y. Nakamura, K. Mukai, Y. Yoshimura, A. Fernandes, A. Cappa, B. Blackwell, F. Sano, Study of Non-Inductive Current in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, 2009

F. Sano, T. Mizuuchi, K. Nagasaki, K. Hanatani, H. Okada, Y. Nakamura, T. Minami, S. Kobayashi, S. Yamamoto, S. Ohshima, S. Watanabe, K. Mukai, K. Minami, S. Kishi, A. Matsuyama, H. Lee, Y. Takabatake, H. Yashiroa H. Yoshino, S. Konoshima, B. Blackwell, Physics Research on the Heliotron J Confinement, 19th International Toki onference (ITC19), 2009

S. Yamamoto, H. Okada, S. Sakakibara, Y. Suzuki, S. Kobayashi, T. Minami, T. Mizuuchi, K. Mukai, K. Nagasaki, Y. Nakamura, Y. Narushima, F. Sano, K.Y. Watanabe, Development of magnetic island detector by magnetic measurement in helical plasmas, 19th International Toki onference (ITC19), 2009

N. Nishino, T. Mizuuchi, S. Kobayashi, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, F. Sano, Peripheral plasma measurement in Heliotron J using fast cameras, 19th International Toki onference (ITC19), 2009

Lee Hyunyong（李炫庸），小林進二，村上定義，水内亨，長崎百伸，南貴司，岡田浩之，山本聡，木島滋，向井清史，高畠優，岸真太郎，南桂史，佐野史道，ヘリオトロン J における NBI プラズマ中の CX-NPA 解析，日本物理学会 2009 年秋季大会，2009

小林進二, 山本聡, 岡田浩之, 長崎百伸, 南貴司，向井清史，岸真太朗，李炫庸，南桂史，高畠優，大島慎介，西野信博，中嶋洋輔，中村祐司，花谷清，佐野史道，ヘリオトロン J における超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ・核融合学会年会，2009

岡田浩之, 山本聡, 榊原悟, 鈴木康浩, 小林進二，長崎百伸，中村祐司，南貴司，水内亨，木島滋，渡邊清政，成嶋吉郎，向井清史，岸真太郎，李炫庸，高畠優，南桂史，佐野史道，磁気計測による磁気島検出器の開発，第 26 回プラズマ・核融合学会年会，2009

高畠優, 水内亨, 西野信博, 長崎百伸, 岡田浩之,

南貴司, 小林進二, 山本聡, 木島滋, 中嶋洋輔, 井尻芳行, 千住徹, 矢口啓二, 坂本欣三, 東使潔, 芝野匡志, 向井清史, 李炫庸, 岸真太郎, 南桂史, 佐野史道, 静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析, 第 26 回プラズマ・核融合学会年会, 2009

岸真太郎, 岡田浩之, 水内亨, 長崎百伸, 花谷清, 南貴司, 小林進二, 山本聡, 木島滋, 武藤敬, 松山顕之, 向井清史, 李炫庸, 高畠優, 南桂史, 佐野史道, ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率, 第 26 回プラズマ・核融合学会年会, 2009

Lee Hyunyong, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 鈴木康浩, 中村祐司, 花谷清, 木島滋, 向井清史, 岸真太郎, 高畠優, 南桂史, 香川輔, 東使潔, 佐野史道, ヘリオトロン J における荷電交換再結合分光計測, 第 26 回プラズマ・核融合学会年会, 2009

向井清史, 長崎百伸, Vladimir Zhuravlev, 福田武司, 水内亨, 南貴司, 岡田浩之, 小林進二, 山本聡, 木島滋, 西大輔, 南桂史, 李炫庸, 高畠優, 岸真太郎, 八代浩彰, 佐野史道, マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測, 第 26 回プラズマ・核融合学会年会, 2009

南貴司, 八代浩彰, 小林進二, 水内亨, 岡田浩之, 長崎百伸, 中村祐司, 花谷清, 山本聡, 木島滋, 大島慎介, 佐野史道, Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画, 第 26 回プラズマ・核融合学会年会, 2009

山本聡, 中村佑司, 岡村昇一, 田部井優, 西岡賢二, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 木島滋, 大島慎介, ヘリカル軸ヘリオトロン磁場配位の最適化研究, 第 26 回プラズマ・核融合学会年会, 2009

南桂史, 長崎百伸, 坂本欣三, 水内亨, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 向井清史, 李炫庸, 岸真太郎, 高畠優, 佐野史道, ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験, 第 26 回プラズマ・核融合学会年会, 2009

杉本大地, 比村治彦, 平松秀朗, 三瓶明希夫, 政宗貞男, 岡田浩之, 山本聡, 小林進二, 水内亨, 佐野史道, 平行電場検証のための立体磁気軸ヘリオトロン J における非中性プラズマ閉じ込め実験, 第 26 回プラズマ・核融合学会年会, 2009

中野賢, 松浦寛人, 水内亨, 岡田浩之, 永岡賢一, ヘリオトロン J 実験グループ, ヘリオトロン J における周辺プラズマ熱流束に関する研究, 第 26 回プラズマ・核融合学会年会, 2009

Presentations

T. Yoshidome, M. Kinoshita, Hydrophobicity at Low Temperatures and Cold Denaturation of a Protein, International Symposium on “Reaction Dynamics of Many-Body Chemical Systems (RDMCS2009), Kyoto University, 2009.6.23

M. Kinoshita, Importance of Translational Entropy of Water in Biological Self-Assembly, International Symposium on Multi-Scale Dynamics of Protein Complex Formation and Function, Sanjo Conference Hall, The University of Tokyo, 2009.7.15

K. Amano, T. Yoshidome, M. Kinoshita, A Theoretical Analysis on the Entropic Potential Field Formed for a Linear-Motor Protein near a Filament, The 1st GCOE International Symposium, Kyoto University, 2009.8.20

R. Kodama, T. Yoshidome, K. Amano, Y. Harano, M. Kinoshita, Thermal stability of proteins and water-entropy effect, The 1st GCOE International Symposium, Kyoto University, 2009.8.20

T.Mizuuchi, S.Kobayashi, S.Yamamoto, H.Okada, K.Nagasaki, T.Minami, S.Watanabe, K.Mukai, S.Kishi, K.Minami, Y.Takabatake, H.Yashiro, N.Nishino, Y.Nakashima, Y.Nakamura, K.Hanatani, S.Konoshima, F.Sano, Effects of gas-fueling control on plasma performance in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

H.Okada, S.Kobayashi, S.Kishi, S.Mihara, T.Mutoh, T.Mizuuchi, K.Nagasaki, Y.Nakamura, T.Minami, S.Yamamoto, S.Ohshima, S.Konoshima, K.Mukai, H.Y.Lee, Y.Takabatake, K.Hanatani, F.Sano, Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

S.Kobayashi, K.Nagaoka, S.Yamamoto, T.Mizuuchi, K.Nagasaki, H.Okada, T.Minami, S.Murakami, H.Y.Lee, Y.Suzuki, Y.Nakamura, Y.Takeiri, M.Yokoyama, K.Hanatani, K.Hosaka, S.Konoshima, S.Ohshima, K.Toushi, F.Sano, Energetic particle transport in NBI plasmas of Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA,

2009.10.12-16

K.Nagasaki, K.Sakamoto, K.Minami, H.Yoshino, T.Mizuuchi, H.Okada, K.Hanatani, T.Minami, K.Masuda, S.Kobayashi, S.Yamamoto, S.Konoshima, Y.Nakamura, S.Ohshima, K.Mukai, S.Kishi, H.Y.Lee, Y.Takabatake, G.Motojima, Y.Yoshimura, A.Fernández, Á.Cappa, B.Blackwell, F.Sano, Study of ECCD Physics and Iota Profile Control in Heliotron J, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

