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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

CONTENTS

FOREWORD

The second period of the midterm action plan (2010-2015) has started. In this second period, the ability of the research institute is more strictly tested since a full-scale action for national university reform will be started. Under the circumstances, we have to further strengthen our capabilities for research and education on the basis of the accomplishment of our academic activities, and need to exhibit our prospective future.

We are working hard toward further progress in research and education, and conducting a lot of collaborative researches in the advanced energy science and technology fields such as plasma systems, bioenergy, lasers and quantum energy in the first period (2004-2009). The Global COE program “Energy Science in the age of Global Warming” (2008–2012) is going well. We are also acting as a core institution of international energy researches, especially in the Asian region. In November 2010, we organized the International Symposium of Advanced Energy Science at the Uji campus. Such symposium is scheduled to be held annually. We applied for the Joint Usage/Research Center program (a core research center program of the MEXT) again in 2010, and our proposal of the core research center program on Zero-Emission Energy was authorized by the MEXT. The program period is 5 years from FY2011 to FY2015. The four-year retrofitting project against earthquake for our main building was completed this year. Besides, we have recovered usable area since the members of the Graduate School of Energy Science, who had resided in the Uji main building, moved to the Yoshida campus. We succeeded in getting a budget from the MEXT in FY2010 to reinforce our free-electron laser research. Now our research environment has been greatly improved.

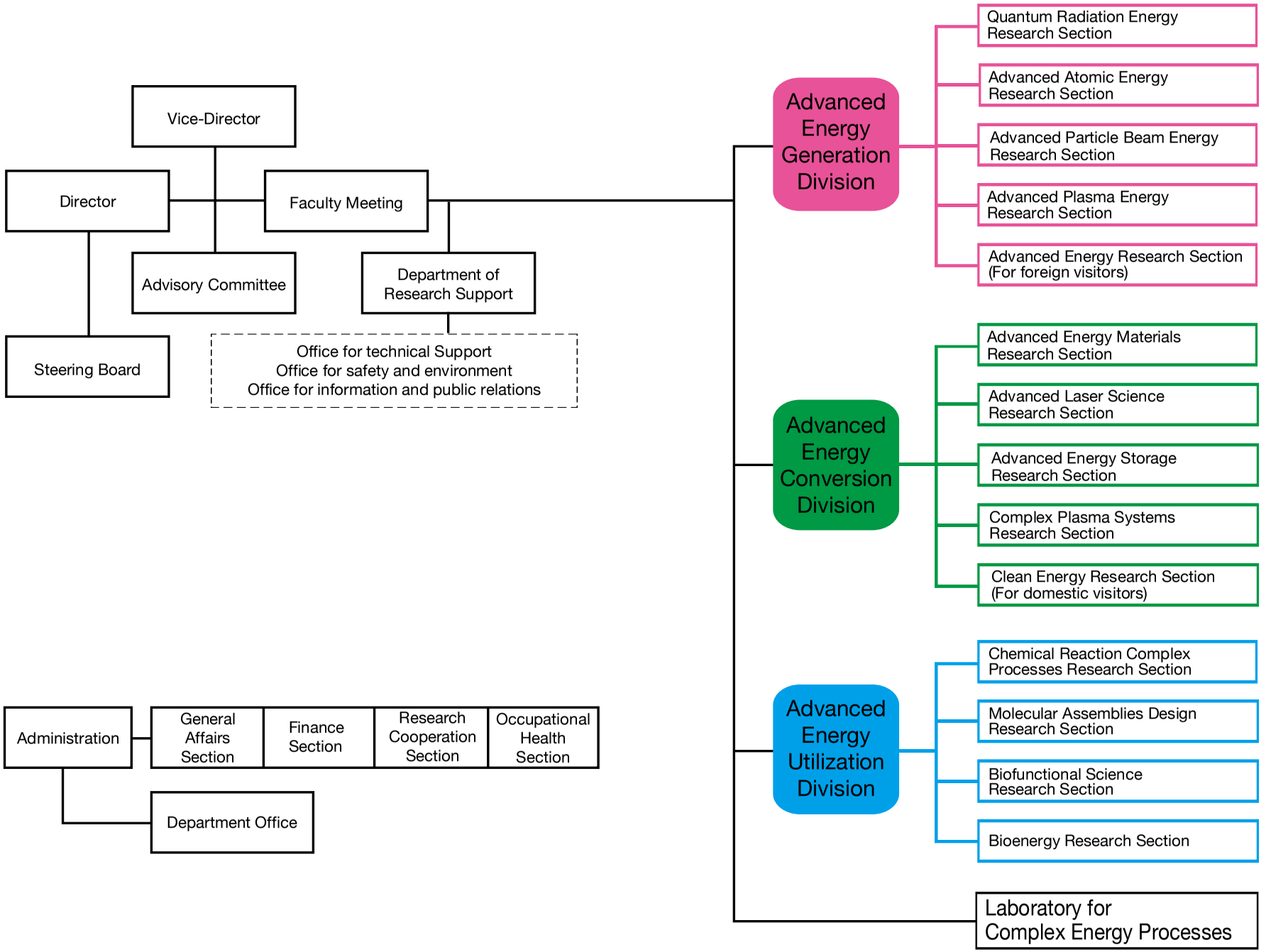
Intensifying worldwide concern regarding energy supplies and global warming drives our efforts, and energy issues demand urgent priority. We shall renew our efforts in the new period, through research and education on advanced energy science and technology, to cope with these critical issues and contribute 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 2011

Yukio H. OGATA
Director
Institute of Advanced Energy
Kyoto University

2. ORGANIZATION CHART



3. RESEARCH ACTIVITIES

3-1. TOPICS

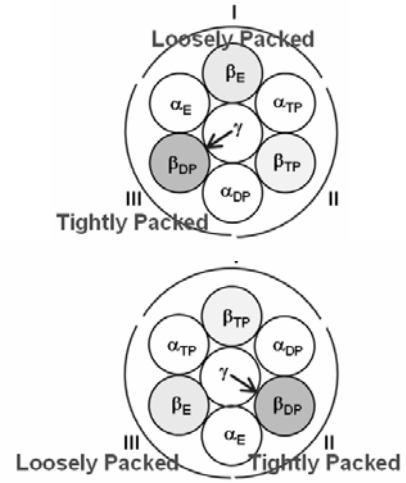
Novel Picture of the Rotation Mechanism of F_1-ATPase: Crucial Importance of the Water-Entropy Effect

Laboratory for Complex Energy Processes Section, M. Kinoshita

T. Yoshidome, Y. Ito, M. Ikeguchi, and M. Kinoshita, "Rotation Mechanism of F_1-ATPase: Crucial Importance of the Water-Entropy Effect", Journal of the American Chemical Society, **130**, 4030-4039 (2011).

We propose a novel picture of the rotation mechanism of F_1-ATPase, a rotary-motor protein complex. The entropy, which originates from the translational displacement of water molecules, is treated as the key factor in the proposal. We calculate the water-entropy gains upon formation of the α-β, α-γ, and β-γ subunit pairs, respectively. The gain is given as the difference between the hydration entropy of a subunit pair and the sum of the hydration entropies of the separate subunits forming the pair. The calculation is made using a hybrid of a statistical-mechanical theory for molecular liquids and morphometric approach. The hybrid method has originally been developed at our laboratory. The water-entropy gain is considered as a measure of tightness of the packing at each subunit interface. The results are highly correlated with the numbers of stable contacts at the subunit interfaces estimated by a molecular dynamics simulation with all-atom potentials. We also calculate the hydration entropies of three different sub-complexes comprising the γ subunit, one of the β subunits, and two α subunits adjacent to them. We discuss how the rotation of the γ subunit is induced by such chemical processes as the ATP binding, ATP hydrolysis, and release of the products.

One of the most probable structures of the $\alpha_3\beta_3\gamma$ complex, which has experimentally been determined, is illustrated in the figure. ATP is bound to the β subunit named β_{TP}. ATP is also bound to the β subunit named β_{DP}, but ATP within β_{DP} is ready to be hydrolyzed into ADP+Pi (or ADP and Pi are within β_{DP}). Nothing is bound to the β subunit named β_E. The three α subunits are named α_{TP}, α_{DP}, and α_E, respectively, as shown in the figure. The conformations of the β subunits are significantly different from one another: β_{TP} and β_{DP} are in closed conformations while β_E takes an open conformation. We define the following three sub-complexes for the arrangement shown in the figure, "Sub-complex I: γ, β_E, α_E, and α_{TP}", "Sub-complex II: γ, β_{TP}, α_{TP}, and α_{DP}", and "Sub-complex III: γ, β_{DP}, α_{DP}, and α_E". The γ subunit performs a 120° step rotation for hydrolysis of one ATP molecule. As illustrated in the figure, the structures of the $\alpha_3\beta_3\gamma$ complex before and after the 120° rotation are the same. The sub-complexes are named in terms of their positions in the structure. For example, when the γ subunit rotates by 120°, the arrangement changes as shown in the figure and sub-complex III now comprises γ, β_E, α_E, and α_{TP}.



Our finding is that the water entropy is maximized when the tight packing in the γ subunit with a special orientation, β_{DP}, α_{DP}, and α_E is locally formed. The overall, impartial packing results in a smaller water entropy. However, due to the ATP binding, hydrolysis, and release of ATP and Pi, respectively, the changes, $\beta_E \rightarrow \beta_{TP}$, $\beta_{TP} \rightarrow \beta_{DP}$, and $\beta_{DP} \rightarrow \beta_E$, take place, and the γ subunit rotates by 120° to recover the tight packing.

We can take the view that it comprises three sub-complexes which are in different states waiting for the ATP binding, hydrolysis, and release of ADP and Pi, respectively. High asymmetry exists for the packing efficiency in the sub-complexes, which is crucial in maximizing the water entropy. In particular, one of the sub-complexes incorporating the γ subunit with a special orientation is tightly packed. Any of the ATP binding, hydrolysis, and release of ADP and Pi leads to a decrease in the system free energy but perturbs the highly asymmetrical packing structure. The perturbation is followed by reorganization of the packing structure by the water-entropy effect. The reorganization accompanies the rotation of the γ subunit. In one cycle the γ subunit rotates by 120° to recover the original, most favorable packing properties. The rotation is repeatable.

3-2. RESEARCH ACTIVITIES IN 2010

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, an energy recovering system, an undulator, etc.

2.1 KU-FEL

The KU-FEL is designed to achieve FEL lasing in MIR (Mid infra-red) regime, from 5 to 25 μm. The tunable IR laser will be used for basic researches 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, a 3 m travelling wave accelerator structure, a 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.

In order to improve wavelength tunability and optical stability of the KU-FEL, replacement of the undulator and introduction of a photo-cathode RF gun are under way.

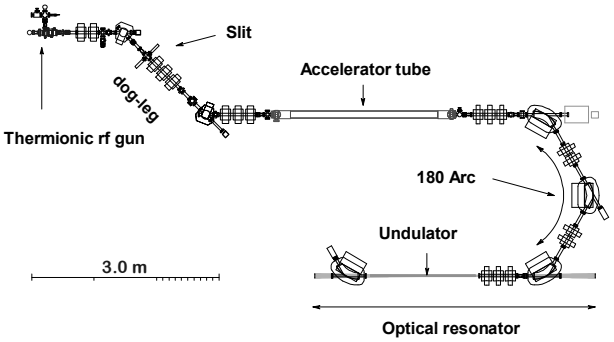


Fig. 1 Schematic drawing of the KU-FEL

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

It is well known that an infrared region light has a good resonance with phonon in some solid compound. In particular, wide-gap semiconducting materials such as ZnO, TiO2, and SiC show unique electrical and optical properties through coupling of phonon with electronic structures, resulting in photochemical phenomena with microwave irradiation. Therefore, it is considered that the irradiation of MIR-FEL on such semiconducting materials possibly give rise to the changes in electronic structures seen in photoluminescence (PL) at low temperature. This study aims at development of new evalu-

ation technique of electron-phonon interaction in such wide-gap semiconducting materials by MIR-FEL (Fig. 2).

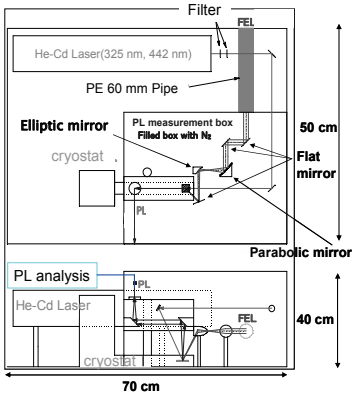


Fig. 2. chematic diagram of MIR-FEL Pump Photoluminescence (PL) Measurement System

3. Bulk HTSC Staggered Array Undulator

An undulator or a wiggler with strong magnetic field will play an important role in future synchrotron light sources and free electron lasers. We proposed the bulk high critical temperature superconductor staggered array undulator (Bulk HTSC SAU) in order to generate a strong periodic field. The Bulk HTSC SAU consists of stacked bulk high-Tc superconductors (HTSs) and a solenoid magnet which is used to magnetize the bulk HTSs as shown in fig.3.

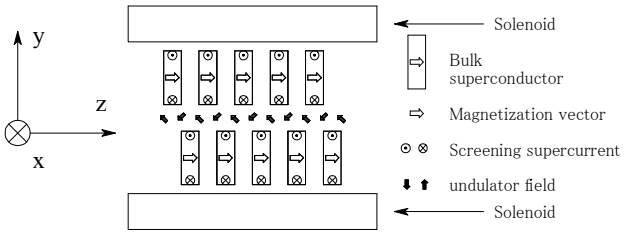


Fig. 3. Conceptual drawing of the bulk HTSC SAU and generation principle of the periodic undulator field using an induced current.

We have developed the prototype of Bulk HTSC staggered array undulator and succeeded in generation and control of a periodic magnetic field. The measured transverse magnetic field for the Bulk HTSC SAU at 77 K was several mT. The performance estimation at relatively low temperature was also performed. The expected undulator field at low temperature (about 20 K) is 0.8 T for the undulator period of 10 mm and the gap length of 4 mm. The expected field strength is better than that of the Halbach structure using permanent magnets.

4. Non-destructive isotope detection using NRF

A Nuclear Resonance Fluorescence (NRF) measurement is a powerful tool for investigation not only of the nuclear physics, but also of isotope detection for the homeland security such as a nondestructive measurement of containers at airports or harbors, detection or identification of special nuclear materials (SNM). Since especially in the case of the homeland security application, high throughput measurement will be quite important, we have proposed a high-flux γ-ray facility utilizing an energy recovery linac (ERL) and a laser Compton scattering scheme as shown in fig. 4. 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. We have investigated performance of a $LaBr_3$(Ce) scintillator for NRF experiment at several MeV gamma ray energy. Excellent timing response was confirmed and relative resolution at the energy regime of greater than 5 MeV was lower than 2 % in FWHM . These properties will be suitable for the gamma ray detector in the high throughput NRF measurement facility based on ERL and LCS-γ.

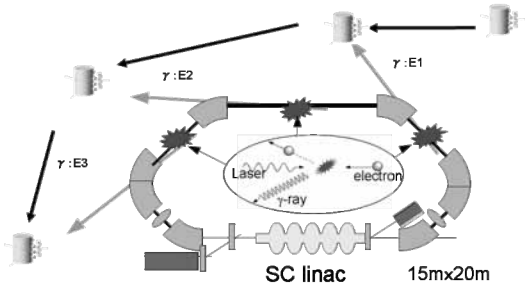


Fig. 4. Conceptual drawing of the ERL Compton-γ NRF facility

Acknowledgment

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Advanced Atomic Energy Research Section

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1. Introduction

The major objective of the study in this section is to pursue advanced energy systems for the sustainable development under global environmental constraints. The studies described below are featured by not only the innovative technology of energy generation, conversion and utilization systems. The attractiveness of the total energy system considered by the socio-economic analysis of future society and markets in the global scale and the scope covering 21st century and beyond are reflected. Typically, we propose a Zero-emission energy 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 and divertor with liquid LiPb and SiC composite for high temperature heat
(3) Conversion of waste biomass by endo-thermic reaction to generate hydrogen and liquid fuel
(4) Design and analysis of DC microgrid system for zero-emission electricity system
(5) Development of compact neutron beam using newly developed cylindrical discharge device.
(6) Analysis of radioactive impact of nuclides from fusion plants.

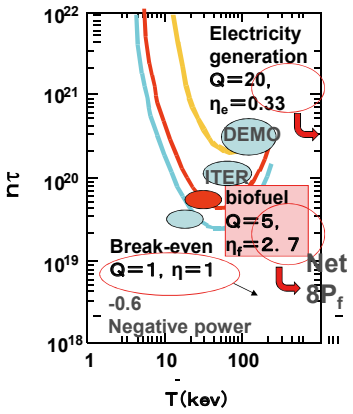

Fig. 1 Schematic illustrations of target of Plasma power balance Q value for biomass-fusion hybrid GNOME.

This annual report introduces the recent results of some of these subjects.

2. Design of biomass-fusion hybrid Tokamak GNOME

An energy plant based on Fusion-Biomass hybrid that takes advantage of both fusion and biomass energy was designed. Compared to the regular electricity generation that cannot overcome the thermal cycle limit of some 33%, this energy "multiplication" significantly relaxes the requirement of plasma energy multiplication factor Q, because original Lawson criteria depends on the conversion efficiency to be recycled to plasma. Although the hybrid obtains product energy as fuel, a part of that could be used for conventional generation with 33% efficiency to sustain plasma.

The modified Lawson criteria are shown in the fig.1-1. While pure fusion electricity DEMO plant is required to achieve Q>20 to yield net plant output corresponding to 6 times larger than the input energy at the generation efficiency 33%, net energy production of 8 times is possible with Q<5 plasma when combined with biomass fuel production, this effect relaxes required Q for energy plant. This "hybrid" effect is well-known for fission fusion hybrid that utilizes fission reaction to multiply output energy of fusion neutron. In the case of biomass-fusion hybrid, net positive energy output is obtained from the plant as a form of commercial fuel product. It could be either liquid fuel that will be immediately applied for existing oil-based infrastructure, or if desired, hydrogen can be produced.

This hybrid concept reduces the technical difficulty of plasma significantly. Unlike in the case of electricity generation, pulsed, and/or driven burning plasma may be used because the chemical reaction does not require steady and stable operation. Assumed technical requirements for this plant concept are realistic ones that are already applied to ITER with currently available scaling, or with reasonable extension of the current technology. Because modest Q is sufficient for biomass-hybrid, tokamak device could be smaller than ITER, and will not require extremely large construction cost. Low pressure

blanket system and throughout the power train is another major safety advantage of this plant concept. Fig.1-2 shows the comparison of the plasma size of GNOME with JT-60SA and ITER, and its view.

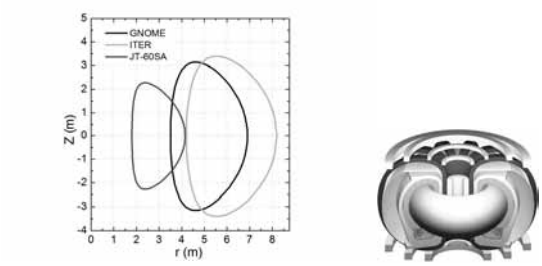

Fig. 2 Comparison of GNOME plasma with ITER and JT-60SA.

3. Design and analysis of DC microgrid

To conform a "best mix" with zero-emission electricity systems, combination of large scale nuclear and small renewables that are expected to share a considerable part of the power system is needed. From the aspect of the reforming of entire power system, we propose the combination of large scale grid largely utilizing nuclear, and large number of "microgrids" powered by renewables such as solar, wind, fuel cells and battery as a reasonable solution for the future energy supply. Many of the renewables except for hydro are controllable, and thus additional backup supply is needed. In order to replace fire power with renewables, storage is inevitable. Also, all the renewables are small in scale, and likely to be used as dispersed sources. Particularly in the advanced countries, large systems are not easy to introduce because of the almost saturated market and slow increase of demand. In the developing countries, while large plants are desired, premature grids and frequent power outage are strong reasons to install small systems.

Both clean sources such as solar, fuel cell and batteries are DC power, and from the demand side, it should be noted that most of the household appliances are already equipped with inverters, or DC-based devices such as PC, TV or LEDs, and thus DC system is considered to be reasonable. Figure 3 shows the concept of the DC microgrid. It is a combination of large scale conventional grid and many microgrids composed of solar, fuel cell and battery that is operated at 400V DC within limited area of community. Large scale grid is mainly powered by nuclear and hydro respectively for base load and load following. Figure 4 shows its typical operation scenario. Batteries with Sodium-Sulfer cells are charged in night from the large grid and supply electricity in daytime to complement solar. For the stability in long term, fuel cells are operated with external fuel supply, that will eventually be provided by biomass conversion. Cost analysis showed

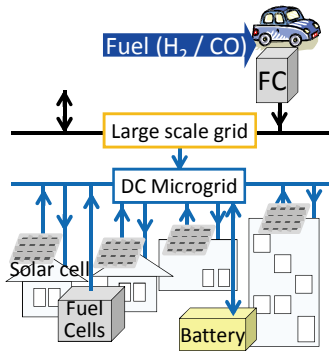

Fig. 3 Concept of the DC microgrid

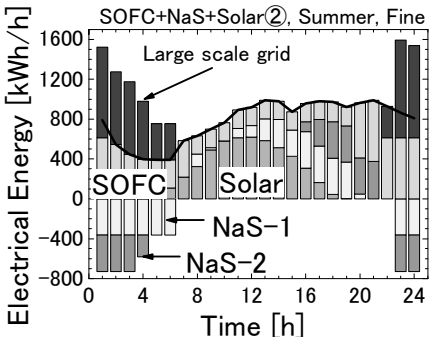

Fig. 4 Operation dayly power profile of the DC microgrid on a summer day

that such an electricity system will be economically reasonable in the cost estimation in 2025. Figure 1-5 shows the cost estimate based on the NEDO data of 1200 K yen/kw for solar and 2000K yen/ SOFE at 2025. After the operation of 7 years total cost will be smaller than the commercial electricity from grid. Thus zero-emission systems can be reasonably introduced at this cost basis.

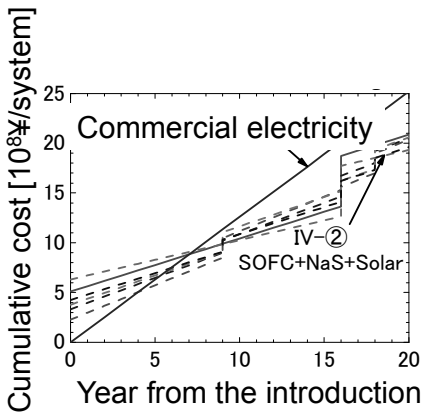

Fig. 5 Cost estimate of the DC microgrid based on the NEDO prediction.

Financial Support

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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. ECE measurement by using two multi-channel radiometer systems in Heliotron J

Electron cyclotron emission (ECE) diagnostic is an important scheme for understanding plasma performance such as electron temperature and high-energy electrons. We have recently installed a new ECE radiometer system, which is set up at different toroidal angle from the existing radiometer system. The main target is to investigate toroidal correlation of electron temperature fluctuations. In the present study, as a first step, we have measured the electron temperature profiles to confirm the validity of the radiometer systems.

Both radiometers are a heterodyne type, consisting of a local oscillator, a mixer, IF amplifiers, attenuators and video amplifiers. The power divided into each channel of IF frequencies is filtered by a band-pass-filter with 1 GHz band width. The frequency range is 72-88 GHz for the new radiometer, and 67-81 GHz for the existing radiometer, respectively. To determine the radial profile, we have performed a relative calibration test by using a noise source.

Figure 1 shows the electron temperature profile in a neutral beam injection experiment at B_T = 1.25 T and n_e = 1.5 × 10^{19} m^{-3}. The centrally peaked profile is obtained. However, it should be noted that the Heliotron J plasmas are optically gray, $\tau \sim 1$ for the second harmonic X-mode, so that the radiation temperature is affected by the radiation from high energy electrons. A density scanning experiment confirms a good correlation between the new and existing ECE profiles.

