USBPO U.S. BURNING PLASMA ORGANIZATION

eNews

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Dear Burning Plasma Aficionados:

This newsletter provides a short update on U.S. Burning Plasma Organization activities. E-News is also available online. Comments on articles in the newsletter may be sent to the Editor (Tom Rognlien) or Assistant Editor (Rita Wilkinson). Thank you for your interest in Burning Plasma research in the U.S.!

Director's Corner by Jim Van Dam

A Personal Message

Last week on Wednesday (June 8), the U.S. Department of Energy announced that I am to become the new Director of the Research Division of the Office of Fusion Energy Sciences, effective September 11, 2011.

It has been my sincere pleasure to serve you as Director of the U.S. Burning Plasma Organization for the past four years. I have greatly appreciated working with all of the wonderful people in the USBPO Council, the Research Committee, and the Executive Committee, as well as with our very capable Administrator and Communications Coordinator.

The new position at the Department of Energy will be an exciting challenge. I believe in the vision for fusion power and the significance of plasma physics, and I hope to contribute to the US and international programs in fusion energy science.

The support of the Office of Fusion Energy Sciences for the USBPO over the years has been invaluable. I have talked with the Office about the process for selecting the next USBPO director. According to the USBPO Bylaws: "*The USBPO Director is appointed by and serves at the pleasure of the Associate Director of the OFES. The USBPO Council will be called upon to develop a slate of candidates to aid in the selection of the person to serve in this position*." You will be hearing more about this later. In the meantime, DOE has requested (and I have agreed) that I continue with the USBPO until I start at USDOE.

USBPO Council Election Results

The Council has a total of 12 members, and each year four of them finish their terms of service and rotate off. This year, the retiring members are Lee Berry, C. S. Chang, Martin Greenwald, and Mike Ulrickson. They have served the Council—and, by extension, the US fusion program—with distinction. We sincerely thank them for their extremely valuable contributions and their dedication.

The USBPO Council recently held an election for new members. The election was carried out with a web-based system provided by the University of Wisconsin, under the competent oversight of Jim DeKock (USBPO Communications Coordinator) and Rita Wilkinson (USBPO Administrator). Ballots were distributed electronically on May 20 and the voting closed on June 4, with 149 regular members of the USBPO casting ballots, slightly less than last year.

Of the four new Council members each year, two are elected and two are appointed. This year, it's a pleasure to welcome Chris Hegna (Wisconsin) and Tom Rognlien (LLNL) as newly elected members of the Council, and Jerry Hughes (MIT) and Don Spong (ORNL) as newly appointed members, all with three-year terms. Congratulations to all of them.

I'd also like to thank the members of the Council's Nominating Committee, chaired by Lee Berry, for their good work in broadly soliciting nominations and then coming up with a slate of well-qualified candidates.

USBPO Topical Group Leadership Rotation

The terms for the USBPO Topical Group leadership positions are staggered so that half of the leaders' terms expire each year. This year, vacancies will open in the leadership of the following groups:

Topical Group	**Outgoing Leader**	**Current Deputy Leader**
Energetic Particles	Donald Spong (ORNL)	Eric Fredrickson (PPPL)
Fusion Engineering Science	Richard Nygren (SNL)	Larry Baylor (ORNL)
Operations and Control	David Gates (PPPL)	Michael Walker (GA)
Pedestal and Divertor/SOL	Tom Rognlien (LLNL)	Tony Leonard (GA)
Plasma-Wave Interactions	Steve Wukitch (MIT)	Gary Taylor (PPPL)

The current leaders for these Topical Groups will rotate out. The current deputy leaders may become the new leaders.

I'd like to express sincere gratitude to the outgoing Topical Group leaders—Don Spong, Richard Nygren, Dave Gates, Tom Rognlien, and Steve Wukitch. The Topical Groups are the "working core" of the USBPO, and these leaders have provided very positive and beneficial representation for these various topical science areas. Three of them also serve as ITPA topical group members. We have definitely appreciated their many contributions.

The members of these five Topical Groups are being asked for nominations. Please feel free to contact the respective outgoing leaders with suggestions.