K.Mukaia, K.Nagasaki, V.Zhuravlevd, T.Fukuda, T.Mizuuchi, T.Minami , H.Okada, S.Kobayashi, S.Yamamoto, S.Konoshima, S.Ohshima, D.Nishi, K.Minami, H.Y.Lee, Y.Takabatake, S.Kishi, H.Yashiro, F.Sano, Electron density profile measurement in Heliotron J with a microwave AM reflectometer, 17th International Stellarator Workshop/Heliotron Workshop, Princeton, New Jersey, USA, 2009.10.12-16

S.Kobayashi, H.Y.Lee, T.Minami, S.Kado, T.Mizuuchi, K.Nagasaki, S.Yamamoto, H.Okada, T.Minami, S.Murakami, Y.Suzuki, Y.Nakamura, K.Hanatani, S.Konoshima, K.Toushi, F.Sano, Development of Highly Spectral-Resolved Charge Exchange Recombination Spectroscopy in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

K.Nagasaki, G.Motojima, K.Sakamoto, K.Minami, T.Mizuuchi, H.Okada, K.Hanatani, T.Minami, K.Masuda, S.Kobayashi, S.Yamamoto, K.Konoshima, Y.Nakamura, K.Mukai, Y.Yoshimura, A.Fernandes, A.Cappa, B.Blackwell, F.Sano, Study of Non-Inductive Current in Heliotron J, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

K.Mukai, K.Nagasaki, V.Zhuravlev, T.Fukuda, T.Mizuuchi, T.Minami, H.Okada, S.Kobayashi, S.Yamamoto, S.Konoshima, D.Nishino, K.Minami, H.Y.Lee, Y.Takabatake, S.Kishi, H.Yashiro, F.Sano, Observation of electron density profile in Heliotron J with a microwave AM reflectometer, Asia Plasma and Fusion Assoshistion 2009 / Asia-Pacific Plasma Theory Conference in 2009, Aomori, Japan, 2009.10.27-30

F.Sano, T.Mizuuchi, K.Nagasaki, K.Hanatani, H.Okada, Y.Nakamura, T.Minami, S.Kobayashi, S.Yamamoto, S.Ohshima, S.Watanabe, K.Mukai, K.Minami, S.Kishi, A.Matsuyama, H.Lee, Y.Takabatake, H.Yashiro H.Yoshino, S.Konoshima, B.Blackwell, Physics Research on the Heliotron J Confinement, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

S.Yamamoto, H.Okada, S.Sakakibara, Y.Suzuki, S.Kobayashi, T.Minami, T.Mizuuchi, K.Mukai, K.Nagasaki, Y.Nakamura, Y.Narushima, F.Sano, K.Y.Watanabe, Development of magnetic island detector by magnetic measurement in helical plasmas, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

N.Nishino, T.Mizuuchi, S.Kobayashi, S.Yamamoto, H.Okada, K.Nagasaki, T.Minami, F.Sano, Peripheral plasma measurement in Heliotron J using fast cameras, 19th International Toki onference (ITC19), Ceratopia, Toki, 2009.12.8-11

H. Oshima, T. Yoshidome, K. Amano, M. Kinoshita, A Theoretical Analysis on Characteristics of Protein Structures Induced by Cold Denaturation, International Symposium on “Molecular Theory for Real Systems”, Kyoto University, 2010.1.7

吉留崇，木下正弘，Hydrophobicity at Low Temperatures and Cold Denaturation of a Protein, 3rd Mini-Symposium on Liquids，岡山大学，2009.6.20

天野健一，吉留崇，木下正弘，Entropic Potential Field Formed for a Linear-Motor Protein near a Filament: Statistical-Mechanical Analysis with Simple Model I, 「水を主役とした ATP エネルギー変換」, 第１回全体会議, 大阪ガーデンパレス, 2009.9.8

小玉諒太，吉留崇，天野健一，原野雄一，木下正弘，Thermal stability of proteins and water-entropy effect,「水を主役とした ATP エネルギー変換」，第１回全体会議，大阪ガーデンパレス，2009.9.8

吉留崇，木下正弘，アラニンベースペプチドのヘリックスーコイル転移に及ぼす圧力効果：統計力学理論解析，日本物理学会 2009 年秋季大会，熊本大学，2009.9.25-28

Lee Hyunyong（李炫庸），小林進二，村上定義，水内亨，長崎百伸，南貴司，岡田浩之，山本聡，木島滋，向井清史，高畠優，岸真太郎，南桂史，佐野史道，ヘリオトロン J における NBI プラズマ中の CX-NPA 解析，日本物理学会 2009 年秋季大会，熊本大学，2009.9.25-28

尾嶋拓，吉留崇，天野健一，木下正弘，蛋白質の低温変性構造に関する理論解析，第 47 回日本生物物理学会年会，徳島文理大学，2009.10.30

吉留崇，木下正弘，アラニンベースペプチドのへ

リックスーコイル転移に及ぼす圧力効果：統計力学理論解析，第 47 回日本生物物理学会年会，徳島文理大学，2009.10.30

天野健一，吉留崇，木下正弘，フィラメント近傍で形成されるリニアーモータータンパク質のエントロピックポテンシャル場：単純化モデル計算Ⅰ，第 47 回日本生物物理学会年会，徳島文理大学，2009.10.30

小玉諒太，吉留崇，天野健一，原野雄一，木下正弘, 蛋白質熱安定性における水のエントロピー効果の重要性，第 47 回日本生物物理学会年会，徳島文理大学，2009.10.30

安田賢司，小玉諒太，吉留崇，天野健一，原野雄一，木下正弘, 蛋白質の二次構造形成における側鎖のパッキングの役割，第 47 回日本生物物理学会年会，徳島文理大学，2009.10.30

吉留崇, 蛋白質低温変性の分子機構, 物性理論セミナー，九州大学，2009.11.27

小林進二, 山本聡, 岡田浩之, 長崎百伸, 南貴司, 向井清史，岸真太朗，李炫庸，南桂史，高畠優，大島慎介，西野信博，中嶋洋輔，中村祐司，花谷清，佐野史道，ヘリオトロン J における超音速分子ビーム入射法の適用とその効果，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

岡田浩之, 山本聡, 榊原悟, 鈴木康浩, 小林進二, 長崎百伸，中村祐司，南貴司，水内亨，木島滋，渡邊清政，成嶋吉郎，向井清史，岸真太郎，李炫庸，高畠優，南桂史，佐野史道，磁気計測による磁気島検出器の開発，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

高畠優, 水内亨, 西野信博, 長崎百伸, 岡田浩之, 南貴司，小林進二，山本聡，木島滋，中嶋洋輔，井尻芳行, 千住徹, 矢口啓二, 坂本欣三, 東使潔, 芝野匡志, 向井清史, 李炫庸, 岸真太郎, 南桂史, 佐野史道, 静電プローブ計測と高速カメラによる可視光計測の組み合わせによるヘリオトロン J 周辺プラズマの揺動解析，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

岸真太郎, 岡田浩之, 水内亨, 長崎百伸, 花谷清, 南貴司，小林進二，山本聡，木島滋，武藤敬，松山顕之，向井清史，李炫庸，高畠優，南桂史，佐野史道，ヘリオトロン J における ICRF 加熱での荷電交換中性粒子束の加熱位置依存性とイオン加熱効率，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

Lee Hyunyong，小林進二，南貴之，門信一郎，水内亨，長崎百伸，岡田浩之，南貴司，山本聡，村上定義，鈴木康浩，中村祐司，花谷清，木島滋，向井清史，岸真太郎，高畠優，南桂史，香川輔，東使潔，佐野史道，ヘリオトロン J における荷電交換再結合分光計測，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