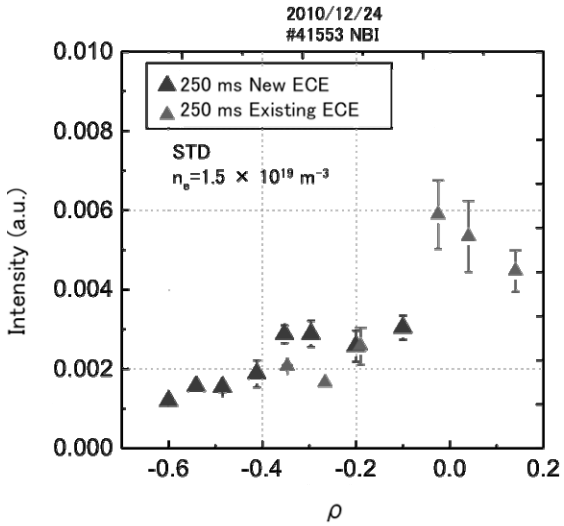

Fig. 1. Electron radiation temperature profile measured with new and existing ECE radiometers.

3. Preionization on Plasma Production in Superconduting tokamaks

In superconducting tokamaks, the toroidal electric field applied for ionization may be too low to start up plasmas reliably. To solve this problem, pre-ionization using Electron Cyclotron Resonance Heating (ECRH) has been proposed. Successful ECRH pre-ionization has been experimentally demonstrated in tokamaks such as JT-60U and DIII-D and KSTAR. Since the electric field may be limited to 0.5 Vm^{-1} in the JT-60SA superconducting tokamak, which is now under construction in JAEA, we need to find out effective plasma production schemes. The ECRH pre-ionization effects are theoretically investigated by a 0-dimensional (0-D) model to examine conditions for reliable startup in JT-60SA and to understand the physical process.

The 0-D model mainly consists of four equations; the electron energy density equation, the ion energy density equation, the particle conservation equation and the electric circuit equation. Figure 2 shows an example of temporal evolution of plasma parameters on the JT-60SA configuration. The absorbed ECRH power is assumed to be P_{ECRH} = 2.4 MW. The calculation results show that there is a threshold of the ECRH power, and the absorbed power of about 2.3 MW may be required for reliable startup. Extension to 1D model is underway for more quantitative estimation.

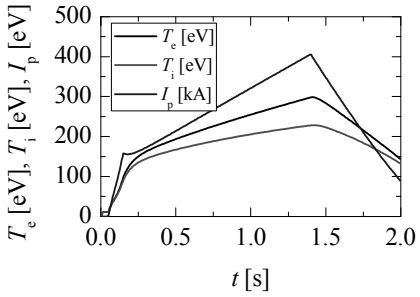

Fig. 2. Temporal behaviors of T_e, T_i, and I_p on JT-60SA configuration

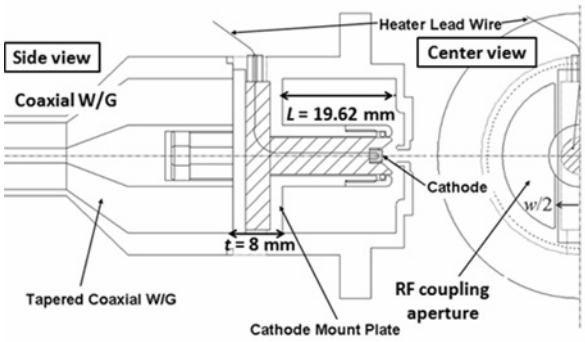

Fig. 3. Cross-sectional views of a prototype coaxial rf cavity for the triode rf gun system

3. Production of Highly Brilliant Electron Beam for Free Electron Laser

Electron beams with high brightness, high peak current, and long macro-pulse duration are preferred for free electron lasers. In the Kyoto University Free Electron Laser (KU-FEL) facility, a 4.5-cell thermionic rf gun has been studied intensively to meet these requirements in a compact and low-cost system. However, thermionic rf guns in general suffer from the back-bombardment of electrons onto the thermionic cathode, that limits the macro-pulse duration and/or peak current of the electron beams. An innovative method is needed to mitigate this problem.

For this purpose, we proposed what we call 'triode rf gun'. Design of the triode rf gun has been completed for the proof-of-principle experiments in the KU-FEL system. The simulation results predicted a drastic (>80 %) reduction of the electron back-bombardment. Based on this design, a prototype of a short-gap rf cavity (Fig. 3) was fabricated, which is to be installed in the existing rf gun in the KU-FEL, and low-power rf tests were carried out. As the results, the prototype demonstrates desired resonance behavior of TM_{010} mode, though modification of the cavity geometry is needed for the next step.

4. Improved Spherical IEC Fusion Scheme Featuring Multistage High voltage Feedthrough

An inertial electrostatic confinement (IEC) fusion device basically consists of a spherical anode at ground potential and a transparent gridded cathode at a negative high potential. Ions are accelerated toward the center as they gain energy relevant to D-D, D-T and D-^{3}He fusion reactions from the applied electric fields.

In order to minimize ion loss by charge exchange collisions with background neutrals that limits the fusion rate per input power in IECs, we have recently developed a new scheme driven by a built-in ring-shaped ion source, which extended the accessible low pressure limit very much down to 5 mPa. This increased the importance of ion beam optics in terms of ion recirculation (oscillatory motion of ions within the anode, prior to striking the feedthrough rod, see Fig. 4), because, for tens keV and 5 mPa, the mean free path for deuterium ion charge exchange is of the order of 10 m (tens cm for the moderate-pressure IECs for comparison), which is much longer than the typical anode diameter.

As shown in Fig. 4, we designed a 5-stage feedthrough with four intermediately biased electrodes. A numerical simulation suggested improvement in ion recirculation current by a factor of 3 due to recovery of the spherical symmetry in electric field distribution.

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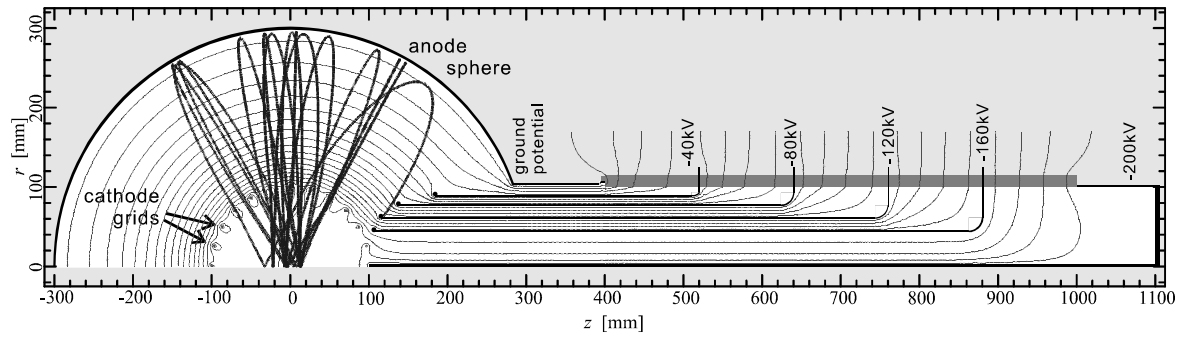

Fig. 4. Cross-sectional view of an IEC with a 5-stage high voltage feedthrough, calculated potential contour lines and ion trajectories

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1. Grant-in-Aid for Scientific Research

長﨑百伸，基盤研究(C)，「非誘導電流駆動を用いた回転変換制御」

増田開，若手研究(A)，「慣性静電閉じ込めプラズマ中の球状集束ビーム衝突核融合反応機構の解明」

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Advanced Plasma Energy Research Section

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1. Introduction

In this research section, studies of plasma energy are performed from a viewpoint of fusion plasma energy science. The current subjects of the research are to understand and control the properties of high temperature plasma trapped in a magnetic field to improve the plasma energy confinement. The experimental and theoretical investigations for the optimization of a unique helical field configuration, the helical-axis heliotron configuration, are in progress under the collaboration with other groups of IAE 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.

This report focuses on two interesting results from the Heliotron J experiments in FY2010; (1) the NBI plasma startup assisted by 2.45 GHz microwave launching and (2) the measurement of edge plasma by fast cameras and a hybrid probe.

2. NBI plasma startup assisted by 2.45 GHz microwave launching[a]

Development of plasma startup method without relying on ECH is important in helical devices, since it has a capability to enrage the operational magnetic field range and the variety of the magnetic field configuration. Here, we report experimental results on startup of NBI plasmas by assistance of 2.45 GHz 5 kW microwaves in Heliotron J. We experimentally demonstrate that the plasma build-up quickly after the NBI turn-on, and the operational magnetic field is extended to B = 0.63 T.

Figure 1 shows a typical time evolution of plasma quantities in the NBI plasma startup discharge. In this case, the magnetic field strength was set to be 0.83 T, and NBI was injected at the port through power of 1 MW (27 kV, H) in total. The microwaves were launched 0.3 s before turning-on of neutral beams. Neither fundamental nor higher harmonic EC resonance for 2.45 GHz microwaves exists in the vacuum chamber during the microwave launching. High electron cyclotron emission (ECE) intensity signal was observed before the injection of the neutral beams (t=150ms), even the line-averaged electron density $\bar{n}_e$ was in the order of 10^{17}m^{-3}. This phenomenon implies thin but hot electrons (seed plasmas) are produced by the 2.45 GHz microwaves. $\bar{n}_e$ increased just after the start of the neutral beam injection, and low density plasmas ($\bar{n}_e \sim 0.2\times10^{19}$ m^{-3}) appeared 10 ms after the beam injection. At the same time, the intensity of the oxygen line emission (OV) increased, which shows a large number of electrons whose energy exceeds the ionization potential (113 eV) were produced in the early phase of the beam injection. After that, an additional gas puff increased $\bar{n}_e$ to over 1×10^{19}m^{-3}.

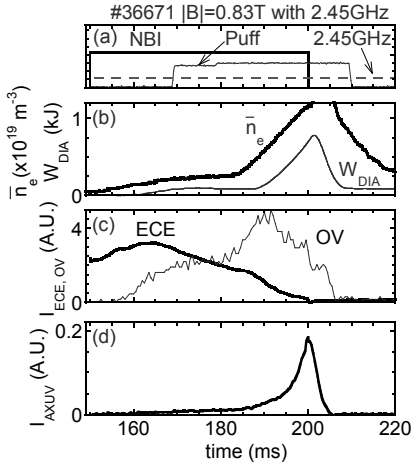

Fig. 1. Typical time evolution of plasma quantities in the NBI plasma startup discharge.

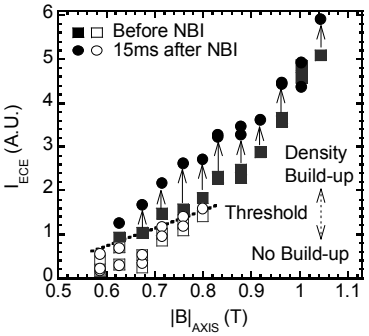

Fig. 2. Comparison of ECE intensity in the case of the successful and unsuccessful density build-up discharges.

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Successful NBI plasma production depends on the magnetic field strength. Figure 2 shows plots of the ECE intensities at 75.5 GHz before and after beam injection as a function of the magnetic field strength. A distinct ECE intensity threshold is found to build up the density in the range of 0.63 T < B < 0.8 T. We have not obtained successful density build up by NBI at magnetic field strengths below 0.6 T up to now. An ECE intensity threshold was not observed for 0.8 T < B < 1.0 T. These results suggest that the production and confinement of the initial plasmas depend on the magnetic field strength. The degradation of the percentage of the successful density build up may be due to a relatively low-power microwaves (< 5 kW). Since the toroidal electric field decreased with decreasing the magnetic field strength, the influence of the plasma breakdown by the toroidal electric field should also be considered to clarify the mechanism of the generation of the initial plasma by the 2.45 GHz microwaves. We are installing and testing a high power (20 kW) magnetron for reliable and robust plasma startup.

3. Measurement of edge plasma by fast cameras and a hybrid probe

It is important to understand the physics of turbulent transport in the plasma confinement. Since filamentary fluctuations, blobs and zonal flows have been observed experimentally in edge region, the experimental understandings of the 3-dimensional structure and the characteristics in these fluctuations are required. In Heliotron J, we are trying the 3-dimensional measurements of the fluctuations in edge plasma by using a fast camera set and a hybrid probe system.

Plasma emission images observed from two directions (horizontal and vertical) at a torus section were simultaneously captured into a single frame of a camera with a two-way image fiber bundle. A Super Molecular Beam Injection (SMBI) was used to obtain high enough intensity of the emission for a high-speed frame rate (20000-80000 fps) necessary for fluctuation analysis. By using this system, we have succeeded two-directional observation of the edge plasma fluctuations. A two-dimensional phase analysis technique revealed that the fluctuation has a filamentary structure elongated in the magnetic field line as shown in in Fig. 3. After sophistication of this system and detailed image analyses, we expect to reconstruct 3-D structure of fluctuation and clarify its motion.

Although the fluctuations observed in the edge plasma emission is considered to be related to the plasma density fluctuations in the edge region, only the fast-camera observation is not sufficient to understand their origins. In order to study more detailed characteristics of the fluctuations observed in plasma emission, a new hybrid probe was developed for Heliotron J experiments. The hybrid probe consists of a Langmuir probe set with four tips and a pic-up coil (magnetic probe) sets for three components of magnetic field (radial, poloidal and toroidal directions). The coherent fluctuations in the low frequency range observed the fast camera system were also detected by the radial and poloidal magnetic probes (Fig. 4), but not detected by the toroidal magnetic probe. This fluctuation was only observed during 10 ms after the SMBI. Since such a coherent fluctuation was not detected by magnetic probes located at the vacuum vessel (far from the plasma edge), the fluctuation may have a fine structure near the plasma edge. On the other hand, such coherent fluctuations were not observed by a Langmuir probe, suggesting the coherent modes have come from magnetic fluctuations.

We are planning to re-arrange the camera system and the hybrid probe optimally and apply the spectral filter to the camera system in order to clarify the physics of detailed three-dimensional structure and characteristics of edge plasma fluctuations.

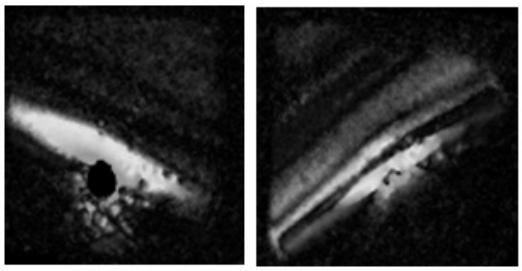

Fig. 3. Example of the phase images of edge plasma fluctuation observed at a plasma section (left: top view, right: side view). Although the scale is not the same, the exposure timing is the same. The filamentary structure elongated to the direction of the magnetic field is observed.

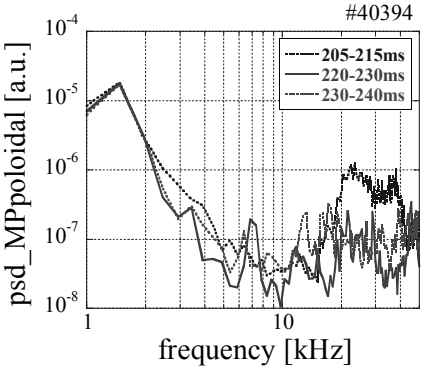

Fig. 4. An example of power spectrum of poloidal magnetic fluctuation for three different timing of a single discharge. The SMB injected at t = 218 ms. A coherent fluctuation are only observed in the 7-8 kHz just after the SMBI (t = 220-230 ms).

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

核融合科学研究所，タンデムミラープラズマにおけるリサイクリング挙動とプラズマ最適化に関する研究，小林進二，水内亨

核融合科学研究所，先進ヘリカルによるプラズマ構造形成・不安定制御と閉じ込め磁場最適化の研究，佐野史道，水内亨，長﨑百伸，花谷清，岡田浩之，南貴司，小林進二，山本聡

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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，水内亨，岡田浩之，長﨑百伸，小林進二

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)，山本聡，佐野史道，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)，小林進二，岡田浩之，南貴司

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(東大)，小林進二，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)，水内亨，岡田浩之，佐野史道

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)，山本聡，長﨑百伸，佐野史道，水内亨，岡田浩之，南貴司，小林進二

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), 南貴司, 佐野史道, 水内亨，長﨑百伸，小林進二，岡田浩之，山本聡

核融合科学研究所，弱磁場ヘリオトロン非中性プラズマ実験のまとめと閉じ込め時間測定のための誘導電荷法の検討，比村治彦(工繊大)，佐野史道，水内亨，岡田浩之，小林進二，山本聡

核融合科学研究所，ヘリオトロン J での反転磁気シア配位プラズマ生成とアルヴェン固有モード特性，東井和夫（核融合研)，山本聡，佐野史道，水内亨，長﨑百伸，岡田浩之，南貴司，小林進二

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Advanced Energy Research Section

Gisle Øye, Foreign Visiting Professor
Ugelstad Laboratory, Department of Chemical Engineering,
Norwegian University of Science and Technology

1. Introduction

Produced water is water co-produced with oil and gas during petroleum production. Globally, the amount of co-produced water is three times higher than the amount of produced oil. Furthermore, the amount of water continues to increase as the oil fields become more mature. Both from an environmental and a processing perspective, it is important to remove pollutants from the produced water streams. Various well-working technologies are developed in this respect. However, there is limited understanding of the underlying mechanisms for the separation processes. Better fundamental knowledge about the produced water fluids is required to further improve the reliability and efficiency of the separation processes, and thereby reduce environmental hazards. The following gives a brief overview of previous and on-going research activities on separation behaviour and interactions between dispersed components in produced water at Ugelstad Laboratory.

2. Produced Water Characterisation

Produced water is a mixture of dispersed solids, oil, gas bubbles and microorganisms, as well as dissolved organics, inorganic ions, gas and various production chemicals. As a first approach to better understand these complex fluids we focused on the behaviour of suspensions containing various types of produced water solids and o/w emulsions. With respect to suspended solids, it has been found that the stability of solids in water is influenced by the presence of surface active oil components. In most cases the stability was increased by the crude oil components, but in a few cases it was decreased. Furthermore, alterations of the surface properties of the solids depended more on the type of solids than on the crude oil components.

In the o/w emulsion studies it was found that the nature of the interfacial layer plays an important role for the separation efficiency of the emulsions. For example, emulsions from crude oils with high viscosity and density were often easier to separate than emulsions from lighter crude oils. This demonstrates that the density difference alone does not account for the emulsion behaviour, and interfacial properties need to be taken into account. Our investigations showed that the lighter crude oils often built up an elastic interfacial layer which reduce or prevent coalescence of the oil droplets, and thereby prevent efficient separation of oil and water. Heavier crude oils, on the other hand, tended to form less elastic interfaces, and are more prone to coalescence.

In order to approach the complexity of real produced water fluids, we have recently started up a project focusing on the ability of solids to stabilise crude oil emulsions and interactions between gas bubbles, oil droplets and solids. The latter is particularly important for flotation as a process for removing oil and solids from the produced water. The overall aim is to obtain better fundamental knowledge about the interfacial and interactions properties of dispersed components in produced water streams, and thereby facilitate better produced water treatment within the oil and gas industry.

Somewhat linked to this project, we are also collaborating with Associate Professor Tetsuo Sakka at Institute of Advanced Energy, Kyoto University. During my stay at Institute of Advanced Energy we initiated an investigation of particles at oil-water interfaces, with the aim at improving the fundamental understanding of interactions between particles at liquid-liquid interfaces. A joint publication of the results is in progress, and we have plans to continue this collaboration. Finally, I would like to express my sincere gratitude to Professors Yukio Ogata, Tetsuo Sakka, Kazuhiro Fukami and all their students for a truly fruitful and enjoyable stay in their group!

Advanced Energy Research Section

Rolf Boelens, Foreign Visiting Professor
(Professor, Department of Chemistry, Utrecht University, Utrecht, The Netherlands)

1. Introduction

From December 31 2010 until the end of March 2011 I was a visiting professor in the laboratory of Professor Masato Katahira at the Institute for Advanced Energy, Kyoto University. My activities included frequent interactions with the coworkers, students and staff in Professor Katahira's research group, attending weekly group seminars and progress meetings with the research group, giving lectures and seminars at different institutes of Kyoto University and other locations throughout Japan. I also assisted in setting up experiments with coworkers of the Katahira lab.

2. Weekly progress meetings and research seminars

I attended the weekly progress meetings and research seminars of the Katahira group. The progress meetings involved a summary of the weekly progress by the students or postdocs on their research activities and their plans for the coming period. These progress meetings were highly informal and gave the students possibilities to show not only their new findings and speculate about their meaning, but also allowed to show unfinished or inconclusive results. I highly appreciate that these presentations were prepared and given in English and that handouts were available for the discussion. This allowed active discussions during and after the meeting and possibilities to provide suggestions for interpretation or improvements. The weekly research seminars, which were also held in English, involved presentations by two students or postdocs. First a scientific presentation was given by one of the students or postdocs on their research project. The presentation involved an introduction to their study, which was very informative to me, their latest results on the project, a conclusion and their next plans. These meetings were chaired by one of the students with considerable discipline. After the presentation there generally arose a lively discussion, with general questions, or on ambiguities, with suggestions for improvements or possible alternative views. In the other presentation an article was discussed. For this one of students had chosen a recent paper that could be important for his project. Also these presentations were accompanied by handouts and were very well prepared. I was also highly impressed by the level of the presentations and discussions. This, and the fact that presentations and discussions were all held in English, must have taken a considerable effort by the students, which I highly appreciate.

3. Seminars and Lectures

During my stay I gave several seminars at different institutes of Kyoto University and at other universities in Japan. Two seminars were held at the Institute of Advanced Energy on the Uji campus, hosted by Professor Masato Katahira. In one seminar I presented the NMR studies of my research group at Utrecht University on the Lac repressor and on DNA repair, whereas in the other presentation I showed the results of our studies on the Photoactive Yellow Protein, the E2-E3 ubiquitination complexes and the Kid-Kis toxin-antitoxin plasmid maintenance system. I gave presentations on similar topics at three other institutes of Kyoto University (Chemistry, Molecular Engineering and ICeMS), at Osaka University (Institute for Protein Research), at Tokyo Metropolitan University and at Yokohama City University. Depending on the research areas of the visited laboratories (ranging from biology, chemistry to biomolecular nmr spcectroscopy) I adjusted the focus and topics of my lectures.

4. Courses

During my stay I also gave several courses in Kyoto and Osaka. At the Institute of Advanced Energy of Kyoto University I gave first an advanced course on biomolecular NMR spectroscopy during three 2.5h sessions. I started with an introduction on multi-dimensional NMR, with the concepts of 2D and 3D NMR, product operators, heteronuclear and triple-resonance NMR, TROSY, assignment strategies and methods for speeding up multidimensional NMR. This was followed by an overview of the practical aspects and concepts modern of heteronuclear 3D and 4D NMR, basic NMR pulse sequences, the sensitivity of triple-resonance NMR experiments. The courses were accompanied with exercises for better understanding the advanced concepts.

In another course at the Institute of Advanced Energy I introduced the concepts of protein docking, our data-driven docking approach (HADDOCK) and the use of HADDOCK for modeling protein-protein,

protein-DNA and protein-ligand complexes. This course was attended by several participants from outside Kyoto University.

I also lectured in an advanced graduate course (organizers: Prof. Chojiro Kojima and Dr. Takahisa Ikegami) on Biomolecular NMR Spectroscopy at the Institute for Protein Research of Osaka University. In this course, which was attended by many young NMR researchers I gave an introduction on multidimensional NMR spectroscopy, followed by an overview and practical aspects of triple-resonance NMR and recent developments for speeding up multidimensional NMR experiments.

5. Research interaction

I was hosted in the research group of Professor Masato Katahira at the Institute for Advanced Energy. Of the different research topics in his research group (RNA aptamer prion protein interaction, anti-HIV enzyme APOBEC and biofuels), I was mainly involved in those of with Dr Ayako Furukawa, who studies the anti-HIV enzyme APOBEC and a virus protease. It has been proposed that the DNA deamination mechanism of APOBEC involves a sliding of the enzyme along the DNA sequence. Professor Katahira, Dr Furukawa and myself had a discussion on DNA sliding mechanisms in relation to APOBEC and brainstormed on possibilities to demonstrate this. This work is ongoing. Progress on the dimeric virus protease is challenged by a possible two-fold asymmetry leading to partial NMR line doubling in spectra of the protein complexes with inhibitors and by a high number of prolines in the polypeptide sequence, which breaks the sequential triple-resonance NMR assignment procedure. Currently we try to setup a triple resonance NMR pulse experiment that allows assignments at proline stretches.

