2. TEXTOR Collaboration

Recently, TEXTOR has two main objectives: (a) serving as a PWI test facility with versatile access and diagnostic options and (b) the scientific exploitation of the worldwide unique Dynamic Ergodic Divertor (DED). On the other hand, Jülich group intends to widen its PWI research activities to nuclear and toxic environments. A linear plasma machine obtained from the Max Planck Institute in Berlin is currently being installed at Jülich as a first test device. Later a new linear plasma machine ("JULE-PSI") will be constructed in the Hot Cells of FZJ. In connection with this plan, we are discussing to create a new IEA Implementing Agreement addressing materials and plasma-wall interaction research in specialized devices such as linear plasma machines. The 12th international workshop on "Plasma Facing Materials and Components for Fusion Applications (PFMC-12)" was held at Jülich Research Centre in May 2009 and several papers were presented based on results of the collaborations. All the activities in this fiscal year are summarized in the following table. Highlights in some of individual programs are described in this report.

DED experiments

The purpose of DED experiments is to excite Alfven eigenmodes (AEs) by superimposing RF current (5A, 50kHz-1MHz) on DED coil and to study damping, stability and suppression of AEs by the magnetic fields perturbation introduced by DC DED current.

In 2009, RF system for AEs excitation was improved to increase more rf current on DED coils in the range of 100-200 kHz where TAEs are expected to be excited. Experiments on the excitation and suppression of AEs in the frequency region of 100-200 kHz were performed for m/n=6/2 DED operation system. It was shown that the TAEs were excited in the frequency range by the small rf current (< 4 A) on DED coils and suppressed by DC DED fields (< 7 kA) depending on plasma and B_t parameters. Detection of fast Mirnov signals (< 500 kHz) was tested to analyze toroidal mode numbers of excited AEs. Furthermore, NBI fast particle induced TAEs were detected and the suppression of the modes were demonstrated by applying DC DED current of ~7 kA. In future, we will make a more statistical investigation of the suppression of AEs with various plasma parameters for m/n=3/1 (and 6/2) DED operation and establish the theoretical model for enhanced damping of AEs by DED fields.

Tungsten material development and characterization

Tungsten (W) is the most promising for use as plasma facing materials (PFM)/components (PFC) and is planned to be applied to the divertor in the international thermonuclear experimental reactor (ITER) because of its high melting point, good thermal conductivity, low thermal expansion coefficients, low tritium inventory, low sputtering yield, etc. However, its use undoubtedly

Japanese Participation in 2009-2010

Subjects	Participants	Term	Key Persons *etc.*
1. PSI studies with test limiters	Y. Ueda (Osaka Univ.)	10. 3. 14 - 3. 21	Y. Ueda/ V. Philipps
2. Tangential X-ray Camera	S. Ohdachi (NIFS)	09. 7. 5 - 7. 12	S. Ohdachi / M. Lehnen
3. Tritium measurement	Y. Torikai (Toyama Univ.) A. Taguchi (Toyama Univ.)	10. 3. 13 - 3. 25 09. 3. 13 - 3. 21	Y. Torikai /V. Philipps
4. DED experiments	T. Shoji (Nagoya Univ.) A. Tsushima (Yokohama National Univ.)	09. 7. 1 - 7. 20 10. 2. 26 - 3. 15 09. 7. 5 - 7. 13 10. 2. 28 - 3. 8	T. Shoji / M. Lehnen
5. Millimeter-Wave Imaging			A. Mase/ A. J. H. Donne
6. Development of PFM	Y. Kurishita (Tohoku Univ.)	10. 3. 14 - 3. 21	Y. Kurishita / J. Linke
7. Divertor plasma simulation	G. Kawamura (NIFS)	09. 10. 4 - 10. 18	Y. Tomita / A. Kirschner
8. Neutral particle transport study in LHD	M. Kobayashi (NIFS)	09. 6. 21 - 7. 5	M. Kobayashi / D. Reiter
9. He measurements in LHD			H. Funaba / M. Lehnen

depends on the degree of improvement in serious embrittlement by high ductile-to-brittle transition temperature, by recrystallization and by neutron and light ion irradiations. It is thus necessary to develop W materials with microstructures capable of mitigating the three types of embrittlement and assess the physical and mechanical properties required for ITER applications.

