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PLASMA-WALL INTERACTION STUDIES AT JET-ILW IN A VIEW OF UPCOMING D, H AND T EXPERIMENTAL CAMPAIGNS

The Joint European Torus (JET) is the largest tokamak in use and currently the only one capable of handling tritium (T). JET equipped with the ITER-like wall (ILW) utilizing the same as ITER material combination: tungsten (W) divertor and beryllium (Be) main chamber, provides the most relevant environment for ITER plasma-wall interaction studies [1].

In 2017 the coordinated on-site and off-site analysis and modelling activities in the frame of the fifteen researcher groups named as "analysis&modelling tasks" were performed: analysis of past experiments & assess of JET D-T campaign readiness, predictive modelling with physics based integrated (edge-core, wall-SOL) codes for JET and ITER, preparation of experimental proposals for C38-C42 D-H-T-H-D upcoming campaigns.

One of the tasks relevant to plasma-surface interaction (PSI) studies is the "T17-12: Isotope wall content control and long term erosion/migration interpretation". The main goals of this task are to elaborate the strategy for reducing D wall inventory before T campaign (and T before D in C40) to stay within neutron activation limits, to monitor isotope ratio in the plasma at various locations and in the key wall components, to determine the T wall retention rate (important because of ITER safety limit) and to improve general erosion/migration/retention prediction capabilities including code development, validation as well as extension allowing for instance treatment of dust particles transport. The task activity was divided into five working groups:

- Isotope ratio estimations and evaluation of wall cleaning methods for reliable control of isotope wall content,
- Spectral modelling of spectroscopic measurements for W, Be as well as Be and N molecules and analysis/modelling of the formation and transport of ND, NH, NH_3 molecules in seeded experiments,
- Validation of PSI and SOL impurity transport models using JET data,

- Quantification of dust formation fraction of the total erosion and retention based on existing JET experiments and prediction of the tritium content for TT operation at JET and DT operation at JET and ITER,
- Validation of integrated plasma-wall interaction models against long-term exposure experiments from “C30C” campaign and other experiments.

In this paper the main results of this task and the accepted proposals for the PSI-relevant experiments in the upcoming JET campaigns are presented.

To develop reliable isotope ratio estimations in the vessel the H/(H+D) ratio data from analysis of residual gas (RGA) for C37 campaign (2016) are analysed. Isotope ratio obtained from RGA signals is shown to agree in general with divertor spectroscopy (see fig. 1). New fitting algorithm for Balmer-α line separation is presented. Test with partially used in RGA optical penning (OP) measurements (“KT5P” diagnostic) demonstrates good quality of the fitting H/[H+D] ratio, in particular for relatively low intensities (0.5% and below).

Available OP data in KT5P have been re-analyzed. Spectral profile comparison revealed that the instrument resolution was altered since JET DTE1 campaign leading to the large error bars for H/[H+D] < 1%. Corrective actions are suggested for the respective “KT5” diagnostic providing increased light collection to improve accuracy at H/[H+D]<1% and improved resolution in order to correctly assess T/(H+D+T).

The isotope exchange efficiency of different wall cleaning (WC) methods is evaluated based on the analysis of the previous experiment data. Several proposals for the control of the isotope wall content have been made, which include wall baking at 320°C, glow discharge and ICRF conditioning (GDC, ICWC), raised strike point magnetic configuration allowing to access the deposits at divertor baffle. Combination of mentioned WC methods is also going to be tested during a dedicated “baking week”, a strategy of which for C39 has been proposed (see fig. 2).

To improve the interpretation of spectroscopic measurements the scripts for fitting ND, BeD, NH and BeH molecular bands are ready and tested for KSRA, KSRB, KSRC, KT3A and KT3B JET spectrometers. It is shown that spectra fitting is uneasy in the divertor region due to the weak signals and multiple blended lines. Using rovibronic-resolved electron collision data (R-Matrix method simulations) the synthetic spectra and the temperature information for BeH, BeD and BeT is calculated and benchmarked with the experiment. New software to subtract the bremsstrahlung background from the “KL11” 2D camera filtered images for WI line emission in the divertor is developed to improve W-erosion analysis. In the frame of ammonia production studies comparison of ammonia formation from RGA signals for different plasma configuration (“M15-29” versus

“H16-05” experiments) is presented. Background plasma parameters profiles for “M15-29” experiment are simulated by the fluid code SOLEDGE2D-EIRENE. It will allow N_2 and NH_3 transport modelling by the ERO code.