向井清史，長崎百伸，Vladimir Zhuravlev，福田武司，水内亨，南貴司，岡田浩之，小林進二，山本聡，木島滋，西大輔，南桂史，李炫庸，高畠優，岸真太郎，八代浩彰，佐野史道，マイクロ波 AM 反射計によるヘリオトロン J プラズマの電子密度分布計測, 第 26 回プラズマ･核融合学会年会, 京都国際交流会館，2009.12.1-4

南貴司, 八代浩彰, 小林進二, 水内亨, 岡田浩之, 長崎百伸，中村祐司，花谷清，山本聡，木島滋，大島慎介，佐野史道，Heliotron J における新しい高繰り返し YAG トムソン散乱計測装置の計画，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

山本聡，中村佑司，岡村昇一，田部井優，西岡賢二，佐野史道，水内亨，長崎百伸，花谷清，岡田浩之，南貴司，小林進二，木島滋，大島慎介，ヘリカル軸ヘリオトロン磁場配位の最適化研究, 第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

南桂史, 長崎百伸, 坂本欣三, 水内亨, 岡田浩之, 南貴司，小林進二，山本聡，木島滋，向井清史，李炫庸，岸真太郎，高畠優，佐野史道，ヘリオトロン J における改良された電子サイクロトロン波入射システムによる電流駆動実験，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

杉本大地，比村治彦，平松秀朗，三瓶明希夫，政宗貞男，岡田浩之，山本聡，小林進二，水内亨，佐野史道, 平行電場検証のための立体磁気軸ヘリオトロン J における非中性プラズマ閉じ込め実験，第 26 回プラズマ・核融合学会年会，京都国際交流会館，2009.12.1-4

中野賢, 松浦寛人, 水内亨, 岡田浩之, 永岡賢一, ヘリオトロン J 実験グループ, ヘリオトロン J における周辺プラズマ熱流束に関する研究，第 26 回プラズマ･核融合学会年会, 京都国際交流会館, 2009.12.1-4

木下正弘，天野健一，吉留崇，フィラメント上におけるリニヤーモーター蛋白質の一方向移動：単純化モデル解析および考察, 次世代スパコンプロジェクト･ナノ分野グランドチャレンジ研究開発第 4 回公開シンポジウム, 岡崎コンファレンスセンター，2010.3.4

吉留崇，伊藤祐子，池口満徳，木下正弘，F1-ATPase の回転のメカニズムに関する一考察：水のエントロピーの重要性, 日本物理学会第

65 回年次大会，岡山大学，2010.3.22

尾嶋拓，吉留崇，天野健一，木下正弘，蛋白質低温変性の統計熱力学理論，日本物理学会第 65 回年次大会，岡山大学，2010.3.22

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 in 1996 simultaneously with the Institute as an attached facility for research on advanced processes of energy production, conversion and application. 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 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.

Research activities have been directed mainly toward the following cooperative projects as the principle research subject of the Institute.

A1 Interdisciplinary Field of Plasma Energy

The scientific and technological researches on advanced plasma energy system aim at the development of a frontier field "complex plasma energy systems research" based on plasma, hydrogen and material sciences. This field includes the basic research on advanced plasma energy related to the plasma confinement improvement, the effective transport of heat and particle fluxes, the system construction for hydrogen fuel cycle, the basic study on POP of advanced divertor, the control of plasma surface interaction and the development of materials under extremely severe environment, application of plasma energy based on plasma basic research, and advanced fission energy research.

A2 Interdisciplinary Field of Bioenergy

Researches in this field include development of highly efficient material/energy-transformation systems on the basis of bio-nano-technologies and biomimetic approaches and elucidation, improvement, and utilization of the biological processes. The environmental aspects associated with the energy utilization are also studied in this field.

A3 Interdisciplinary Field of Photon and Quantum Energy

This specially-promoted field includes researches for extending advanced functions peculiar to photon, quantum and related materials, studies of fundamentals and /or technology for generating new functions of the energy, and interdisciplinary studies using the energy functions aiming at the creation of a new field of science and technology.

B. Cooperative use of facilities and equipments

Facilities and equipments of the laboratory are provided to cooperated researches for the scientists in the university.

2. The cooperative research project consists of (a) a specific program for “Promotion of a priority project” and (b) a standard program.

(a) A specific program was not planned in this year.

(b) Summary of the standard cooperative research subjects carried out in the year of 2009.

A public collection of cooperative research application was carried out, in this year, for a program which consits of 3 group of “Kiban” , “Syorei” and “Kikaku-chosa” cooperative research. The “Kiban “ cooperative research means a program to promote leading research themes of the Institute projects. The “Syorei” cooperative research means a program to promote general research themes with respect to the Institute projects. The “Kikaku-chosa” cooperative research means a program to promote the cooperative research through a seminar or symposium.

As a result, the research themes of 69 were applied and applications of 65 were accepted after the approval by a steering committee of the laboratory. The number of research subjects are 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 65

		category A			B	total
		A1	A2	A3		
Kibann *1	inside	2*	3*	3*	0	8*/(3Excluding field-overlapped applications)
	outside	0	0	0	0	0
Syorei *2	inside	10	4	7	0	21
	outside	25	5	6	3	39
Kikaku -chosa *3	inside	2	0	0	0	2
	outside	0	0	0	0	0

"inside" or "outside" : Numbers applied by the inside or outside of the Institute
The individual research subjects are as follows, *1, *2 and *3 mean the "Kiban", "Syorei" and "Kikaku-chosa' cooperative research theme, respectively,

The individual Research subjects are as follows.

A1,A2,A3

"Development of Advanced Plasma and Quantum Energy Studies"

(1) K.Nagasaki, K.Masuda, H.Okada, T.Minami, S.Kobayashi, S.Yamamoto, F.Sano, T.Mizuuchi, K.Hanatani, S.Konoshima
(2) Y.Nakamura, K.Mukai
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University

"International Collaborative Research on Advanced Energy Materials Science and Technology"

(1) A.Kimura, R.Kasada
(2) C.H.Zhang
(3) H.Kishimoto
(4) S.Noh
(1) Institute of Advanced Energy, Kyoto University
(2) Institute of Modern Physics, China Academy, China
(3) Graduate School of Engineering, Muroran Institute of Technology
(4) Graduate School of Energy Science, Kyoto University

A2,A3

"Studies on Stable Lasing in KU-FEL"

(1) H.Ohgaki, Section of Promotion for Photon and Energy Nano-Science research
(1) Institute of Advanced Energy, Kyoto University

A1,

"Experimental Studies of the Cylindrical Inertial Electrostatic Confinement Neutron Source -Study of Long Line Source Ⅲ-"

(1) Y.Yamamoto, Y.Takeuchi, S.Konishi
(2) K.Noborio
(3) T.Kanagae
(1) Institute of Advanced Energy, Kyoto University
(2) Institute of Sustainability Science, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

"Control of Rotational Transform by Using Non-inductive Current in Helical Systems"

(1) K.Nagasaki, K.Masuda, K.Sakamoto, F.Sano, T.Mizuuchi, K.Hanatani, T.Minami, H.Okada, S.Kobayashi, S.Yamamoto, S.Konoshima
(2) Y.Nakamura
(3) Y.Yoshimura, G.Motojima
(4) N.Marushchenko
(5) A.Cappa
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) National Institute for Fusion Science
(4) Max Plank Institute, Germany
(5) CIEMAT, Spain

"Study of Density Control with SMBI Technique in Heliotron J Plasma"

