2. TEXTOR Collaboration

In this fiscal year, TEXTOR operation has been mainly continued for work on plasma-surface interaction (PSI) studies: 3D edge transport modeling, mirror and dust experiments, Tungsten material development, PSI simulation by ERO code and diagnostic development on PSI studies. The collaboration on exploration of Tungsten as a divertor material with Japan is highly evaluated in TEXTOR colleagues. Now it has been recognized again that plasma-wall interaction (PWI) is of great importance for realizing a steady-state fusion reactor. JET has started operation with ITER-like-wall and then the selection of wall material for ITER will be intensively discussed. The TEXTOR collaboration has contributed to a wide range of PWI researches and the activities will be taken over by the new implementing agreement on development and research on PWI facilities by using linear plasma devices, which allow the PWI researches under conditions relevant to DEMO and beyond. The workshop on "Plasma Material Interactin Facilities for Fusion Research (PMIF)" has been established and the second workshop was held at Jülich Research Centre in September 2011. All the activities in this fiscal year are summarized in the following table. Highlights in some of individual programs are described in this report.

Ejection of pre-characterized carbon dust in TEXTOR

Dust studies are important issues related to radioactive impurity accumulations into core plasmas and tritium retentions in thermonuclear fusion devices with magnetic confinement. For understanding dust dynamics, movements using pre-characterized dust particles are analyzed in TEXTOR. Dust particles of spherical glassy carbon are installed and exposed to plasma discharges by the movable limiter. Two kinds of spherical dust, these diameters of 8 and 120 microns, are used in these experiments to compare effective forces of dust dynamics, such as Lorentz, rocket, gravity, friction and electrostatic forces. After dust particles leave their holder due to exposing of plasma, these lifetimes measured by high-speed visible camera are about 1-10 ms.

These dust injection experiments are considered as a demonstration of moving dust particles produced by chemical reactions and erosions. It is also an effective method to investigate a lifetime of dust particles. Lifetimes of dust particles and moving areas related plasma parameters are compared experimental results with theoretical model in the future works.

Three-dimensional MHD equilibrium with resonant magnetic perturbed fields in tokamaks

In recent tokamak experiments, it is noted that stochastic field lines reduce strong heat load driven by the edge localize mode (ELM) to the divertor plate. Stochastic field lines are produced by the external perturbed field and it is called the Resonant Magnetic Perturbation (RMP). However, in present analysis of RMP fields, a vacuum

Japanese Participation in 2011-2012

Subjects	Participants	Term	Key Persons *etc.*
1. PSI studies with test limiters	Y. Ueda (Osaka Univ.)	12. 1. 22- 1. 27	Y. Ueda/ V. Philipps
2. Development of PFM	Y. Kurishita (Tohoku Univ.)	12. 1. 22 - 1. 29	Y. Kurishita / J. Linke
3. Tritium measurement	Y. Torikai (Toyama Univ.) A. Taguchi (Toyama Univ.)	12. 1. 21 - 1. 29	Y. Torikai /V. Philipps
4. DED experiments	T. Shoji (Nagoya Univ.) A. Tsushima (Yokohama National Univ.)	11. 6. 5 - 6. 20	T. Shoji / M. Lehnen
5. Divertor plasma simulation	G. Kawamura (NIFS)	12.1.15 -2.5	Y. Tomita / A. Kirschner
6. Simulation study of tokamak MHD equilibrium with 3D modeling	Y. Suzuki (NIFS)	12. 3. 10 - 3. 19	Y. Suzuki / Y. Liang
7. Carbon dust experiments	N. Ashikawa (NIFS)	11. 5. 1 - 5. 7	N. Ashikawa / A. Litnovsky
8. Tangential X-ray Camera	S. Ohdachi (NIFS)		S. Ohdachi / M. Lehnen
9. He measurements in LHD	H. Funaba (NIFS)		H. Funaba / M. Lehnen

helical perturbed field superimposed on a 2D MHD equilibrium, a so-called vacuum approximation, is widely used. Since the vacuum approximation does not include the plasma response, considerations including the plasma response and its impact are critical and urgent issue.

In this study, as a first step of 3D MHD modeling, the fully 3D MHD equilibrium of non-axisymmetric tokamak is solved numerically and equilibrium responses are studied. We use a 3D MHD equilibrium code HINT2, which is widely used to analyze the 3D equilibrium of helical system plasmas. Since HINT2 uses the real coordinate system, HINT2 can treat magnetic island and stochastic field in the computational domain. 3D MHD equilibrium of DIII-D plasma, which includes the effect of the EFCC (Error Field Correction Coil) and RMP (Resonant Magnetic Perturbation) fields, was studied.

