2. TEXTOR Collaboration

TEXTOR collaboration experiments in PWI and material research have been going on. In particular, Tungsten material development in Japan is highly evaluated and the collaboration activities are focused on investigation of physical and mechanical properties for application to plasma facing materials (PFM). On the other hand, the linear plasma machine (PSI-2) has been completed at Jülich and first plasma was produced. A new linear plasma machine ("JULE-PSI") will be constructed in future. Now, we are discussing to create a new IEA Implementing Agreement addressing materials and PWI research in TEXTOR Executive Committee Meeting and Domestic Technical Committee Meeting. The International Workshop on Requirements for Next Generation PSI Facilities in Fusion Research (PMTS2010) was held at Oak Ridge National Laboratory in September 2010 and our future PSI research plans were presented. All the activities in this fiscal year are summarized in the following table. Highlights in some of individual programs are described in this report.

Tungsten material development and characterization

Plasma facing materials/components (PFM/PFC) will be subjected to heavy thermal loads in the steady state or transient mode combined with high-energy neutron irradiation that will cause serious material degradation. Tungsten (W) is the most promising for use as PFM/PFC because of its many advantageous properties, and commercially available pure W plates in the stress relieved state are planned to be employed as the divertor material in ITER (International Thermonuclear Experimental Reactor). However, the stress-relieved W plates exhibit much lower recrystallization temperatures (1200~1300°C) than the melting point (3410°C) as well as coarse-grained structures with less amounts of effective sinks for radiation-induced defects. Hence, the anticipated ambience for PFM/PFC to be exposed would cause serious embrittlement to the W plates by recrystallization and radiation. Kurishita and his coworkers succeeded in significantly decreasing the ductile brittle transition temperature of W-1.1%TiC compacts in the recrystallized state by applying a new microstructural modification method based on superplasticity to ultra-fine grained (UFG) W-1.1%TiC: 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.

Kurishita's visit to FZJ this time was also to exchange information on updated progress in the research collaboration. We are pleased to report here that it was very productive in respects that we succeeded in obtaining very noteworthy results of thermal shock tests on TFGR

Japanese Participation in 2009-2010

Subjects	Participants	Term	Key Persons *etc.*
1. PSI studies with test limiters	Y. Ueda (Osaka Univ.)	10. 12. 9 - 12. 19	Y. Ueda/ V. Philipps
2. Tangential X-ray Camera	S. Ohdachi (NIFS)		S. Ohdachi / M. Lehnen
3. Tritium measurement	Y. Torikai (Toyama Univ.) A. Taguchi (Toyama Univ.)	10. 12. 8 - 12. 19	Y. Torikai /V. Philipps
4. DED experiments	T. Shoji (Nagoya Univ.) A. Tsushima (Yokohama National Univ.)	10. 7. 10 - 7. 17	T. Shoji / M. Lehnen
5. Development of dispersion type interferometer	T. Akiyama (NIFS)	10.6.21 - 7.4	T. Akiyama / D. Heiko
6. Development of PFM	Y. Kurishita (Tohoku Univ.)	10. 12. 12 - 12. 19	Y. Kurishita / J. Linke
7. Divertor plasma simulation	G. Kawamura (NIFS)	11. 2. 7 - 2. 19	Y. Tomita / A. Kirschner
8. Simulation study of tokamak MHD equilibrium with 3D modeling	Y. Suzuki (NIFS)	11.3. 6 – 3. 13	Y. Suzuki / Y. Liang
9. He measurements in LHD			H. Funaba / M. Lehnen

W-1.1%TiC together with UFG W-0.5%TiC by using JUDITH 1 (e-beam) operating at FZJ. The tests on such nanostructured W materials were the first in the world: The tests were performed by applying repetitive ELM like loads (n = 100) at various base temperatures (RT, 100°C, 150°C) with a pulse duration of 1 ms and an absorbed power density of ~1 GW/m^2.

Test limiter experiments in TEXTOR

Melt layer behavior of tungsten in a strong magnetic field was studied by exposing tungsten thin plates (2 mm thickness) with gaps. These W plates were installed on a newly fabricated graphite roof limiter. The experiments were performed in the TEXTOR NBI discharges. By placing the limiter at around r ~ 46 cm, melting near the tip of the plates was observed. Melt layers on all W samples behaved similarly as they moved in the direction of JxB force. It was clearly observed that the nano-structure disappeared at around 1500 ~ 1700 K, which took place before the melting. Therefore, because of disappearance of He decorated layer before melting as well as its thinness, it can be concluded that these He induced surface morphology does not affect melt behavior. Detailed analysis of surface morphology of molten layers and comparison with simulation works is planned.