(1) T.Mizuuchi, T.Minami, S.Kobayashi
(2) R.Sakamoto, J.Miyazawa
(1) Institute of Advanced Energy, Kyoto University
(2) National Institute for Fusion Science

"Realization of High Performance Advanced Helical Plasma by Plasma Profile Control"

(1) T.Minami, F.Sano, T.Mizuuchi, K.Hanatani, H.Okada, S.Kobayashi, S.Yamamto, K.Nagasaki
(2) Y.Yoshimura
(1) Institute of Advanced Energy, Kyoto University

(2) National Institute for Fusion Science

"Study of Magnetic Fourier Components Effect on Energetic Particle Transport in NBI Plasmas of Heliotron J"

(1) S.Kobayashi, T.Mizuushi, T.Minami, F.Sano, K.Nagasaki, H.Okada, S.Yamamoto, K,Hanatani, S.Konoshima, K.Tohshi
(2) Y.Nakamura, K.Mukai, Lee Hyunyong
(3) Y.Suzuki, K.Nagaoka, Y.Takeiri, S.Okamura, K.Toi
(4) Y.Nakashima
(5) S.Murakami
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) National Institute for Fusion Science
(4) Plasma Research Center, University of Tsukuba
(5) Graduate School of Engineering, Kyoto University

"Turbulent Heat Transfer for Heating of Water in a Short Swirl Tube"

(1) K.Hata
(2) K.Fukuda
(3) S.Masuzaki
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Maritime Sciences, Kobe University
(3) National Institute for Fusion Science

"Theory & Modeling Study of Fusion Plasma-material Interaction"

(1) K.Morishita, K.Hanatani
(2) Y.Watanabe, J.Yoshimatsu, Y.Yamamoto
(3) H.Iwakiri
(4) D.Kato
(5) Y.Kaneta
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) Faculty of Education, University of the Ryukyus
(4) National Institute for Fusion Science
(5) School of Engineering, The University of Tokyo

"Confinement Optimization Study of an Advanced Helical System for a Compact, High-beta, Steady-state Reactor"

(1) F.Sano, T.Mizuuchi, K.Nagasaki, K.Hanatani, H.Okada, T.Minami, S.Kobayashi, S.Yamamoto, S.Konoshima, M.Takeuchi
(2) T.Mutoh, S.Okamura, K.Ida, K.Toi, Y.Takeiri, H.Iguchi, S.Nishimura, Y.Yoshimura, M.Isobe, C.Suzuki, K.Nagaoka, M.Yokoyama, O.Yamagishi, K.Tanaka, T.Akiyama, Y.Suzuki
(3) Y.Nakamura, Y.Kishimoto, K.Mukai, A.Matsuyama
(4) S.Murakami
(5) T.Fukuda
(6) N.Nishino
(7) Y.Nakashima
(8) A.Isayama, N.Oyama
(9) S.Ohshima
(1) Institute of Advanced Energy, Kyoto University
(2) National Institute for Fusion Science
(3) Graduate School of Energy Science, Kyoto University
(4) Graduate School of Engineering, Kyoto University
(5) Graduate School of Engineering, Osaka University
(6) Graduate School of Engineering, Hiroshima University
(7) Plasma Research Center, University of Tsukuba
(8) Japan Atomic Energy Agency
(9) Kyoto University Pioneering Research Unit for Next Generation

"Study of Fast Ion Confinement and Heating Efficiency Using ICRF Heating in Heliotron J Plasmas"

(1) H.Okada, S.Kobayashi, S.Yamamoto, T.Minami, T.Mizuuchi, K.Nagasaki, F.Sano, K.Hanatani
(2) Y.Nakamura
(3) T.Mutoh
(4) Y.Nakashima
(5) N.Nishino
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) National Institute for Fusion Science
(4) Plasma Research Center, University of Tsukuba
(5) Graduate School of Engineering, Hiroshima University

"Studies of MHD Stability in Heliotron J Plasmas"

(1) S.Yamamoto, F.Sano, T.Mizuuchi, K.Nagasaki, H.Okada, T.Minami, S.Kobayashi, K.Hanatani, S.Konoshima
(2) Y.Nakamura, K.Mukai
(3) Y.Suzuki
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) National Institute for Fusion Science

"Comparison Study of Neoclassical Transport Theory in Helical and Tokamak Plasmas"

(1) M.Kikuchi
(2) K.Nagasaki, T.Mizuuchi, K.Hanatani, F.Sano
(3) Y.Nakamura,
(1) Japan Atomic Energy Agency
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

“Simultaneous ECE Measurements by Two Radiometers in Heliotron J”

(1) Y.Yoshimura, S.Okamura, S.Kubo, T.Shimozuma, H.Igami, H.Takahashi
(2) K.Nagasaki, F.Sano, T.Mizuuchi, H.Okada, S.Kobayashi
(3) H.Yoshino
(1) National Institute for Fusion Science
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

“Boundary Plasma Diagnostics and RF Heating in Heliotron J”

(1) K.Uehara, H.Kawashima
(2) Y.Sadamoto
(3) T.Mizuuchi, S.Yamamoto, M.Takeuchi
(4) S.Ohshima
(1) Japan Atomic Energy Agency
(2) Joetsu University of Education
(3) Institute of Advanced Energy, Kyoto University
(4) Kyoto University Pioneering Research Unit for Next Generation

“Development of Analysis Method for Fast Camera Images”

(1) N.Nishino, T.Hirooka, T.Mio, S.Iida, S.Kohiki
(2) T.Ueno, K.Senba
(3) F.Sano, T.Mizuuchi, H.Okada, T.Minami, K.Nagasaki, S.Kobayashi
(1) Graduate School of Engineering, Hiroshima University
(2) Faculty of Engineering, Hiroshima Univaersity
(3) Institute of Advanced Energy, Kyoto University

“Neutral Particle Measurement of Heliotron J Plasmas Using Multi-channel H-alpha Line Emission Detectors”

(1) Y.Nakashima
(2) K.Hosoi, R.Yonenaga, H.Ozawa
(3) S.Kobayashi, T.Mizuuchi, H.Okada, S.Konoshima
(4) K.Mukai, Lee Hyunyong, Y.Takabatake
(1) Plasma Research Center, University of Tsukuba
(2) Graduate School of Pure and Applied Sciences, University of Tsukuba
(3) Institute of Advanced Energy, Kyoto University
(4) Graduate School of Energy Science, Kyoto University

“Radiation Effect on NITE SiC/SiC Composite Produced by Mass Production Techniques”

(1) A.Kohyama, Joon-Soo Park
(2) T,Hinoki, S.Kondo
(1) Graduate School of Engineering, Muroran Institute of Technology
(2) Institute of Advanced Energy, Kyoto University

“Aging and Irradiation Effects for Microstructure of Duplex Stainless Steels for Nuclear System”

(1) H.Kishimoto, J.Kannari, A.Kohyama
(2) T.Hinoki
(1) Graduate School of Engineering, Muroran Institute of Technology
(2) Institute of Advanced Energy, Kyoto University

“Investigation of Alumina Coating Fabricated by Sol-gel Method for PbLi MHD Thermofluid Research”

(1) T.Kunugi, Y.Ueki
(2) T.Hinoki
(1) Graduate School of Engineering, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

“High-fluence Irradiation Behavior of Reduced Activation Fusion Reactor Materials”

(1) H.Tanigawa, M.Ando
(2) T.Hinoki, R.Kasada,
(1) Japan Atomic Energy Agency
(2) Institute of Advanced Energy, Kyoto University

“Evaluation on Shear Strength for the HIP Joint of the Low-activation Ferritic/Martensitic Steel Using a Miniature Torsion Specimen”