6. Lab visits

During my stay at the Institute for Advanced Energy I visited several additional institutes in Kyoto, Osaka and Tokyo. At Kyoto University I visited the group of Professor Hiroshi Sugiyama in Laboratory of Chemical Biology of the Department of Chemistry. Professor Sugiyama and his coworkers introduced me to their research on DNA chemistry, gene regulation and DNA nanostructures and showed me the considerable possibilities of advanced atomic force microscopy for such studies. On another occasion I visited the research group of Professor Masahiro Shirakawa at the Department of Molecular Engineering, at the Katsura campus. Professor Shirakawa gave an overview of his research on his studies on protein sumoylation, chromatin and DNA repair complexes, on developments in in-cell NMR and on novel MR based detection methods. I also visited Professor Yoshie Harada at the Laboratory of Single-Molecule Physiology in the Institute for Integrated Cell-Material Sciences. She introduced me to her single-molecule studies of DNA-protein interactions in DNA replication, repair and recombination, and the use of optical microscopes for her studies.

In Tokyo I first visited Professor Masatsune Kainosho and Professor Yutaka Ito in the Laboratory of Organic and Structural Biochemistry at the Department of Chemistry of Tokyo Metropolitan University. Professor Yutaka Ito introduced me to his research on in-cell NMR, methods for studying large complexes and new sampling methods for multidimensional NMR, whereas Professor Masatsune Kainosho showed me his recent improvements for biomolecular NMR. In Yokohama I visited the research group of Professor Yoshifumi Nishimura in the Department of Supramolecular Biology at Yokohama City University. He and his coworkers introduced me to their research on DNA binding proteins and their developments in linking NMR and mass spectrometry. His coworkers also introduced me to other members of the Department and showed me the NMR park in the adjacent RIKEN complex. Finally at Osaka University I visited Professor Haruki Nakamura at the Institute for Protein Research, who introduced me to his computational modelling and biomolecular docking studies and the various bioinformatics tools that he developed.

6. Plans for further collaboration

Continued collaboration can be foreseen for the APOBEC and virus protease projects. On the APOBEC project we plan to further explore the sliding mechanism, whereas for the virus protease we will continue to interact on resolving the spectral complications.

Advanced Energy Research Section

Timothy M. Dore, Foreign Visiting Associate Professor
(Associate Professor, Department of Chemistry, University of Georgia, Athens, Georgia, USA)

1. Introduction

Professor Takashi Morii extended me an invitation to spend three months at Kyoto University's Institute of Advanced Energy, which I gladly accepted and commenced on May 5, 2010. It was an amazing scientific and cultural experience in which I worked in the Morii laboratory learning about RNA aptamer technology and applying it to the development of a selective sensor for adenosine triphosphate (ATP). It was wonderful to work under the guidance of Professor Morii and his graduate students, postdoc, and assistant professor.

2.Scientific Exchange

During my stay in Japan, I presented three seminars on the design of light-based tools to study physiological function and the discovery and development of inhibitors of Ras converting enzyme (Rce1p). I was hosted by three distinguished researchers at Kyoto University: Professor Hiroshi Sugiyama in the Department of Chemistry on the Yoshide campus, Professor Yasuo Mori at the Katsura campus in the Department of Synthetic and Biological Chemistry, and Professor Motonari Uesugi at the Institute for Chemical Research on the Uji campus.

I attended many Morii group laboratory meetings during which I engaged in rich scientific discussions with members of his team. Professor Morii's research is in a different field from my own background in synthetic organic chemistry and photochemistry, so these meetings were extremely important for exchanging knowledge and expertise. I also regularly participated in the laboratory meetings of Professor Uesugi, whose work in chemical biology is widely known. My interactions with his research group led to an opportunity for his assistant professor Shinichi Sato to visit UGA in October 2010. I had the opportunity to engage in scientific exchange with other faculty members and their research groups on the Uji campus and with distinguished visitors to the IAE.

Working closely in the laboratory with Professor Morii's students was one of the most enriching experiences during my stay. They have tremendous expertise in RNA technology and come from diverse backgrounds, so it was incredible to work so closely with them.

3. Collaborative Research

My research project was to address a longstanding challenge in developing RNA aptamers to selectively bind ATP, but not adenosine diphosphate (ADP) or adenosine monophosphate (AMP). The Morii lab has developed a unique strategy of using a protein scaffold to stabilize the RNA aptamer structure, which enables more effective use of the aptamer-based recognition element in biological sensing applications. Working with Mr. Shun Nakano, we set out to create an ATP-selective aptamer-protein conjugate by first selecting for a set of RNA aptamers that bind ATP, and then in later selection rounds, negatively selecting against those that bound ADP and AMP. By the end of my three-month stay, we were successful in producing a pool of RNA aptamers that had undergone twelve rounds of positive and negative selection. Mr. Nakano carried out the process of separating the individual aptamers and sequencing them. We discovered that we had selected several unique RNA sequences. After my departure, Mr. Nakano continued to work on the project, aiming to characterize the ATP, ADP, and AMP binding properties of these new protein-aptamer conjugates.

4.Cultural Exchange

In addition to the wonderful scientific experience, my wife, Lisa, and I were able to experience many wonderful Japanese cultural activities in and around Kyoto. The city is rich in Japanese heritage and we explored it to the fullest extent possible. We also traveled to Shikoku, the Inland and Japan seas, Mt. Fuji, Nagoya, Nara, Osaka and the Japan Alps. Nevertheless, the richest part of our experiences were when Professor Morii and his colleagues graciously included us in their laboratory events.

5.Summary

The quality of the work conducted in the laboratory of Professor Morii and other faculty members at the IAE is extremely impressive, and the work ethic of Professor Morii's team is extraordinary. My time spent at the Institute was extremely rewarding scientifically and personally.

Advanced Energy Materials Research Section

K. Matsuda, Professor
T. Hinoki, Associate Professor
K. Jimbo, Assistant Professor

1. Introduction

We are investigating the scientific principle and applications of new materials including nano-materials for advanced energy science. In Advanced Energy Material Research section, the physical properties of nano-carbon materials (carbon nanotube, and graphene) by advanced optical spectroscopy and compositional ceramics (SiC) materials by multi-scale experiments for the material properties (MUSTER) are studied. Followings are main research achievements in the year of 2010.

2. Observation of charged excitons in hole-doped carbon nanotubes using photoluminescence and absorption spectroscopy

Single-walled carbon nanotubes (SWNTs) exhibit unique optical and electronic properties, originating from their strong quantum confinement in one dimension. Here, we reported the first observation of trions (charged excitons) in carbon nanotubes. The trion is a three-particle bound state consisting of an electron and two holes due to Coulomb interactions. When *p*-type dopants are added to carbon nanotube solutions, the photoluminescence and absorption peaks of the trions appear far below the lowest singlet E_{11} exciton peak (dotted circles in Fig. 1-1), regardless of the dopant species (solid circles in Fig. 1-1) . The unexpectedly large energy separation between the lowest bright excitons and the trions is attributed to the strong exchange interaction in carbon nanotubes. The observation of room-temperature trions in carbon-based materials will provide a deeper understanding of many-particle correlations for future applications in electronics, optics, and quantum information processing.

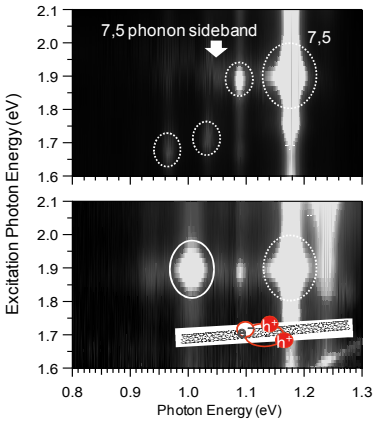

Fig. 1-1 Photoluminescence excitation map hole-doped single-walled carbon nanotubes. Upper panel: without hole-doping of CoMoCAT SWNT, Lower panel: with hole-doping

3. Diameter-based separation of single-walled carbon nanotubes through selective extraction with dipyrene nanotweezers

The host-guest methodology for separation of SWNTs has been developing according to the handedness and diameter with gable-type chiral diporphyrins, designated as porphyrin nanotweezers. As an extension of the strategy, novel nanotweezers having two pyrenes instead of porphyrins have been designed. The pyrene 2 nanotweezers consist of two 1- or 2-pyrenes and 3,6-carbazolylenes with various N-substituents. They were synthesized through Suzuki coupling reactions between 1- or 2-substituted pyrene with 3,6-disubstituted carbazoles. For the extraction of SWNTs, the 1- and 2-pyrene nanotweezers show the marked contrast; 1-pyrene nanotweezers selectively extracted SWNTs with diameters ranging from 0.84 nm to 0.97 nm, while 2-pyrene nanotweezers were not able to extract SWNTs at all. The pyrene nanotweezers have advantage in their much more facile preparation over the porphyrin ones. The selectivity by tuning the angles and the distance of two pyrenes were convinced to improve as in the case of porphyrin nanotweezers. This study was carried out through collaboration with Prof. N. Komatsu's group in Shiga University of Medical Science.

4. Silicon carbide matrix development for LWR microencapsulated fuels

Silicon carbide (SiC) is a proven attractive nuclear material in part because of its chemical and environmental inertness, exceptional irradiation stability, low neutron capture, and very high temperature performance. Specifically, experimental results for very high purity, high density forms of SiC indicate that mechanical properties such as strength and elas-

tic modulus are essentially unchanged, or slightly improved, by under relevant fission reactor irradiation conditions. Similarly, irradiation-induced dimensional change of the high purity SiC saturates at around 1dpa neutron irradiation (or about a few months in a fission core) over a wide irradiation temperature range. The exceptional performance of SiC is the key factor in its selection as the matrix compacting material for proposed LWR microencapsulated (TRISO-type) fuel. Such a SiC matrix would be in replacement to the historic graphite matrix historically used in the fuel pellets of HTGR reactors, which would be unsatisfactory in an LWR application due to the extreme dimensional instability of graphite: large densification causing a fuel-zircaloy gap followed by uncontrolled swelling. The objective is the process optimization of the fully ceramic micro-encapsulated inert matrix fuel pellets. To date the fuel fabrication program has followed parallel paths of 1) understanding and improving the quality and quality control of the SiC matrix, and 2) fabrication of fuels of variable fuel loading (TRISO volume fraction) for irradiation and scale-up. The overarching goal of this work is to provide irradiation stable, impermeable matrices for these fuels with exceptional thermal conductivity and thermal conductivity which would then be taken into irradiation.

Inert SiC matrix was formed utilizing liquid phase sintering (LPS) technique. Sintering additives of Y_2O_3 and Al_2O_3 were used in addition to silicon carbide powder in the LPS method. Porosity was found to decrease with increasing amounts of sintering additives. However, considering the possible implication of sintering aids on irradiation degraded properties minimization of these sintering aids is considered a driver. Figure 2-1 shows SEM images and EDS analysis results of the interface the inert matrix and the coated particle. The inert matrix and the coated particle, concentration of sintering additives was observed within SiC adjacent to interface.

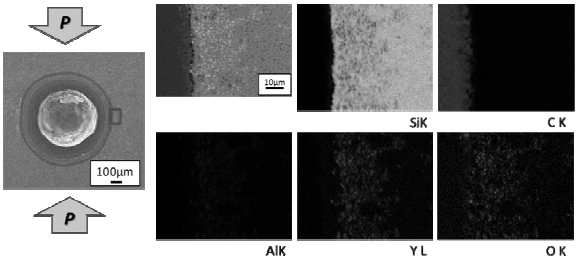

Fig. 2-1, EDS analysis result at SiC matrix/coated particle interface

5. Simulation of neutron damage on nuclear ceramics by ion irradiation

Due to the absence of operating fusion reactors or intense fusion spectrum neutron sources at present, fusion materials research relies upon simulation of fusion environments. A Multiple Beams–Material Interaction Research Facility (DuET facility) at IAE, Kyoto University, composed of two parallel accelerators for helium and heavy ions, has been a useful tool to study the synergistic effects of accumulation of atomic displacement damage and transmutant gases on material properties. Existing fission reactors have been used for the simulation study so far. The neutron data is unquestionably essential but cope with many problems such as cost and accuracy of thr irradiation conditions. The highly controllable and accurate irradiation conditions of DuET facility would help to achieve comprehensive experiment with the significant advantage in time (~1/1k) and cost (~1/100).

Our research group have demonstrated that the exceptionally high irradiation tolerances of the SiC and SiC/SiC composites such as the retaining of the initial strength after irradiation in a wide temperature range of 280-1400ºC and the lack of measurable void swelling below 1200ºC. Most ion-irradiation data was confirmed to be comparable to fission-neutron data in the quantitative and qualitative aspects. Recently, we are trying to understand the irradiation induced creep, which is the remaining key issue lacking in certain irradiation data for the SiC. Because the creep rates are presumably associated with the rates of accumulation of lattice defects and/or its aggregates, testing by ion-irradiation is suitable for understanding such temperature- and fluence-sensitive phenomena. The strain rates showed nearly linear dependence on the non-stressed swelling rates with temperature dependent proportional constants at 280-1000°C, where the largest constant was found at 800°C. The transmission electron microscopy indicated that the anisotropic dislocation loop formation found in irradiated and crept SiC was one of the irradiation creep mechanisms.

6. Transverse laser cooling of a magnesium ion beam by synchro-betatron resonance

As collaboration research with Advanced Research Center for Beam Science, Institute for Chemical Research, we engage in a laser cooling experiment of an ion beam at Small Laser-equipped Storage Ring (S-LSR: the circumference is 22 m). A magnesium ion beam $^{24}Mg^{+}$ was cooled by a laser, which consists of a 560 nm Ring Dye laser pumped by a frequency-stabilized Nd:YVO_4 (frequency doubled) laser with a frequency doubler. The frequency tunable UV laser of 280 nm is guided into a straight section of the S-LSR ring and co-propagates with ions so that they constitute 3s2S1/2→3p2P3/2 absorption-emission cycle. The minimum observed longitudinal beam temperature was 3.6 K. Recently a reduction of transverse beam temperature through "synchro-betatron resonance" was observed. Efforts have been made to confirm this result experimentally.

Collaboration Works

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核融合科学研究所, 液体ブランケット二重冷却システム用炭化珪素材料の開発，檜木達也

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2. Others

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檜木達也，共同研究(日本原子力研究開発機構)，SiC/SiC 複合材料の照射下強度予測のため SiC 照射特性に関する研究

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Advanced Laser Science Research Section

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1. Introduction

Our research interest is focused on the development of advanced lasers and their applications to pioneering new fields of photon energy technology. The laser development is aiming at the generation of high-intensity, few-cycle laser pulses with stabilized carrier envelope phase (CEP). The intense cycle laser pulses allow us to approach sub-fs (< 10^{-15} s) to attosecond (10^{-18} s) time regions in the experimental study of ultrafast strong-field interaction with atoms, molecules and solid surfaces. The goal is to demonstrate potential abilities of coherent radiation sources in new regimes and to contribute to the progress of science and technology.

2. High-intensity ultrashort pulse lasers

Three Ti:sapphire laser chirped-pulse amplification (CPA) systems are working in our laboratory, which emit high-intensity fs pulses at the center wavelength of 800 nm. One of them produces a peak power of 1 TW (40 mJ in 40 fs). This system has been used for the study of ultrafast strong-field interactions with atoms and molecules. The second CPA laser system, producing 10 mJ in 100 fs pulses with a fine intensity distribution, was developed for the purposes of materials control and processing.

A new fs Ti:sapphire laser oscillator-amplifier system is operating for the study of attosecond (as) science. The system consists of a mode-locked oscillator producing 6.8 fs pulses at 80 MHz, a pulse stretcher, a pulse selector, a multi-pass amplifier, and a grating compressor. The average output power is 1.6 W with CEP-locked 25 fs pulses at a repetition rate of 1 kHz. The 25-fs pulses can be compressed to a few cycles (< 7 fs in duration) by a pulse compressor consisting of a long gas-filled hollow fiber and chirped mirrors for dispersion compensation. Figure 1 shows an example of the autocorrelation trace of the output pulse and its spectrum. The intense few-cycle laser pulses are used for the high-order harmonic generation in a gaseous medium to produce attosecond EUV pulses. The experimental apparatus for the EUV pulse generation is under development.

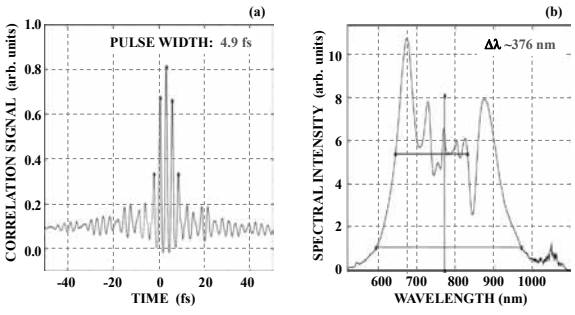

Fig. 1. (a) Autocorrelation trace of the amplified and compressed fs pulse and (b) its spectrum.

3. Retrieving angular distribution of high-order harmonic generation from a single molecules

High-order harmonic generation (HHG) from nonadiabatically aligned molecules provides an effective tool for studying structures and dynamics of molecules, where the angle-dependent harmonic yield around the molecular axis is the key to deduce the property of a single molecule. The harmonic distribution observed in the HHG experiment, however, always includes a broadening of molecular axis distribution that blurs the shape of a single molecule, due to the imperfect alignment of molecules.

We have developed a method to obtain the angular distribution of HHG from *a single molecule*, together with the accurate value of the rotational temperature T_{rot} of molecules, where no theoretical assumption is necessary. We employ an iterative procedure to retrieve the HHG distribution, based on two kinds of harmonic signals observed in the pump and probe experiment. One of them is the temporal dependence of HHG signal produced from coherently rotating molecules under field-free conditions, and the other is the signal measured as a function of the relative angle between pump and probe polarizations at a fixed time delay. The experiment was done with 40 fs pulses from a Ti:sapphire laser and a pulsed supersonic molecular beam jetted in vacuum.

In the iterative procedure we start with the time dependent Schrödinger equation to calculate the molecular axis distribution for a test value of T_{rot} and the angular distribution of n-th harmonic intensity produced from a single molecule. A convolution of the

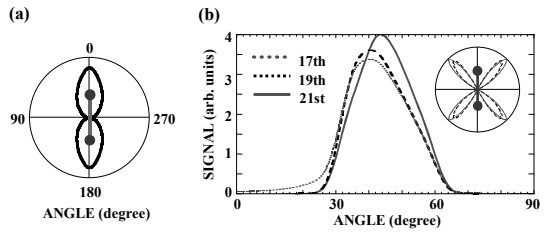

Fig. 2. (a) Angular distribution of HHG retrieved for a single N_2 molecule, and (b) angular distributions of HHG of different orders for a single O_2 molecule, where the inset represents the polar plots of intensity.

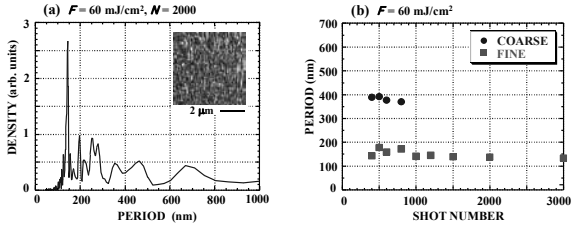

Fig. 3. (a) Power spectrum of the Si surface image and (b) structure period observed as a function of *N*.

calculated results is compared to the experimental. The iterative procedure is repeated by changing T_{rot}, until a good agreement is obtained.

The angular distribution of HHG from a single N_2 and O_2 molecule with different orbital symmetries has successfully been retrieved for several harmonic orders. Figure 2 shows examples of the results. It is noted that the angular distribution for a single N_2 molecule is certainly subject to the σ_g symmetry of the highest occupied molecular orbital, while the result for O_2 has a peak around the angle $\theta = 40^\circ - 45^\circ$ and nodes at $\theta = 0^\circ$ and 90° due to the π_g symmetry. These are the first results representing the HHG distribution for a single molecule.

4. Nanostructuring in fs laser ablation

Intense ultrashort laser pulses are able to produce periodic nanostructures through ultrafast ablation of solid surfaces, where the observed size of nanostructures is much smaller than the laser wavelength. Intensive studies have been made for a variety of target materials to elucidate the nanostructuring, but the physical process is not completely understood yet. Based on a series of experimental studies for hard thin films, we have shown that *near-field* enhanced with fs laser pulses plays the essential role in initiating the nanoscale ablation on the target surface, and the origin of nano-periodicity observed can be attributed to the excitation of *surface plasmon polaritons* (SPPs) in the surface layer where the dielectric properties are rapidly changed due to the generation of high-density free electrons.

An experimental study of nanostructuring has been made to demonstrate the applicability of our model based on the near-field and SPPs to semiconductors. The target materials used were the crystalline Si, GaAs, GaN, InP, and InAs. A small piece of target was placed in a cell filled with distilled water. The ablation experiment was performed with linearly polarized, 800 nm, 100 fs laser pulses from a Ti:sapphire laser system operated at 10 Hz. The fs laser pulses were focused on the target with a 1000-mm focal length lens, through the water layer of 2 mm thickness and a quartz window of the cell.

Nanostructuring of surfaces was observed with multiple fs laser pulses at low fluence around the ablation threshold. For Si, as well as the others, we have found that the nanostructure size observed consists of two groups, depending on the superimposed pulse number *N* and the fluence *F*: one is fine with the mean period of d = 140 – 200 nm, and the other is coarse with d = 400 – 500 nm. Figure 3 shows (a) an example of the Fourier spectrum of the Si surface image in the inset, and (b) a typical result of the nanostructure size observed as a function of *N*. The fine structure was observed for Si only in water and was never created in air. The fine and coarse structures, formed in the direction perpendicular to the laser polarization, are created so as to intermingle on the target with a small number of *N*. With increasing *N*, the area of the coarse structure on the surface decreases, while the fine structure area increases to cover the whole structured surface area. It is noted in Fig.3 (b) that the nanosize observed is almost independent of *N*.

The nanostructuring process in water was analyzed with the model based on the near-field and SPPs. The characteristic property of nanostructuring reconciles with the picture of our model and the observed period of fine structure is in good agreement with the calculation.

5. Theoretical study of ultrafast laser-matter interactions

We have considered a simple and robust scheme to polarize nuclear-spin, with which the degree of spin-polarization of muonium can be made as high as 90%. This is a significant result, since none of the currently known techniques works to polarize muonium due to its short lifetime (2.2 μs) and short pumping wavelength (121 nm). We have also explored the possibility of using a modified Gaussian mode to improve the fs filament.

6. Study of turbulent heat transfer for heating of water in a short vertical tube

Theoretical equations for turbulent heat transfer in a circular tube of a 6 mm in diameter and a 636 mm long were numerically solved for heating of water by using PHOENICS code. The results are in good agreement with the experimental values.

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畑幸一，基盤研究(C)，「強制対流サブクール沸騰限界熱流束発生機構の研究」

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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 opera-tion 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 Super ODS steels for the Advanced Nuclear Energy Systems" in MEXT Innovative Nuclear Research and Development Program.

(2) Multiscale modeling of fusion blanket struc-tural 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 severe high-energy particle irradiation. The multiscale modeling approach is very useful to understand and predict the degradation.

(3) Lifetime evaluation and damage mechanism of fission nuclear structural materials: For the sake of the highly efficient and safe operation of nuclear fission reactors, the mechanisms of irradiation embrittlement and stress corrosion cracking have been investigated.

