2. TEXTOR Collaboration

The IEA TEXTOR Implementing Agreement was decided to be amendment. The name of the new IA is "Development and Research on Plasma Wall Interaction Facilities for Fusion Reactors". The objective of this Agreement is to advance physics and technologies of the plasma-wall interaction research by strengthening co-operation among plasma –wall interaction facilities (in particular, by using dedicated linear plasma devices), to enhance the research and development effort related to the first wall materials and components for fusion reactor. The amendment needs the approvals of the participants, and it was approved by US-DOE on 29 May 2013 and by NIFS on 3 September 2013. The approval by European Commission is not yet available. Therefore the amendment to the IA has not been completed. On the other hand, the IEA CERT (Committee on Energy Research and Technology) approved the extension of the TEXTOR IA for the term from 1 July 2013 to 30 June 2018, and the collaboration research activities are not affected by the delay of the amendment. The TEXTOR machine was shut down at the end of 2013 as planned.

In this fiscal year, collaboration on PWI studies and plasma diagnostics were carried out. All the collaboration activities are summarized in the following table. Highlights in some of individual activities are described in this report.

Japanese Participation in 2013-2014

Subjects	Participants	Term	Key Persons *etc.*
Effects of microstructure on deuterium retention in tungsten materials exposed to deuterium plasma	H. Kurishita (Tohoku Univ.)	13. 9. 8 - 9. 15	H. Kurishita / D. Nishijima
Deuterium retention in tungsten exposed to mixed D+N plasma at Magnum-PSI	H.T. Lee (Osaka Univ.)	13. 9. 22 - 9. 29	H.T. Lee / G. Temmerman
Analysis of Be and W Tiles Exposed to Tokamak Plasma	Y. Hatano (Toyama Univ.)	13. 9. 15 - 10. 6	Y. Hatano / A. Widdowson
Collaboration of plasma diagnostic study on Magnum-PSI and Pilot-PSI	M.Yoshikawa (Univ. Tsukuba)	13. 10. 28 - 11. 1	M. Yoshikawa / G. vanRooij
Arcing on W Fuzz Triggered by ELM-like Heat Pulse in the Pilot PSI Device	N. Ohno (Nagoya Univ.)	14. 2. 1 - 2. 9	N. Ohno / K. Bystrov
High-heat and -deuterium particle irradiation study for tungsten at FOM-DIFFER (Pilot-PSI)	M. Tokitani (NIFS)	14. 2. 1 - 2. 9	M. Tokitani / G. Temmerman
Development of plasma-wall interaction modeling for ERO simulation	G. Kawamura (NIFS)	14. 2. 4 - 2. 12	G. Kawamura /A. Kirschner
Tritium loading study of tungsten pre-irradiated to TEXTOR D-plasmas	Y. Torikai (Toyama Univ.)	14. 2. 22 - 3. 2	Y. Torikai / U. Samm

Tritium loading study of tungsten pre-irradiated to TEXTOR D-plasmas

Due to its favourable properties, such as high melting point, low sputtering yield, and low hydrogen solubility, tungsten (W) is a candidate material for plasma-facing high heat-flux structures in future fusion reactors. From a safety point of view, the tritium inventory in plasma-facing materials is one of the important key issues due to the limitation of tritium inventory inside of fusion machines. Tritium accumulation in W pre-irradiated to the TEXTOR D-plasmas and subsequently loaded with tritium was examined by using imaging plate (IP) technique. The distribution of tritium on the surface is rather non-homogeneous. The maximum of the tritium accumulation was found on the surface areas covered with carbon deposition. On the areas without carbon deposition, only little amount of tritium is accumulated and the IP intensity is almost the same as for W without the D-plasma exposures. Tritium accumulation behavior in W pre-irradiated to TEXTOR D-plasmas was compared with that in W irradiated to D-plasmas by the linear plasma generator (LPG) in JAEA and PSI-2 in FZJ. Tritium has accumulated on the plasma-irradiated areas after pre-exposed to the LPG D-plasma. Tritium trapping behavior is quite different between TEXTOR D-plasma irradiated W and LPG D-plasma irradiated W. The D-plasma irradiated W samples in PSI-2 will be loaded to tritium gas and measured tritium accumulation behaviors, and then compare the tritium accumulation behavior with that of W specimens irradiated by TEXTOR and JAEA LPG D-plasmas.