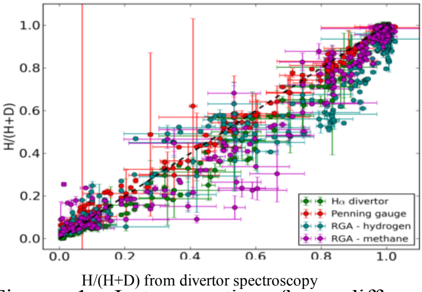

Figure 1. Isotope ratios from different diagnostics versus KS3B spectroscopy data [A. Drenik, PFMC 2017]

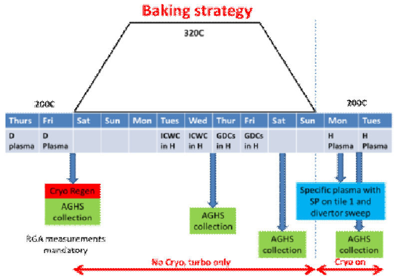

Figure 2. Cleaning strategy defined for C39 campaign

A new powerful tool (ERO2.0) for erosion and migration modelling is applied for simulation of Be erosion and transport for limiter plasmas taking into account 3D wall geometry and machine-sized simulation volumes. A good agreement between measured “KS3” line-of-sight (LOS) averaged effective yields and Be sputtering yields simulated by ERO2.0 is obtained assuming a certain Be background concentration in the modelling. Reproduction of KL1 2D images shows good agreement near contact point, however too low emission further upstream (see fig. 3). The first comparison with heat flux from IR images seems also to give positive outcome.

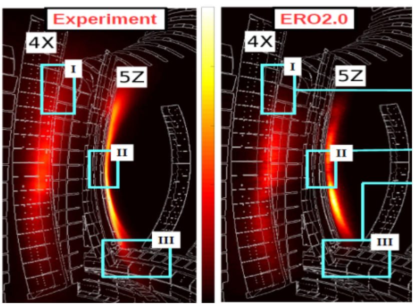

Figure 3. KL1 Be II 467nm line emission intensity from experiment and rendered by the ERO2.0 synthetic camera model from the simulated volumetric emission data

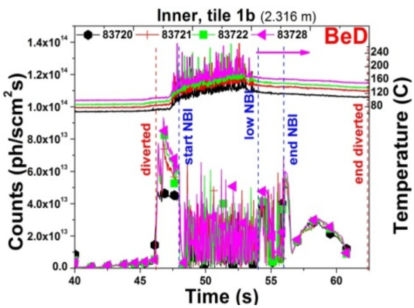

Figure 4. Analysis of BeD emission using “KS3” signals from the inner divertor for “C30C” plasmas

Using the dust trajectory code DUSTTRACK the trajectory and the evolution of the physics parameters of Be and composite dust particles with different size and initial conditions are simulated. It was found that hydrogen isotopes are mainly released within the SOL from dust particles launched from the main wall. Post-mortem analysis shows the large melting areas at the upper dump plates. Modelling of Be dust particles migration launched from the upper dump plates is performed and the possible areas of preferential dust accumulation and T inventory within the JET-ILW vessel are investigated.

The W sputtering source under intra-ELM and inter-ELM conditions in JET-ILW hydrogen plasma discharges with compound and Type-III ELMs is analyzed and benchmarked with WI spectroscopy. The impact of the Be ionization state and the Be concentration in the impinging ion flux on the W sputtering is estimated. The influence of the prompt deposition of eroded W is simulated by ERO code under intra-ELM and inter-ELM conditions. It is found that net erosion is about a factor of 30 lower than gross erosion at the strike point under intra-ELM due to deposition and about 5 under inter-ELM conditions and the net erosion rate is similar for intra- and inter-ELM conditions for relatively high inter-ELM temperature.

The JET adaptation of the 2D particle-in-cell (PIC) full kinetic massively parallel code for SOL modelling (BIT2) is ongoing aiming to reach the productive stage for full kinetic runs for the JET SOL.

Extensive analysis of the H-mode discharges during a two-week lasting JET ILW operation (“C30C”) [2] with quasi steady-state wall conditions is performed. First IR and TC data analysis for ILW tiles 0/1 (divertor baffle) for the “C30C” campaign is presented. Detailed analysis of Be and BeD optical emission in divertor co-deposits (see fig. 4) and outer strike point is presented and discussed. Transport in the sub-divertor including louvres, pump and the sub-divertor pressure gauge is implemented into the SOLPS-ITER code and the respective extended grid is generated. Simulated upstream ne/Te profiles are in good agreement with experiment. A diffusion trapping model is applied to study the dynamic outgassing from Be-covered tiles 0/1 in JET during type-I ELMy H-modes and to explain post-peak occurring up to 8ms after first peak in measured ion particle flux.

This task is extended to continue in 2018-19 with updated deliverables. Some deliverables of this task will move to the experiments. The task has helped to develop the PSI-relevant experiment proposals accepted now for the upcoming JET campaigns: wall cleaning, W source, H/D/T monitoring etc.

[1] G. Matthews et al. Phys. Scr. T145 (2011) 014001
[2] S. Brezinsek et al, Nucl. Fusion 53 (2013) 083023