USBPO Activities at APS-DPP Meeting

The US Burning Plasma Organization is developing the agenda for a contributed oral session on ITER-related research at the 53rd Annual Meeting of the Division of Plasma Physics, which will take place in Salt Lake City, Utah, on November 14-18. If you or somebody from your institution is interested in making a presentation in this session, please send the title and the author's contact information to Chuck Greenfield and Mike Mauel as soon as possible (and no later than June 30). Also, the abstract itself should be submitted via the conference website no later than 5:00 PM Eastern Daylight Time on July 15. Please indicate "Research in Support of ITER" in the placement requests box for the abstract. The DPP Program Committee may place abstracts that are not selected for the ITER session into other sessions.

As in previous years, the USBPO also plans to organize an evening ITER Town Meeting at the 2011 APS-DPP Meeting. More details will be forthcoming as speakers are lined up.

Fusion Miscellany

Pat Boone continues to write columns in *World Net Daily* about fusion energy:

- June 4: "The Holy Grail of energy: Nuclear Fusion"
- May 28: "A brief history of nuclear fusion"
- May 7: "Fusion: Nature's choice for energy"
- April 9: "Fusion: Our 1st, Best, and Only Hope"

As a new feature, the ITER web site now has a Frequently Asked Questions page. If you prefer to learn about ITER on Facebook, click here.

USBPO Topical Group Highlights

(Editor's note: THE BPO Engineering Sciences Topical Group works to inform the members of the BPO of ongoing efforts in fusion technology and the relationship to research in other areas of the fusion program [leaders are Richard Nygren and Larry Baylor]. This month's highlight summarizes a measurement of wall erosion in the EAST tokamak that is a coordinated activity involving ITER, Sandia, the University of Toronto and the Chinese Academy of Science Institute of Plasma Physics. BPO members are welcome to propose future Research Highlight articles to the editor.)

EAST erosion/deposition experiments

W. R. Wampler *(Sandia National Laboratories, Albuquerque);* ***G. Xianzu*** *(Academy of Science, Institute of Plasma Physics, Hefei);* ***R. Pitts, S. Carpentier-Chouchana*** *(ITER Organization, Caderache);* ***P. Stangeby*** *(University of Toronto, Toronto)*

Erosion and co-deposition of tritium onto the first wall and divertor in ITER are concerns that have prompted extensive analysis and evaluation. A recent initial experiment in EAST, the superconducting tokamak at the Chinese Academy of Sciences Institute of Plasma Physics in Hefei, is providing benchmark data on erosion for the ITER Project as well as practical experience that will help in the plans for subsequent experiments. The activity is a collaboration between Richard Pitts and Sophie Carpentier-Chouchana at ITER, Bill Wampler at Sandia, Gong Xianzu at the Chinese Academy of Sciences, Institute of Plasma Physics (ASIPP) in Hefei, and Peter Stangeby at the University of Toronto and a frequent collaborator on the DIII-D tokamak at General Atomics. The goal of the experiments is to obtain data from plasma exposure to compare with results from LIM-DIVIMP and also ERO code simulations being performed for ITER with realistic configurations for the ITER first wall panels. This work is motivated by the concern that erosion and re-deposition of beryllium near the secondary magnetic X-point at the top of the main chamber might increase tritium inventory in ITER.

EAST has moveable start-up limiters made of graphite tiles coated with silicon carbide (SiC). An initial test of the concept for the erosion experiment used these limiters with their existing tile geometry but with four of the tiles modified by depositing a carbon film over a tungsten coating that acts as a depth marker. Figure 1 shows the interior of EAST and the four tiles on the start-up (SL) limiter. Existing diagnostics measure the plasma edge conditions. The resulting data on erosion represent an average over the exposure to plasma discharges totaling 37,100 s in the 2010 campaign. This eNews article reports as yet unpublished data that has been provided to ITER and discussed among the collaborators.

Figure 1. Interior of EAST (top) with location of startup-limiter; closeup of limiter (bottom) with coated tiles (S1 ... S4) indicated.

The critical measurement of erosion is the change in thickness of the thin carbon film. ASIPP sends the tiles to Sandia for deposition of the carbon film and the tungsten layer, and for measurements of the thickness of the carbon layer before and after the exposure in EAST. Deposition of a C over-layer ~1 µm thick follows initial vapor deposition of a tungsten layer ~1 nm thick. The thickness of the deposited C layer is measured using Rutherford backscattering (RBS) at the 3 sets of 9 points shown in Fig. 2. The points lay along a centerline down on the face of the tile and two other lines offset by 23 mm.