(1) T.Nozawa, H.Tanigawa
(2) T.Hinoki
(1) Japan Atomic Energy Agency
(2) Institute of Advanced Energy, Kyoto University

“Optimization of Mechanical Properties in SiC/SiC Composites and W Joining and It’s Irradiation Effects”

(1) T.Shibayama, S.Watanabe
(2) T.Hinoki
(3) H.Kishimoto
(1) Center for Advanced Research of Energy Conversion Materials, Hokkaido University
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Engineering, Muroran Institute of Technology

“Relations Between Configuration of Constituent Materials in SiC/SiC Composite and Their Electrical and Thermal Conductivities”

(1) T.Tanaka, T.Muroga
(2) T.Hinoki
(1) National Institute for Fusion Science
(2) Institute of Advanced Energy, Kyoto University

“Study on Creep Deformation of High Crystalline SiC”

(1) S.Nogami, A.Hasegawa
(2) T.Hinoki
(1) Faculty of Engineering, Tohoku University

(2) Institute of Advanced Energy, Kyoto University

“Radiation Damage of Advanced Ni-base and Co-base ODS Superalloys for Space Reactor Materials**”**

(1) S.Ukai, S.Hayashi

(1) Graduate School of Engineering, Hokkaido University

“Strength characteristic by minute specimen of nuclear fusion reactor material.”

(1) S.Sato, S.Suzuki

(2) A.Kimura

(1) Fukushima National College of Technology

(2) Institute of Advanced Energy, Kyoto University

“A Study of Surface Damage due to Laser Irradiation for Quantitative Analysis of Hydrogen in Nuclear Materials on Laser Plasma Induced Breakdown Spectroscopy”

(1) K.Fukumoto

(2) A..Kimura

(1) Graduate School of Engineering, University of Fukui

(2) Institute of Advanced Energy, Kyoto University

“Modeling of Mechanical Properties of Structure Materials for Nuclear Fusion Reactors”

(1) M.Satou

(2) K.Morishita

(1) Faculty of Engineering, Tohoku University

(2) Institute of Advanced Energy, Kyoto University

“Radiation-induced Defect Formation and Its Stability in Oxide and Nitride Ceramics”

(1) K.Yasuda, S.Matsumura

(2) T.Kawase, T.Koga

(1) Faculty of Engineering, Kyushu University

(2) Graduate School of Engineering, Kyushu University

“Study on Irradiation Induced Non-uniform Deformation of Austenitic Stainless Steel”

(1) A.Hasegawa, M.Satou, S.Nogami, T.Tanno

(2) A.Kimura, R.Kasada

(1) Faculty of Engineering, Tohoku University

(2) Institute of Advanced Energy, Kyoto University

“Property Change on Plasma Facing Materials for Fusion Reactor by High Energy Ion Irradiation”

(1) K.Tokunaga, K.Araki, T.Fujiwara, Y.Miyamoto, K.Nakamura

(2) Qiu Xu

(3) A.Kimura, R.Kasada

(1) Research Institute for Applied Mechanics, Kyushu University

(2) Kyoto University Research Reactor Institute

(3) Institute of Advanced Energy, Kyoto University

“Theoretical Simulations for Irradiated Materials Based on First Principles Method”

(1) Y.Kaneta

(2) K.Morishita

(3) Chin Ying

(4) J.Yoshimatsu

(1) School of Engineering, The University of Tokyo

(2) Institute of Advanced Energy, Kyoto University

(3) Materials Phases Data System, Switzerland

(4) Graduate School of Energy Science, Kyoto University

“Surface Degradation Behavior of Plasma Diagnostic Mirrors Irradiated with Hydrogen/Helium Ion”

(1) M.Miyamoto, K.Ono

(2) K.Morishita

(1) Interdisciplinary Faculty of Science and Engineering, Shimane University

(2) Institute of Advanced Energy, Kyoto University

“Interaction of Helium and Defects in Metals”

(1) Qiu Xu, T.Yoshiie

(2) K.Morishita

(1) Kyoto University Research Reactor Institute

(2) Institute of Advanced Energy, Kyoto University

“First-principle and Thermodynamics Study on Point Defects in Fusion Reactor Materials”

(1) D.Kato

(2) K.Morishita

(1) National Institute for Fusion Science

(2) Institute of Advanced Energy, Kyoto University

“Improvement of Thermophysical and Mechanical Properties of Tungsten-coated Vanadium Alloy by Microstructure Control”

(1) T.Nagasaka, T.Muroga

(2) R.Kasada, A.Kimura, N.Iwata

(1) National Institute for Fusion Science

(2) Institute of Advanced Energy, Kyoto University

“Advanced Helical Studies for High-performance Helical Plasma”

(1) T.Mizuuchi

(2) S.Kitajima

(3) M.Yokoyama

(4) N.Nishino

(5) Y.Kishimoto

(1) Institute of Advanced Energy, Kyoto University

(2) Faculty of Engineering, Tohoku University

(3) National Institute for Fusion Science

(4) Graduate School of Engineering, Hiroshima University

(5) Graduate School of Energy Science, Kyoto University

“Workshop on the Multiscale Modeling of Radiation Damage Processes in Fusion Materials”

(1) K.Morishita
(2) S.Ounuki
(3) M.Satou
(4) D.Hamaguchi, I.Hoshino
(5) S.Ishino
(6) Y.Kaneta, T.Oda, H.Tsuchihira
(7) D.Kato, N.Ashikawa
(8) N.Ohno
(9) Y.Watanabe, J.Yoshimatsu, Y.Yamamoto
(10) T.Kenmotsu
(11) M.Miyamoto
(12) M.Sakamato, M.Yagi, H.Watanabe
(13) H.Iwakiri
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Engineering, Hokkaido University
(3) Faculty of Engineering, Tohoku University
(4) Japan Atomic Energy Agency
(5) The University of Tokyo
(6) School of Engineering, The University of Tokyo
(7) National Institute for Fusion Science
(8) Graduate School of Engineering, Nagoya University
(9) *Graduate School of Energy Science, Kyoto University*
(10) Doshisha University Graduate School of Life and Medical Science
(11) Interdisciplinary Faculty of Science and Engineering, Shimane University
(12) Research Institute for Applied Mechanics, Kyushu University
(13) Faculty of Education, University of the Ryukyus

A2

“Fabrication of Crystalline Organic Thin-films for Organic Photovoltaics”

(1) T.Sagawa, S.Yoshikawa
(2) S.Nagaoka
(3) H.Ihara
(1) Institute of Advanced Energy, Kyoto University
(2) Kumamoto Industrial Research Institute
(3) Graduate School of Science and Technology, Kumamoto University

“Development of the Artificial Oxidase Driven by Solar Energy”

(1) K.Tainaka, T.Morii,
(2) I.Saito
(1) Institute of Advanced Energy, Kyoto University
(2) College of Engineering , Nihon University

“Bioethanol Production from Algae Grown in the Lake Using Genetic Recombinant Yeast”

(1) T.Kodaki, S.Watanabe, Kattab Sadat Mohamad
(1) *Institute of Advanced Energy, Kyoto University*

“Design of Non-FRET type Biosensors Based on Circularly Permutated GFP”

(1) T.Endoh, T.Morii
(2) Y.Mori
(3) N.Fujieda
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Engineering, Kyoto University
(3) Graduate School of Engineering, Osaka University

“Relationship between Structure and Energies of Si(111) Twist Boundaries”

(1) K.Ishihara
(2) A.Otsuki
(1) Graduate School of Energy Science, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

“Development of Smart Bioreactor Using Micro-rod Arrayed Polymer Gel”

