Institute for Magnetic Fusion Research

WEST

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Last run for the inertially cooled lower divertor

The tungsten coated graphite tiles of the lower divertor used during the first phase of operation to test the prototypes of the ITER-like tungsten monoblocks have successfully completed their mission.

The 934 tungsten coated graphite tiles are now going to be replaced by the series of ITER-like tungsten monoblocks elements to get a fully actively cooled divertor and access 1000s long pulse operation. They will have endured more than 3000 short pulses, 5h30 of plasma and around 15 GJ of injected energy with peak Radio Frequency power of 9MW and surface temperature above 1000°C. They have also seen many other events that make tokamak everyday life (disruption, venting, boronization, etc.). In addition, the last weeks of operation were dedicated to helium plasmas to study their interaction with tungsten (see WEST science at the back).

The plasma pattern is clearly visible on the tiles showing erosion areas around the divertor strike point positions and redeposition waves in the periphery. The ripple modulation of the toroidal field is also discernable.

The tiles were coated with a 15 µm layer of tungsten by the Institute of Atomic Physics (Romania) and some of them received a specific coating with erosion markers (100 nm Molybdenum interlayer) in VTT (Finland). They will be removed and post mortem analysis will be performed with a large number of WEST partners (Aix-Marseille University, FZJ, IPP /Germany, VTT/Finland, JSI/Slovenia, ORNL/USA , NIFS/Japan, etc.) in order to get further insight into plasma tungsten interactions.

The new ITER-like elements are in manufacturing by Chinese industry (cf. WNL 23). The first batch have been completed and the assembly of the 12 divertor sectors will start in February. The installation in the tokamak is planned during the summer.

This concludes the first phase of WEST operation paving way for steady-state operation in full tungsten environment.

Inertially cooled lower divertor made of Tungsten coated graphite tiles that surround the 14 ITER-like Tungsten monoblock elements.

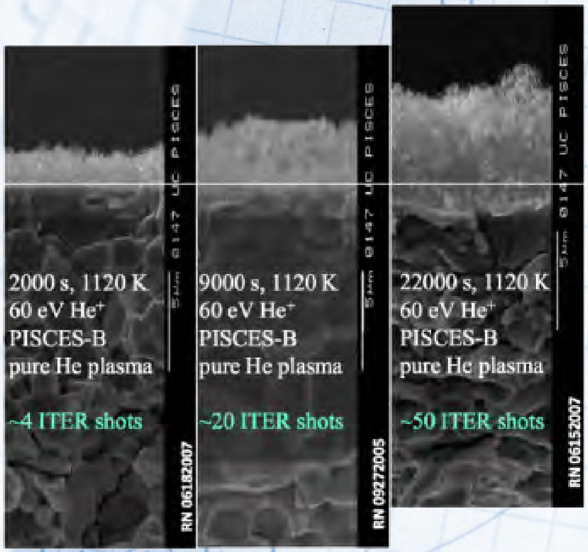
WEST Science

The Helium-Tungsten interaction

How large are the Tungsten-surface modifications by Helium in a real tokamak environment?

After the initial Hydrogen (H) phase, a Helium (He) campaign is planned during the non-nuclear phase of the ITER operation, motivated by the fact that He should allow to operate in H-mode while H should not. As a counterpart of this advantage, the He plasma strongly interacts with Tungsten (W), which is the material used for the ITER divertor. It was shown in extensive studies in linear devices (Magnum in the Netherlands, PSI-2, Germany and Pisces-B, USA) that, with increasing plasma irradiation and fluence, He bubbles are formed in the subsurface, micro-cavities and nanostructures (also known as «fuzz») appear on the surface itself. In addition, the emissivity and thermo-mechanical properties of the material are modified.

However, investigating these phenomena in a real tokamak environment is crucial for complementing the studies already performed and evidencing the competition between erosion-redeposition and modification of the surface morphology. For this reason, a He-Plasma Wall Interaction experiment was performed at the end of the WEST-C4 campaign, with the objective to reach the fuzz formation threshold conditions on the most loaded part of the divertor, i.e a fluence larger than $\sim 10^{24}$m^{-2}, an incident energy greater than ~20 eV in the plasma edge and a surface temperature larger than 700 C. Waiting for the results from the tungsten components surface analysis ...



Tungsten surface modification under increased Helium fluence in ITER relevant conditions in PISCES-B.

Visiting WEST for tungsten sputtering in helium

This fall WEST conducted experiments on tungsten divertor sources in helium discharges and it was my privilege to join these on behalf of EUROfusion as scientific coordinator.

The work was a follow-up of similar studies in 2018 in deuterium. Obviously, having the ultimate goal of superior fusion performance means lowest possible tungsten content in the plasma core. Thus, starting at the source of it makes sense, which is the sputtering of tungsten in the divertor.

At the same time, the subject might seem to be boringly trivial. Our fusion students in Eindhoven are taught how to calculate sputter fluxes on basis of given plasma conditions and composition. For me, that sentence indicates precisely where the complexity and added value of the tungsten sputtering experiments find their origin: the limited insight into the plasma that faces the divertor wall. It is a region dominated by transport and recycling so that e.g. impurity concentrations, charge state distributions, and temperature gradients are difficult to assess in a self-consistent manner.

Given this complexity, it might be the tungsten source determination that is the most local and sensitive diagnostic in its own right and an important basis for comparison with modelling. And what have we learned from these helium experiments ? Although analysis is still ongoing, it is safe to say that neither "softening" of the walls by the helium nor sputtering by helium itself was observed. So far so good for helium campaigns in ITER.

Written by G. van Rooij