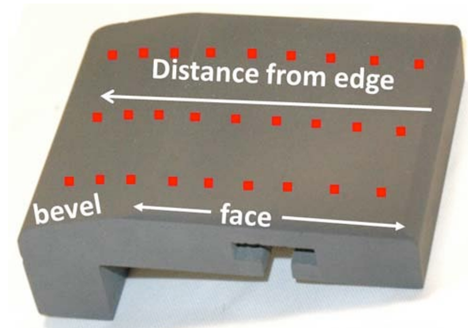

Figure 2. Pattern for Rutherford backscattering scans on EAST tile.

Rutherford backscattering provides measurements of energy loss by He^4 ions, initially at 2 MeV, that penetrate the surface and scatter back into a sensor that analyzes particle energy. The amount of the energy loss depends on the thickness (and stopping power) of the material from the front surface to the depth from which the He^4 scatters.

The upper plot in Fig. 3 shows RBS spectra for tile S2 before exposure in EAST. Also shown are the spectra from the tile before coating (heavy red curve) and from a reference sample of graphite with a thin tungsten coating on the surface (heavy blue curve). The step in the signal near 1200 keV corresponds to beam particles scattered from silicon at the surface. The step near 500 keV is due to scattering from carbon at the surface. The carbon over-layer causes an energy loss ΔE for particles scattered from tungsten and silicon on the coated tile. The heavy black curve is a simulation using SIMNRA [1]. The thickness of the carbon over-layer is determined by matching the energy shift ΔE in the simulated backscatter spectra. The variations among spectra from the individual spots (indicated in the legend) are mainly due to small variations in thickness of the deposited carbon layer.

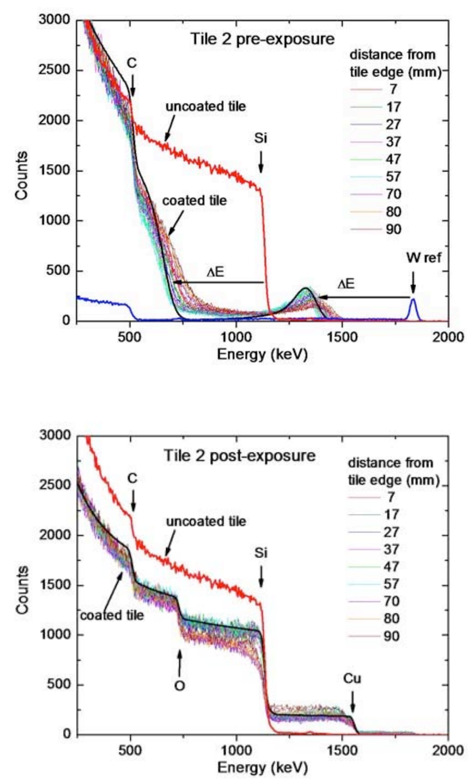

Figure 3. Rutherford backscattering data from pre- (top) and post-erosion (bottom) measurements at the same positions on tile S2.

The bottom plot in Fig. 3 shows post-exposure measurements for the same tile and locations. The second set of measurements were done after Bill Wampler and co-workers relocated equipment from their previous lab into Sandia's new Ion Beam Laboratory [2]. The long exposure time in EAST eroded much of the carbon layer. On a fine scale, due to the peaks and valleys associated with surface roughness, simultaneous erosion and deposition occurs [3].

The height of the Si edge signal gives the fractional area within the beam spot that is bare SiC. The Si feature in Fig. 3 shows that the carbon over-layer was completely removed from about 50% of the area. The additional RBS edges that appear in the post-exposure plot indicate that deposits containing C, O, and transition metals (Cr-Cu) cover the remaining half of the area. The deposited material has an average metal concentration of 0.6-3% of the atoms. The erosion and re-deposition process is fairly uniform over the four tiles.

The large amount of erosion means that only a minimum erosion rate can be deduced from the initial experiment. A planned follow-on experiment will take advantage of a new materials evaluation system on EAST that has a retractable probe similar in concept to the MiMES mid-plane materials probe on the DIII-D tokamak. The ASIPP staff expects to have this probe operational for the next campaign in October. The size of the probe (300×200 mm) permits exposure of fairly large targets to the plasma, and with a retractable probe, surface experiments of short duration will permit better control of the plasma conditions during the exposure.

