Wall conditioning in WEST first experimental campaigns

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The superconducting tokamak WEST, resulting from the transformation of Tore Supra to a full tungsten (W) tokamak with a diverted magnetic configuration, is in operation since end 2016. The WEST program focusses on power exhaust studies with the ITER actively cooled divertor technology and long pulse operation in a metallic environment [1]. To this aim, wall conditioning turned out to be an essential tool to maximize plasma operational space, performance and reproducibility in WEST. This contribution reports on wall conditioning in WEST and its effect on operational achievements.

While WEST plasma facing components are operated at 70°C, i.e. the inlet temperature of the ITER pressurized water cooling loop, the conditioning system of WEST allows baking of the vacuum vessel at wall temperatures up to 200 °C (up to 180°C for the divertor). WEST is also equipped with a Glow Discharge Cleaning (GDC) system, with six toroidally distributed anodes (pressure 0.3Pa, total current of 6A, voltages U~600-700V). The first nominal plasmas in WEST, with plasma current up to 800kA in diverted configuration, were obtained by the end of 2017 in the C2 campaign after several 200°C bakings and 400h of deuterium glow discharge conditioning, which allowed significantly reducing low-medium Z impurities, as seen by residual gas analysis. Taylor Discharge cleaning was also used to recover adequate wall surface state and ease breakdown and current ramp-up. Post-mortem EDX analysis of first wall samples, as well as visible and VUV spectroscopy during plasma operation, however evidenced erosion of high-Z first wall material by intensive use of GDC. The obtained plasmas were prone to runaway electron production, indicating a too high level of impurities, and the radiated power fraction was as high as 80% in ohmic discharges. In addition, plasma density could not be raised without radiative collapse.

In order to enlarge the operational domain in terms of density and additional power, 3 boronizations were conducted in WEST during the C3 campaign in 2018. A mixture of He-15%B2H6 being firstly used, boronizations were followed by D2-GDC in order to restore an isotopic ratio D/[H+D]>95%. As expected, the deposited boron layer (~200 nm) immediately reduced low-medium Z as well as high Z contamination in subsequent plasmas. The operational space hence opened up, in particular in terms of density. This also allowed highly reliable startup and increase of injected additional power, with a fraction of radiative power around 50%. Post-mortem EDX analysis of inboard-side first wall samples indicated complete – although not toroidally uniform - coverage by boron coating, with reduced oxygen and carbon contamination in layers deposited during boronization compared to those deposited in-between.

While the impact on the oxygen content was observed to last over several weeks of operation, other beneficial effects, in particular in terms of reduction of radiative losses, were found to be limited to the few shots following boronizations (typically <1 min. of diverted plasma operation). More frequent boronizations were performed in the C4 campaign, typically every week, using a He-10%B2D6 mixture. Repetitive long L-mode discharges were obtained (up to ~1 min.), as well as injection of up to 9 MW of combined lower hybrid (LH) and ion cyclotron resonance heating (ICRH). A first 4 s long improved confinement phase with a density pedestal could be maintained with LH and ICRH together.