(1) T.Yamauchi, N.Tsubokaewa
(2) Y.Ogata, T.Sakka, K.Fukami
(1) Graduate School of Science and Technology, Niigata University
(2) Institute of Advanced Energy, Kyoto University

“Development of Fluorescent Ribonucleopeptide Sensors for Detecting Intracellular Signaling Molecules”

(1) M.Fukuda
(2) T.Morii, K.Tainaka
(1) Graduate School of Energy Science, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

“Photocurrent Generation Systems Based on Nucleic Acid-Organic Dye Conjugates”

(1) K.Yamana
(2) T.Morii
(1) Graduate School of Engineering, University of Hyogo
(2) Institute of Advanced Energy, Kyoto University

“Establishment of Methods for Dynamic Structural Analysis of Disease-related Peptide Aggregation”

(1) T.Konno
(2) T.Morii, T.Sakka, K.Tainaka
(1) Faculty of Medical Sciences, University of Fukui
(2) Institute of Advanced Energy, Kyoto University

A3

“Magnetic Field Control of New Type of Bulk HTSC Undulator”

(1) T.Kii, H.Ohgaki, K.Masuda
(2) R.Kinjyo

(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University

"High-Brightness Electron Beam Production by a Thermionic Triode RF Gun for"
(1) K.Masuda, H.Ohgaki, T.Kii, K.Nagasaki
(2) Heishun Zen
(3) Mahmoud A.Bakr, K.Higasghimura, R.Kinjyo
(1) Institute of Advanced Energy, Kyoto University
(2) Institute for Molecular Science
(3) Graduate School of Energy Science, Kyoto University

"Polarization Control of Femtosecond Coherent Vacuum Ultraviolet Pulse with Aligned Molecules"
(1) K.Miyazaki, G.Miyaji
(2) K.Yoshii
(3) Farhad H.M.Faisal
(4) Abdurrouf
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) Bielefeld University
(4) University of Brawijaya

"Frequency Up-Conversion Using KUFEL"
(1) T.Nakajima, H.Ohgaki, T.Kii, T.Sakka, Yu Qin
(2) T.Sekigawa
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Engineering, Hokkaido University

"Development of High-intensity Cycle Pulse Laser System"
(1) G.Miyaji, K.Miyazaki, Ravi Bhushan
(2) H.Takada
(1) Institute of Advanced Energy, Kyoto University
(2) *National Institute of Advanced Industrial Science and Technology*

"Optical Emission from Solute Species in LIBS Analysis of Solid Surfaces in Liquid"
(1) T.Sakka, T.Nakajima, K.Fukami, Y.Ogata
(2) Y.Suzuki
(3) H.Yamagata
(1) Institute of Advanced Energy, Kyoto University
(2) Uyemura & Co.,Ltd.
(3) Graduate School of Energy Science, Kyoto University

"**Formation of Porous Silicon Field with Noble Metals and Its Photoelectrochemical Responses"**
(1) K.Fukami, T.Sakka, Y.Ogata
(2) Y.Suzuki
(1) Institute of Advanced Energy, Kyoto University
(2) Uyemura & Co.,Ltd.

"On the Frontier Study of Atomic Interaction Processes Involving Relativistic Electrons"
(1) A.Itoh, H.Tsuchida, M.Imai
(2) H.Ohgaki, T.Kii, K.Masuda
(1) Graduate School of Engineering, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

"Study on Interferometer with Infrared Free Electron Laser"
(1) M.Yasumoto
(2) H.Ohgaki, K.Masuda, T.Kii
(3) T.Sonobe
(1) National Institute of Advanced Industrial Science and Technology
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

"Performance Study of Glass Cherenkov Counter by Using Electron Beam"
(1) H.Fujioka
(2) H.Ohgaki, T.Kii, K.Masuda
(1) Graduate School of Science, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

"Measurement and Stabilization of Electron Bunch Phase in a Free Electron Laser Driver Linac"
(1) Heishun Zen
(2) H.Ohgaki. K.Masuda. T.Kii
(3) Mahmoud A.Bakr, K.Higashimura
(1) Institute for Molecular Science
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

"Development of Single Harmonic Separator"
(1) T.Sekikawa, M.Itoh, Y.Kataoka
(2) T.Nakajima
(1) Graduate School of Engineering, Hokkaido University
(2) Institute of Advanced Energy, Kyoto University

"C-O Bond Activation of Non-activated Aliphatic Alcohols by means of Mid-IR Pulse Laser Irradiation"
(1) K.Fugami
(2) T.Sakka
(1) Graduate School of Engineering, Gunma University
(2) Institute of Advanced Energy, Kyoto University

B

“Study of Scintillation Efficiency Universal Curves for Crystals”

(1) Y.Uozumi, Y.Koba, T.Nagasaki, G.Wakabayashi, M.Ueyama
(2) H.Ohgaki, T.Kii
(1) Faculty of Engineering, Kyushu University
(2) Institute of Advanced Energy, Kyoto University

“Development of Single-electron Irradiation Technique for Microscopic Track Structure Study”

(1) G.Wakabayashi, Y.Uozumi, T.Nagasaki, M.Ueyama
(2) H.Ohgaki, T.Kii
(1) Faculty of Engineering, Kyushu University
(2) Institute of Advanced Energy, Kyoto University

“Development of Landmine Detection System with D-D Neutron Source by Measuring Radiations from Landmine”

(1) T.Misawa, Cheolho Pyeon
(2) K.Masuda,
(3) Y.Takahashi, T.Yagi
(1) Kyoto University Research Reactor Institute
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

SYMPOSIUM IN THE LABORATORY

Symposium
The Symposium has been arranged in order to introduce the research activities in sections and to enhance the mutual cooperation among different fields. In 2009 Three regular meetings and the annual meeting for the cooperative research results were held with following theme.

1. The regular meeting

The First Meeting, July 10, 2009
中西周次「エネルギー変換における非線形現象」
S.Nakanishi, “Nonlinear Kinetics in Energy Conversion”, *Research Center for Advanced Science and Technology, The University of Tokyo*

The 2nd. Meeting, October 23, 2009
福元謙一「福井県と原子力工学研究 ーレーザー光による原子炉材料中のオンサイト水素分析技術の開発についてー」
K.Fukumoto, “Research of Nuclear Energy in Fukui -On the Development of On-Sight Laser Analysis of Hydrogen in Nuclear Materials-”, *Research Institute of Nuclear Engineering, University of Fukui*

The 3nd. Meeting, January25, 2010
田中謙治「レーザーおよびマイクロ波光源を用いた高温プラズマの干渉、散乱計測」
K.Tanaka, “Interferometric and Scattering Technique for High Temperature Plasma Using Laser and Microwave Sources”, *National Institute for Fusion Science*

2. The Annual Meeting for the Cooperative Research Results, April 2, 2010

長崎百伸「先進プラズマ・量子エネルギー研究の推進」
K.Nagasaki **“**Development of Advanced Plasma and Quantum Energy Studies**”,** *Institute of Advanced Energy, Kyoto University*

南　貴司「プラズマ分布制御による先進ヘリカルプラズマの高性能化の研究」
T.Minami, “Realization of High Performance Advanced Helical Plasma by Profile Control”, *Institute of Advanced Energy, Kyoto University*

山本　聡「ヘリオトロン J プラズマの MHD 安定性に関する研究」
S.Yamamoto, **“**Studies of MHD Stability in Heliotron J Plasmas**”,** *Institute of Advanced Energy, Kyoto University*

大垣英明「光・エネルギーナノサイエンスの推進に関する研究」
H.Ohgaki, “Studies on Stable Lasing in KU-FEL”, *Institute of Advanced Energy, Kyoto University*