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

Cladding materials development is a key issue to achieve high burn-up operation of Generation IV nuclear energy systems such as supercritical pressurized water reactor (SCPWR), sodium-cooled fast reactor (SFR), and lead bismuth-cooled fast reactor (LFR) and so on. The candidate cladding materials must have a high resistance to neutron irradiation embrittlement and void swelling as well as a good performance of mechanical properties at elevated temperatures. In addition, a good corrosion resistance of the claddings in the relevant environments has been certainly required for practical long term operation of the advanced fission reactors. Fusion blanket materials have been also required of high performances similar to the Generation IV nuclear systems, although there are characteristic issues for the fusion application, such as transmutation helium/hydrogen effects and material design towards low activation. Oxide dispersion strengthened (ODS) ferritic/martensitic steels containing 9–12 wt.% chromium

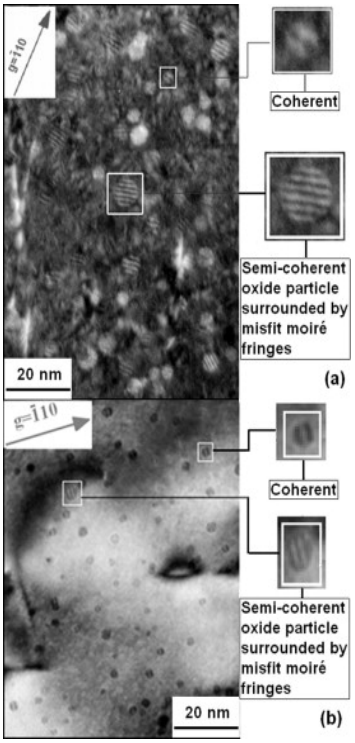

Fig. 1 Weak beam dark field image of the oxide particles dispersed in the matrix of SOC-9 (a) and two-beam dynamical bright field image of the oxide particles dispersed in the matrix of SOC-9-ET-1 (b).

have been developed as the fuel cladding material of SFR because of their high creep strength at elevated temperatures and enough resistance to neutron irradiation embrittlement. However, the (9–12)Cr-ODS ferritic/martensitic steels are not suitable for SCWR owing to an insufficient corrosion resistance of the materials. Corrosion resistance of iron based alloys is influenced by chromium (Cr) and aluminum (Al). It is expected that an adequate combination of the contents will be available for Cr and Al in the steels for each blanket system. The Cr content can be balanced between a merit of corrosion resistance and a demerit of aging embrittlement with maintaining strength at elevated temperatures. The technology development for strengthening of the Al-added steel has been desired by controlling nano-scaled oxide dispersion morphology as shown in Fig. 1. Furthermore, low activation material scenario limits the use of Al as an alloy element of fusion materials. The feasibility check is also demanded for Al free 16Cr-ODS steels as a candidate material for fusion blanket structural material. In this work, alloy design methodology of high-Cr ODS steels was shown to improve corrosion resistance with maintaining high strength at elevated temperatures. The effects of Al addition on the high-Cr ODS steels were discussed to assess the feasibility of the Al free ODS steel to apply it to fusion blanket.

3. Modeling of formation process SIA clusters in β-SiC during irradiation

SiC/SiC composites are the candidate material of nuclear fusion reactor blankets because of high mechanical strength and low activation properties. A variety of experiments showed that nm-size self-interstitial atom (SIA) clusters are observed in irradiated β-SiC at temperatures above 600 ˚C. Such microstructural changes cause the degradation of the material's properties and they should therefore be understood well and controlled. In the present study, the formation kinetics of SIA-clusters in β-SiC during irradiation was evaluated by the kinetic Monte-Carlo (KMC) simulation technique that employs the defect energies obtained by MD.

Growth or shrinkage of a defect cluster is determined by a balance between the influx and outflux of point defects into and from the defect cluster, in which the influx and outflux indicates the absorption and emission of point defects, respectively. The influx of point defects into a disc-shaped SIA-cluster is described by the following equation,

$$\nu_k^{\text{influx}} = 2\pi^2 R D_k C_k \Big/ \Omega \ln\left(r^m / r_0\right) \quad (1)$$

where D_k and C_k are the diffusion coefficient and concentration of the type k point defect in the matrix, respectively, in which k denotes silicon interstitials (I^{Si}) and carbon interstitials (I^C). In the present study the vacancies (V^{Si} and V^C) were neglected for simplicity. Ω is the mean atomic volume and R is the cluster radius. Here, the cluster volume is given by $V=n\Omega=\pi R^2 b$, where the cluster size $n=n_I^{Si}+n_I^C$ is the number of interstitials contained in the cluster, in which n_I^{Si} and n_I^C are the numbers of silicon- and carbon-interstitials in an SIA-cluster, respectively, b is the thickness of the disc in the <111> direction.

The outflux of point defects from a disc-shaped SIA-cluster is given by the following equation,

$$\nu_k^{\text{outflux}} = 2\pi^2 R D_k \exp\left(-E_B^{\text{cluster-k}} \Big/ kT\right) \Big/ \Omega \ln\left(r^m / r_0\right), \quad (2)$$

where $E_B^{\text{cluster-}k}$ is the binding energy of a point defect to an SIA-cluster. Since k denotes the interstitials (I^{Si} and I^C). The binding energy here is given by a function of size and chemical composition ratio of SIA-cluster, as obtained in the previous study.

Our KMC simulations have provided interesting knowledge about formation kinetics of SIA clusters in β-SiC during irradiation. At 973 K, incubation period for the nucleation of SIA-clusters strongly depends on the ratio ($D_I^{Si}C_I^{Si}$:$D_I^C C_I^C$), and is the shortest at the ratio of 1:1. The growth rate of SIA-clusters also depends much on the ratio. However, independent of the ratio, the growth paths of each SIA-cluster are almost identical, in which n_I^{Si}:n_I^C=1:1, in short, an SIA-cluster prefers to grow while keeping its chemical composition stoichiometric. This is because such clusters are thermally stable. On the other hand, at 673 K, both incubation period and growth rate of SIA-clusters are independent of the ratio. In addition, the chemical composition of an SIA-cluster is determined by the ratio. This is because the emission (thermal dissociation) of interstitials from an SIA-cluster hardly occurs at 673 K that is a relatively low temperature for SiC materials.

4. Lifetime evaluation and damage mechanism of fission nuclear structural materials

The present work investigates the irradiation hardening of Fe-based model ferritic alloys after Fe-ion irradiation experiments in order to deduce mechanistically-based nominal hardness from the nano-indentation tests on the ion-irradiated surface. Ion-irradiation experiments were carried out at 290 °C with 6.4 MeV Fe^{3+} ions. The constant stiffness measurement (CSM) was used to obtain the depth-profile of hardness. The results has been analyzed and discussed based on the Nix-Gao model and an extended film/substrate system hardness model. The depth-sensing nano-indentation techniques with CSM revealed that the hardness gradient of the unirradiated Fe-based model alloy can be explained through the indentation size effect (ISE). On the other hand, the gradient of ion-irradiated surface of these samples includes not only the ISE but also softer substrate effect (SSE). We have proposed a new approach to evaluate a nominal hardness, which may connect to the bulk hardness, from experimentally-obtained nano-hardness depth profile data.

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Complex Plasma Systems Research Section

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1. Introduction

This research section seeks to investigate the confinement optimization of "hot" 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. Recent results of Heliotron J in FY2010 are summarized as follows: (1) Measurements of edge plasma turbulence of NBI plasmas have been made using the multiple electrostatic probes inserted about 4mm inside the LCFS at the toroidally and poloidally different locations with special regard to the so-called meso-scale structure formation as well as the relevant influences on the transport property. From the bicoherence analysis of the probe signals, the coherent mode at the frequency range of 20 kHz is found to be non-linearly coupled with the ambient turbulent fluctuations. The spatial structure of this mode was found to be very localized (~2cm) in the radial direction while it proves a definite long-range-correlation in the toroidal/poloidal direction. With regard to L-H transition physics in Heliotron J, more extensive measurements and analyses will be required on the basis of the configuration dependences. (2) Plasma start-up using neutral beam injection (NBI) assisted by non-resonant 2.45 GHz microwaves was found to be a very promising approach to the low field plasma operation. Research and development of this method will be required to realize high beta plasma operation in Heliotron J with special regard to the studies of the magnetic well effects on the anomalous transport and MHD properties. (3) The experimental results of electron cyclotron current drive (ECCD) in Heliotron J have revealed that the EC driven current can be controlled by the parallel refractive index $N_{\parallel}$, depending on the magnetic configuration. Comparative studies of experimental ECCD and TRAVIS-code predictions clarified the important role of trapped particles on ECCD. The effects of localized ECCD on the rotational transform profile will be the next targets for the ECCD experiments. (4) Characterization of energetic-ion-driven MHD instabilities has progressed using magnetic probes, soft X-ray diagnostics, and hybrid directional Langmuir probes. With regard to the energetic ion transport, the present data of the bursting mode suggest that the energetic ions oscillate locally due to the magnetic fluctuation and that the relevant energetic-ion loss onto the wall is not serious. (5) The supersonic molecular beam injection (SMBI) has expanded the operation region of Heliotron J, providing unique plasma evolution including the induced H-mode plasmas. It was found that the temporal evolutions of T_e and n_e in SMBI operation differ very much from those of Intense Gas Puff fueling even under the same peak plasma energy conditions; the dynamic T_e variation in the core plasma region is remarkable in SMBI operation due to its beneficial effects of core fueling.

2. Monte Carlo computation of neoclassical poloidal and toroidal viscosity coefficients in L=1 helical-axis Heliotrons

Recently developed Monte-Carlo-based code [l] has been applied to calculate the neoclassical transport in helical plasmas to L=1 helical-axis heliotrons. This code can predict not only parallel but also poloidal and toroidal viscosities in the framework of the moment-equation approach [2]. A particular feature of our Monte-Carlo code is that the required mono-energetic diffusion L^* and viscosity coefficients, M^*, and N^* are obtained by the Einstein-Helfand relation, which has been employed in molecular dynamics simulations. Using this code, L^*, M^*, and N^* can be determined for arbitrary collisionality with radial electric fields. Furthermore, the poloidal and toroidal viscosity coefficients including the nondiagonal coupling, M_{PP}^*, M_{TT}^*, and M_{PT}^* can be calculated. These, viscosity coefficients characterize the effect of the magnetic field ripple on the toroidal and poloidal flows tangent to flux surfaces.

The validity of our Monte-Carlo based calculation has so far been demonstrated for simple L = 2 heliotrons. We have obtained numerical results for L = 1 helical axis heliotrons. The L = 1 helical-axis heliotron is characterized by the toroidal mirror harmonics of the B-field spectrum when represented in the Boozer coordinates; this harmonics is often referred to as bumpiness. The effect of bumpiness on the confinement properties in helical devices has been studied in the Heliotron J device, both experimentally and theoretically. In the past numerical studies, it has been shown that the bumpiness that has sign opposite to the helicity can reduce the l/ν ripple diffusion, and also affect the magnitude and the sign the bootstrap current. We investigated the effect of

bumpiness on the neoclassical poloidal and toroidal viscosity because of their important role in momentum transport and flows in such devices. To illustrate the role of bumpiness on the neoclassical viscosity, we retain only three dominant magnetic field ripples in the L = 1 heliotron model. We performed the computation of the poloidal and toroidal viscosity coefficients M_{PP}*, M_{TT}*, and M_{PT}*. The radial electric field is of importance in the relatively low collisionality regime owing to its crucial influence in determining the viscosity.

3. Studies of magnetic island by optimized magnetic measurement in Heliotron J plasma

In magnetically confined plasmas, a magnetic island, which disturbs the structure of nested magnetic flux surface, would lead to degradation of plasma confinement. The magnetic islands caused by external error field and/or MHD instability are observed and high performance plasmas are achieved by the shrinkage of magnetic islands using a resonant magnetic perturbation (RMP) field in many torus 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 loops with high spatial and time resolution, and to clarify the physics and effect of magnetic island in helical plasmas. We target on low-n (n: toroidal mode number) magnetic island of which width can be easily expanded in whole plasma region because of low magnetic shear in Heliotron J.

In order to effectively develop magnetic island detector and clarify the characteristics of magnetic island, we utilize the RMP field which can control the characteristics including width and phase of the low-n magnetic island. We designed and installed the RMP coils to externally control low-n magnetic islands and saddle loops to detect them with the help of three dimensional numerical analysis by HINT2 [3] MHD equilibrium solver and JDIA [4] external magnetic field solver. The RMP coils consist of two pair of rectangular coils located at the opposite toroidal section to generate quadra-pole or dipole magnetic fields for the controlling m=2 or 1/n=1 magnetic island, respectively. Optimized new magnetics consist of two saddle loop 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 field to the plasma experiment in the configuration with rotational transform of 0.5. We observed the signal differences in amplitude of each saddle coil in this configuration, only. Figure 1 shows the magnetic island width detected by each saddle coils (named as SL1~6) as a function of RMP coil current which corresponds to magnetic island phase and width can be contorlled. The observed magnetic island width is decreased

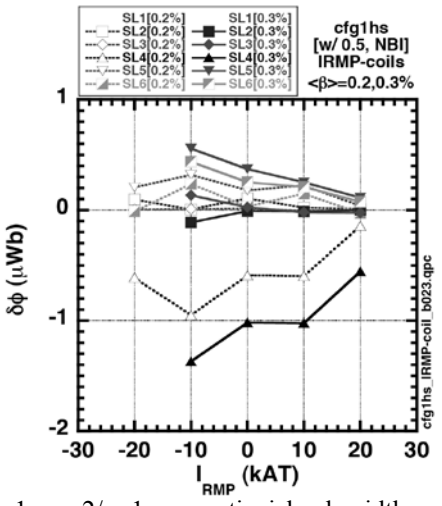

Fig.1. m=2/n=1 magnetic island width as a function of RMP coil current.

with the increasing of RMP coil current. Finite value of signal amplitude at zero amps of RMP coil current indicates the exsistance of m=2/n=1 magentic island without RMP field. We can succsesfully contol the magnetic island width and eliminate the exsisting magnetic island using RMP field. We have plan to real-time (feedback) control of magnetic island to get high perfonamnce plasma using both saddle loops and RMP coil systems.

4. Energetic-ion-driven MHD instabilities in a low magnetic shear helical plasmas.

We have to clarify the physics of energetic-ion-driven MHD instabilities related to the shear Alfvén wave and reduce anomalous loss of ions for burning plasmas. Base on the Heliotron J experiment, we investigated the energetic-ion-driven MHD instabilities in low magnetic shear helical plasmas, of which concept is applied into almost advanced helical plasmas, under the international collaboration between Heliotron J of IAE, Kyoto University and TJ-II of CIEMAT (Spain) and W7-AS of IPP (Germany). From the experiment database and numerical analysis for each device, we clarified that global AEs (GAEs) consisted of single helicity are mainly unstable in Heliotron J and W7-AS with low rotational transform and helicity-induced AE (HAE) with consisted of multi helicity are mainly unstable in TJ-II with high rotational transform.

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Clean Energy Conversion Research Section

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1. Introduction

Enhancement of the efficiency of photoenergy conversion process requires not only the improvement of materials that interact with photons but also the development of nanostructures that localize photon energy. Here we focus on high-quality inorganic nanoparticles (NPs) for highly efficient photoenergy conversion viewed in both lights. The first topic includes a significant improvement of photocatalytic properties of overall water splitting reaction over $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ solid solution (abbreviated as GaN:ZnO) by using Rh NPs and Mn_3O_4 NPs as hydrogen and oxygen evolution sites, respectively. The second topic concerns the localization of an enhanced electromagnetic field around conductive metal oxide NPs with very high spatial resolution induced by a localized surface plasmons in the near infrared (NIR) region.

2. Overall water splitting promoted by modification of GaN:ZnO photocatalyst with cocatalysts

The first topic concerns overall water splitting photocatalyst driven by visible light. Overall water splitting using a particulate photocatalyst and solar energy has attracted much attention as a potential means of large-scale H_2 production (Fig. 1).

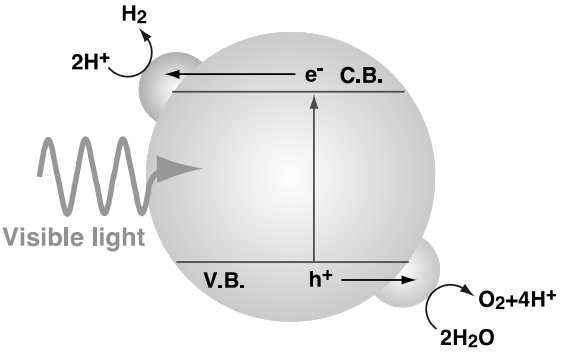

Fig. 1 Schematic of visible light-driven overall water splitting over semiconductor photocatalyst modified with two different cocatalysts.

GaN:ZnO solid solution works as a photocatalyst for overall water splitting under visible light by loading suitable cocatalysts for H_2 evolution [1,2]. Conventinally, Rh/Cr_2O_3 core-shell ($Rh@Cr_2O_3$) NPs were loaded on GaN:ZnO as H_2 evolution sites by a photodeposition technique, which easily leads to the formation of Rh aggregates. A uniform loading of 1.7±0.3 nm Rh NPs on GaN:ZnO through hydrogen bonding and acid–base interaction enhanced the photocatalytic acvitity 3 times higher, compared to the previous method.

On the other hand, manganese oxide NPs (Fig. 2a), which are known to have catalytic activity for water oxidation, were loaded onto the GaN:ZnO together with a cocatalyst for H_2 evolution to use for the photocatalytic reaction. 9.2±0.4 nm MnO NPs were adsorbed on the GaN:ZnO through hydrogen bonding and loaded by annealing in air at 673 K for 3h, which converted MnO into Mn_3O_4 NPs. The photocatalytic measurements revealed that both H_2 and O_2 evolution rates were remarkably improved by loading manganese oxide NPs due to an effective charge separation, as shown in Fig. 2b [3]. Although the quantum yield of this system was relative low (ca. 1 %), this is the first demonstration that loading two different kinds of cocatalysts can effectively promote overall water splitting, along with direct evidence of the functionality of each cocatalyst in the reaction.

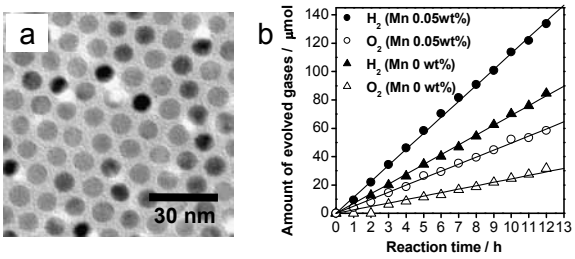

Fig. 2 (a) TEM image of 9.2±0.4 nm MnO NPs and (b) overall water splitting under visible light (λ > 420 nm).

3. Creation of enhanced elecrtromagnetic field around conductive metal oxide NPs in the NIR region

The second topic is related to localized plasmons in conductive NPs, which allow the localization, energy, phase, and wave vector of the field to be controlled by changing the structure of the conductive NPs [4-6]. Especially, an effective use of low-energy NIR photons is of great importance. Noble metal NPs, such as Au and Ag NPs, have been the primary focuses of LSPR research, because Au and Ag NPs exhibit LSPRs, large absorption coefficients and large enhancement factors in the vis-NIR region. Note that for all the conductive

materials that have free carriers, their surface plasmon resonances greatly depend on the carrier density. Namely, the square of the bulk plasma wavelength is inversely proportional to the charge carrier density [7].

Recently, we have demonstrated that the localized surface plasmon resonance (LSPR) peaks of indium tin oxide (ITO) NPs were tunable by controlling the electron carrier densities. The concentration of Sn doping {%Sn = 100% × [Sn]/([Sn] + [In])} was tuned from 0 to 30% without the formation of tin oxides such as SnO and SnO_2, which generate carrier traps at the grain boundaries and lower the resulting carrier densities. Figures 3a and 3b show the UV-vis-NIR spectra of ~11 nm ITO NPs with different %Sn values. The ITO NPs had an interband transition at 400 nm and weak absorption in the red visible region. The In_2O_3 NPs did not have an LSPR peak, but the ITO NPs had well-defined LSPR peaks from 1626 to >2200 nm. The LSPR peak underwent a gradual blue shift from >2200 to 1618 nm as the %Sn increased from 3 to 10% (Fig. 3a). In this case, the %Sn over the 0–10% range afforded high free-electron densities. However, further doping of Sn into the ITO NPs led to a gradual red shift of the LSPR peak from 1626 to 1836 nm as the %Sn increased from 15 to 30% (Fig. 3b). This is because further Sn doping leads to electron trapping near the Sn atoms, which decreases the electron density and results in a longer LSPR wavelength.[32] The NPs with shorter LSPR wavelengths have higher free-electron densities, which indicates that 10% Sn-doped ITO NPs have the highest electron density of ITO NPs (Fig. 3c) in this study. These results are in good agreement with those for ITO thin films produced using a sol-gel process, in which 10% Sn-doped ITO films had both the highest electron density and the lowest resistivity. The LSPR wavelength is affected by the refractive index of the surrounding medium. According to Mie theory, a plasmonic material that is surrounded by a medium with a refractive index greater than its own is expected to have a longer-wavelength LSPR. In accord with this prediction, the ITO NPs had varying LSPR wavelengths that reflected the refractive indices of the solvents (Fig. 3d).

The femto-second transient absorption measurements (Pump: 2200 nm, Probe: 1175 nm) revealed that two NIR-photon excitation efficiency of dye (IR26) was greatly increased by the enhanced electric field induced by NIR-SPR of ITO NPs and that the enhancement factor of ITO NPs was comparable with that of metal NPs [9].

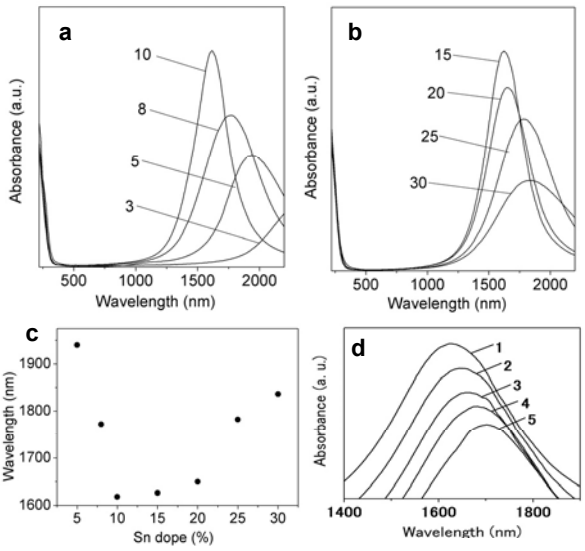

Fig. 3 UV-vis-NIR spectra of ITO NPs doped with (a) 3–10 %Sn and (b) 15–30 %Sn. (c) The dependency of the LSPR peaks of ITO NPs on the doped %Sn. (d) NIR spectra of 8 %Sn-doped ITO NPs in hexane (1, n = 1.37, 1626 nm), cyclohexane (2, n = 1.42, 1646 nm), decahydro-naphthalene (3, n = 1.48, 1664 nm), o-dichlorobenzene (4, n = 1.55, 1682 nm), and nitrobenzene (5, n = 1.55, 1702 nm). The refractive indexes of the solvents (n) and peak wavelengths are given in the parentheses.

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Simulation to Upgrade of KU-FEL using modified GENESIS code

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1. Introduction

A mid-infrared free electron laser (MIR-FEL) system, which is referred to as KU-FEL, based on the 40MeV linac has been developed at Institute of Advanced Energy (IAE), Kyoto University[1,2]. The saturation of the FEL gain was achieved at the wavelength around 13μm in 2008 using a Halbach-type undulator that has the 40mm period and the number of periods of 40. For providing a stable FEL beam for the application studies, however, it is desirable to improve the FEL gain. Thus, it is planned to replace the undulator with a new one which has been transferred from Japan Atomic Energy Agency (JAEA). The new undulator has the maximum K-value 1.5 times larger than that of the present undulator, and it is expected that the FEL gain would be doubled.

The FEL gain and the saturation power level strongly depend on the profile of the electron beam bunch and the cavity detuning. Therefore, the time-dependent simulation is required for the estimation of such quantities. In order to forecast the available FEL power using the JAEA undulator, simulations using GENESIS code modified for cavity-type FEL were performed.

2. GENESIS code modified for cavity-type FEL

GENESIS is one of the most successful codes for simulation on SASE-FEL[3]. The original GENESIS, however, is not equipped with the function of the optical cavity. A modified version of GENESIS code system for cavity-type FEL was developed at the Laboratory for Electron Beam Research and Application (LEBRA), Nihon University, which is one of the active FEL facilities in Japan[4]. The LEBRA-version GENESIS treats the wave front as "RADIATION DATA" and can simulate the growth of the temporal and the spatial profiles of the FEL beam[5]. The RADIATION DATA is a time slice data set of the complex amplitude, where one wavelength is a longitudinal unit length. In this code system, the effect of the cavity detuning is taken as a number of time slice shift per one round trip. For example, the detuning of 1.5 λ corresponds to 3 slice shift per 2 round-trips. Actually, the shapes of the macropulse depending on the cavity detuning were calculated for the LEBRA-FEL in the range of the wavelength from 1 to 3μm. The calculated time width of the FEL micropulse also agrees with the experimental results measured using an interferometer [6].