References

[1] SIMNRA: http://home.rzg.mpg.de/~mam/

[2] For capabilities of Sandia's new Ion Beam Lab, see: http://www.sandia.gov/pcnsc/departments/iba/ibatable.html

[3] K. Schmid et al., Nuclear Fusion **50** (2010) 105004.

ITPA Reports

Summary of the 6th meeting of the ITPA Transport and Confinement Topical Group, San Diego, CA

Stan Kaye *(Princeton Plasma Physics Laboratory)*

The 6th meeting of the Transport and Confinement (T&C) ITPA meeting was held at General Atomics, San Diego, CA on April 4-5, 2011. This two-day meeting immediately preceded the Joint US-EU Transport Task Force meeting, also held in San Diego, and most of the attendees of the ITPA also attended the TTF. Since the focus of the TTF meeting was on physics results, the ITPA meeting concentrated on specific group tasks and action items.

The meeting started with two talks by G. Xu and S. Yoon on the first high-confinement (H) mode results in superconducting EAST and KSTAR tokamaks, respectively. EAST H-modes were routinely obtained after lithium conditioning of the vessel walls. H-modes with durations of up to 6.4 s with energy confinement enhancement factors of $H_{98y,2}$~0.9 have been obtained. Stationary H-modes up to 3.6 s in duration were also obtained. Requirements for ease of access to the H-mode included outer separatrix-to-limiter gap optimization, local gas puffing near the lower-hybrid (LH) wave launcher for improved coupling, early divertor configuration to reduce radiation, and gas puffing during the discharge current (I_p) ramp to reduce energetic runaway electrons. Both Type I and Type III edge localized modes (ELMs) were observed, along with something called "Mossy" (as opposed to "Grassy") ELMs. Geodesic acoustic modes (GAMs) were found to disappear after the transition into H-mode. KSTAR has had approximately 30 H-mode discharges, all in a double-null divertor configuration. The threshold auxiliary power required is consistent with that given by the Martin '08 scaling, and $H_{98y,2}$ is found to be 1.3 to 1.5, although more detailed analysis of these plasmas has to be done to confirm the enhanced confinement. Observed in the KSTAR H-modes were high frequency ELM precursors, edge localized filaments and non-local transport induced by ELMs.

Inter-machine comparisons

A number of presentations where given of progress on inter-machine comparisons and possible contributions to upcoming international meetings. In short summary format:

Joint Experiment/Joint Activity Results

1) L-mode to H-mode (L-H) transition database (J. Hughes)
2) TC-1 – Beta Scaling of Confinement (C. Petty)
3) TC-11 – Impurity and He Transport (C. Angioni)
4) TC-15 – Dependence of Momentum Transport on Collisionality (T. Tala)
5) TC-17 – Intrinsic Torque (W. Solomon)
6) TC-18 – I-mode AUG/DIII-D/C-Mod Similarity Expt (F. Ryter)
7) TC-18/19 – I-mode on C-Mod (J. Rice)
8) TC-9 – Rotation Reversals and Saturated Ohmic Confinement (J. Rice)

Discussion of H-mode Workshop and IAEA Papers

1) TC-2 – L-H and H-L Hysteresis for H98y,2~1 (Y. Martin)
2) Momentum Database (M. Yoshida)
3) TC-4 – Isotope Scaling of L-H Threshold (P. Gohil)

<u>Stellarator/Tokamak Joint Work Activities</u>

Following up joint activities of the stellarator/heliotron working group (CWG) with the T&C group, a session on joint activities and proposals for joint experiments and analysis was held. Specific requirements from current issues in tokamak transport and confinement benefitting from experiments in inherently 3D devices were discussed aiming at specific actions.

To employ the flexibility in 3D magnetic configuration, C. Hidalgo pointed out the influence of magnetic topology effects (field-line stochasticity, rational magnetic surfaces) in the interplay between equilibrium radial electric fields and zonal flows. Also aiming at a general understanding of zonal flows, the characterization of mean and fluctuating radial electric fields as a multiscale effect in tokamaks and stellarators involving isotope dependence has been proposed. Also utilizing the 3D configurational flexibility, investigations of joint probability distributions of fluctuations in gradients and radial transport (tokamaks vs stellarators) to reveal the roles of edge magnetic shear and plasma parameters have been proposed. Discussing the role electron versus ion dominated transport on profile stiffness in stellarators showed the necessity of a more comprehensive revision of existent data and results.