Kurishita developed nanostructured W-(0.25-1.5)%TiC compacts with ultra-fine grains (50~200nm) and fine TiC dispersoids. Thermal shock resistance is an indispensable property for PFM/PFC, however, nanostructured W-0.5%TiC is presumed to be not tough enough to exhibit good thermal shock resistance because no ductility occurred at room temperature mainly due to insufficient strengthening of weak grain boundaries (GBs) and the presence of residual pores. Such insufficient strengthening of weak GBs resulted in poor resistance to irradiation with 1keV H_3 containing ~0.8%C, which did not cause appreciable blistering but produced many small holes, probably due to ejection of grains. Recently, Kurishita developed a new microstructural control method based on superplasticity and succeeded in producing toughness enhanced fine grained (TFG) W-1.1%TiC in the recrystallized state. TFG W-1.1%TiC possesses strong GBs and hence exhibits an appreciable bend ductility at room temperature and much improved performance against grain ejection by low-energy hydrogen (D) irradiation to $5x10^{25}$ D/m^2 at 573K; no holes on the surfaces of TFG W-1.1%TiC. It is thus worth evaluating the thermal shock resistance of TFG W-1.1%TiC by JUDITH 2 (e-beam) operating at FZJ. Linke will examine the effect of specimen thickness on thermal shock test results for TFG W-1.1%TiC material before this summer.

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. The 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 r ~ 46 cm, melting near the tip of the plates was observed. During two days of experiments, 13 melt shots were made with only two disruptions, though tungsten accumulation was always observed by UV spectroscopy and radiation profile measurement. Bridging over gaps was observed for severe melting conditions. By reversing both toroidal field and plasma current (in order to keep the magnetic structure unchanged), direction of melt layer motion reversed, which clearly indicates that melt layer motion is dominated by JxB force. Detailed analysis of melt layer motion and surface morphology will be made later. Recently, linear plasma simulator experiments showed that surface bubbles and cotton-like nano structures on tungsten were formed by He plasma exposure in the temperature above ~850 °C. We have been studying how the nano-structure changes under actual edge plasma conditions in TEXTOR. Surface nano-structure was produced by high density He plasma exposure with NAGDIS (Nagoya University). In the 2009 campaign, thick and thin fuzz samples were exposed to standard OH discharges (He/D ion density ratio ~50/50) at two different temperatures (~300 °C and ~800 °C). It was found that nano-structures were either eroded or covered by carbon deposit. No growth of the nano-structured layer was observed. In the 2010 campaign, flat W surface and nano-structured surface were exposed to pure D Ohmic plasma to investigate difference of carbon deposition between flat and nano-structured surface and difference of erosion measured by visible spectroscopy. Nano-structure was either eroded or (probably) covered by carbon deposit, which is similar to the 2009 results by He/D mixed plasma exposure. WI visible line from the W surface was not clearly observed because it was very weak. Surface analysis by NRA, XPS, SEM will be made later.

Tritium decontamination of fusion reactor materials

The development of efficient procedures for the decontamination of fusion reactor materials from tritium is a subject of continuing interest for ITER. Within this framework a parametric study on the potential application of autoclaves for the decontamination of stainless steel waste was carried out. Essentially, tritium-loaded type SS316 stainless steel specimens were placed inside of an autoclave containing a defined amount of water and heated to temperatures in the range 393 – 473 K for extended periods of time. Water was added to "trap" released tritium. This is based on the fact that more than 99 % of bulk tritium is liberated from stainless steel as HTO. It could be shown that by and large released tritium is accumulated in the purposely introduced water. The achieved degree of decontamination was estimated from the tritium concentration in the water and tritium depth profiles in the stainless steel specimens. The latter were determined by chemical etching. Tritium in the surface layer of stainless steel remained essentially unaffected by the isochoric thermal treatment in the presence of moist air.

Other Collaborations

The boundary plasma layer is modeled by the one dimensional fluid approach. In order to investigate the redeposition profiles on the first wall near the divertor plate in LHD, the developed boundary plasma modeling is applied to give the boundary condition on plasma facing wall of ERO code, which is developed at FZJ.

The 3D neutral transport code EIRENE coupled with EMC3 is applied to evaluate thermal component of hydrogen neutrals (halo-neutrals) in core plasma produced by charge exchange reaction between neutral beam injection component (40keV) and background thermal hydrogen plasma (~ a few keV) in LHD.

A VUV telescope system is developed in LHD. We can measure 2-dimensional emission profile of CVI, which reflects local electron density fluctuations. It is more suitable to the fluctuation study. We are planning to install a VUV telescope system on TEXTOR.

(Nakamura, Y.)