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Plasma-surface interaction studies in preparation of JET-ILW TT and DT operation: insight and extrapolation to ITER by the ERO2.0 modelling

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JET is a unique tokamak equipped with the ITER-like wall (ILW) comprised of beryllium (Be) main chamber and tungsten (W) divertor; JET-ILW is the closest to ITER existing device by size and configuration providing relevant conditions to study the plasma-wall interaction (PWI). JET allows operation with tritium (T), thus studying the H/D/T isotope effect on the PWI as well as simulating ELMs of various ITER-relevant types. The PWI experience during the ELMy H-mode flat-top phases at JET can be extrapolated for ITER. However, the numerical modelling is indispensable for proper prediction and accounting of the plasma conditions. The validated at JET codes with the underlying data constitute the essence of the ITER-relevant experience. Good example and one of the focuses of this talk is the new 3D Monte-Carlo PWI and impurity transport ERO2.0 code [1] including the whole ITER-like wall volume and utilizing the synergy from various diagnostics was applied to both Be and W erosion studies at JET (and other devices) with extrapolation to ITER [2].

The main focus of the work is on erosion, as it determines the W and Be impurity sources and the lifetime of plasma-facing components (PFC). The source of high-Z W impurity is critical due to the radiation cooling issue. Be source is important due to contribution of Be ions to the W sputtering – the H/D/T sputtering is often prevented (except intra-ELM) by the sputtering threshold energy $\boldsymbol{E_{th}}$ (very high for W, $\boldsymbol{E_{th}}$ ***>150eV*** even for ***W→T***). Be erosion is also important due to the significant contribution of the co-deposition with Be (***>40%*** at JET) to the total retention. A fraction of the erosion (up to ***50%*** for Be) was shown to be caused by the chemically assisted physical sputtering (CAPS) with strong dependence on the surface temperature (suppressed at **~500°C**).

The erosion, impurity transport, material migration and retention issues are strongly interconnected. Modelling is needed to account for the difference between gross and net erosion due to the prompt re-deposition (***>90%*** for W). It was shown that 3D distribution of the plasma parameters, magnetic shadowing, PFC shaping and roughness can have a significant impact on the simulation results. The procedure for effective sputtering yield calculation accounting for local sheath effects is developed and validated at JET. In addition, chemical processes can play a significant role at the surface and in the edge plasma. For instance, N impurity (seeding as detachment actuator) was recently shown to have a strong impact on both the Be (suppressing of CAPS is observed) and W (increases with N concentration until saturation) erosion in JET. Obviously, specific transport and decay of molecular species including ions in the edge plasma affect the overall migration and retention pictures. For validation the *in situ* spectroscopic measurements at JET are used preferably with some supporting post mortem results and quartz micro balance (QMB) deposition data resolved per pulse. A significant part of the problem is the edge plasma backgrounds simulated by the EDGE2D-EIRENE and similar codes. The uncertainties in this critical input are discussed on the example of the related ERO applications to JET experiments.

The talk presents the general understanding of the PWI picture at JET in Be/W environment [3], gives an overview of key JET experiments (including the outlook for TT/DT) and modelling efforts. Finally, it uses ERO2.0 modelling for JET and ITER to give a more detailed example of the knowledge extrapolation approach based on combination of experiments and modelling.

[1] J.Romazanov et al., invited at PSI-2018, NME 18 (2019) 331–338
[2] D. Borodin et al., NME 19 (2019) 510–515
[3] S.Brezinsek et al., invited at IAEA FEC-2018, submitted to NF

♦ See the author list of "Overview of the JET preparation for Deuterium-Tritium Operation" by E.Joffrin et al. to be published in Nuclear Fusion Special issue: 27th Fusion Energy Conference (Ahmedabad, India, 2018)