Fine-grained tungsten with TiC dispersoids, developed by Prof. Kurishita in Tohoku University, is attracting an increasing attention because of its low embrittlement under low temperature, recrystallization, and neutron irradiation conditions. We exposed fine-grained W to TEXTOR edge plasma for the study of retention and surface damage under actual edge plasmas. Detailed analysis such as TDS (Thermal Desorption Spectroscopy) and surface observation will be performed. In parallel, we will study retention characteristics by the ion beam device HiFIT in Osaka University.

Tritium accumulation in tungsten exposed to TEXTOR plasmas

Tungsten (W) is one of the candidate plasma-facing materials for future fusion reactors due to its high melting temperature, low sputtering yield and low hydrogen solubility. In this study, we have investigated the tritium accumulation on W exposed to TEXTOR plasmas by using imagine plate (IP) technique.

The tungsten rods are mounted on the TEXTOR limiter and exposed by TEXTOR plasmas. Specimens, 5 mm in thickness, were cut from the rods so that the surfaces of the specimen represent the surface of the rods. The specimens were clean in an ultrasonic acetone bath and put then into a tritium exposed apparatus. The specimens were annealed at 573 K for 3 h in vacuum of 10^{-6} Pa, and then loaded with tritium from D-T mixed gas at pressure of 1.2 kPa at 573 K for 3 h. Tritium concentration along the specimen surfaces was measured by the IP technique and indicated an intensity of the photo-stimulated luminescence (PSL) in PSL $mm^{-2} h^{-1}$. According to the IP images, tritium was retained in the narrow central part of the plasma-exposed rod surface. We suggest the relatively high T concentration in this area is related to a carbon deposition layer, which acts as tritium trapping sites. It should be note that the rod surface was subjected to high flux plasma exposure. Tritium amount in this deposition layer is about 40 times higher than that on other surface area.

Future tasks will be performed to reveal mechanisms responsible for tritium accumulation on plasma-exposed W: Tritium loading of W (i) exposed to the TEXTOR plasmas at various conditions and (ii) W exposed to D plasma in linear plasma generator (FOM, JAEA Rokkasho, etc.) and determination of accumulated tritium by the IP technique.

Kinetic treatment of incident ions on a plasma-facing wall and its effect on the sputtering yield

Main source of impurity generation in a fusion device is originated from divertor plate and the modeling of sputtering is an important issue for impurity transport simulation. The model used in codes like ERO, however, assumes plasma without magnetic field and that can cause underestimation of the yield. In order to analyze the effect of magnetic field, PIC simulation technique was used to obtain velocity distribution function of ions in front of a plasma-facing wall. Statistical information of incident ions was analyzed and then the sputtering yield of deuterium on carbon was calculated from the kinetic information and the sputtering model. The enhancing effect of the yield is significant for large magnetic field angle measured from the surface normal, especially when the angle is larger than 75 degree. The enhancement factor reaches four in the case of nearly parallel magnetic field. On the other hand, the dependence of the yield is very weak when the angle is less than 60 degree. The parameter r_i/l_{De} is ration of the mean ion Larmor radius to the Debye length and stands for inverse of normalized magnetic field strength. Although the effect of the parameter is not significant, small r_i/l_{De}, i.e. strong magnetic field, causes larger yield because of the strong effect on the particle trajectories.

Other Collaborations

Experiments on excitation and suppression of Alfven Eigenmodes (AEs) by using DED coils were carried out and we identified externally excited AEs (TAE) for various plasma parameters (I_p, B_t and n_e) and they reasonably agreed with the theoretical prediction.

A dispersion interferometer is one of the candidates of the density measurement on future fusion device. We investigate the dispersion interferometer on TEXTOR and discuss the difference between systems on TEXTOR and ours. It is found that optical system of TEXTOR and ours are suitable for a fluctuation measurement and a density monitor, respectively.

As a first step of 3D MHD modeling, fully 3D MHD equilibrium of non-axisymmetric tokamak is solved numerically and equilibrium responses are studied. We found the difference of the edge structure between the 3D MHD equilibrium and vacuum approximation.

(Nakamura, Y.)