3. Simulation to KU-FEL project

To carry out the simulation on KU-FEL using the LEBRA-version GENESIS, the parameters listed in Table 1 were used for the present and the JAEA undulators of KU-FEL. With respect to the electron beam, the same parameters except electron energies were used as shown in Table 2. The electron energies for the present and the JAEA undulators were 28MV and 33MeV, respectively, and these conditions correspond to the FEL wavelength around 13.5 μm. Although the optical cavity of KU-FEL, of which length is 4.52m, is set up in the asymmetric arrangement, the LEBRA-version GENESIS can treat only symmetric cavities. Thus, the actual cavity was replaced with a symmetric one with Rayleigh length of 1.25m in these simulation. This Rayleigh length corresponds to cavity mirrors of curvature radius 2.95m. As the value of the cavity loss per one round-trip, 8% and 3% were used based on the design and the experimental results. Since the mirror loss is estimated to be approximately 2%, these values correspond to the hole-coupling efficiencies of 6% and 1%, respectively.

Table. 1 Parameters of KU-FEL undulators.

undulator	present	JAEA
period length (mm)	40	33
period number	40	52
total length (m)	1.6	1.716
K-value	0.99	1.54

Table. 2 Parameters of electron beam.

macropulse current (mA)		90
mucropulse duration (μs)		6
peak current (A)		17
rms bunch length (mm)		0.22
energy spread (%)		0.5
normalized emittance		10π
rms beam size (mm)	x:	0.6
	y:	0.4
electron energy (MeV)	present:	28
	JAEA:	33

At first, the calculations in the case of using the present undulator were carried out. Figure 1 shows the comparison between the FEL macropulse shapes in the cases of the cavity losses of 3% and 8%, where the cavity detuning is -λ. The time structure of the FEL micropulses after 6μs from the

start of the electron macropulse is also shown in Fig. 1. Figure 2 shows the dependence of the FEL lasing on the cavity detuning in the case of 3% cavity loss. One can see that the FEL gain is sufficient to achieve the gain saturation when the absolute value of the cavity detuning is longer than λ. When the cavity detuning is -0.5λ, the FEL micropulse has the maximum output power over 1 MW and the width of 600fs. These values roughly agree with the experimental results.

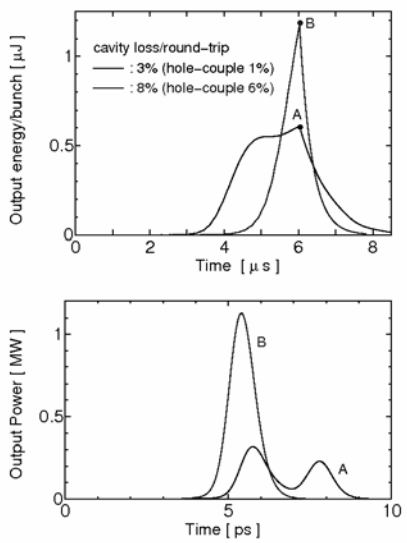

Fig. 1 Macropulse and micropulse time structure depending on the cavity loss when the cavity detuning is -l.

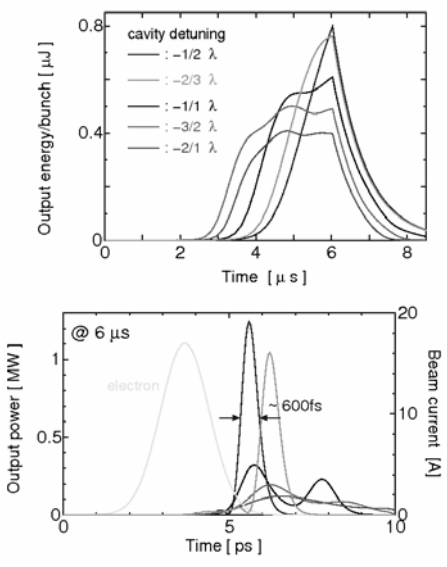

Fig. 2 Macropulse and micropulse time structure depending on the cavity detuning when the total cavity loss is 3%.

3. Potential of the JAEA undulator

The calculations in the case of using the JAEA undulator were also carried out and the results are shown in Fig. 3. Here, the value of 8% is used as the cavity loss, and each micropulse curves shows the time structure at the mark of same color on the macropulse curves. As the result of the simulation, it is expected that both of the total macropulse energy and the micropulse peak power would increase at least several times compared with using the present undulator. Since the FEL gain is sufficiently large, improvements in the total charge of the electron beam bunch and the macropulse duration are significantly effective for the further increase of the FEL output.

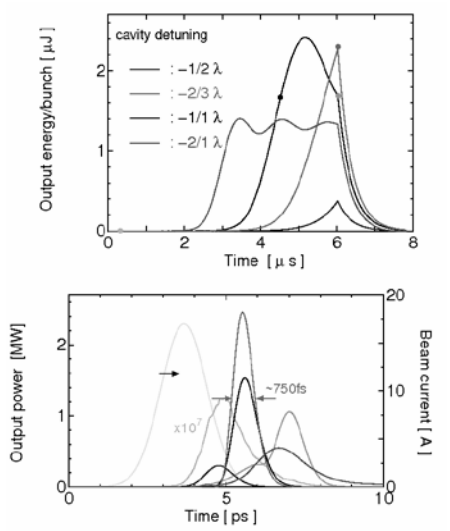

Fig. 3 Macropulse and micropulse time structure in the case of using JAEA undulator when the total cavity loss is 8%.

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Chemical Reaction Complex Processes Research Section

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T. Sakka, Associate Professor
K. Fukami, Assistant Professor

1. Introduction

Surfaces and interfaces play an important roles in many photoenergy conversion processes. In this research section surface and interfacial phenomena, and fabrication and characterization of various surface structures are investigated. We utilize electrochemical methods and laser spectroscopic techniques to perform research in this subject.

In this academic year we have performed research works on the filling of microporous electrode with platinum nanoparticles, the formation mechanism of porous silicon in view of solvent polarity, self-assembly of colloidal particles at oil-water interfaces, application of laser ablation to composite particle formation directly in water, and emission spectroscopy of laser plasma in water. Some details are given below.

2. Platinum electrodeposition within chemically-modified microporous silicon

Porous silicon is formed by anodization of silicon in HF solution. Microporous silicon, the pore size of which is several nanometers, is formed when anodizing a lightly-doped silicon substrate. In this study, we found that the hydrophobicity of pore wall plays an important role in the filling of chemically-modified microporous silicon by electrodeposition.

We prepared two different types of chemically-modified microporous silicon substrates by hydrosilylation reaction with methyl propiolate or propiolic acid in *n*-hexane. Microporous silicon modified with methyl propiolate shows a water contact angle of 122°, while that modified with propiolic acid show 78°. Electrodeposition of platinum was performed using the two chemically-modified microporous silicon substrates in an aqueous deposition bath. SEM observation and EDS analysis of cross-sections after platinum electrodeposition revealed that the hydrophobic porous electrode (after the methyl propiolate modification) enhanced the platinum deposition within the microporous layer, while the deposition within the porous layer was strongly suppressed when using the hydrophilic porous electrode (after the propiolic acid modification). Scanning TEM observation also revealed that platinum was deposited as dispersed nanoparticles with a diameter of ~3 nm. The nanoparticles were uniformly deposited from the pore bottom to the opening. These results can be explained by taking into account the free energy gain of water molecules near the hydrophobic pore wall.

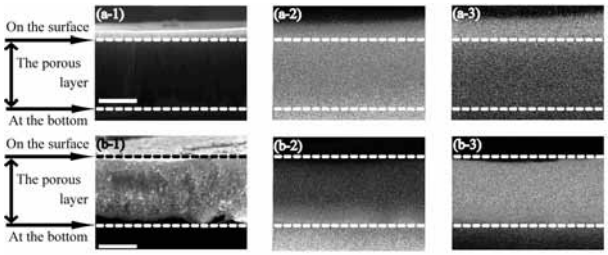

Fig. 2-1 Cross-sections of chemically-modified microporous silicon after platinum electrodeposition observed and analyzed by SEM and EDS. The images of (a-1), (a-2) and (a-3) show an SEM image, EDS mapping of Si and Pt of a microporous silicon substrate modified with propiolic acid. The images (b-1), (b-2) and (b-3) are the same as the upper ones but obtained with a microporous silicon substrate modified with methyl propiolate.

3. Effect of solvent polarity on porous silicon formation

During the formation of porous silicon, the pore wall is often terminated with Si-H_x, which results in the formation of hydrophobic pore wall. Here, we report that solvents affect the formation of porous silicon.

In order to evaluate the formation of porous silicon, we prepared rugate-type mesoporous silicon, which is formed under sinusoidal modulation of anodization current. Rugate-type mesoporous silicon shows a periodic change in contrast parallel to the top surface due to the change in porosity. We evaluated the deviation of the periodicity by changing the solvent for the HF solution. In the experiments, methanol, ethanol, 2-propanol and *t*-butanol were used as solvent of the HF solution. The deviation of the periodicity between near the top surface and at the bottom gradually increased with decreasing the polarity of solvent. In addition, the average porosity of the rugate-type mesoporous silicon, which is estimated by the reflectance spectra, gradually decreased with decreasing the solvent polarity.

These results might be explained by considering the

free-energy gain of the solvent containing fluoride ions near the hydrophobic pore wall.

4. Ordering of colloid particles at oil-water interfaces

The formation of well-ordered structure at interfaces is important for the formation of various surface structures. Self-assembly provides a low-cost process, and also, enables large area patterning in a fairly short time. Once the well-ordered structure is formed, further modification of the surface is comparatively easy.

We studied self-assembly of polystylene particles at oil-water interfaces. The structure can be transferred to solid substrate, and therefore, can be used as a precursor of ordered structures at solid surfaces. The polystylene particles form hexagonal array structure, of which the inter-particle distance can be as long as ~20 μm. This is explained by the equilibrium between the repulsive electrostatic force and the attractive dispersion force.

Fig. 4-1 shows the optical microscope image of polystylene particles at a vertical *n*-decane-water interface, which is prepared in a glass ring with 6 mm in diameter. It is clearly seen that upper part of the particle assembly shows larger inter-particle distances compared with the bottom part due to the gravity. By analyzing the inter-particle distance as a function of height, inter-particle interactions were estimated quantitatively. We are also studying the effect of the addition of electrolyte upon inter-particle interactions. The results can be used to find the best condition for the self-assembly of polystylene particles at oil-water interfaces.

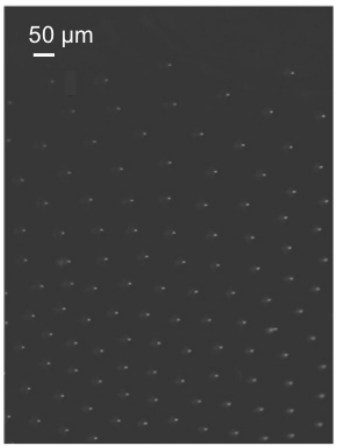

Fig. 3-1 Optical microscope image of polystylene particles self-assembled at the vertical interface of water and *n*-decane.

5. Laser ablation of metals in plating solution: Formation of metal-semiconductor composite structure

Generally, laser ablation gives highly reactive species, and hence, various reactions are expected in the ablation plume. It is well known that the laser ablation of metal target in water gives metallic colloids directly in water. In the present work the laser ablation of a Ti target was performed in K_2PtCl_4 aqueous solution, aiming at the simultaneous reactions of the oxidation of Ti particles originating in the ablated Ti in water and the reduction of $PtCl_4^-$ into Pt metal. The SEM images show spherical TiO_2 particles with a few hundred nm in diameter deposited with Pt nanoparticles, and EDS analyses suggest the formation of TiO_2-Pt composite. Such structure can be used for photocatalysis, where metal nanoparticles are expected to chemically catalyze the reaction. TiO_2-Au composites were also prepared in a similar way. $HAuCl_4$ aqueous solution was used in this case. TiO_2-Au composites were obtained, as in the case of Pt. Photocatalytic behavior of these composites is under investigation.

6. Atomic emission spectra of laser plasma in water without time-gated detection

In previous works we have clarified that the use of a long ns pulse gives clear atomic emission lines from the laser plasma in water, if time-gating of the detector is properly adjusted. This technique enables *in situ* elemental analysis of a solid target in water. In the present term we found that the time-gating operation of the detector is unnecessary, if we further optimize the irradiation conditions.

The secret is in employing multi-pulse irradiation with optimizing the pulse interval. We used a multi-pulse microchip laser. The number of pulses in one shot of the laser is typically 11. The pulse interval is ~15 μs. Each pulse has the width of ~3 ns, and the energy of ~0.5 mJ.

Narrow and clear atomic emission lines of Cu were observed, even though the whole emission throughout the ablation event was integrated in the detector (Fig. 6-1). This suggests that we do not need the time-gated operation of the detector when the irradiation conditions are properly adjusted. The use of the microchip laser enables considerable downsizing of the detection system as well as the laser itself, and makes it possible to setup the system for various on-site measurements.

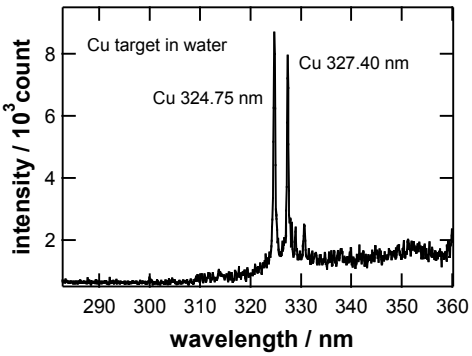

Fig. 5-1 Optical emission spectrum of Cu atoms in the laser plasma produced by the irradiation of Cu target in water by the multi-pulse microchip laser.

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尾形幸生，基盤研究(B)，「電気化学ツールによるシリコンのナノ・マイクロ構造微細加工」

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Molecular Assemblies Design Research Section

H. Sakaguchi, Professor
T. Sagawa, Associate Professor
Y. Suzuki, Assistant Professor

1. Introduction

Nanometer-scale technology and science are so important to produce the unprecedented materials for energy. Our group studies the basics of assembling small molecules into the advanced materials and devices in energy sector with high efficiency. Followings are main research achievements in Molecular Assemblies Design Research section in the year of 2010.

2. Molecular Wires Transistor by Electrochemical Epitaxial Polymerization

Key to realize the high performance of organic devices using conjugated polymers is how to fabricate a highly organized structure on surface at a single molecular scale. Here we have demonstrated a unique single-molecular processing-technique using electrochemistry, called 'electrochemical epitaxial polymerization' (ECEP). This technique is based on a step-by-step electropolymerization of monomer along the lattice of iodine-covered Au(111) surface to form the single conjugated-polymer wires by applying voltage-pulses into monomer-electrolyte solution. By using this technique, we have succeeded in building a uniform high-density array of single conjugated-polymer wires on electrode as long as 200 nm, with controlling wire's density, length, direction and shape. This first observation will open the door to a mass-production of single molecular-scale devices using conjugated-polymers. Also our findings unveiled the mechanism of electropolymerization unknown so far, showing the direct evidence that conjugated polymers grew from adsorbed nuclei on surface.

Electrochemical polymerization of two different kinds of thiophene monomers on an iodine-covered gold surface created the highly assembled conjugated copolymers with different electronic structures. STM revealed images of several linkage types: diblock, triblock and multiblock. Single strand of conjugated copolymers exhibited an anomalous swinging motion on surface. This tec hnique presents the possibility of understanding the copolymerization process from the different monomers on the single-molecular scale, and of building single-molecule superlattices on a surface through controlled electropolymerization.

We propose a multistep ECEP technique to create single-molecular heterowires. This technique comprises two electropolymerization processes in a different monomer solution. The STM images for the sample obtained by multistep ECEP successfully depict heterowires with a C8OMT-polymer and a C8MT-polymer joined together at the ends of respective chains.3 Molecular-scale deposition and Transfer Printing of Wires to Insulator Substrate.

Epitaxially polymerized conjugated polymers can be successfully deposited layer by layer on I-Au(111) up to 10nm thickness. We have recently demonstrated polymerized wires on I-Au(111) could be transferred to insulator substrates such as surface-oxidized Si, glass and various insulating polymers.

Electric double layer capacitor (EDLC) FET devices using epitaxially polymerized molecular wires showed highest hole mobility of 12.3 $cm^2V^{-1}s^{-1}$ that have never been reported so far in conjugated polymers. Other types of FET using different gate dielectrics were compared with these results.

3. One-dimensional nanostructured semiconducting materials

We prepared conjugating polymer fiber with highly oriented structures, which focused on electrospinning of a blend solution of regioregular poly(3-hexylthiophene) (*rr*-P3HT) and poly(vinyl pyrrolidone) (PVP). SEM observation revealed that the blend system forms homogeneous composite nanofibers as shown in Fig. 1. This system exhibits the specific feature of strong interchain contribution of P3HT from UV-vis absorption (Fig. 1 right), fluorescence spectroscopic (Fig. 2 left), XRD, and photoelectron spectrometric (for HOMO levels) investigations. We also demonstrated the removal of the PVP component from the P3HT/PVP composite fibers through the selective extraction and such strong interchain stacking of pristine P3HT fiber mat can be remarkably maintained. Further investigations to apply the obtained fibers to organic photovoltaics are underway.

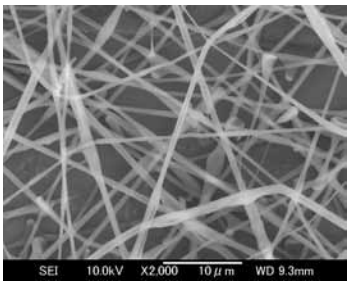

Fig. 1 SEM image of electrospun P3HT–PVP (1:3) nanofibers.

Fig. 2 Absorption (right) and fluorescent (left, Ex. 530 nm) spectra of various P3HT and/or P3HT/PVP.

4. Porous $MgTi_2O_5$ with Pseudobrookite-type Structure Toward Third Generation Diesel Particulate Filter (DPF) Material

Porous ceramics based on refractory double oxides are promising for light-weight structural components and high-temperature filter materials. In this study, porous $MgTi_2O_5$ ceramics with pseudobrookite-type structure have been prepared by *in situ* processing (viz. reactive sintering). High-temperature XRD revealed the *in situ* reaction behavior of the mixed powder, and indicated suitable sintering temperatures to obtain single phase $MgTi_2O_5$ (≥1000°C). Uniformly porous $MgTi_2O_5$ ceramics with very narrow pore-size distribution at the diameter of ~1 μm were obtained by the pyrolytic reactive sintering at 1000-1200°C, where decomposed CO_2 gas from a carbonate source acted as an intrinsic pore forming agent. The linear thermal expansion of porous $MgTi_2O_5$ sintered at 1100°C (porosity: 42%) was 6.82×10^{-6}/K at 1000°C. This work was supported by MEXT, Japan (Grant-in-Aid for Scientific Research No. 19685020 For Young Scientist: Category A). We would like to thank NGK Insulators Ltd. for the experimental aid.

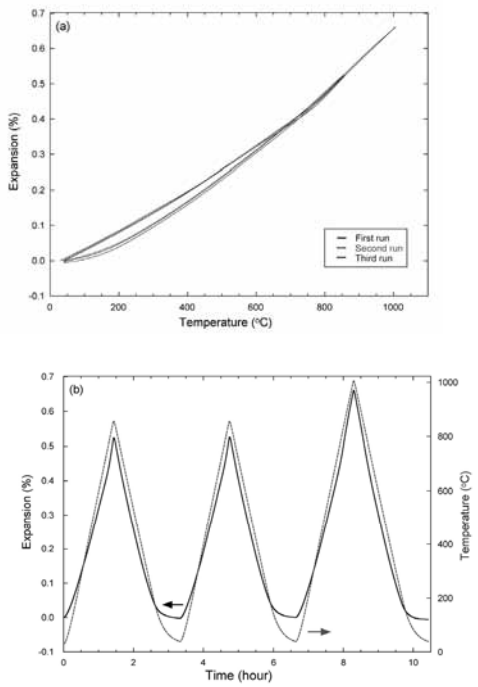

Fig.3 Bulk thermal expansion of porous $MgTi_2O_5$ sintered at 1100°C. Up to 850°C for the first and second runs, and 1000°C for the third run. (a) Thermal expansion curves, and (b) expansion vs. time plot. (Y. Suzuki and M. Morimoto, *J. Ceram. Soc. Jpn.*, **118** (2010)1212)

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Financial Support

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吉川暹（特任教授），受託研究（新エネルギー・産業技術総合開発機構），太陽エネルギー技術研究開発太陽光発電システム次世代高性能技術の開発，有機薄膜太陽電池モジュール創製に関する研究開発

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Biofunctional Science Research Section

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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. Rational design and functional evaluation of semi-synthetic miniature proteins, synthetic peptides and RNA/peptide assemblies enable precise recognition and fluorescence detection of biologically important molecules and in water, the solvent of life. Followings are main research achievements in fiscal year 2010.

2. Structual Aspects for the Recognition of ATP by Ribonucleopeptide Receptors

The availability of receptors with appropriate affinity and specificity to the target has been expanded by in vitro selection of RNA or DNA aptamers for targets ranging from small molecules to proteins. Application of the selection and evolution technique is not limited to obtaining functional macromolecules solely composed of RNA or DNA. It can also used on ribonucleopeptides (RNP), such as the structurally well characterized complex of the Rev peptide and RRE (Rev Responsive Element) RNA. A randomized nucleotide sequence was introduced into the RNA subunit of RNP to construct an RNP library onto which the in vitro selection method was applied (Figure 1a). In the second step, the Rev peptide was modified with a fluorophore without greatly disturbing the affinity and specificity of the RNP receptor. In the absence of a ligand for RNP, fluorescence emission was effectively quenched in the RNP complex, but it recovered upon ligand binding. RNP sensors thus created allow monitoring of the ligand-binding event by measuring the fluorescent signals. RNP receptors targeting ATP, histamine, or phosphotyrosine in the specific amino acid sequence have been isolated and were successfully converted to the corresponding fluorescent sensors.

Though the method can conveniently provide receptors and fluorescent sensors for various target ligands, a rational design of the functional RNPs would be possible by understanding the structural aspects for the function of RNP receptor. Structures of RNP receptors and sensors that have been constructed have not been determined yet. Hence, the relationship between the affinity to the substrate and the structure of RNP receptors or the mechanism that exerts fluorescence changes of RNP sensors are not clear. Therefore, we aim to determine the secondary structure of ATP-binding RNP receptors and to clarify the essential structural parts for ATP binding.

A combination of NMR measurements, enzymatic and chemical mapping, and nucleotide mutation studies of the RNP-adenosine complex show that RNP interacts with the adenine ring of adenosine by forming a U:A:U triple with two invariant U nucleotides (Figure 1b). It should be noted that the observed recognition mode for the adenine ring is very different from those of RNA aptamers for ATP derivatives reported by others previously. The RNP-adenosine complex is folded into a particular structure by formation of the U:A:U triple and a Hoogsteen type A:U base pair (Figure 1b). This recognition mechanism was successfully utilized to convert the substrate-binding specificity of RNP from ATP- to GTP-binding with a C^+:G:C triple recognition mode.

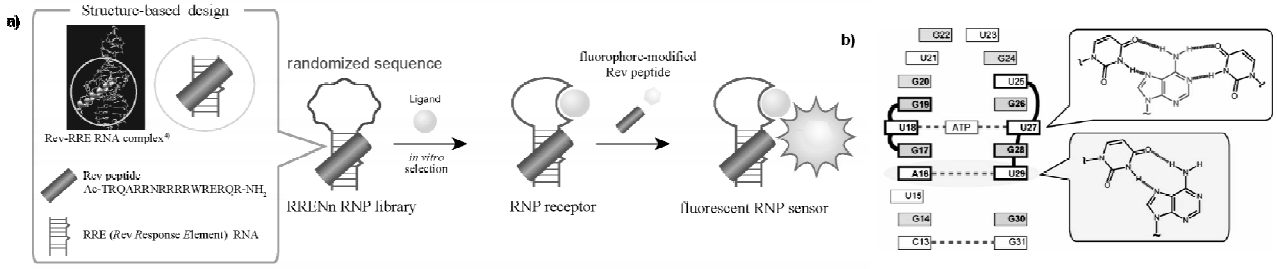

Figure 1 (a) A scheme shows the stepwise construction of RNP receptors and fluorescent RNP sensors. (b) An illustration shows the proposed recognition mode of ATP-binding RNP receptor clarified in this study.