K. Tanaka reported comparative studies between ELMy and ELM-free L-H transitions in the LHD stellarator and the DIII-D tokamak. Differences were found in the triggering mechanism of the transition: in LHD, plasma effects cause the transition whereas in DIII-D external perturbations can suppress the ELMs. Also differences in the particle transport were found: a reduction in LHD with reduced fluctuation level in contrast to an increase in DIII-D with increased fluctuations. G. McKee surveyed the complementary configurations of 3D magnetic field coil systems on various tokamak and spherical torus (ST) experimental devices (DIII-D, NSTX, MAST & AUG), and the similarities and differences in transport responses between the various experiments. Understanding the importance of the physics of 3D-induced transport in tokamaks is critical to the pending ITER decision (coming in June, 2012) on whether to install internal 3D magnetic coils. The increase and spatially varying dynamical response of turbulence to applied 3D fields as measured in DIII-D with beam-emission spectroscopy (BES) and Doppler backscattering (DBS) was presented, along with increased particle transport rates obtained from gas-puff modulation and fast plasma profile reflectometry. Understanding the link between the increased turbulence, enhanced transport and ELM suppression is a key near term goal that can benefit from strong tokamak-stellarator research linkage.

In a general discussion, a set of joint actions of the T&C group and the stellarator/heliotron working groups was discussed. Highest priority was given to fluctuations and transport driven by 3D fields (stability assessments, variations of plasma parameters in different magnetic and divertor configurations).

<u>Discharge Ramp-Up Model Validation</u>

Since the last meeting, data for four ITER-similar, current-ramp Alcator C-Mod discharges have been added to the Profile Database. Some discharges include ion cyclotron resonant heating (ICRH) during the discharge current ramp-up, and one includes a ramp-down. Five modelers have begun benchmarking their independent implementations of the 'mixed Bohm-gyroBohm' transport model; the Plasma Operation group at the ITER Organization (IO) recently provided a file-sharing site for this benchmark activity. The next step will be to benchmark time-dependent predictions of electron temperature (T_e) during a simulated ramp-up, and to benchmark predictions of current profile evolution based on experimental T_e profiles. Data from EAST's slow current-ramps may be suitable for this validation activity; this is being discussed.

J.M. Park has used the TGLF and GLF23 transport models (with and without paleoclassical transport) to simulate ITER-similar current-ramp discharges in DIII-D. As is often reported for current ramps, the GLF23 model predicts higher edge temperatures than are measured, and the TGLF model has the same characteristic. Adding the paleoclassical contribution reduces the electron temperature for radial positions in the outer half of the cross-section ($r > a/2$), and the internal inductance is more similar to the measured value.

I. Voitsekhovitch summarized the activities of the EU's ITER Scenario Modeling (ISM) group. Current-ramp simulation has been used as a benchmark of the European Tokamak Solver (under development by the ISM group). While the Bohm-gyroBohm model works fairly well for hot JET discharges with slow current-ramp rates, it does poorly in discharges with higher density and lower T_e. In simulations of current penetration based on measured T_e, the magnetic safety factor on axis, q(0), often falls faster than in the experiment if neoclassical resistivity is used together with a flat radial profile for Zeff. The q(0) evolution can be well modeled if the Zeff profile is centrally peaked in some ohmic JET discharges, but is peaked off-axis in some ICRH JET discharges; measured Zeff profiles are clearly needed for validation work.

D.C. McDonald outlined a computational strategy for self-consistent ITER simulations with L-H and H-L transitions with the goal of learning how shape-control systems respond to rapid changes in stored energy induced by the transport dynamics of L-H and H-L transitions. The current transition model does not fully reflect the behavior of actual discharges, but it has qualitatively illustrated the plasma control issues. Darren proposed a limited study involving AUG, C-Mod, DIII-D and JET concentrating on 0D analysis of one to two shots from each machine.

