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	9

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 weekly Glow Discharge (GD) in H_2 and daily in helium for impurity and hydrogen removal respectively [2]. and Electron Cyclotron Wall Conditioning (ECWC) in H and He plasma (in the form of pulse trains) is applied for density control in hydrogen plasmas during experimental days, its effects have been reported ([1],[4] and EUROFUSION WPS1-PR(16) 16175). Eventually, W7-X will leverage the ICRF antenna to perform ICWC.

boronized graphite

The interaction of the hot plasmas will erode the first (boronized) 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. The aim is to then predict with an erosion code like ERO or rustBCA the observed erosion. If this is possible, it would showcase the effectiveness of the erosion codes, enabling it's deployment on W7-X measured/calculated wall fluxes.

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 cannot directly mimick W7-X, TOMAS lacks in power and magnetic field strength and as such doesn't have the same heating fundamentals and wall conditioning scenario. However it is possible to compare the two, mainly by predicting the de-trapping rate according to relevant pde's, as e.g mentioned in McCracken[3]. Observing these kinds of rates in W7-X relevant ICWC plasmas at TOMAS would make it possible to interpolate to W7-X itself given the right amount of insight.

3 TOMAS setup and days estimate

GDWC

The GD settings used at TOMAS will mimick the ones used in W7-X, namely 1.5A $\approx$ 300V at $\approx 4.5 \times 10^{-3}$mbar for H_2 and 1.0A $\approx$ 200V at $\approx 3.5 \times 10^{-3}$mbar for He[2] and one with both H and He. As the current and voltage relate via ohms law it might not be possible to exactly reproduce both the current and voltage. As sputtering rates are predicted to be linear with flux (or current) but behave as a power law with energy, matching the voltage is of higher importance.

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 frequency of the ICRF antenna will be set to 38MHz, keeping the pressure at the sample manipulator as as close to the ones used in W7-X's wall as possible. The gasses used will be once helium and once helium+hydrogen. To interpolate power differences need to be observed as well as time traces. As such with two gasses each having one time trace at maximum power of at least 4 exposures and one energy trace of at least 4 exposures, each hosting 3 samples (to have a simple error estimate) the total amount of samples comes to $2 \times 2 \times 4 \times 3 = 24$ samples which should take 9 days to expose.

How the days are estimated

The days estimate comes from the possibility to do 2 exposures per day, with one day of preparatory work, calculated on a maximum of 3 exposure days 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 should probably be used.

References

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[3] G.M. McCracken and P.E. Stott. Plasma-surface interactions in tokamaks. *Nuclear Fusion*, 19(7):889, jul 1979.

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