Analysis of Be and W Tiles Exposed to Tokamak Plasma

Tests of ITER reference materials in a tokamak environment have been performed in JET ITER-like wall (ILW) campaigns. Some of beryllium (Be) limiter and first wall tiles, and tungsten (W) divertor tiles were extracted from the vacuum chamber after the first ILW campaign in 2011–2012. In this study, 2-dimensional tritium (T) distributions on those tiles were examined using an imaging plate (IP) technique. Tritium detected in this study was one produced by DD fusion reactions and/or that remaining in the vacuum vessel since previous DT campaigns with carbon walls. Therefore, T was present as a minor isotope of hydrogen in the vessel. To avoid contamination with T and Be, IPs were wrapped with 1.2 or 2 μm-thick polyphenylene sulphide (PPS) films, and then put on the tiles in the dark for 15–21 hours. After removing PPS films, the 2-dimensional distribution of intensity of the photo-stimulated luminescence (PSL) was analysed using a laser scanner. As the results, the distributions of T on the W divertor tiles and Be first wall tiles were obtained, and the distributions are position-dependent. For example, on the vertical divertor tiles, the distributions were quite uniform, whereas those on the "high field gap closure tile" was clearly inhomogeneous. Comparison of these results with those of ion beam analysis and surface morphology observations will allow understanding of the mechanism underlying such non-uniform T distributions.

Effects of microstructure on deuterium retention in tungsten materials exposed to deuterium plasma

It is well known that W exhibits significant embrittlement by recrystallization (recrystallization embrittlement) and by radiation (radiation embrittlement). Efforts to suppress both types of embrittlement in W has leaded to the birth of TFGR (Toughened, Fine Grained, Recrystallized) W-1.1%TiC and TFGR W-3.3%TaC.

Based on a critical review of results obtained so far on W including commercially available pure W and TFGR W materials, during the period of September 9-13 in 2013 Kurishita visited UCSD to clarify the effects of nanostructure on D retention in W materials by using the linear divertor plasma simulator of PISCES-A. The simulator allows D ion bombardment at low energy, high flux (~10^{22} $m^{-2}s^{-1}$), high fluence and moderate temperature (~573 K). The W samples used for this study are TFGR W-(1.1-1.2)%TiC and W-(2.2-3.3)%TaC with 10 kinds of different microstructures due to slightly different fabrication processes, which were prepared in 2012 fiscal year. The microstructural effects on D retention will be thoroughly examined and reviewed for the irradiated W samples.

Arcing on W Fuzz Triggered by ELM-like Heat Pulse in the Pilot PSI Device

The fuzz structure on W (fuzz W) becomes an important issue for the usage of W as plasma-facing materials in ITER because it degrades the property of W. It is also found in the linear device NAGDIS-II that arching on the fuzz W is easily initiated by pulse laser irradiation. In tokamaks, arching on the fuzz W could be triggered by heat plasma pulse due to Edge Localized Modes (ELMs). However, there has been no systematic investigation on arching triggered by plasma heat pulse. We have demonstrated arching on fuzz W triggered by ELM-like heat pulse in the Pilot PSI device. The surface temperature of the fuzz W increases up to 1600 ℃ from 700 ℃ due to the heat pulse. In some cases, arching triggered by the heat pulse was clearly observed. Arching spots are mainly observed at the peripheral area of the W sample, which could be associated with radial profile of sheath potential. Detailed surface observation of the W sample by SEM and analysis of threshold value of heat pulse to trigger arching are ongoing.

Development of plasma-wall interaction modeling for ERO simulation

Impurity ions coming from SOL to divertor plates are primary source of sputtered impu-rities in ERO simulation. That implies the importance of the sputtering yield by the back-ground ions in the plasma. However, their flux and incident angle distribution have to be calculated from fluid quantities like density and temperature. An enhancement effect of inclined magnetic field on sputtering yield was clarified in our previous works. A solution for that is a preparatory ERO simulation to calculate the incident angle and energy distri-bution. However, the electric field distribution in the plasma is given by a simple model and is not consistent with magnetic field and wall biasing. PIC (particle-in-cell) simulation is necessary to take them into account. Comparisons of the incident angle and the energy distributions between the ERO and PIC simulation were carried out. The incident angle distribution of ERO and PIC simulation agrees to a certain extent, but the energy distribution has larger discrepancy. PIC simulation gives much larger energy of hydrogen ions than ERO. The difference is caused by the initial velocity distribution of injected ions into the simulation box.

Other collaborations

Examination of the D retention in tungsten (W) exposed to mixed D+N plasma at divertor relevant fluxes was conducted in the Magnum-PSI. The change of microstructure due to the high flux deuterium plasma irradiation at relative low temperature (~200°C) and high ion energy (~60 eV) case is observed in Pilot-PSI. For the first step of the development of 2D density measurement system in linear devices in DIFFER, the frequency multiplier type 70 GHz microwave interferometer system developed in GAMMA-10 was sent to DIFFER and installed in Pilot-PSI.

(Masuzaki, S.)