W7-X relevant TOMAS wall conditioning experiments

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1 Short overview

Amount	kind of samples	need	project	TOMAS days
22	boronized graphite	H & He and H+He GD	W7-X	6
24	hydrogen doped boronized graphite	H & H+He ICWC	W7-X	8

The boronized graphite (non-doped) is ideally made as soon as possible, instructions on when the hydrogen doped boronized graphite should be made will follow.

2 Scientific relevance and reasoning

W7-X employs Glow Discharge Cleaning in hydrogen and helium in the initial wall conditioning stage after the vacuum vessel venting. It is also conducted weekly in hydrogen to further improve the wall conditions and daily in helium to desaturate the walls from hydrogen[2] unless the hydrogen/helium ratio is desired to be close to 1 in the constitutive experiments. The GDC cleaning is done only before the first boronization. After the boronization it is suspended to avoid a possible boron layer erosion. However, it is not scientifically proven. ECWC in the form of pulse trains is used in helium or hydrogen to establish the density control throughout experimental days ([1],[3] and EUROFUSION WPS1-PR(16) 16175). The installed ICRH antenna provides an opportunity to employ ICWC, which should be more effective than ECWC, and, moreover can be used when ECWC is not operable, for example at low (1.7/1.8 T) magnetic field operation. Since the mechanism of ICWC for W7-X is supposed to rely on moderate fluxes of charge-exchange neutrals, it can also contribute to the erosion of the boron layers in the main PFCs.

boronized graphite

As mentioned GD is avoided except prior to the first boronisation as it is thought to erode the wall, it would be interesting to be able to predict to what extend, to this end we will measure ion energy distributions for W7-X relevant GD settings using the Retarding Field Energy Analyzer (RFEA) and expose samples for chosen environments. As the GD system on tomas and the one on W7-X are the same with just a smaller volume, measurements obtained on TOMAS directly predicts what will be observed at W7-X.

As we have a RFEA and ToF-NPA, we also aim to predict with an erosion code like ERO or rustBCA the (possibly) observed erosion.

hydrogen doped boronized graphite

W7-X has diverted EC plasma, this means that the divertor area is the only part conditioned by ECWC which erodes the present boron layer within seconds. As such it is not relevant to study ECWC on TOMAS, and we will focus on ICWC. The ICWC settings used for the exposures at TOMAS, due to low confinement, may mimick at TOMAS's sample manipulator, the charge-exchange flux at the edge of W7-X. We will also attempt to predict de-trapping rates using rustBCA.

3 TOMAS setup and days estimate

GDWC

The GD settings used at TOMAS will mimick the ones used in W7-X, namely $1.5\text{A} \approx 300\text{V}$ at $\approx 4.5 \times 10^{-3}$mbar for H_2 and $1.0\text{A} \approx 200\text{V}$ at $\approx 3.5 \times 10^{-3}$mbar for He[2] and one with both H and He. There are thus three main scenarios, for each of these we will expose 6 samples and 2 dummy (non-coated) samples. Additionally 4 samples will serve as control samples, which won't be exposed to see if atmospheric effects deteriorate the sample. In total we thus require 22 samples. Each exposure will take one day with a preperatory day and as such this will take 6 days in TOMAS time.

ICWC

The ICWC settings at TOMAS will mimick W7-X where it can, namely the frequencies of the ICRF antenna will be 25MHz and 38MHz, keeping the pressure at the sample manipulator as close to the ones used in W7-X's wall as possible. The gasses used will be once helium and once helium+hydrogen. As such with two gasses each having two frequencies each hosting 6 samples (to have good statistical accuracy) the total amount of samples comes to $2 \times 2 \times 6 = 24$ samples which should take 8 days to expose.

How the days are estimated

The days estimate comes from the possibility to do 1 exposures per day, with one day of preparatory work, calculated on a maximum of 3 exposures per week. During experiments the QMS, the MW interferometer and optical spectroscopy will be acquiring data.

4 Sample analysis

GD erosion rates

As it might be interesting in the erosion predictions, surface roughness will also be measured (as it may affect the rapidity), in total the steps are:

1. roughness measurement before exposure (using a profilometer at the mirror lab)
2. (if adequate) ellipsometry before exposure (mirror lab)
3. exposure to relevant conditions
4. rougness measurement after exposure (using a profilometer at the mirror lab)
5. (if adequate) ellipsometry after exposure (mirror lab)
6. FIBSEM after exposure (dr. Rasinski)

De-trapping amount

Dr. Houben may be able to measure the amount of trapped hydrogen before and after exposure using thermal desorption, if this is not the case, or if it may be less accurate, IBA methods should probably be used.

References

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[2] A. Goriaev, T. Wauters, R. Brakel, H. Grote, M. Gruca, O. Volzke, S. Brezinsek, A. Dinklage, M. Kubkowska, and U. Neuner. Development of glow discharge and electron cyclotron resonance heating conditioning on w7-x. *Nuclear Materials and Energy*, 18:227–232, 2019.

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