3. Positional effects of phosphorylation on the stability and the morphology of tau-related amyloid fibrils

Hyperphosphorylated forms of tau protein is the main component of paired helical filaments (PHFs) of neurofibrillary tangles in the brain of Alzheimer's disease patient. To understand the effect of phosphorylation on fibrillation of tau, we utilized tau derived phosphorylated peptides. The $V_{306}QIVYK_{311}$ sequence (PHF6) in the microtubule-binding domain is known to play a key role in the fibrillation of tau, and the short peptide corresponding to PHF6 forms amyloid-type fibrils similar to those generated by full-length tau. We focused on the amino acid residue N-terminal to the PHF6 sequence where serine or lysine located in the native isoform of tau, and synthesized the PHF6 derivative peptides with serine or lysine at the N-terminal of PHF6 together with the phosphorylated serine and/or tyrosine containing derivatives. The critical concentrations of the fibrillation of peptides were determined to quantitatively assess the fibril stability. The stability of fibril was reasonably explained by the net-charge of peptides, that is, the peptide with the net-charge of near zero tended to form stable fibrils. Interestingly, the peptide phosphorylated at the N-terminal serine residue showed remarkably low fibrillation propensity as compared to the peptide phosphorylated at tyrosine that possessed the same net-charge. TEM and AFM measurements of the fibrils visualized the paired-helical or straight fibers, segregated masses of the fibers or heterogeneous rod-like fibers depending on the phosphorylation status. Further analyses of the fibrils by the X-ray fiber diffraction method and FT-IR spectroscopic measurements indicated that all the peptides shared a common cross-β structure with phosphoserine-containing peptides showing the characteristics of β-sandwiches that could interact in both faces of β-sheet. Based on these observations, possible protofilament models with four β-sheets were constructed to consider the positional effects of the serine and/or tyrosine phosphorylations. The electrostatic intersheets interaction between phosphate groups and the amino group of lysine enhanced the lateral association between β-sheets to compensate the excess charge. In addition to the previously postulated net-charge of the peptide, the position of the charged residue plays a critical role for the amyloid fibrillation of tau.

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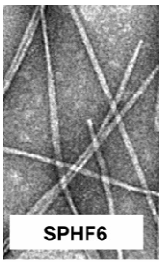
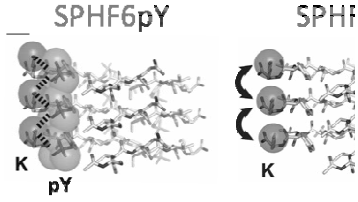
a)

Peptide	Sequence
SPHF6	Ac-SVQIVYK-NH_2
SPHF6pY	Ac-SVQIVpYK-NH_2
pSPHF6	Ac-pSVQIVYK-NH_2
pSPHF6pY	Ac-pSVQIVpYK-NH_2

b)



c)



net-charge (pH7.5)	-1	1
fibrillation propensity	+++	++

Figure 2 a) PHF6 derivative peptides. Abbreviations: pY, phosphotyrosine; pS, phosphoserine; Ac, acetyl group. b) TEM images of fibrous aggregates of SPHF6 derivative peptides. All samples were transferred directly from reaction mixture to carbon-coated grids and stained with 2% phosphotungstic acid. Scale bar: 100 nm. c) Illustrated models for the fibril core structure of each peptide and structure and fibrillation propensity relationship.

Collaboration Works

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Bioenergy Research Section

M. Katahira, Professor
T. Kodaki, Associate Professor

1. Introduction

We explore how biomolecules such as proteins (involving enzymes) and functional nucleic acids (DNA and RNA) work at atomic resolution based on structural biology with NMR. We determine both static and dynamical structures with the new methodology developed by ourselves and elucidate the underlying functional mechanism of these biomolecules. For example, recently we have successfully developed the way to monitor the base conversion reaction by anti-HIV enzyme, A3G protein, in real-time by NMR for the first time. This new method has provided critical information on how this enzyme exerts the catalytic action on DNA. Currently, we are developing the way to extract energy and valuable materials that can be used as starting materials of various products from wood biomass. Thus, we pursue to contribute to the paradigm shift from oil refinery to biorefinery. Followings are main research achievements in the year of 2010.

2. Real-time monitoring of the enzymatic reaction of APOBEC3G possessing anti-HIV activity by NMR

Human APOBEC3G (A3G) exhibits anti-HIV-1 activity by deaminating cytidines of the minus strand of HIV-1. We already reported a solution structure of the C-terminal deaminase domain of wild-type A3G and the mode of the interaction with substrate single-stranded (ss) DNA. We have demonstrated that the deamination reaction of A3G is successfully monitored using NMR signals in real-time. This method is superior to conventional biochemical methods to examine the enzymatic reaction in terms of its higher temporal and spatial resolution. We have applied this method to monitor the deamination of DNA that contains two substrate sites. It has been demonstrated that a substrate site located close to a 5' end of DNA is deaminated faster than that to a 3' end (Figure 1). This result suggests that A3G processively deaminates multiple substrate sites through sliding in a 3'---> 5' direction on DNA. We have demonstrated that with the aid of the residue-specific ^{13}C labeling of DNA, this method would be applicable to DNA with the length of longer than ca. 100 nt. We have also demonstrated that the time resolution would be less than 0.5 s. Thus, this method can provide the unique information on how the enzyme exerts its biological function.

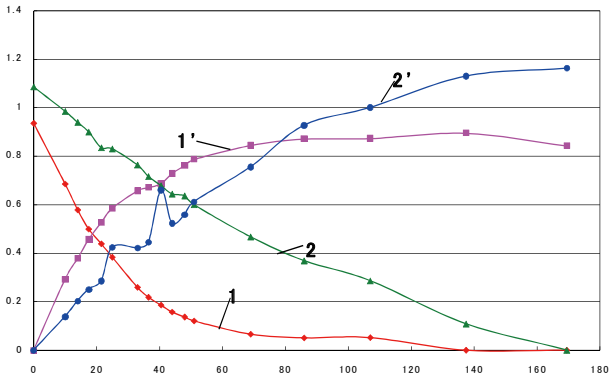

Figure. 1. Time-course (hr) of the intensity after the addition of A3G. Peaks 1 and 2 correspond to each cytosine in the substrate site located close to either 5' or 3' end, respectively. Peaks 1' and 2' correspond to each uracil converted from the two cytosines, respectively.

3. Structural basis of the high affinity of the RNA aptamer against prion protein by NMR

RNA aptamers against bovine prion protein (bPrP) were obtained, most of the obtained aptamers being found to contain the r(GGAGGAGGAGGA) (R12) sequence. We already reported the structure of R12. The interaction of R12 with bPrP was also examined. Two lysine clusters of bPrP were identified as binding sites for R12.

We have determined the structure of R12 in complex with the peptide (P16) corresponding to one of the lysine clusters (Figure 2). The stoichiometry was found to be that two P16 bound to the dimer structure of R12. The dimer structure of two quadruplexes of R12 was maintained in the complex. The electrostatic interactions with three lysine residues of P16 were identified for the uniquely arranged phosphate groups of R12. Additionally, the stacking interaction with the tryptophan residue of P16 was found for the tetrad plane of R12. These contribute to the high affinity of R12 against bPrP. It was indicated that the R12 dimer interacts with another lysine cluster of bPrP basically in the same manner. Taking into account these things, it is very likely that the one monomer of the R12 dimer binds to the one lysine cluster of bPrP and that the other monomer of the R12 dimer simultaneously binds to the other two lysine cluster of bPrP, resulting in even higher affinity.

Recently it was reported that the prion protein is a receptor of amyloid-β-oligomers that are related to Alzheimer's disease. Thus, the atomic coordinates of R12 would be useful for the development of R12 as a therapeutic agent against not only prion diseases but also Alzheimer's disease.

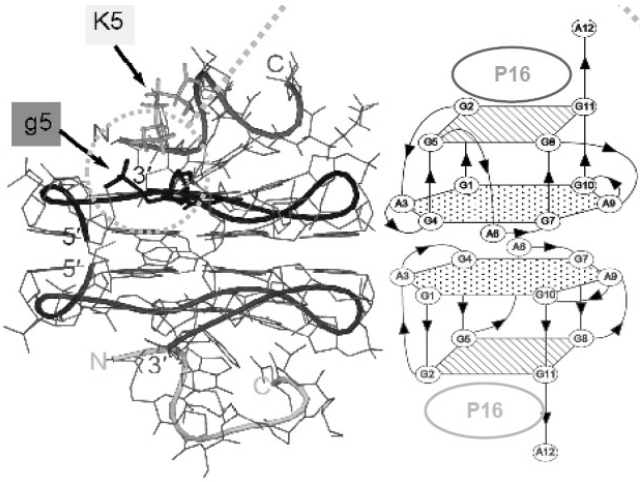

Figure 2 The structure of the RNA aptamer, R12, in complex with the binding site of prion protein, P16. Electrostatic interaction between guanine 5 of R12 and lysine 5 of P16 is indicated.

4. Analysis of wood biomass degraded by a selective lignin-degrading fungus, *Ceriporiopsis subvermispora*, by solution NMR

Lignin is one of the three major components of the wood biomass and is potentially a valuable material with the wide range of use because it is the polymer composed of the aromatic units. So far, however, the lignin has not been used effectively due to the difficulty of its decomposition. We have started the study aiming to make use of lignin in collaboration with Prof. Takashi Watanabe's group, RISH, Kyoto University. We have caused the bio-degradation of wood with a selective lignin-degrading fungus, *Ceriporiopsis subvermispora*. Then, we have succeeded to analyze the whole components of the degraded wood at once with the ^{1}H-^{13}C HSQC NMR spectrum with the aid of a highly sensitive cryoprobe (Figure 3). Lignin and polysaccharides were clearly identified from the NMR spectrum at functional group resolution. It was confirmed that *Ceriporiopsis subvermispora* selectively degraded lignin without the degradation of polysaccharides. It was found that the β-O-4' side-chain linkage of the lignin was degraded in an earlier stage than the aromatic unit. The examination of the Syringyl/Guaiacyl ratio of the aromatic unit of lignin was possible. It was also found that the degradation depends on the carbon/nitrogen ratio of the medium. These results have indicated that the solution NMR method is very powerful to examine the chemical conversion of valuable biomass such as lignin.

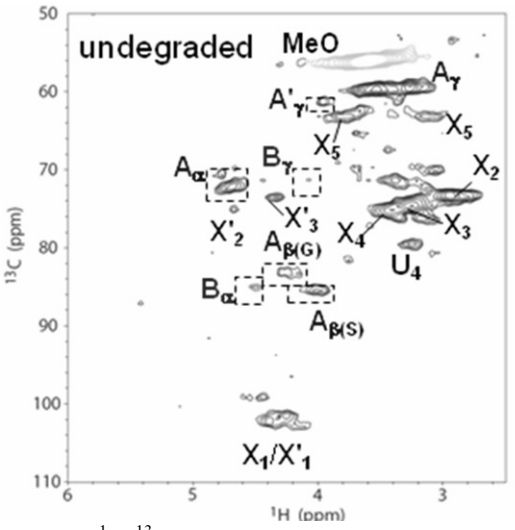

Figure. 3 ^{1}H-^{13}C HSQC spectrum of all components of wood biomass. A and B indicate lignin peaks and X and U indicate polysaccharide peaks.

5. Development of Highly Efficient Bioethanol Production Yeast Using Protein Engineering

Since Xylose is one of the major fermentable sugars present in lignocellulosic biomass, the efficient fermentation of xylose is required to develop economically viable processes for producing bioethanol. Although a few xylose fermenting yeasts are found in nature, *Saccharomyces cerevisiae* is used universally for industrial

Ethanol production because of its ability to produce high concentrations of ethanol and high inherent ethanol tolerance. However, native *S. cerevisiae* can not ferment xylose, so engineering *S. cerevisiae* for xylose utilization has focused on adapting the xylose metabolic pathway from the xylose-utilizing yeast such as *Pichia stipitis*. We have already developed the mutated XDH by protein engineering and the change of coenzyme specificities of XDH has been shown to have the positive effects on the production of bioethanol from xylose. In this study, construction of the first strictly NADPH dependent xylose reductase from *Pichia stipitis* was succeeded by site directed mutagenesis, where two double mutants with almost the same activity of wild-type were generated. By introducing the strictly NADPH dependent PsXR with the strictly $NADP^{+}$ dependent PsXDH, the more efficient xylose fermentation is expected to be observed, probably due to the full recycling of coenzymes between the mutated XR and XDH.

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Laboratory for Complex Energy Processes Section

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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 for plasma physics in this section 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 fusion reactors since the alpha particles produced in the D-T reaction should be utilized to heat plasma efficiently. Fast-ion velocity distribution has been investigated using ion cyclotron range of frequency (ICRF) minority heating in Heliotron J with special emphasis on the effect of toroidal ripple of the magnetic field strength ('bumpiness'). Optimization of the ICRF heating is important for a three-dimensional magnetic configuration like Heliotron J. For analyzing experimental results, Monte-Carlo simulations were performed. The calculation results agree well with the experimental results for high-energy tail formation.

(A-1) Effects of heme on thermal stability of mesophilic and thermophilic cytochromes *c* [1]

We have recently proposed a measure of the thermal stability of a protein: the water-entropy gain at 25°C upon folding normalized by the number of residues, which is calculated using a hybrid of the angle-dependent integral equation theory combined with the multipolar water model and the morphometric approach. A protein with a larger value of the measure is thermally more stable. Here we extend the study to analyses on the effects of heme on the thermal stability of four cytochromes *c* (PA c_{551}, PH c_{552}, HT c_{552}, and AA c_{555}) whose denaturation temperatures are considerably different from one another despite that they share significantly high sequence homology and similar three-dimensional folds. The major conclusions are as follows. For all the four cytochromes *c*, the thermal stability is largely enhanced by the heme binding in terms of the water entropy. For the holo states, the measure is the largest for AA c_{555}. However, AA c_{555} has the lowest packing efficiency of heme and the apo polypeptide with holo-like structure, which is unfavorable for the water entropy. The highest stability of AA c_{555} is ascribed primarily to the highest efficiency of side-chain packing of the apo polypeptide itself. We also argue that due to covalent heme linkages, the number of accessible conformations of the denatured state is decreased by the steric hindrance of heme, and the conformational-entropy loss upon folding becomes smaller, leading to an enhancement of the thermal stability. For the apo states, AA c_{555} has a much larger value of the measure than the other three. Overall, the theoretical results are quite consistent with the experimental observations (e.g., at 25°C the α-helix content of the apo state of AA c_{555} is almost equal to that of the holo state while almost all helices are collapsed in the apo states of PA c_{551}, PH c_{552}, and HT c_{552}).

(A-2) Rotation mechanism of F_1-ATPase [2]

We propose a novel picture of the rotation mechanism of F_1-ATPase, a rotary-motor protein complex. The entropy, which originates from the translational displacement of water molecules, is treated as the key factor in the proposal. We calculate the water-entropy gains upon formation of the α-β, α-γ, and β-γ subunit pairs, respectively. The gain is given as the difference between the hydration entropy of a subunit pair and the sum of the hydration entropies of the separate subunits forming the pair. The calculation is made using a hybrid of a statistical-mechanical theory for molecular liquids and morphometric approach. The water-entropy gain is considered as a measure of tightness of the packing at each subunit interface. The results are highly correlated with the numbers of stable contacts at the subunit interfaces estimated by a molecular dynamics simulation with all-atom potentials. We also calculate the hydration entropies of three different

sub-complexes comprising the γ subunit, one of the β subunits, and two α subunits adjacent to them. The major finding is that the packing in F_1-ATPase is highly asymmetrical and this asymmetry is ascribed to the water-entropy effect. We discuss how the rotation of the γ subunit is induced by such chemical processes as the ATP binding, ATP hydrolysis, and release of the products. In our picture, the asymmetrical packing plays crucially important roles and the rotation is driven by the water-entropy effect.

(A-3) Model of insertion and release of a large solute into and from a biopolymer complex [3]

Insertion of a large solute into a biopolymer complex followed by release of the same solute from it is a principal function for sustaining life. We show that the switch from insertion to release is achieved by altering the solute conformation to reduce the excluded volume (EV) generated by the solute for solvent molecules and to increase the solute solvophilicity. The reduction in the EV weakens the insertion power induced by the entropic force, and the increase in the solvophilicity promotes preferential solvation not in the solvent confined within the complex cavity but in the bulk solvent.

(B-1) Numerical analysis of ICRF minority heating in Heliotron J

Fast-ion velocity distribution has been investigated using ICRF minority heating in Heliotron J with special emphasis on the effect of toroidal ripple of the bumpiness. Good confinement of fast ions and high-efficiency of ICRF heating for a high bumpiness have been achieved. To interpret the experimental results and to determine the fast-ion distribution in a plasma volume, Monte-Carlo simulations were performed. The numerical model includes orbit tracing, Coulomb collisions, and acceleration by ICRF heating. Minority protons are used as test particles and heating is simulated by the velocity kick in the perpendicular direction in velocity space when ions cross the cyclotron layer. In this calculation, the acceleration term for ICRF heating is proportional to the ICRF electric field amplitude, which is an input parameter. The electric field amplitude is determined from the input power for ICRF heating. Although it is possible to determine the heating profile as a function of the magnetic field, plasma parameters, and wave frequency, it is not simple to calculate the rf electric-field structure and the absorption profile for the magnetic configuration of Heliotron J. Here, the rf electric-field profile was assumed to be parabolic, as in previous calculations for Heliotron E plasmas. The initial test ion distribution is uniform in the toroidal and poloidal directions and parabolic in the radial direction. The initial ion energy is randomly selected from the Maxwell distribution characterized by the bulk ion temperature.

Using 500,000 particles, the velocity distributions of the minority protons were calculated for the three bumpinesses. The plasma parameters are $T_e(0)$=0.7 keV, $T_i(0)$=0.3 keV, $n_e(0)=0.5\times10^{19}$ m^{-3}, and Z_{eff}=3.0. The input rf field is adjusted so that the input power is about 100 kW in each case. Orbit tracing with acceleration and collisions is performed for 2 ms. Under these conditions, the velocity distribution reaches steady state within 1 ms. All figures in the present study show the distribution at 1 ms since the particle number subsequently decreased gradually due to loss. The calculated particles are summed within some bounded region in velocity space. This bounded region is specified in term of the particle energy and the pitch angle in this calculation. This pitch angle (120°) gives the largest energy tail observed in the charge-exchange neutral particle energy analyzer (CX-NPA) measurements. The calculation reproduces the high-energy tail up to 20 keV at this pitch angle, which was measured only in the high bumpiness case. No detectable data was obtained in the CX-NPA measurements for energies above 6 and 8 keV for the medium and low bumpinesses, respectively. The measured and calculated energy spectra are identical at energies below 10 keV for the medium and low bumpinesses.

The high bumpiness gives the largest energy-tail from the calculated result. The energy spectrum is calculated at pitch angle intervals of 2°. High-energy ions are observed at 90°, but there are not very many. High-energy ions are observed at pitch angles of 60 and 120°. The results are asymmetric about a pitch angle of 90°. The tail near 120° is larger than that near 60°. In the experiment, a high-energy tail is observed for the high bumpiness and it has a peak near 120°. The medium and low bumpinesses have small tails. The effective temperature estimated from the calculation for the high bumpiness has two peaks at 60 and 120° and it is the highest for the three bumpinesses at almost all pitch angles. For the medium bumpiness, the effective temperature has small peaks at 67, 80, 100 and 115°. In the experimental, a peak is observed at 118° and it gradually decreases toward 108°. The effective temperature for the low bumpiness is the lowest for the three bumpinesses. It has peaks at 70 and 110° and decreases near 90°, just as for the high bumpiness. The results from the experiment and calculation are consistent except for the low bumpiness for pitch angles in the range 107 to 117°. In this region, the absolute value differs, although the pitch angle dependences are almost identical.

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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(広大)，水内亨，佐野史道，岡田浩之，小林進二，山本聡，長﨑百伸

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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)，山本聡，長﨑百伸，佐野史道，水内亨，岡田浩之，南貴司，小林進二

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Grant-in-Aid for Scientific Research
木下正弘，基盤研究(B),「液体論を基盤とした蛋白質立体構造予測法の構築」

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3-3. NEW RESEARCH FACILITIES

Biofunctional Science Research Section

Accu TOF Mass Spectrometer, JEOL

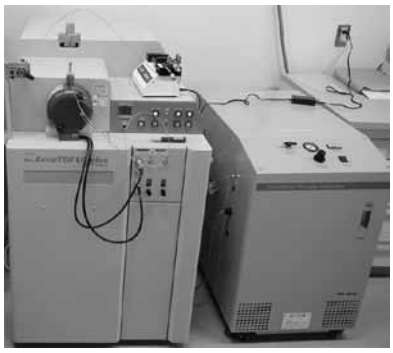


Figure 1. **Accu TOF Mass Spectrometer**

Accu TOF Mass Spectrometer combines high sensitivity, high resolution, and high mass accuracy in an easy to use instrument. These features make the Accu TOF an ideal instrument for accurate mass measurement of trace components. The system also includes a new, highly durable, orthogonal spray ESI source.

Ion souse of this system: ESI, nanoESI, CSI, APCI

FT/IR-6200 FT-IR Spectrometer, JASCO

Figure 2. **FT/IR-6200**

FT/IR-6200 offers the absolute highest level of performance in the industry with the highest signal-to-noise specifications. Designed for a wide range of critical research and development applications, the model is capable of measuring from the Near IR (15000 cm^{-1}) to the Far IR (50 cm^{-1}) with full vacuum.

The FT/IR-6200, with a higher level of resolution offers an excellent choice for gas analysis and other critical applications such as measurement of impurities in semiconductor processing.

Optima MAX-XP Micro-Ultracentrifuge, Beckman Coulter

Figure 3. **Optima MAX-XP Micro-Ultracentrifuge**

Optima MAX-XP Micro-Ultracentrifuge is a power-packed solution that delivers fast, efficient separations from samples as small as 175 µl up to 13.5 ml, and at speeds up to 150,000 RPM and more than 1,000,000 x g.

PharosFX Gel imager, Bio-rad

Figure 4. **PharosFX**

PharosFX can be used for the detection and analysis of DNA, RNA, or protein samples in gels, blots, or microplates. The system provides application flexibility and is expandable — unlike other fluorescent scanning systems. In the application-oriented software, simply select the type of sample being analyzed, and the optimal combination of lasers (488 nm, 532 nm, 635 nm) and filters (530 nm BP, 605 nm BP, 640 nm BP, 695 nm BP) will be automatically selected.

Infinite 200 PRO (M200 NanoQuant) microplate reader, TECAN

Figure 5. **Infinite 200 PRO (M200 NanoQuant)**

Infinite 200 PRO is a user-friendly and affordable multimode reader [absorbance and fluorescence intensity (UV-NIR & wavelength scan)], designed to

cater for the needs of today's applications (e.g. FRET measurement, temperature control, and so on). The Infinite 200 PRO can provide a full range of leading detection methods in one easy-to-use modular instrument with monochromator. The Infinite 200 PRO offers excellent sensitivity, multiplexing capabilities and high format flexibility, including 6- to 384-well microplates and Tecan's patent pending NanoQuant Plate™ for low sample volumes.

Bioenergy Research Section

600 MHz NMR machine equipped with high sensitivity detector (CryoProbe), Bruker BioSpin

600 MHz NMR machine equipped with high sensitivity detector (CryoProbe) has been installed under the collaboration contract with RIKEN. Totally two 600 MHz NMR machines are under operation for structural and functional studies of biomolecules and biomass.

Figure 1. 600 MHz NMR machines installed this year (front) and last year (back).

3-4. STUDENT AWARDS

Excellent Poster Award in JCS-10.