増田　開「三極管型熱陰極 RF 電子銃による高輝度電子ビーム生成」
K.Masuda, “High-Brightness Electron Beam Production by a Thermionic Triode RF Gun for”, *Institute of Advanced Energy, Kyoto University*

田井中一貴「太陽光エネルギー駆動型オキシダーゼの作製」
K.Tainaka, “Development of the Artificial Oxidase Driven by Solar Energy”, *Institute of Advanced Energy, Kyoto University*

木村晃彦「先進エネルギー材料工学に関する国際共同研究」
A.Kimura, “International Collaborative Research on Advanced Energy Materials Science and Technology”, *Institute of Advanced Energy, Kyoto University*

佐川　尚「結晶性有機薄膜の作製と有機太陽電池への応用」
T.Sagawa, “Fabrication of Crystalline Organic Thin-films for Organic Photovoltaics”, *Institute of Advanced Energy, Kyoto University*

深見一弘「貴金属微粒子を充填した多孔質シリコンの作製とその光電気化学応答」
K.Fukami, “Formation of Porous Silicon Field with Noble Metals and Its Photoelectrochemical Responses”, *Institute of Advanced Energy, Kyoto University*

6. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS

Asian CORE (Center Of Research and Education) program, 2008-2012

The second year of the Asian CORE (Center Of Research and Education) program for the "Advanced Energy Science" between Japan, Korea and China was granted by the JSPS (Japan Society for the Promotion of Science) of 5 year collaboration was completed. In this program, Japan and core institutes in Asian nations will establish the network of research and education by the extensive collaboration of mutually equal contribution, in the advanced and important field of sciences. The Institute of Advanced Energy is assigned as a hub institute in Japan to represent universities and research institutes, with Prof. Yukio Ogata as the representative and Prof. Satoshi Konishi as the Program Coordinator. Counterparts are Prof. Hangyu Joo in Seoul National University in Korea and Prof. Kan Wang in Tsinghua University in China Figure 1 shows the concept of the framework of this program.

Advanced energy science and technology are of common interests in these countries where industrial application of energy is extensive. This program supports the exchanges of scientists and students in the field of advanced energy research, for collaboration, workshops and other research activities. This program is operated by equal contribution basis, and it requires "matching fund" from counterpart countries, and Korea and China have different types of funding to send and accept approximately same level of exchanges. Subtasks on five technical areas were agreed for the collaboration as follows.

Task 1 Advanced Nuclear Energy Systems: liquid metal technology, high temperature nuclear energy conversion, neutronics, and fusion technology.

Task 2 Fusion Plasma Science: plasma physics, simulation and theory, heating and current drive, diagnostics and plasma wall interaction.

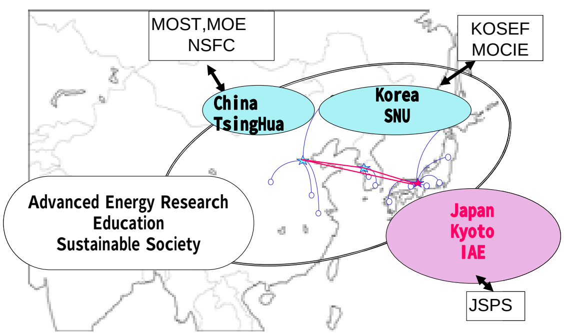


Fig.1 Concept of the newly approved Asian CORE Program.

Task 3 Bioenergy: Synthesis of biofuel from biomass materials and energy production systems.

Task 4 Advanced Energy Materials: nuclear materials for high temperature use, ODS and ceramics, irradiation, and microscopy.

Task 5 Application of Quantum Radiation: electron beam, accelerator technology, free electron laser, tera hertz wave and its application.

	J→K	K→J	J→C	C→J
SCM	2/2	2/8	0/0	1/5
Task-1	7/21	13/46	7/27	3/13
Task-2	3/9	3/12	4/19	1/4
Task-3	6/18	0/0	6/18	2/8
Task-4	9/32	5/26	2/21	2/23
Task-5	3/9	7/23	3/16	1/2
Seminar	0/0	6/23	0/0	5/21
subtotal	30/91	36/138	22/101	15/76
Total	103/406			

Fig.2 Conducted exchanges in 2009 under the Asian CORE.(man/man-day)

In the fiscal year 2009, we have conducted the exchanges in these areas as summarized in the fig.2. Activities were started in the above five areas, and exchanges of the researchers and students were supported under the program.

One of the highlights of the accomplishment in this fiscal year was the Winter School/seminar held in Sapporo on Feb.22~23 with total 46 students and 30 lecturers. Presentations and discussions on fusion technology, fission technology , tritium, material, were successfully conducted. In these areas under R-1, R-2 and R-4, collaboration and information exchange was very effective for three parties, because the interest, facilities and technology are identified to be useful to exchange. In the fiscal year 2010, intermediate review of the program is planned.

Global COE Program "Energy Science in the Age of Global Warming – Toward CO_2 Zero-emission Energy System-"

Securing energy and conservation of the environment are the most important issues for the sustainable development of human beings. Until now, people have relied heavily on fossil fuels for their energy requirements and have released large amounts of Greenhouse gases such as carbon dioxide (abbreviated to CO_2 below). CO_2 has been regarded as the main factor in climate change in recent years. It is becoming a pressing issue in the world how to control over the CO_2 release. The energy problem cannot be simply labeled as a technological one, as it is also deeply involved with social and economic elements. It is necessary to establish the " Low carbon energy science " in the interdisciplinary field adding the social science and the human science to the natural science.

From FY2008, four departments of Kyoto University, Graduate School of Energy Science, Institute of Advanced Energy, Department of Nuclear Engineering, Research Reactor Institute have joined together, and also with the participation from Institute of Economic Research have been engaging in "Energy Science in the Age of Global Warming - Toward a CO_2 Zero-emission Energy System " for a Global COE Program of the Ministry of Education, Culture, Sports, Science and Technology under the full faculty support taking advantage of characteristics of the university. This program aims to establish an international education and research platform to foster educators, researchers, and policy makers who can develop technologies and propose policies for establishing a scenario toward a CO_2 zero-emission society no longer dependent on fossil fuels, by the year 2100.

In the course of implementing the Global COE, we placed the GCOE Unit for Energy Science Education at the center, and we proceed from the Scenario Planning Group, the Advanced Research Cluster to the Evaluation, forming mutual associations as we progress. The Scenario Planning Group sets out a CO_2 zero emission technology roadmap and establishes a CO_2 zero emission scenario. They will also conduct analysis from the society values and human behavior aspect. The Advanced Research Cluster, as an education platform based on research, promotes the socio-economic study of energy, study of new technologies for solar energy and biomass energy, and research for advanced nuclear energy by following the road map established by the Scenario Planning Group. Evaluation is conducted by exchanging ideas among advisors inside and outside of the university and from abroad, to gather feedback on the scenario, education, and research.