Test limiter experiments in TEXTOR

Melt layer behavior and erosion of tungsten in a strong magnetic field was studied by exposing newly developed tungsten grade; TFGR (Toughened, Fine-Grained, Recrystallized) –W1.1TiC and 3.3TaC. In this campaign, TFGR W1.1TiC and 3.3Tac were exposed to higher heat flux to observe melt layer behavior and structure of resolidified layer.

For the erosion experiment, two TFGR W(1.1TiC and 3.3TaC) were mounted on one roof limiter. For TFGR-W1.1TiC, Ti release from the sample increased significantly at temperatures above about 1500 ˚C, which is very close to the melting point of Ti (1668˚C). Therefore, Ti atoms which were not combined with C (TiC) were released at this temperature. In addition, TiC dispersoids could be decomposed by plasma exposure. But this Ti release decreased with plasma shots and eventually almost stopped. This indicated that Ti existed in only near surface area was released. This will be examined by postmortem analysis. On the other hand, release of Ta was very moderate and was not significantly increased until surface temperature reached the melting temperature of tungsten.

Resolidified surfaces of both TFGR-W grades showed quite different morphologies. For TFGR-W3.3TaC, most of surface was relatively smooth but showed many cracks and blistering. This W grade could be brittle at elevated temperatures. In addition, it could contain some gaseous materials along grain boundaries. On the other hand, for TFGR-W 1.1TiC, surface morphology was very rough with many small pits, which could be formed by the burst of Ti in the bulk at elevated temperatures. More detailed analysis is in progress.

Tungsten material development and characterization

The W-1.1%TiC compacts exhibit recrystallized nanostructures with a large number of effective sinks and appreciable ductility even at room temperature, and is designated as TFGR (Toughened, Fine Grained, Recrystallized) W-1.1%TiC. Given the recent progress in materials research on W-TiC, it is appropriate to assess the alloys under closer conditions to the anticipated ambience in ITER. Furthermore, it is indispensable to develop a fabrication technology in an increased scale for TFG R W-1.1%TiC components with the dimensions needed for the ITER divertor tiles. We have successfully scaled up the available size of TFGR W-1.1%TiC to a tile with the dimensions of 30 x 30 x 8 (mm) to be employed in the ITER divertor. On the other hand, for TEXTOR experiments we have prepared 4 sheets of TFGR W-1.1%TiC and W-3.3%TaC with rather complex shapes. Main purpose of the experiments is qualification of new tungsten grades (doped fine-grain tungsten) with respect to their thermomechanical and PMI properties in tokamak environment. The experiments were quite successfully performed.

Tritium accumulation in tungsten exposed to TEXTOR plasmas

Tungsten (W) is a promising plasma-facing candidate material for limiters installed in future fusion reactors because of such favourable properties as high melting point, low sputtering yield, and low hydrogen solubility. For the final selection of the most adequate type of W-based material, however, further improvement of the present data base is needed. As plasma-facing material, W subjected to low-energy deuterium-tritium plasmas containing carbon impurities.

In this study, the diffusion-induced distribution and accumulation of tritium on W previously exposed to TEXTOR plasmas was examined utilizing the imaging plate (IP) technique. In practice, a sheet of polycrystalline W was placed on the TEXTOR limiter at the ion diamagnetic drift side and exposed to several deuterium plasmas. Subsequently, the W sheet was cut into smaller samples completely avoiding the use of oil. The obtained specimens were then introduced into a vacuum system, annealed at 573 K for 3 h under a vacuum of 10^{-6} Pa and finally exposed to 1.2 kPa of a gaseous D-T mixture at 573 K for 3 h. Tritium concentrations on the specimen surfaces were evaluated by IP.

The IP image technique reveals that tritium is distributed non-homogeneously on the surface of the plasma-exposed and non-exposed W plates, the distribution being different on both sides. It should be noted that the T areal density on the unexposed W sheet is comparable to that of the plasma-exposed side except for a narrow zone close to the centre. In the central part of the plasma-exposed W plates, the T areal density is about 10 times higher than that on other surface area. It is likely that the relatively high concentration of tritium in this small area is caused by a carbon deposition layer containing abundant tritium trapping sites.

Further experiments are under way to expose tungsten (i) to TEXTOR plasmas (D and He plasmas) under a variety of conditions, i.e. low temperature, melting layer, etc and (ii) to D plasmas in a linear plasma generator (MAGNUM, VISION 1 and JAEA Rokkasho, etc.).

(Nakamura, Y.)