Advanced energy storage research section
Katsuhito Nakagawa (M2)

The Japan-China Symposium (JCS-10) on Materials for Advanced Energy Systems and Fission & Fusion Engineering has been held every two years in Japan and china alternatively. Initiated in Hefei, China in 1993, the symposium has become an important forum for scientists to exchange new information about materials and technologies for advanced fission & fusion systems. The tenth symposium held in Obaku Plaza had the topics on system & design, blanket & first wall technology, fission & fusion materials and technologies, radiation damage mechanism, and modeling & database.

Mr. Nakagawa have investigated stress corrosion cracking (SCC) behavior of austenitic 316L stainless steel for reactor components including the award presentation "Correlation between oxide film thickness and SCC susceptibility inSUS316L steel tested in high temperature water". The SCC is the primary form of component cracking such as core shrouds and primary loop recirculation (PLR) pipes in boiling water reactor (BWR). An understanding of the mechanism of SCC initiation is required for long time operation. In his study, slow strain rate tests (SSRT) were conducted in a simulated BWR environment at 288 deg. C under a pressure of 7.8MPa. The test environment was pure water chemistry at the testing condition with dissolved oxygen (DO ; 18, 8, 4, 1, 0.2 ppm) or dissolved hydrogen (DH ; 0.4, 0.1ppm) or without oxygen and hydrogen (DH/DO ; 0 ppm). Field emission auger electron spectroscopy (AES) and atomic force microscopy (AFM) were used to clarify the effect of the thickness on the passive layer. No SCC was observed in the DO condition with a thick (> 1300 nm) oxide film formation. On the other hand, SCC occurred in the DH environment and the condition, DH & DO = 0 ppm, at this condition, a thin oxide film (< 350 nm) was formed. The large amount of localized deformation in dislocation channels may result in the formation and dislocation cells. When the localized deformation on the specimen surface overwhelms the thickness of oxide film, SCC may occur.

Young Scientist Excellent Poster Award in 8th Fusion Energy Union Conference.

Advanced energy storage research section
Kiyohiro Yabuuchi (D2)

The fusion energy union conference has been held every two years and alternatively operated by the Japan Society of Plasma Science and Nuclear Fusion Research and the fusion nuclear technologies division of the Atomic Energy Society of Japan. The eighth symposium held in Takayama, Gifu, had a main theme "Fusion as a new energy technology revolution".

Mr. Yabuuchi is studying irradiation hardening mechanism of Fe-based alloys for fission and fusion reactor structural materials. The effects of different solutes on the microstructural evolution, especially dislocation loops, and irradiation hardening in a series of bcc Fe binary alloys under high flux and high fluence ion-irradiation were investigated. The materials used were Pure-Fe (99.99%), Fe-1Cr, Fe-1Mn, Fe-1Ni, Fe-1Cu and Fe-1Mo (at.%). Ion irradiations with 6.4MeV Fe^{3+} were carried out at temperatures of 200, 290 and 350 °C up to irradiation doses of 0.1 - 10 dpa with different flux of 1.0×10^{-4} dpa/s and 1.0×10^{-3} dpa/s, which were calculated from TRIM code at a depth of 600 nm from the ion-irradiated surface. The changes in hardness were measured using Nanoindenter. The microstructure of the cross-sectional specimens was investigated by transmission electron microscopy (TEM). Comparing the binary alloys with Pure-Fe after irradiations up to 1 dpa at 290 °C, the irradiation hardening in Fe-1Mn and Fe-1Ni was significantly larger than Pure-Fe and was comparable to the well-known Fe-1Cu. The TEM observation revealed that the dislocation loops in Fe-1Mn are smaller size and higher density than those in Pure-Fe. In addition, no clear evidence of Mn-related precipitation was obtained by TEM. On the other hand, the irradiation hardening of Fe-1Cr and Fe-1Mo was similar to that of Pure-Fe. The different irradiation hardening behaviour in the various bcc Fe binary alloys will be explained by the effect of solute trapping on point defect agglomeration and extended defect evolution. These results are beneficial to understand the microstructural development and following structural degradation under irradiations.

Poster presentation award in the 12th Kansai Surface Finishing Forum.

Complex Reaction Chemical Process Section
Ryo Koda (M1)

The 12th Surface Finishing Forum was held in Obaku Plaza in Uji. The topics of the forum are electrochemical deposition of metals, electrochemical treatment of surfaces, new aspects of surface treatments and surface analyses. This forum is not limited to academia but gives a good opportunity to discuss between academic and industrial researchers.

In the 12th Surface Finishing Forum, I gave a poster presentation entitled "Metal Electrodeposition within Porous Silicon: the Effect of Hydrophobicity and Hydrophilicity." In this presentation, I reported on a method to prepare nanostructures of metal by electrodeposition using a porous template. In general, it is believed that the wettability of substrate should be as high as possible to control electrodeposition within a complex-shaped template. However, our results suggested that electrodeposition within a hydrophobic template having extremely small nanopores was much controllable compared with that within a hydrophilic template when the electrodeposition was carried out in an aqueous deposition bath. Even the experts of electrodeposition did not expect this result. Due to this new finding, I was awarded a poster presentation in the forum. Our research will open a new aspect of electrodeposition within extremely narrow spaces.

First Place Winner in Science as Art Awards at 2010 MRS Spring Meeting.

Molecular Assemblies Design Research Section
Surawut Chuangchote (Post-doc)

The Materials Research Society (MRS) is an association of material science researchers from academia, industry, and government that promotes communication for the advancement of interdisciplinary materials research to improve the quality of life. Founded in 1973, MRS now consists of over 15,100 members from the United States, as well as nearly 70 other countries. Two major annual meetings offering approximately 100 topical symposia have been held every year at San Francisco (spring meeting) and Boston (fall meeting).

The Science as Art competition has being held during the fall and spring meetings since 2005 in the concept of visualization methods provide an important tool in materials science for the analysis and presentation of scientific work. Images can often convey information in a way that tables of data or equations cannot match. Occasionally, scientific images transcend their role as a medium for transmitting information, and contain the aesthetic qualities that transform them into objects of beauty and art. The awarded pictures in this competition are generally micrographies of artworks carefully constructed with many different materials.

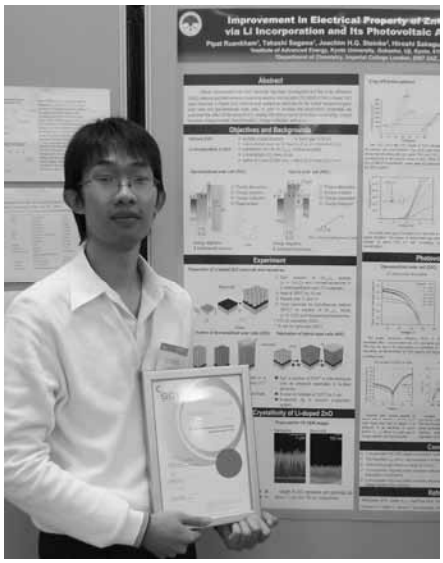
In the 2010 MRS Spring Meeting, San Francisco, April 5-9, 2010, I submitted a work named "ZnO Nanowires Arrays" to this competition. SEM image of vertically aligned ZnO nanowire arrays with a standing human-like form in a scale of nanometers. I called that human-like form as "Nano Man". ZnO nanowire arrays on the ITO substrate were prepared by hydrolysis with a solution method. Color was added to the original image. Finally, this image won the first place award.

SCI electrochemical technology group poster prize at Electrochem 2010.

Molecular Assemblies Design Research Section
Pipat Ruankham (M2)

Electrochem is an annual event organized by Royal Society of Chemistry (RSC) and Society of Chemical Industry (SCI). The conference is supported by the International Society of Electrochemisty (ISE). The aim is to bring together members of the international community involved in the practice and promotion of electrochemistry and electrochemical engineering. Energy generation and environmental protection have become the topics of interest and seem to dominate the field, in recent years. Electrochem 2010 in Telford, England, covered many symposia themes, all emphasizing on sustainability.

In the Electrochem 2010, I presented a poster of my work on the improvement in electrical proprieties of zinc oxide nanorod via lithium incorporation. At the beginning part, the investigation of morphology, cyrstallinity, and optical band gap of the Li-doped ZnO nanorods was discussed. Then, applications on dye-sensitized solar cells and hybrid inorganic/organic solar cell using Li-doped ZnO nanrods as electrode were presented. The enhancement of photovoltaic parameters in solar cells through Li incorporation was demonstrated. The poster was well received, and even garnered a poster award.



Best Poster Award and Nucleic Acids Research Award in the 37th International Symposium on Nucleic Acids Chemistry

Structural aspects of the fluorescence Intensity changes of the ATP-binding ribonucleopeptide sensors

Biofunctional Science Research Section
Shun Nakano (D3)

The nucleic acid symposium has been held to contribute to the development of the field concerned the nucleic acid that is a chemical main body of the gene through the announcement and the discussion about various researches that relate to the nucleic acid study. The chemical study for the clarification of the nucleic acid function and application are subjects and standout feature of this symposium among a lot of societies and academic societies regarding the nucleic acid.

In the 37th International Symposium on Nucleic Acids Chemistry, I presented a work on the structural and functional analysis for the ribonucleopeptide (RNP) receptors and sensors. Structure and function of the ATP-binding RNP sensor were evaluated by means of the secondary structure analysis and the fluorescence responses of the mutants of RNP. The RNP sensors showed different behaviors in the fluorescence intensity upon mutation not only in the consensus region but also in the non-consensus region. Functional and structural analyses of the mutant of the ATP-binding RNP sensors indicated that the structural model previously constructed for the ATP-binding RNP receptor was a valid one to explain the relationship between the nucleotide sequence of RNP and the fluorescence intensity changes of the RNP sensor.

Poster presentation award in Symposium of GCOE Energy Science in the Age of Global Warming

Assembly of biological macromolecules on DNA nanostructures

Biofunctional Science Research Section
Li Hongmei (D1)

The symposium of GCOE energy science in the age of global warming has been held every year. The research toward the realization of zero CO_2 emission system and development of renewable energy are discussed actively.

In the meeting of GCOE Energy Science in the Age of Global Warming, I presented the research about assembly of biological macromolecules on DNA nanostructures by zinc finger proteins. In this study, we have explored a novel strategy to target specific sites on DNA scaffolds. We have prepared rectangular-shaped DNA nanostructures of dimensions 60 x 90 nm as previous report, and incorporated indexed nucleic acid probes at predetermined positions of the DNA scaffold. Formation of the predicted DNA nanostructure and the address of indexed nucleic acid probes were successfully confirmed by atomic force microscope (AFM). Subsequently, we attempt to immobilize multiple proteins onto the desired position of the rectangular DNA motif mediated by the interaction between DNA and zinc finger protein. Two types of zinc finger proteins with different DNA sequence specificity were designed and were expressed by E. coli. At the present stage, the assembly of rectangular DNA motif and zinc finger proteins was investigated by AFM images. Targeting the specific address on the rectangular DNA motif was discussed with functional molecules modified zinc finger protein.

Best Poster Award at "The 2nd International Symposium Kyoto University Global COE Program"

Laboratory for Complex Energy Processes Research Section
Ken-ichi Amano (D2)

The symposium was held at Kihada Hall, Kyoto University, Kyoto, Japan in August, 2010. The title of the presentation was "Import and Export of a solute using solvation effects: a study on chaperonin GroEL" (by Ken-ichi Amano and Masahiro Kinoshita).

ABSTRACT: Insertion of a large solute into an even larger vessel comprising biopolymers followed by release of the same solute from it is a fundamental function in biological systems for sustaining life. A typical example is as follows: An unfolded protein is inserted into the chaperonin GroEL from bulk aqueous solution, protein folding occurs within the GroEL cavity, and the folded protein is released back to the bulk solution (a variety of proteins are inserted and released). The question is the following: How can the solute, which has already been inserted into the vessel and is constrained inside it, be released from it to the outside? We show that the main physics can be understood through a simple model focused on solvation properties of a solute in the solvent confined on the scale of a nanometer which are substantially different from those in the bulk solvent. We analyze the spatial distribution of the potential of mean force (PMF) between a large spherical solute and an even larger vessel with cylindrical shape, which are immersed in small spheres forming the solvent. The analysis is made using an elaborate statistical-mechanical theory in liquid-state physics. The PMF is decomposed into entropic and energetic components. We find that insertion is driven by the entropic effect arising from the translational displacement of solvent molecules. The switch from insertion to release is achieved by altering the solute conformation to reduce the excluded volume (EV) generated by the solute for solvent molecules and to increase the solute solvophilicity. The reduction weakens the insertion power induced by the entropic force, and the increase promotes preferential solvation of the solute not in the solvent confined within the complex cavity but in the bulk solvent. The latter effect is energetic in origin. A protein becomes much more compact and its EV decreases largely upon folding. Further, the exposed surface of an unfolded protein comprises solvophobic groups as well as solvophilic groups, but the protein becomes dominantly solvophilic after the folding is finished. We argue that the mechanism of the insertion/release function of GroEL can be elucidated by our theoretical model.

4. 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. On the other hand, resource and energy problems as well as global warming problems become very serious in recent years. We must concentrate all our knowledge and wisdom to find solutions to these problems. From such a viewpoint, the laboratory has been recognized again since FY2006 so that the research targets of the laboratory should be focused on two specific fields, (i) "advanced studies of science and technology on plasma energy and quantum energy" and (ii) "innovative studies of nano-bio functional materials for power generation". Therefore, two sections (A2 and A3 mentioned below) are founded. Section of promotion for international collaborative research arranges and promotes international and domestic research collaborations.

In order to perform the research objectives of the Institute of Advanced Energy, it is essentially necessary to organize the cooperative research program with much close connection between related research fields in the institute. The laboratory takes charge of organizing and promoting the cooperative research project as a center of research activity in the Institute. The research staffs in the institute participate in specific projects to carry out their subjects. The scientists of other faculties in Kyoto University can also participate the cooperative project to enhance the progress of research and educational activities. The laboratory also manages various functions such as symposium and seminar for related topics on energy field. The cooperative research activities will be published in a publication edited in the laboratory at the end of the year.

A1 Section of Promotion for International Collaborative Research

This section promotes international collaborative research on advanced energy to lead the field of energy science and technology as an international pioneer. Collaborative researches between the institute and domestic/international organizations are supported towards realization of advanced energy system as practical applications with contributions to human society. This section also promotes personal exchange, cooperative research activities and multi-lateral collaborative research with industries. Establishment of infrastructure and human resource development are supported for execution of collaborative R&D activities on advanced energy.

A2 Section of Promotion for Advanced Plasma and Quantum Energy

This section promotes studies on advanced plasmas and quantum energy for realizing future energy systems, integrating plasma energy science and advanced energy material research. In particular, based on the results obtained in our related group, we aim at extending the research fields and contributing to human society by utilizing the existing key devices such as Heliotron J, DuET and MUSTER which have been developed in IAE.

A3 Section of Promotion for Photon and Energy Nano-Science Research

This section promotes studies on photon and energy nano-science for realizing next generation renewable energy system. In particular, functional nano- and bio-materials to utilize solar energy and bio-energy are studied by unifying laser science, nano-technology, and bio-technology, We aim at extending our research field by utilizing the existing devices such as System for Creation and Functional Analysis of Catalytic Materials, SEMs, SPM, Solar Simulator, TW fs laser, MIR-FEL, and so on.

B Cooperative use of facilities and equipments

Facilities and equipment of the laboratory are provided to researches cooperated 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 three groups 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 72 were applied and applications of 72 were accepted after the approval by a steering committee of the laboratory. The number of research subjects is listed in Table 1 according to the project categories.

Table 1, Number of the accepted research subjects according to the standard project theme

The whole sum 72

		category A			B	total
		A1	A2	A3		
Kibann *1	inside	1*	3*	4*	0	8*/(5Excluding field-overlapped applications)
	outside	0	0	0	0	0
Syorei *2	inside	2	11	9	0	22
	outside	15	13	11	4	43
Kikaku -chosa *3	inside	1	1	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

"International Collaborative Research on Advanced Energy Materials Science and Technology"

(1)T. Yamamoto, Y. Wu, G.R. Odette
(2) K. Yamabuchi
(3) R. Kasada, T. Hinoki, A. Kimura
(1) Dept. of Mechanical Engineering, University of California Santa Barbara
(2) Graduate School of Energy Science, Kyoto University
(3) Institute of Advanced Energy, Kyoto University

A2,

"Development of Advanced Plasma and Quantum Energy Studies"

(1) K. Nagasaki, T. Konishi, M. Takeuchi
(1) Institute of Advanced Energy, Kyoto University

A2, A3

"Basic Studies on Photon and Energy Nano-Science Research"

(1) H. Ohgaki, Section of Promotion for Photon and Energy Nano-Science research
(1) Institute of Advanced Energy, Kyoto University

"Development of the Enzyme and Aptamer that Function in Response to the Surrounding Environment"

(1) M. Katahira, T. Morii, T. Kotaki
(2) T. Nagata, A. Hurukawa
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Nanobioscience, Yokohama City University

"Development of an advanced experimental apparatus for attasecond time-resolved measurements with a CEP-stabilized femtosecond laser-"

(1) K. Miyazaki, G. Miyaji
(2) K. Yoshii
(3) N. Yasumaru
(4) A.E. Kaplan
(5) F.H.M. Faisal
(6) J. Reif
(7) H. Niikura
(8) S.M. Abdurrouf
(1) Institute of Advanced Energy, Kyoto University
(2) The University of Electro-Communications
(3) Fukui Nat. Coll. Technology
(4) John Hopkins Univ.
(5) Bielefeld Univ.
(6) Brandenburg Tech Univ.
(7) Waseda University
(8) Univ. Brawijaya

A1

"Advanced Pore-Structure Analysis of New Porous Ceramics for Diesel Particulate Filters"

(1) Y. Suzuki
(1) Institute of Advanced Energy, Kyoto University

"Experimental Studies of the Cylindrical Discarge type Fusion 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

"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

"Micro-structural control of Co-base ODS superalloys"
(1) S. Ukai, S. Hayashi, K. Takezawa
(1) Graduate School of Engineering, Hokkaido University

"Surface Degradation Behavior of Plasma Diagnostic Mirrors Irradiated with Hydrogen/Helium Ion"
(1) M. Miyamoto, K. Ono
(2) K. Morishita
(3) S. Hasuike, S. Kumode, K. Nakano
(1) Interdisciplinary Faculty of Science and Engineering, Shimane University
(2) Institute of Advanced Energy, Kyoto University
(3) Interdisciplinary Faculty of Science and Engineering, Shimane University

"Optimization of SMBI nozzle shape"
(1) N. Nishino, T. Hirooka, T. Mio, S. Iida, S. Kohiki, T. Ueno, K. Senba
(2) F. Sano, T. Mizuuchi, H. Okada, T. Minami, K. Nagasaki, S. Kobayashi, M. Takeuchi
(1) Graduate School of Engineering, Hiroshima University
(2) Institute of Advanced Energy, Kyoto University

"Modeling of Mechanical Properties of Structure Materials for Nuclear Fusion Reactors"
(1) M. Satou
(2) K. Morishita
(3) Y.Watanabe
(1) Faculty of Engineering, Tohoku University
(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
(2) H. Kawashima
(3) Y. Sadamoto
(4) T. Mizuuchi,
(5) S. Ohshima
(1) Japan Aerospace Exploration Agency
(2) Japan Atomic Energy Agency
(3) Joetsu University of Education
(4) Institute of Advanced Energy, Kyoto University
(5) Kyoto University Pioneering Research Unit for Next Generation, Kyoto University

"Porous Silicon Carbide for Super-low Friction in Water"
(1) K. Adachi, Y.Morito
(2) T. Hinoki
(3) M.Suh
(1) Faculty of Engineering, Tohoku University
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

"Study of role of symmetry in collisional transport in toroidal 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

"Theoretical Simulations for Irradiated Materials Based on First Principles Method"
(1) Y. Kaneta, J. Gotoh
(2) K. Morishita
(1) School of Engineering, The University of Tokyo
(2) Institute of Advanced Energy, Kyoto University

"Strength evaluation by plate thickness change of nuclear fusion material."
(1) S. Sato, S. Suzuki
(2) A. Kimura
(1) Fukushima National College of Technology
(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, S. Miyake
(1) Faculty of Engineering, Kyushu University
(2) Graduate School of Engineering, Kyushu University

"Microstructure and Thermal Properties of Porous SiC materials"
(1) H. Kishimoto, K. Satori, T. Abe, A. Kohyama
(2) T. Hinoki
(1) Graduate School of Engineering, Muroran Institute of Technology
(2) Institute of Advanced Energy, Kyoto University

"Ion Irradiation Effects of Monolithic SiC Produced by Greensheet"
(1) A. Kohyama, K. Hayakawa, H. Kishimoto, J.S. Park, Y. Kohno
(2) T, Hinoki, S. Kondo
(1) Graduate School of Engineering, Muroran Institute of Technology
(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

“Characteristics of Traps for Hydrogen Isotope in Irradiated Materials”

(1) H. Iwakiri, S. Inamine, R. Nakamori
(2) K. Morishita
(3) R. Yoshida
(1) Faculty of Education, University of the Ryukyu
(2) Institute of Advanced Energy, Kyoto University
(3) Research Institute for Applied Mechanics, Kyushu University

“Design Study of Helical Plasma Demonstrator”

(1) T. Mizuuchi, T. Minami, S. Yamamoto, M. Takeuchi, K. Nagasaki, H. Okada, K. Hanatani, F. Sano, S. Kobayashi K. Yaguchi, T. Senju, K. Toushi, K. Sakamoto, M. Shibano
(2) Y. Nakamura
(3) H. Himura
(1) *Institute of Advanced Energy, Kyoto University*
(2) *Graduate School of Engineering, Kyushu University*
(3) *Advanced Fibro-Science Division Kyoto Institute of Technology*

A2

“Control of Rotational Transform by Using Non-inductive Current in Helical Systems”

(1) K. Nagasaki, K. Sakamoto, F. Sano, T. Mizuuchi, K. Hanatani, T. Minami, H. Okada, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima, M. Takeuchi
(2) Y. Nakamura
(3) Y. Yoshimura, G. Motojima
(4) N. Marushchenko
(5) A. Cappa
(6) B. Blackwell
(7) S. Ohshima
(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
(6) The Australian National University
(7) Kyoto University Pioneering Research Unit for Next Generation, Kyoto University

“Indentation size effect on nano-hardness of ion-irradiated iron”

(1) R. Kasada, A. Kimura
(2) Y. Takayama, K. Yabuuchi
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University

“Numerical Analysis of Twisted-tape-Induced Swirl Heat Transfer in a Short Circular Tube”

(1) K. Hata
(2) N. Kai, Y. Shirai
(3) S. Masuzaki
(4) M. Hamura
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) National Institute for Fusion Science
(4) CHAM-Japan

“Irradiation Correlation of Radiation Damage Process in Materials.”