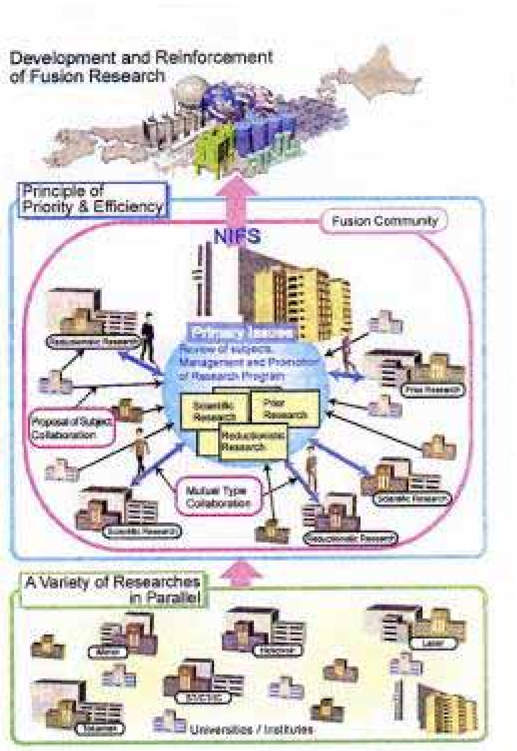
For education, which is the central activity of the Global COE, we establish "the GCOE Unit for Energy Science Education" and select students from the doctoral course, and foster these human resources. The students plan and conduct interdisciplinary group research containing both the social and the human science and the natural science toward CO_2 zero emission at the initiative of the students themselves. The students will acquire the faculty to survey the whole "energy system" through participation in scenario planning and interaction with researchers from other fields, and apply it to their own research. This approach is expected to become a major feature of human resources cultivation. We will strive to foster young researchers not only who will be able to employ their skills and knowledge with a wide international perspective as well as expertise in their field of study in order to respond to the needs of the society in terms of the variety of energy and environmental problems, but who will also lead people to a 21st century full of vitality and creativity, working towards harmony between the environment and mankind.

In FY2009, we carried on full-scale operations at the education programs of the students, and also promoted the study at both the Scenario Planning Group and the Advanced Research Cluster earnestly. In order to report the developments and to discuss the future activities widely, we held the First International Symposium of the Global COE titled "Zero-Carbon Energy, Kyoto 2009" in parallel with the First International Summer School on Energy Science for Young Generations on August, 2009 and the annual symposium of the Global COE on February, 2010. We also made a strong effort to the international exchange promotion activities such as co-hosting SEE (Sustainable Energy and Environment) forums held in Thailand on May, 2009 and Indonesia on November, 2009 and other related seminars and symposiums.

Bidirectional Collaborative Research Program

Since 2004, the Heliotron J group at Kyoto University has joined the bidirectional collaborative research program of National Institute for Fusion Science (NIFS). The purpose of this program is to extend the activities of nuclear fusion research at universities in Japan after the Committee of the Science Subdivision under the Council for Science and Technology has decided to set up its master plan for Japanese fusion research and development by promoting collaborative research activities. This plan was summarized in the report "Policy for executing Japanese nuclear fusion research", where it was pointed out that continuous scientific research activities for comprehensive understanding of toroidal plasma physics are needed under the parameters which can be extrapolated to the fusion reactor. It was also noted in the report that the university researchers should contribute to the studies of important issues in nuclear fusion research, such as (i) the function of electrostatic potential on plasma confinement, (ii) high beta plasma physics, (iii) optimum magnetic configuration for plasma confinement, (iv) steady-state plasma generation, and so on. NIFS was requested to play a leading role in these studies as the inter-university institute.

In the past collaborative programs of NIFS, university researchers came to NIFS and joined the research activity at NIFS. But in this program, the opposite movement of researchers became possible, that is, NIFS researchers can come to the universities. Hence a more efficient use of resources in both facilities became possible and the synergetic effect was expected.



The current program involves four major university research centers; Plasma Research Center, University of Tsukuba; Laboratory for Complex Energy Processes, Institute of Advanced Energy, Kyoto University; Institute of Laser Engineering, Osaka University; Advanced Fusion Research Center, Research Institute for Applied Mechanics, Kyushu University. In this collaborative program, the researchers of these four research centers and those of NIFS can move back and forth to each other to work on the same research subject. In addition, each research center can have its own collaborative programs with use of its major facility so that the researchers of other universities can join as if the facility belongs to NIFS. All these activities are supported financially as the research subjects of the NIFS bidirectional collaborative research program.

The collaboration between the Heliotron J group and other university groups such as the LHD group at NIFS has been continued during these 20 years. After the establishment of this collaborative program, both research activities have been highly stimulated, for example, from the viewpoints of adopted research subjects and research participants to understand machine-independent torus plasma physics through a systematic and exhaustive investigation. The main objective of the research is to improve the confinement and stability performance for advanced helical magnetic configurations such as the helical-axis heliotron, Heliotron J. The five topics for the collaboration research for this FY are selected; (1) study of the transport and the high-energy particle confinement by controlling the advanced magnetic field configuration, (2) study of the MHD equilibrium and stability by controlling the advanced magnetic field configuration, (3) experimental study of toroidal current control under the advanced magnetic configuration, (4) understanding ECH heating mechanism and its improvement, (5) study of heat and particle exhaustion control using the advanced magnetic field control, and (6) research and development of measurement system aiming at density and potential fluctuation diagnostics. These studies are now progressing very favorably.

Application of DuET and MUSTER for Industrial Research and Engineering (ADMIRE Project)

1. Introduction

ADMIRE PROJECT at Institute of Advanced Energy (IAE) in Kyoto University is a MEXT supported program "Open Advanced Facilities Initiative for Innovation (Strategic Use by Industry)" for 5 years to delivery of science and technology from Kyoto University to companies. ADMIRE provides and supports companies to utilize advanced facilities, such as DuET and MUSTER, IAE, Kyoto University for acceleration of cooperative research and developments among industries and IAE-Kyoto University. ADMIRE PROJECT provides services to utilize the equipments such as TEM, SEM and ion accelerators with free of charge for maximum 2 years.

2. Project details

Application of DuET and MUSTER for Industrial Research and Engineering (ADMIRE) PROJECT launched in 2006 and continues for 5 years funded by Ministry of Education, Culture, Sports, Science and Technology (MEXT) of JAPAN. DuET and MUSTER are representing facilities in Institute of Advanced Energy (IAE) at Kyoto University dedicated for the research of energy science and technology, with the special emphasis on fusion and fission materials R & Ds. ADMIRE PROJECT aims to deliver the research resources of IAE to public. Thus, programs to be approved are NOT restricted within fission and fusion materials, nor energy science and technology. We expect many proposals from varieties of fields all over the world. Users can use the facilities with free of charge. ADMIRE PROJECT has two areas of proposal;

Strategic Use for Energy Science and Technology

This area is progressed under the sub-title of “Production and Conservation of Materials for Energy Equipments” for the collaboration research of applicants and IAE faculties. Main scope of this area is to contribute to the innovation and conservation of whole energy systems from small thermoelectric elements to huge generating stations of thermal, solar, fission and fusion etc. The period of use in this area is one year, and optionally extension of one more year. The intellectual intelligence relates to ADMIRE PROJECT is treated along the Intellectual Property Policy of Kyoto University as same as usual Industry-Kyoto University collaboration.

Innovative Application for Industrial Users

This area is flexible to accept any new ideas from industries for supporting their efforts to make progress. Applicants are able to choose collaboration or simple utilization of the facilities. The collaboration is handled under the standard Industry-Kyoto University collaboration procedure. The simple utilization of the facilities is available for companies having seeds of new products or very basic R & Ds. The simple utilization (non-collaborative utilization) is allowed for the applicant to hold all the Intellectual Properties from the activities. ADMIRE project nor IAE never demands right of Intellectual Property arising from the activities for the case of simple utilization. The Project provides services for contributing innovation of science and technology. The period of use in this area is 6 months, and optionally extension of 6 months will be available.

3. Benefits for companies

- Rapid progress of products development by use of high performance equipments.
- Reduction of expenditure for equipments.
- Rapid investigation of new idea.
- Use of very expensive equipments.
- Access to excellent faculties and research resources at IAE.

Figure 1: Dual-Beam Facility for Energy Science and Technology

7. HOW TO GET TO IAE