2. TEXTOR Collaboration

Discussions on the amendments of TEXTOR Implementing Agreement have been carried out in the Executive Committee Meeting for these past three years. As a result, we decided a new name (“Development and Research on Plasma Wall Interaction Facilities for Fusion Reactors”) and a new scope of post TEXTOR IA. 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 a fusion reactor. This work has been progressing with keeping an eye on the prolongation of TEXTOR IA in June 2013. The TEXTOR machine will be shutdown in the end of 2013. In this year, two types of collaboration activities have been done. One is collaboration experiment with TEXTOR. The other is collaboration on PWI studies with linear plasma devices. The workshop on “Plasma Material Interaction Facilities for Fusion Research (PMIF)” was held at Tsukuba Plasma Research Centre in August 2012. All the activities in this fiscal year are summarized in the following table. Highlights in some of individual programs are described in this report.

Tritium accumulation in tungsten exposed to TEXTOR plasmas

Tungsten (W) is a promising candidate of plasma facing material in future fusion reactors because of such favourable properties as high melting point, low sputtering yield, and low hydrogen solubility. In this study, the retention of tritium in tungsten pre-exposed to deuterium plasmas of low energy in the limiter region of TEXTOR was compared with that retained in materials exposed to deuterium plasmas in the target region of the linear plasma device JAEA BA.

In TEXTOR, tungsten specimens were placed on the limiter in such a way that the top of the specimen was 47 cm and the bottom 50 cm from plasma centre. At this position they were exposed consecutively to several deuterium plasmas. Another tungsten samples were exposed to deuterium plasmas in a linear plasma device. Both samples were treated with deuterium-tritium mixtures in the same manner. The accumulation of tritium on the surface of the various W specimens was visualized by the imaging plate (IP) technique, which can deliver interesting information on the formation of trapping sites for tritium. The IP images of the plasma facing side of specimens show that the distribution of tritium on the surface is rather non-homogeneous. This is attributed to tritium accumulation in zones having a carbon deposition layer. In zones without carbon deposition, only little tritium has accumulated, the level being almost same as on non-exposed tungsten. On the other hand, the specimens in a linear plasma device were exposed to deuterium plasmas at 495, 545 and 550 K, respectively. The IP images show

Japanese Participation in 2012-2013

Subjects	Participants	Term	Key Persons *etc.*
1. PSI studies with linear plasma devices	S. Kajita (Nagoya Univ.)	12. 9. 25 - 10. 4 13. 3. 9 - 3. 17	S. Kajita / G. Temmerman
2. Development of PFM	Y. Kurishita (Tohoku Univ.)	13. 1. 26 - 2. 1	Y. Kurishita / J. Linke
3. Tritium retention	Y. Torikai (Toyama Univ.) A. Taguchi (Toyama Univ.)	13. 1. 26 - 2. 1	Y. Torikai / V. Philipps
4. Divertor plasma simulation	G. Kawamura (NIFS)	12.10.23 -10.29	Y. Tomita / A. Kirschner
5. Simulation study of tokamak MHD equilibrium with 3D modeling	Y. Suzuki (NIFS)	12. 5. 27 - 6. 2	Y. Suzuki / Y. Liang
6. Design study of compact DC plasma discharge system	N. Ohno (Nagoya Univ.)	12. 11. 14 - 11. 22	N. Ohno / U. Samm
7. PWI studies with W materials	M. Tokitani (NIFS)	13. 12. 9 - 12. 16	M. Tokitani / G. Temmerman
8. Development of plasma diagnostics in linear plasma devices	M. Yoshikawa (Tsukuba Univ.)	13. 3. 11 - 3. 16	M. Yoshikawa / G. vanRooij

only tritium accumulated on the plasma facing side. The degree of tritium accumulation increases with temperature. This behaviour, which is quite different from that observed with TEXTOR samples. It may be explained by the influence of plasma temperature, plasma flux, plasma composition and energy of the particles hitting the surface.

