W7-X and ITER relevant exposures on TOMAS

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1 Short overview

Amount	kind of samples	need	project	TOMAS days
12	hydrogen doped graphite	Test ICWC vs ECWC	W7-X	18
6	hydrogen doped boron-coated graphite			
3	boron-coated graphite			
18	Boronized tungsten, doped with deuterium	test efficiency of IC vs EC vs GD	ITER	18
4	Pure tungsten, doped with deuterium			

2 Scientific relevance and reasoning

W7-X

Glow discharge in H_2 plasma and ECWC in He plasma have been actively used on W7-X to condition the wall and it's effects have been reported ([2],[4] and EUROFUSION WPS1-PR(16) 16175). However, ECWC is only able to deposit power near the fundamental, as such the EC wall conditioning is inhomogeneous. ICWC shouldn't have this kind of shortcoming and should provide a more efficient cleanup[3]. as a preparation to the eventual usage of ICWC in W7-X it should be investigated how ECWC and ICWC compare both in outgassing from pure graphite and from boron-coated graphite (as both are possible PFMs in W7-X). To this end baseline ECRH experiments need to be carried out on TOMAS, as well as ICWC experiments to compare to as to draw conclusion to W7-X.

ITER

It has quite recently been decided that ITER will not have a Berillium wall but a tungsten wall, experiments have been carried out at JET with an "ITER-like wall"[1] which was, at the time, a Berillium wall. The author is unaware of any

published wall conditioning experiments carried out on tungsten walls, as such the proposal is to compare all 3 ITER available wall conditioning schemes using both boronized tungsten, as regular boronization will be done. As well as pure tungsten experiments to gain information on de-trapping of exposed tungsten.

3 TOMAS setup and days estimate

3.1 W7-X

As mentioned in EUROFUSION WPS1-PR(16) 16175, ECWC outgassing follows a time law, this law needs to be measured on TOMAS to show that it is equiped to compare IC and EC, after which the same kind of experiment needs to be carried out to determine the IC time law and scale difference. To get a W7-X relevant condition, the IC frequency will be set to 38MHz, mimicking the minority heating and the second harmonic heating scenarios. The power level will be kept as high as possible whilst the pressure will be set such that the electron density approximates the one observed at W7-X (reflectometer measurements), the plasma species used in W7-X are deuterium and helium, we will be using helium to have a more distinct signal from the removed hydrogen.

The exposures will all keep these same settings and vary in time to make a time-outgassing relation possible. 6 samples will be used to do the EC discharges, grouped as 2 each to make error estimation possible. After which 6 samples will be used to do the IC discharges.

As W7-X also boronizes their walls (monthly), IC experiments will also be carried out on 6 boronized graphite samples. as the EC-IC relation should already be established from previous experiments, this should give additional insight into the de-trapping efficiency of boron. As the rapidity of boron erosion under plasma operation is still an open question, this will also be measured using the remaining 3 samples.

At TOMAS, the right parameters need to be found, as such a scan using langmuir probes need to be done to figure out the electron density vs position to know the ideal exposure position. This takes 1 preparatory day and a morning to comfirm later. After confirmation, in the afternoon, the samples need to be mounted and pumped down, this takes one afternoon. The exposure and removal of the samples are then performed in the morning the day after. In the afternoon or in the morning if time permits another scan for a different setting can be done or the mounting of new samples for longer exposure times can be done. As such 2 typical experiments (here involving 2 samples each) should take 3 days, 3 experiments could be carried out over 4 days. Keeping this in mind, 2 days will be preparatory (finding the right configurations such as IC matching capacitor positions, EC matching and gas flow), the EC exposures will take 4 days, IC exposures will take 2 times 4 days (6 boron coated and 6 non-coated samples). and the erosion experiments will take 4 days. In total

the W7-X-TOMAS project will thus take at least 1+4+1+4+4+4=18 TOMAS operation days.

3.2 ITER

6 Boronized tunsten samples will be used for ICWC estimates, 6 for ECWC estimates, and 6 for GD estimates. and 4 pure tungsten for ICWC estimates. Similar to the W7-X-TOMAS project, ITER relevant electron density and frequency (the maximum, 40MHz, as ITER will be operating around 50MHz) will be sought. The minimum operation time will thus be 1+4+1+4+3+1+4=18 days.

4 Sample analysis

Most of this will probably be outsourced to experts within FZJ whom will be credited appropriately, nevertheless here will follow a short overview of the analysis methodology.

4.1 Rougness measurements

The exposure to the plasma may give inhomogeneous sputtering which might be of interest, as such a simple 1D profilometry measurement may be made before and after exposure, or, if needed, a full 2D surface map. Both of the needed devices are located in the mirror lab overseen by dr. Litnovsky.

4.2 Thickness estimate

The erosion rates may be measured using both the non-destructive ellipsometry, also located in the mirror lab, which gives, due to the nature of the device/physics, multiple thickness estimates. And the destructive FIBSEM (Focused Ion Beam Scanning Electron Microscopy) whereby a cut is made using an ion beam and imaged using SEM, providing a direct thickness measurement. This device is the speciality of dr. Rasinski.

Erosion estimates may be made using ellipsometry on the doped specimens prior to being analysed using IBA, after which also a thickness estimate may be made using an appropriate amorphous boron density to find the closest lying ellipsometry prediction, and on the W7-X-TOMAS erosion estimate samples, where also FIBSEM may be used to get a more direct measurement.

4.3 Outgassing estimates

For the samples loaded with impurities (all of them, aside from the ones on the ITER-TOMAS project whom will purely be used for erosion estimates). The elemental concentrations need to be inferred, this will be accomplished using the destructive IBA method, overseen by dr. Möller, yielding atoms/cm^2

directly, assuming homogeneous impurity doping during initial boron coating and negligable erosion on the pure tungsten and graphite, we can conclude that this measurement does not need to account for the erosion of the layer and is a direct consequence of the wall conditioning.

References

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