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Long discharges in steady state with D2 and N2 on the actively cooled tungsten upper divertor in WEST

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Heat load control on plasma facing components (PFC) is a critical issue for fusion devices like ITER: power injection and exhaust systems should be regulated and high radiating plasma scenario at the edge are investigated. Future fusion reactors will have to rely on impurity seeding to enhance the radiative fraction in the range of ~90% in order to cool the edge plasma and prevent PFC damages. Among the different gases tested in present fusion experimental devices, nitrogen (N2) is a viable seeding candidate for the size and conditions of present day divertors. However, the potential reactivity of N2 with hydrogen isotopes can lead to tritiated ammonia (NT3) formation which should be considered for the re generation of cryo pumps and processes in de-tritiation plants. Using N2 in the ITER facility as radiator in the edge plasma and particularly in the divertor is still nevertheless considered as a viable option. In the WEST tokamak [1, 2], designed for long pulse operation with diverted magnetic configuration and tungsten (W) PFC, long discharges were seeded with N2. The objectives of these experiments were to study plasma surface interaction (PSI) and ammonia formation in a full tungsten device in order to improve the understanding of physics of ammonia production, decomposition and transport in a magnetically confined plasma devices. This paper reports on various aspects of these discharges: power balance, impact of N2 injection on plasma parameters, and ammonia formation. In WEST, the upper divertor is equipped with actively cooled copper based PFC, coated with ~20µm of tungsten allowing long discharges in steady state conditions in upper single null configuration (USN). Although no active pumping has been installed, long discharges in USN configuration are now routinely operated.

In this context, 15 repetitive long and steady state discharges (up to 55s) have been performed in USN plasma configuration, cumulating 8 min of plasma and 1.18GJ of injected energy. The discharges were achieved in L-mode, with a plasma current of Ip= 400 kA, lower hybrid (LH) power of PLH= 1.5 to 3.2 MW, a plasma density of ne=3.3x1019m-2, a radiated fraction of ~55% and a diamagnetic energy Wdia ~200kJ. During the four last discharges cumulating more than 3 minutes of plasma, N2 has been seeded through a toroidal ring located below the divertor in the vicinity of the outer strike point (OSP) at a rate ranging from 0.1 to 0.22 Pam3s-1 for a total duration of 100s for investigating both the potential legacy of N2 injection on plasma performances and the formation of ND3 in steady state conditions. For all these discharges, the main radiative impurities have been identified as W, O, Cu (mainly during the LH power phase) including some traces of C whilst a rather weak contribution of N in the overall radiation is observed during the N2 seeding phases. The edge plasma characteristics are documented through density and temperature (ne and Te) measured with the set of Langmuir probes in the divertor and the reciprocating probe, whilst the potential ND3 formation during and after the discharges was monitored by a residual gas analyser (RGA) located in the pump duct at the outer mid plane. Performing long discharges also allows assessing more accurately the global power balance and distribution on various PFC. The overall power balance (conducted and radiated power) is evaluated through the main diagnostics of infrared thermography, bolometry and calorimetry, showing the complementarity of these diagnostics for closing the power balance within a range better than 90%. A typical discharge is displayed on [figure 1][1] showing the main plasma parameters. The plasma temperature at the OSP region is in a range of 5-10eV in the ohmic phase prior the LH power whilst it increases around ~15 eV during the heating phase. Several plunges have been performed with the reciprocating Langmuir probe. The profiles of both Te and ne have been measured up to a normalised radius of ⊠=r/a~1.05 corresponding to about Te~75eV and ne~1.6x1019m-3 at the separatrix. Over the entire heating phase, no effect of N2 can be detected all along the N2 injection on the Langmuir probe signals. Consistently with these results, the maximum surface temperature at the OSP region is around 300°C and no significant drop of the surface temperature is observed during the N2 injection. The N2 effect is observed in the bulk plasma through a weak increase of the N VII signal exhibiting an increase from pulse to pulse although the N2 seeding rate over these consecutive pulses is maintained in a range between 0.1 to 0.22 Pam3s-1. However, this increase is too weak to be detected through the bolometry track probing the bulk plasma whilst at the OSP region, the edge bolometry exhibits an increase by ~8%. It is worth noting that there is no significant/measureable change on the bolometrer tracks monitoring the lower part of the plasma. This shows that the radiation pattern is only weakly modified as confirmed by both the Langmuir probes and the IR measurements. Finally, and even for the discharge containing the largest nitrogen injection (# 55792 with 6.5Pam3of N2 injected @ ~0.22 Pam3s-1 from 10 to 40 s and 11Pam3 of D2), no ND3 is detected in the RGA during the discharge, at the end of the discharge when the plasma recombines and during the ~25min of outassing between pulses.

In these conditions, over such long time scales and in the absence of active pumping in USN configuration, these experiments suggest that the majority of the injected N2 sticks to the wall in the vicinity of the injection point and that the produced ammonia also sticks to the walls and is then released at a low rate below the sensitivity of the RGA system between pulses.

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