<u>Turbulence in the Region between Plasma Core and Edge</u>

A session on the physics of turbulence and transport in the core-to-edge transition region has been motivated by the observation that, still today, simulations in this plasma region, even with the most recent and comprehensive theoretical models, often yield fluctuation levels and heat fluxes which are well below those measured experimentally. This disagreement is likely to be the consequence of missing physical ingredients and/or insufficient spatial resolution at some scales in presently applied models. This problem is not only of high relevance for the understanding of turbulent transport, but it also implies a severe limitation in the transport modeling of many tokamak scenarios, particularly those of current-ramp phases, with evident negative consequences in our present prediction capabilities of critical parameters like the internal inductance during these critical phases of a plasma discharge. The session was structured around two review talks, one by L. Schmitz who reviewed the recent progress in several devices with the possibility of diagnosing fluctuation levels and turbulence characteristics in this plasma region. The second talk by C. Bourdelle reviewed the instabilities and turbulence types that have been found in previous theoretical studies to be potentially responsible for fluctuations and turbulent transport in this plasma region. In addition, in shorter presentations, R. Waltz showed the unsuccessful attempts performed so far with GYRO to reproduce the edge fluctuations levels and heat fluxes obtained in a well diagnosed L-mode discharge in DIII-D and G. Dif-Pradalier has discussed the possibilities of a flux driven global code like GYSELA in addressing some issues of this problem.

Future meetings

The next T&C meeting will be held in Cadarache, France on Wed.-Fri. Oct. 5-7, 2011, just prior to the H-mode Workshop, which will be held at Culham Lab, UK.

Summary of the 15th meeting of the ITPA Divertor and Scrape-Off Layer Topical Group, Espoo, Finland

Bruce Lipschultz *(Massachusetts Institute of Technology)*

For its 15th meeting, members of the ITPA Divertor and Scrape-off Layer (DivSOL) Topical Group (TG) gathered from 16 – 19 May in Espoo, Finland at the Dipoli Congress Centre. This meeting is the first time the group has met in Finland and is a reflection of the now firmly established presence of the hosts, Aalto University and VTT Technical Research Center, in the field of plasma-wall interactions (PWI). Meetings of the DivSOL TG are traditionally extremely well attended, reflecting the size of the PWI and edge physics community, and this 15th assembly was no exception with more than 60 participants. The summary below is divided into the main topics discussed at the meeting.

Hydrogenic particle retention in materials

The primary modeling done by our ITPA members to estimate tritium (T) retention in tungsten is based on diffusion trapping codes. These are empirical based models using assumed activation energies for the hydrogenic (H) traps and their number density within the material. While such codes can treat the large time and spatial scales of retention in W tiles, they are limited in the proper treatment of the various sinks and transport of H in the lattice. At this meeting we asked another class of modelers to join and educate us about more fundamental codes - ones that utilize molecular dynamics (MD) or density functional theory (DFT) approaches. The DFT calculations work at the smallest spatial and time scales to provide a basic model of the electrostatic lattice potentials for different situations (e.g., different kinds of traps in W and different atomic lattice potentials for He or H). The MD models can use the potential information to model the evolution of the traps – their diffusion, growth and annihilation. The drawbacks are their short timescales (ps) and spatial sizes (*e.g.,* 100s of atoms). For example, the size of the area modeled does not allow for grain boundaries. It is difficult (and not possible yet) to derive the lattice potentials for high-Z materials. There is also no model for what happens to the lattice near the surface where the H implantation flux is so high that the local neutral density is much higher than the solute-allowable density. All of the above limitations appear to be under study at the many institutions worldwide, but it is not clear how long it will take to address such limitations. On the other hand we were told that a more integrated approach of bringing models together having different time and spatial scales (*e.g.,* the work by the Helsinki group presented by K. Heinola) is our current best possibility of taking into account microscopic attributes of the material on the spatial and time-scales needed for fusion. There were also detailed discussions of how MD models could be applied to graphites and processes of carbon/hydrogenic co-deposition.

There were several experimental investigations of fuel retention and removal reported. Laser heating of co-deposited H-C has been shown to be quite efficient. More recent work showed that the retention properties of the material were not altered by surface heating. Laser heating of W and Be plasma-facing component (PFC) surfaces has also been investigated. The fuel removal efficiency is not as good as for laser heating of C, in that the fraction of retained H that was removed was typically below 50% (sometimes closer to 10%). Modeling of flash heating of W with absorbed H indicates that the heating may cause the H fuel to be driven further into the bulk instead of to the surface and released. A new study of H retention at neutron damage sites was reported with results similar to past studies for ion-induced damage. It is hoped that the next meeting will have presentations on the use of isotope exchange for fuel removal from laboratory experiments.