Tungsten material development and characterization

We have developed nanostructured, TFGR (Toughened, Fine Grained, Recrystallized) W-TMC (TMC: TiC, TaC) with a high density of dispersoids and grain boundaries that are significantly strengthened by enrichment of the TMC components. The purpose of this study is to fully characterize the TFGR W-TMC for their PFMC applications through domestic and international research collaborations.

Firstly, we have found that enhancement in D retention due to displacement damages caused by 2.4MeV Cu ion irradiation is much more suppressed in TFGR W-1.1%TiC than in Pure W. This result is very important for the safety issue in light of radiation tolerance, and more comprehensive studies are in progress. Secondly, we have established more efficient methods for fabrication of TFGR W-1.1%TiC/W-3.3%TaC because the fabrication methods that we have already developed and employed so far are time-consuming. Lastly, in 2012-TEXTOR experiments we have continued studies on qualification of TFGR W-1.1%TiC and W-3.3%TaC with respect to their thermo-mechanical and PWI properties in the tokamak environment. As a continuation of 2011-TEXTOR experiments, 2012-TEXTOR experiments were performed to study the behavior of erosion and D retention in TFGR W-1.1%TiC and W-3.3%TaC at 2000~2500C, during the period of January 28-February 1.

Development of simulation modeling of LHD boundary plasma and plasma-wall interactions

Plasma and impurity transport is one of essential physical issues in engineering of fusion devices. Two simulation-modeling studies related to impurity transport have been progressed and are reported here briefly.

Impurity ions coming from SOL to divertor are primary source of sputtered impurities in transport simulation code including ERO. That implies the importance of sputtering yield by the background impurities in 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 by hydrogen bombardment was clarified in our previous work.

In order to investigate the effect for impurity ions, we developed a particle tracing code to obtain incident angle and energy distribution in pre-calculated electric field by PIC simulation. The enhancement effect of inclined magnetic field in the case of carbon self-sputtering is observed. Since the effect is caused by large incident angle due to gyration, larger q/m leads to larger enhancement. Ion mass and charge are denoted by q and m, respectively. In the case of tungsten self-sputtering, which has smaller q/m ratio than carbon, the dependence on the magnetic field angle is weaker.

Dynamics of impurity depends significantly on plasma profiles and surface geometry. Three-dimensional calculation of LHD boundary plasma can be essential for impurity transport studies. A technical issue in distorted mesh of vacuum region has been solved and extension of a global fluid-simulation code EMC3-EIRENE to divertor legs has done. The electron temperature distribution in the edge and divertor legs is investigated. The following conditions are used; inward-shifted configuration, 8MW input power, $2x10^{19}/m^3$ fixed electron density at inner boundary and Bohm condition at divertor plates. It is confirmed that the distribution in the edge is connected to those of the legs without numerical discontinuity. Development of closed divertor simulation is in progress. Three-dimensional plasma distribution is essential for impurity transport simulation. ERO simulation with background plasma given by EMC3-EIRENE is a future issue.

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, which is called the Resonat Magnetic Perturbation (RMP). From the viewpoint of the RMP experiment, an important subject is the experimental study of the plasma response. In this study, as a first step of the identification of the plasma response, the experimental study of the heat load on the divertor is studied in the JET. Then the divertor heat load is modeled by a 3D particle simulation. The divertor heat load is measured by the Infrared Camera. In the experiments, changing of the heat load is clearly observed with superposed the RMP field. This suggests the splitting of flux tubes on the X-point. The heat load pattern on the divertor plate is compared with the footprint pattern by the particle simulation of electrons for the vacuum approximation. Clear differences are found. This suggests the plasma response reflects the magnetic topology. As next step, we will study particle simulations based on the 3D MHD equilibrium calculation by the HINT2.

Other collaborations

Discussions on new research plans under a post TEXTOR agreement have been started. In order to utilize this post-TEXTOR agreement effectively and to contribute to studies of the edge plasma and plasma-wall interaction toward ITER and DEMO, an attractive joint research plan, which employed the feature of the linear divertor plasma simulators of each country efficiently, should be established. First of all, collaborations on PWI studies with W materials and plasma diagnostic studies with 2D microwave interferometry and reflectometry have been started.

(Nakamura, Y.)