W7-X relevant TOMAS wall conditioning experiments

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1 Short overview

Amount	kind of samples	need	project	TOMAS days
28	boronized graphite	H & He and H+He GD	W7-X	6
20	hydrogen doped boronized graphite	He ICWC	W7-X	4

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],[3] 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, as such only the divertor area is conditioned by ECWC which erodes the boron layer within seconds. As such it is not relevant to study ECWC on TOMAS, and we will focus on ICWC. We wish to observe a time law for de-trapping to interpolate to W7-X.

3 TOMAS setup and days estimate

GD

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]. As the current and voltage relate via ohms law it might not be possible to exactly reproduce both the current and voltage. As classically sputtering is linear with flux (or current) and a power law with energy, matching the voltage is of higher importance.

GD experiments will be carried out on 28 boronized graphite samples, grouped 4 per shot for 7 shots. 4 samples per exposures to have reasonable statistics and 4 exposures for different energies each to have reasonable confidence in the yield-energy curve form. Furthermore 4 samples per exposure for 3 exposures will be conducted for yield-time estimation (should be linear, extra measurement for validation).

EC

EC experiments will be carried out on 20 hydrogen-doped boronized graphite samples, grouped 4 per shot for 6 shots to have sufficient statistics in outgassing per time and in the observation of the time law.

Both

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

Most of this will be outsourced to experts within FZJ whom will be credited appropriately. On the non-doped samples mainly erosion will be measured while on the doped samples outgassing will be measured. On the erosion samples other measurements will also be performed

1. roughness measurement before and after
2. (if adequate) ellipsometry before and after
3. FIBSEM after and on one control

4.1 Roughness 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

Thickness estimates may be made using ellipsometry on the non-doped specimens prior to the exposure and after exposure prior to being analysed using FIBSEM (dr.Rasinski).

References

[1] A Goriaev, T Wauters, R Brakel, S Brezinsek, A Dinklage, J Fellinger, H Grote, D Moseev, S Sereda, O Volzke, and W7-X team. Wall conditioning at the wendelstein 7-x stellarator operating with a graphite divertor. *Physica Scripta*, 2020(T171):014063, mar 2020.

[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.

[3] Tom Wauters, Andrei Goriaev, Arturo Alonso, Juergen Baldzuhn, Rudolf Brakel, Sebastijan Brezinsek, Andreas Dinklage, Heinz Grote, Joris Fellinger, Oliver P. Ford, Ralf König, Heinrich Laqua, Dmitry Matveev, Torsten Stange, and Lilla Vanó. Wall conditioning throughout the first carbon divertor campaign on wendelstein 7-x. *Nuclear Materials and Energy*, 17:235–241, 2018.