Fuel retention in the gaps between wall and divertor tiles is clearly a significant fraction of fuel retention in current tokamaks and likely will be for ITER. Previous studies showed that the retention is dominated by co-deposition (when C is present); the areal density drops off as a function of distance from the front surface along the tile side, yielding an e-folding decay length several times the gap width. The newest study from JT-60U confirms these characteristics of retention in tile gaps. Assuming toroidal symmetry, it is inferred that the amount of T in gaps would be roughly 1/5 of that on the front surface. It is not clear how this projects to ITER. Further work with Be (*e.g.,* in JET) will determine if the co-deposition of fuel with Be has the same properties as for H-C layers.

Dust formation and transport

The investigation of dust has been primarily through two avenues: analysis (post-campaign) of the dust found in the tokamak, and experimental observations of the trajectories of injected dust (DSOL-21). An automatic procedure of a SEM/EDX device has been developed (IPP-Garching) to obtain statistically relevant distributions of dust, allowing a reconstruct of the distribution function for different dust species. This technique has been applied to ASDEX-Upgrade (AUG) and will be applied to dust from other tokamaks. New dust collection diagnostics are being installed on a few other tokamaks as well. The experimental work of DSOL-21 is now complete as the last experiments with the same pre-characterized dust on LHD, DIII-D and TEXTOR are completed. The next step in the dust work is comparison of models and code results.

Heat flux width on divertor plates

Over the past year there have been parallel efforts in the EU and US to coordinate research on divertor-plate heat flux widths in current machines in order to identify the most important factors determining the width, thus helping understand the physics of heat transport across and parallel to the magnetic field. There is general consensus across the machines (AUG, C-Mod, DIII-D, JET) that the steady state (between ELM) divertor footprint scales inversely with plasma current (I_p), and in this first analysis, independent of device size. More work is needed to bring all contributions to these scalings into line with how the widths are measured and entered into the database. Furthermore, the discussion resulted in general consensus that the upstream profiles are needed for the same discharges to better understand the heat transport both parallel and across the magnetic field.

The analysis of heat load footprints during edge-localized modes (ELMs) is less developed. While data has been collected at a number of machines, there was only one presentation of an initial analysis of DIII-D data.

One session was dedicated to models of the steady-state heat footprint. The general review of models applied to JET data found some that led to parameter scalings that roughly approximated the data. The best overall match to data was with a combination of parallel electron conduction and drift ordered (gyro-Bohm) radial convection. One particular drift-based model (R. Goldston) appeared to match JET and AUG data very well and also, when applied to the US and EU data gave a good match. This model reproduced the $1/I_p$ scaling observed in experiment.

Divertor-plasma detachment

We received an update on the status of modeling of divertor-plasma detachment. There are some hints that variations in classical particle drifts and chemical-sputtering rates offers a better match for the onset of detachment at the inner and outer divertor plates as well as the details of the detached plasma (*e.g.,* amount of recombination light and location of the ionization front). However, there was general agreement that it was very possible that some basic physics is missing from the codes. The suggestions of missing physics centered around cross-field transport – due to turbulence (using the Braginskii fluid equations), which could lead to large convective transport. Such processes would have the effect of reducing the heat arriving at the strike point region, thus bringing on the detachment onset at earlier separatrix densities.

Impurity production at material surfaces

With respect to general modeling issues, a review was presented of the sheath treatment of impurities coming from a surface and the formation of the magnetic pre-sheath.

In the last year has been surge of activity in the area of modeling material erosion and subsequent impurity migration. The most important aspects of the new plasma transport code development concerned extending the grids to the PFC and wall surfaces, and having local models for the plasma wall interaction. These two aspects are crucial to determine what the relative fraction of local re-deposition of eroded material vs. long distance migration occurs. The local geometry of the surfaces and the density of the plasma (setting how far from the plate a neutral particle goes before being ionized) are the primary determining factors involved, and it was agreed that better investigation of local density and source rates are needed to be coupled to the codes for benchmarking them and reducing the current large uncertainties in predictions. The local plasma surface interaction models used varied from point models (0D with local sections of the wall connected by probabilities in WallDyn) to local 3D Monte Carlo with the ERO code.

Damage to material surfaces

A number of experiments aimed at examining damage W under heat loads were reported. When the number of repetitive heat loads (ELM-like) is in the range of 10^5 to 10^6, the energy threshold for crack formation drops as low as 0.13 MJ/m^2. Such cracks, by themselves, may not be a concern in that they effectively form castellations on the surface.