(1) K. Morishita
(2) Y. Watanabe, Y. Yamamoto
(3) Y. Kaneta, S. Ishii
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) School of Engineering, The University of Tokyo

“Nozzle Optimization for Supersonic Molecula Beaminjection”

(1) T. Mizuuchi
(2) N. Nishino
(3) H. Masahiro
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Engineering, Hiroshima University
(3) Faculty of Engineering, Kyoto University

“Investigation of transport characteristics of advanced helical plasma by density profile control”

(1) T. Minami, S. Kobayashi, K. Nagasaki, S. Yamamto, H. Okada, F. Sano, T. Mizuuchi, M. Takeuchi, S. Konoshima, K. Hanatani
(2) S. Ohshima
(1) Institute of Advanced Energy, Kyoto University
(2) Kyoto University Pioneering Research Unit for Next Generation, Kyoto University

“Study on Reconstruction of the Density Profile by Multi Channel Far Infrared Laser Interferometer in Advanced Plasma”

(1) M. Takeuchi, T. Minami, K. Nagasaki, T. Mizuuchi, H. Okada, S. Kobayashi, S. Yamamto, S. Konoshima, F. Sano, K. Hanatani,
(2) S. Ohshima
(3) Y. Nakamura
(4) K. Tanaka
(1) Institute of Advanced Energy, Kyoto University Kyoto University Pioneering Research Unit for Next Generation
(2) Graduate School of Energy Science, Kyoto University National Institute for Fusion Science
(3) Graduate School of Energy Science, Kyoto University
(4) National Institute for Fusion Science

“**Precise measurement of ion temperature and rotation velocity in high-temperature plasmas of helical-axis configuration.”**

(1) S. Kobayashi, T. Minami, T. Mizuuchi, K. Nagasaki, H. Okada, S. Yamamoto, K. Hanatani, S. Konoshima, K. Tohshi, F. Sano
(2) Y. Nakamura, H.Y. Lee, K. Mukai, T. Kagawa
(3) Y. Suzuki, K. Nagaoka, Y. Takeiri, S. Okamura, K. Toi
(4) Y. Nakashima
(5) S. Murakami
(6) S. Kado,
(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
(6) School of Engineering, The University of Tokyo

"Studies of effects of magnetic island on plasma confinements in magnetically confined high temperature plasmas"
(1) S. Yamamoto, H. Okada, F. Sano, T. Minami, K. Hanatani, T. Mizuuchi, S. Kobayashi, S. Konoshima, M. Takeuchi
(2) Y. Nakamura,
(3) Y. Suzuki, S. Sakakibara, K. Watanabe
(4) S. Ohshima
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University
(3) National Institute for Fusion Science
(4) Kyoto University Pioneering Research Unit for Next Generation, Kyoto University

"Study of Mechanism of Ion Cyclotron Range of Frequency Heating of Plasma in a Non-Axisymmetric Magnetic Field"
(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

"Energies of Σ3 coincidence boundaries in 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

"Interaction between dislocation and precipitate in a BBC metal using the in-situ TEM observation method"
(1) K. Fukumoto, K.Nomura, K.Tougou
(2) *Research Institute of Nuclear Engineering, University of Fukui*

"The Solid Surface Characteristic Effects on Contact Angles of The Molten Lead-Lithium Eutectic Alloy"
(1) T. Kunugi, Y. Ueki
(2) T. Hinoki
(1) Graduate School of Engineering, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

"Research on the reactivity of unstable fragments produced by femtosecond laser ablation."
(1) T. Kobayashi, Y. Mathuo
(2) T. Nakajima
(1) Riken
(2) Institute of Advanced Energy, Kyoto University

"Study on Helium Embrittlement of Austenitic Stainless Steel"
(1) A. Hasegawa , S. Nogami, K. Abe
(2) A. Kimura, R. Kasada
(1) Faculty of Engineering, Tohoku University
(2) Institute of Advanced Energy, Kyoto University

"Correlation measurement using two ECE systems in torus plasmas"
(1) Y. Yoshimura, S. Okamura, S. Kubo, T. Shimotuma, 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

"Environmental Effect on Creep Deformation of High Crystalline SiC"
(1) S. Nogami, M. Takahashi, K. Abe, A. Hasegawa
(2) T. Hinoki
(1) Faculty of Engineering, Tohoku University
(2) Institute of Advanced Energy, Kyoto University

"The effect of surface sink on irradiation damage structure"
(1) K. Sato, T. Yoshiie, Q. Xu
(2) J. Kinomura
(3) M. Oomura, R. Kasada, A. Kimura, K. Morishita
(1) Kyoto University Research Reactor Institute
(2) National Institute of Advanced Industrial Science and Technology
(3) 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) Q. 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

"Measurement of electrical resistivity distribution in SiC/SiC composite material"

(1) T. Tanaka, T. Muroga
(2) T. Hinoki
(1) National Institute for Fusion Science
(2) Institute of Advanced Energy, Kyoto University

"Study for multi-channel measurement and analysis method to investigate nonlinear evolution of turbulence in high temperature plasma"

(1) S. Ohshima
(2) S. Yamamoto, M. Takeuchi, S. Kobayashi, N. Nagasaki, T. Mizuuchi, F. Sano, H. Okada, K. Hanatani, S. Konoshima
(1) Kyoto University Pioneering Research Unit for Next Generation, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

"Study on neutral particle transport and elementary process of particle fueling in high-temperature plasmas"

(1) Y. Nakashima, K. Hosoi, R. Yonenaga, H. Ozawa
(2) S. Kobayashi, T. Mizuuchi, H. Okada, S. Konoshima, F. Sano
(3) K. Mukai, H.Y. Lee, T. Kagawa,T. Minami
(1) Plasma Research Center, University of Tsukuba
(2) Institute of Advanced Energy, Kyoto University
(3) Graduate School of Energy Science, Kyoto University

"Irradiation effects on microstructure evolution at the interface of SiC/.SiC composites and W joining at elevated temperatures"

(1) T. Shibayama, J. Wajima, 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

"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

"Workshop on the multiscale modeling of radiation damage processes in fusion materials"

(1) K. Morishita
(2) S. Ounuki
(3) Y. Kaneta, S. Ishii
(4) M. Sakamoto
(5) D. Kato, N. Ashikawa, M. Tokitani
(6) Y. Watanabe, Y. Yamamoto
(7) Q. Xu
(8) Y. Ueda
(9) M. Miyamoto
(10) N. Yoshida, H. Watanabe, K. Ohsawa,
(11) H. Iwakiri
(12) K. Hoshino
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Engineering, Hokkaido University
(3) School of Engineering, The University of Tokyo
(4) Plasma Research Center, University of Tsukuba
(5) National Institute for Fusion Science
(6) Graduate School of Energy Science, Kyoto University
(7) Kyoto University Research Reactor Institute
(8) School of Engineering, Osaka University
(9) Interdisciplinary Faculty of Science and Engineering, Shimane University
(10) Research Institute for Applied Mechanics, Kyushu University
(11) Faculty of Education, University of the Ryukyu,
(12) Japan Atomic Energy Agency

A3

"Development of a highly efficient bioethanol production yeast from non-edible biomass"

(1) T. Kodaki, M. Katahira, K.S. Mohamad
(2) S. Sawayama
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Agriculture, Kyoto University

"Optical radiation from porous Si by electron beam irradiation"

(1) T. Kii, K. Hukami, Y. Ogata, T. Sakka, H. Ohgaki, K. Masuda
(1) Institute of Advanced Energy, Kyoto University

"Construction of the system for the pulse width measurement of KUFEL"

(1) T. Nakajima, Yu Qin, T. Kii, T. Sakka, H. Ohgaki
(2) T. Sekigawa
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Engineering, Hokkaido University

"Development of the ion channel composed of nucleic acids"

(1) M. Katahira, T. Morii, T. Kotaki A. Hurukawa
(2) S. Nishikawa
(1) Institute of Advanced Energy, Kyoto University
(2) National Institute of Advanced Industrial Science and Technology

"A highly-efficient photoenergy-conversion system consisting of noble metal/porous silicon composite with fractal hierarchy"
(1) K. Fukami, T. Sakka, Y. Ogata
(2) S. Nakanishi
(3) Y. Suzuki
(1) Institute of Advanced Energy, Kyoto University
(2) Research Center of Advanced Science and Technology, The University of Tokyo
(3) Uyemura & Co.,Ltd.

"High-Brightness Electron Beam Production by a Thermionic Triode RF Gun for"
(1) K. Masuda, H. Ohgaki, T. Kii, K. Nagasaki
(2) M. Takasaki, R. Kinjyo
(1) Institute of Advanced Energy, Kyoto University
(2) Graduate School of Energy Science, Kyoto University

"Stability of optical emission from the laser plasma in liquid"
(1) T. Sakka, A. Tamura, T. Nakajima, K. Fukami, Y. Ogata
(2) S. Suzuki
(1) Institute of Advanced Energy, Kyoto University
(2) Uyemura & Co.,Ltd.

"Observation and control of surface plasmon polaritons in femtosecond laser ablation"
(1) G. Miyaji, K. Miyazaki
(2) A.E. Kaplan
(3) J. Reif
(1) Institute of Advanced Energy, Kyoto University
(2) Johns Hopkins University
(3) Brandenburgische Technische Univ.

"Development of the Artificial Oxidase Driven by Solar Energy Based on Charge Transport through DNA"
(1) K. Tainaka, T. Morii
(2) I. Saito
(1) Institute of Advanced Energy, Kyoto University
(2) College of Engineering, Nihon University

"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

"Optimization of a Single-order Harmonic Separator for High Harmonis
(1) T. Sekikawa, M. Itoh, Y. Igarashi, A. Makita
(2) T. Nakajima
(1) Graduate School of Engineering, Hokkaido University
(2) Institute of Advanced Energy, Kyoto University

"Repairing Composite Materials through the Photothermal Effect of the Carbon Nanotubes"
(1) M.S.A. Hassan
(2) H. Ohgaki
(1) Advanced Fibro-Science Division Kyoto Institute of Technology
(2) Institute of Advanced Energy, Kyoto University

"Development of tools for observing mechanical and chemical energy produced from thermal fluctuations by deaminase"
(1) T. Nagata
(2) A. Hurukawa, M. Katahira
(1) Graduate School of Nanobioscience, Yokohama City University
(2) Institute of Advanced Energy, Kyoto University

"Functional transformation of aliphatic acetals by means of mid-IR irradiation."
(1) K. Fugami
(2) T. Sakka
(1) Graduate School of Engineering, Gunma University
(2) Institute of Advanced Energy, Kyoto University

"Study on the photoluminescence of ZnO thin film by MIR-FEL"
(1) T. Sonobe, K. Hachiya
(2) H. Ohgaki, T. Kii, K. Masuda
(1) Graduate School of Engineering, Kyoto University
(2) Institute of Advanced Energy, Kyoto University

"Phase Measurement of VUV Pulse Using Coherently Excited States of Alkali Metal Atoms"
(1) R. Itakura
(2) T. Nakajima
(3) J. Chen
(1) Japan Atomic Energy Agency
(2) Institute of Advanced Energy, Kyoto University
(3) China Jiliang Unversity

"Development of 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

“Development of multi-pulse laser for KU-FEL”
(1) R, Kuroda
(2) H. Ohgaki, T. Kii
(1) National Institute of Advanced Industrial Science and Technology
(2) Institute of Advanced Energy, Kyoto University

“Development of smart optical devices with arrayed micro-rod polymer gel ”
(1) T. Yamauchi, N. Tsubokawa
(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 RMS Electron Bunch Length Monitor for KU-FEL”
(1) H. Zen
(2) M.A. Bakr, Yong-Woon. Choi H. Ohgaki. K. Masuda. T. Kii
(1) Institute for Molecular Science
(2) Institute of Advanced Energy, Kyoto University

B.
“Study of Scintillation Efficiency Universal Curves for Crystals”
(1) Y. Uozumi, M. Ueyama, Y. Yanagida, S. Hirayama
(2) H. Ohgaki, T. Kii
(1) Faculty of Engineering, Kyushu University
(2) Institute of Advanced Energy, Kyoto University

“Establishmenta of Single-electron irradiation Technique
(1) G. Wakabayashi, M. Ueyama, Y. Yanagida, Y. Uozumi
(2) H. Ohgaki, T. Kii
(1) Faculty of Engineering, Kyushu University
(2) Institute of Advanced Energy, Kyoto University

“Compatibility of weld joints of the low-activation ferritic/martensitic steel with liquid lead-lithium metal”
(1) T. Nozawa, H. Tanigawa
(2) C.H. Park, Y. Yamamoto
(1) Japan Atomic Energy Agency
(2) Institute of Advanced Energy, Kyoto University

“Photoenergy Conversion Devices Based on Nucleic Acid-Dye Conjugates”
(1) K. Yamana
(2) T. Morii
(1) Graduate School of Engineering, University of Hyogo
(2) Institute of Advanced Energy, 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

(1) **The First Meeting, November 12, 2010**

Prof. Gisle Øye, "Interfacial chemistry in Produced water treatment", Department of Chemical Engineering, NTNU

(2) **The Second Meeting, January 14, 2011**
Dr. Sergej Polisski, "Noble metal/porous silicon nanocomposits in catalysis", Postdoctoral Fellow, Department of Physics University of Bath, UK

2. The Annual Meeting for the Cooperative Research Results, April 8, 2011

(1) H. Ohgaki, "Basic Studies on Photon and Energy Nano-Science Research", *Institute of Advanced Energy, Kyoto University*

(2) K. Miyazaki, **"**Development of an advanced experimental apparatus for attasecond time-resolved measurements with a CEP-stabilized femtosecond laser-", *Institute of Advanced Energy, Kyoto University*

(3) K. Nagasaki, **"**Development of Advanced Plasma and Quantum Energy Studies**",** *Institute of Advanced Energy, Kyoto University*

(4) H. Okada, "Study of Mechanism of Ion Cyclotron Range of Frequency Heating of Plasma in a Non-Axisymmetric Magnetic Field", *Institute of Advanced Energy, Kyoto University*

(5) T. Sakka, **"**Stability of optical emission from the laser plasma in liquid**",** *Institute of Advanced Energy, Kyoto University*

(6) A. Kimura, "International Collaborative Research on Advanced Energy Materials Science and Technology", *Institute of Advanced Energy, Kyoto University*

(7) R. Kasada, "Indentation size effect on nano-hardness of ion-irradiated iron", *Institute of Advanced Energy, Kyoto University*

(8) M. Katahira, "Development of the Enzyme and Aptamer that Function in Response to the Surrounding Environment", *Institute of Advanced Energy, Kyoto University*

5. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS

Asian CORE (Center Of Research and Education) program, 2008-2012

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 its third year. In this program, Japan and core institutes in Asian nations are expected to 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.

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. Because the sources in Korea and China are not from the similar programs in these countries, steering Committee Meetings are not held in this fiscal year and operation are controlled by electronic communications.

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.

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.

In the fiscal year 2010, we have conducted the exchanges in these areas as summarized in the fig.1. Large number of exchanges were planned in March when many of the participating institutes have chance to travel at the occasion of the academic society meetings in Japan , however due to the earthquake, a number of the visits were cancelled. These outstanding exchanges will be completed in the FY2011.

One of the highlights of the accomplishment in this fiscal year was the Winter School/seminar held in Busan in March on advanced nuclear technology and material science. Presentations and discussions on fusion technology, fission technology, tritium, material, were successfully conducted. under R-1, R-2 and R-4. Figure 2 shows the group photo of the participants at this seminar.

	J→K	K→J	J→C	C→J
SCM	0/0	0/0	0/0	0/0
Task-1	6/27	3/25	7/21	0/0
Task-2	4/20	0/0	3/20	1/29
Task-3	5/13	2/8	1/3	0/0
Task-4	10/36	0/0	7/30	4/22
Task-5	2/8	0/0	8/32	0/0
Seminar	16/62	0/0	0/0	0/0
subtotal	27/104	5/33	26/106	5/51
Total	63/294			

Fig.1 Conducted exchanges in 2010 under the Asian CORE program.(man/man-day)

Fig.2 Asian CORE seminar held in Busan in March 2011.

Global COE Program "Energy Science in the Age of Global Warming – Toward CO2 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 CO2 below). CO2 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 CO2 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 CO2 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 CO2 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 CO2 zero emission technology roadmap and establishes a CO2 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 CO2 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 FY2010, 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 2nd International Symposium of the Global COE titled "Zero-Carbon Energy, Kyoto 2010"in August, 2010 and the annual symposium of the Global COE on January, 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 Vietnam on September, 2010, 2nd Nuclear Energy Seminar in Thailand and other related seminars and symposiums, as well as a summer school in Brunei dispatching the G-COE young scholars and students.

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.

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) studies of confinement improvement by controlling magnetic configuration and of related plasma self-organization, (2) study of instability suppression by controlling magnetic configuration, (3) experimental study of plasma current control, (4) studies of fueling control and of exhaust control of heat and particles, and (5) research and development of measurement system aiming at density and potential fluctuation diagnostics. These studies are now progressing very favorably. The results of several subjects are described below.

Study of electron cyclotron current drive (ECCD) [1]: Second-harmonic electron cyclotron current drive (ECCD) experiments have been performed in the stellarator/heliotron device (S/H), Heliotron J. A focused Gaussian beam is injected with the parallel refractive index, $N_{||}$, ranging from -0.05 to 0.6. The EC driven current is estimated by excluding the bootstrap current from the total current. The experimental results show that the EC driven current is determined by the local magnetic field structure where the EC power is deposited. The maximum EC driven current is attained around $N_{||}$=0.4 when the EC power is deposited at nearly the top of the magnetic ripple. A large increase in electron cyclotron emission (ECE) signals is observed when the EC current is driven, indicating an important role for high-energy electrons in the ECCD.

Effect of the fueling control on plasma confinement [2]: The optimization study of gas fueling scenario has been performed to control the plasma profile, resulting in high performance plasma formation in Heliotron J. Supersonic Molecular Beam Injection (SMBI) fueling is successfully applied to Heliotron J plasma. A supersonic H_2-beam is effective to increase fueling efficiency and make a peaked profile. In a combination heating condition of ECH and Co-NBI, the stored energy reached about 50% higher value than the maximum one achieved so far under the similar heating condition with conventional gas-puff fueling in Heliotron J. However, under conventional gas-puff fueling, probably due to the edge cooling caused by excess neutrals in wider area of plasma surface, the stored energy becomes saturated or decreased. Local fueling with a short pulse by SMBI can increase the core plasma density avoiding the degradation due to the edge cooling. Higher density and peaked profile of a target plasma is preferable for NBI since both of the power absorption rate and the global confinement time are expected to increase in such a target plasma.

Plasma Startup using Neutral Beams Assisted by 2.45GHz Microwaves in Heliotron J [3]: Neutral beam injected (NBI) plasmas have been successfully started up by assistance of 2.45GHz microwaves of 5kW power in a medium-sized heliotron device, Heliotron J. Plasmas of the line-averaged electron density more than 1×10^{19} m^{-3}, are produced at the NBI power of around 1 MW in the magnetic field range of $B > 0.63T$ within 20 ms after the NBI turn-on. Electron cyclotron emission measured with a radiometer shows that population of high-energy electrons generated by 2.45GHz microwaves is critical for reliable startup

References

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Application of DuET and MUSTER for Industrial Research and Engineering (ADMIRE Project)

1. Introduction

The Application of DuET and MUSTER for Industrial Research and Engineering (ADMIRE) Project at the Institute of Advanced Energy (IAE), Kyoto University is one of the MEXT-supported programs "Open Advanced Facilities to Industry" to provide private companies with utilization of experimental facilities and expertise of IAE, Kyoto University. Scientists and engineers of private industries are welcomed to use advanced facilities, such as the DuET and the MUSTER in the IAE. Technical guidance to operate experimental equipments as well as consulting on the experimental results is also offered to the users. Experimental equipments such as high-performance TEM, SEM, FIB, EPMA, Auger and ion accelerators are included in the list covered by the ADMIRE Project free of charge up to 2 years in the "Trial use mode".

2. Project details

The ADMIRE Project was launched in 2006 funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. The DuET and MUSTER are two of the representative facilities in the IAE, Kyoto University dedicated for the research of energy science and technology, with special emphasis on fusion and fission reactor materials R&Ds. The ADMIRE Project aims to provide the wide range of the public with the research resources of IAE. Thus, research topics to be accepted by the ADMIRE Project are NOT restricted to fission or fusion reactor materials, nor energy science and technology. We welcome many proposals from a variety of fields all over the world.

The ADMIRE Project has four modes of facility use: a) Trial use mode, b) Charged use mode-X (exclusive use of data), c) Charged use mode-N (non-exclusive use of data), and d) Collaborative use.

a) Trial use mode

In this mode, users are allowed to utilize the ADMIRE facilities free of charge for a fixed term, i.e. six months for the MUSTER facilities or twelve months for the DuET facilities. The term may be repeated once if requested and approved. This enables a MUSTER user to use the facility up to one year, and a DuET user up to two years, if approved by the Subject Selecting Committee. The only obligation of the user is to submit a relatively simple report at the end of the term. If the user requests to postpone the immediate dissemination of the outcome, in order to secure its intellectual property rights (IPR), a moratorium up to twelve months may be given.

b) Charged use mode-X (exclusive use of data)

This mode is programmed for those users who have strong interests in the IPR to be obtained through the ADMIRE utilization. There is no obligation to submit reports, etc. to the ADMIRE. The subject title and the name of the user may be kept undisclosed if the user so requests.

c) Charged use mode-N (non-exclusive use of data)

This mode is similar to the mode-X but is different only in that submission of a report is obligatory. The charge rate for facility use is lower compared to the mode-X. The IPR basically belongs to the users in this mode, too.

d) Collaborative use

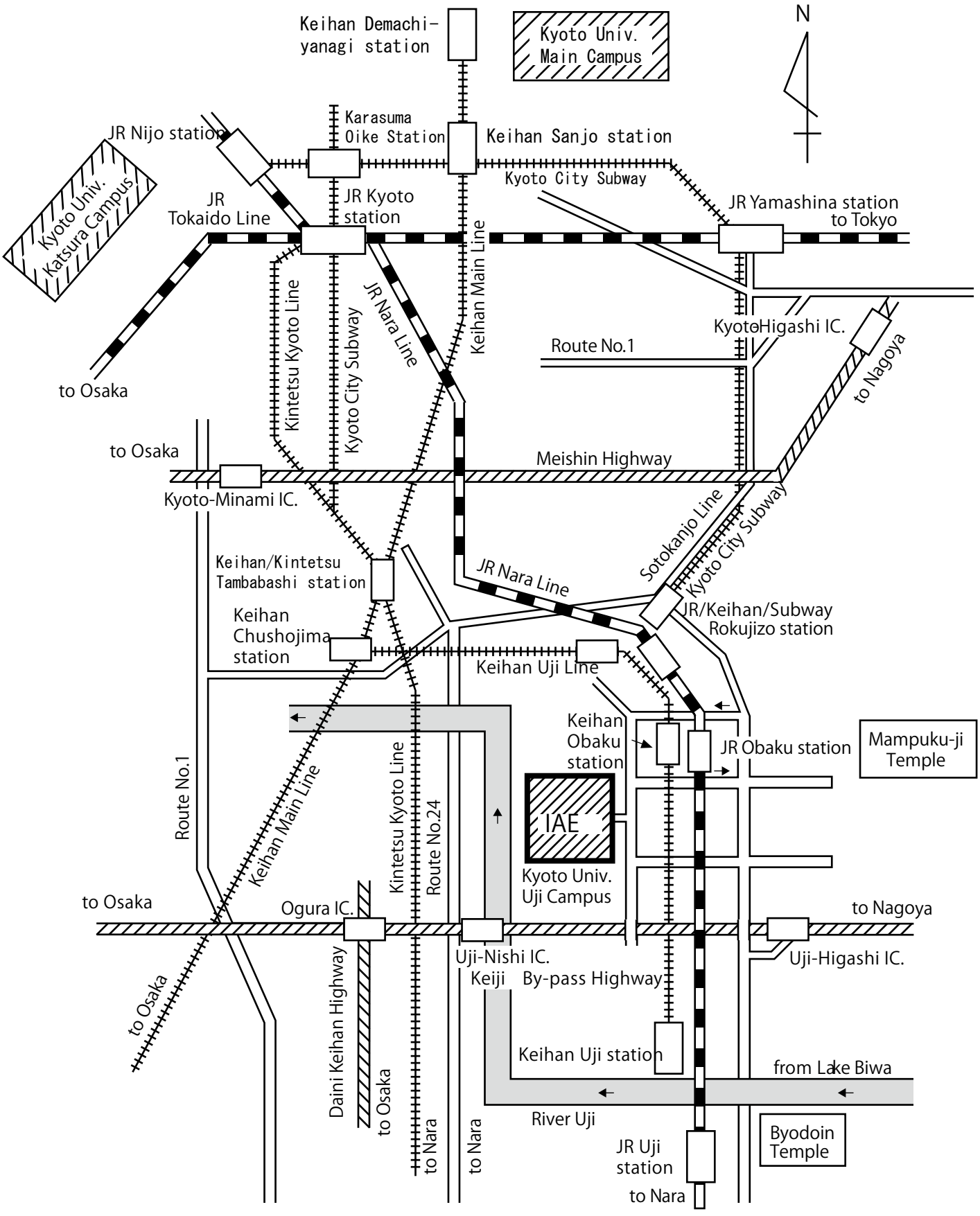
This mode is similar to the standard collaborative research conducted jointly by private companies and university staff under a contract on which both parties agreed. This is not just utilization of the facility but full collaboration on specific subjects.

3. Benefits for companies

- Rapid progress of products development by use of high performance equipments.
- Reduction of expenditure for equipments.
- Rapid exploration 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

6. HOW TO GET TO IAE



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