Of more concern is the effect of melting. Laboratory experiments aimed at understanding melt-layer evolution continue to identify **J**x**B** Lorentz forces as the primary in moving molten W around on the surface. Modeling reproduces the basic aspects of this movement. Unfortunately, in addition to raised surfaces, which become leading edges, melting also leads to degraded bulk material characteristics such as grain structure, creation of voids, and general decrease in ductility (more cracking and potential for failure). It was also found that pre-exposure of materials to He ion fluences reduced the melting threshold in W and Mo.

Future plans

The next DivSOL meeting is planned for either the 2nd or 3rd week of January, 2012, hosted by the Forschungzentrum group in Juelich, Germany. As is done every two years, this meeting will share the week with the paper selection committee for the International Plasma Surface Interaction Conference to be held in Juelich in May 2012. The following 2012 DivSOL meeting could be in the US, possibly associated with the IAEA meeting in San Diego during October 2012. The meeting may be co-located in San Diego or somewhere else in the US. Potential session topics for the Juelich meeting within the R&D areas are a), T retention/removal - the fuel retention database (E. Tsitrone), ICWC (Ion-Cyclotron Wall Cleaning) vs. HFGDC (High-Frequency Glow-Discharge Cleaning), laboratory isotope exchange experiments, flash heating of surfaces; b), tungsten R&D - operation on damaged W, melt layer dynamics, lab results for surface erosion under different fluxes (particle vs. just heat or the two combined); c) heat flux – ELM dynamics, heat-load footprint scalings/physics, and disruption power load footprint; d), dust – measurement of initial velocities of dust, dust production rates, modeling; e), material migration – more on model development; and finally f), a joint task force - tokamak fueling being organized across TG's by A. Loarte of the ITER Organization.

Announcements

Submit BPO-related announcements for next month's eNews to Tom Rognlien.

Upcoming Burning Plasma Events

2011 Events

Jun 20-24, 2011
ITER International Summer School on MHD and Energetic Particles
Aix en Provence, FRANCE

Jun 26-30, 2011
38th IEEE International Conference on Plasma Science (ICOPS) and the 24th Symposium on Fusion Engineering (SOFE)
Chicago, IL USA

Jun 27-Jul 1, 2011
38th European Physical Society Conference on Plasma Physics
Strasbourg, FR EPS

Fall 2011
ITPA Diagnostics Topical Group Meeting
CHINA

Sep 5-7, 2011
IAEA Technical Meeting on Theory of Plasma Instabilities
Austin, TX USA

Sep 8-10, 2011
IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems
Austin, Texas USA

Sep 12-13, 2011
7th Meeting of the ITPA Energetic Particles Topical Group
Austin, Texas USA

TBA---tentatively scheduled
ITPA MHD Topical Group Meeting
Padova, ITALY

Sep 11-16, 2011
10th International Symposium on Fusion Nuclear Technology
Portland, Oregon USA

Sep 14-16, 2011 NEW
BOUT++ Workshop
LLNL, Livermore, California USA

Sep 19-21, 2011
13th International Workshop on Plasma Edge Theory in Fusion Devices
South Lake Tahoe, California USA

Oct 5-7, 2011
ITPA Transport & Confinement Topical Group Meeting
Cadarache, FRANCE

Oct 5-7, 2011
ITPA Pedestal and Edge Topical Group Meeting
York, UK

Oct 10-12, 2011 abstract deadline June 30, 2011
13th International Workshop on H-mode Physics and Transport Barriers
Oxford, UK

Oct 16-21, 2011
15th International Conference on Fusion Reactor Materials (ICFRM-15)
Charleston, SC USA

Oct 18-21, 2011
ITPA Integrated Operational Scenarios Topical Group
Kyoto University, JAPAN

Nov 14-18, 2011
53rd APS Division of Plasma Physics Annual Meeting
Salt Lake City, Utah USA

Dec 12-15, 2011
ITPA CC & CTP-ITPA Joint Experiments Meeting
Cadarache, FRANCE

Dec 2011 or Jan 2012
ITPA Divertor and SOL (PSI Selection Committee) Topical Group Meeting
Jüelich, GERMANY

Directories of Other Plasma Events

IEEE Directory of Plasma Conferences
Fusion Ignition Research Experiment (FIRE) Physics Meetings

Please contact the administrator with additions and corrections.