Outgassing measurements for the ITER EC H&CD Upper Launcher

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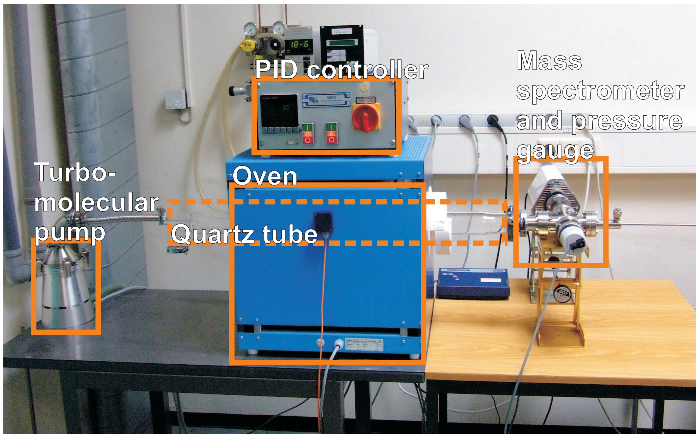
Introduction

In most applications involving both vacuum and high temperatures, outgassing of structural materials is a critical issue. For instance, this is the case of fusion devices, where the gas released from the vessel walls contaminates the plasma.

Four upper ports in the ITER vacuum vessel are reserved for Electron Cyclotron Heating and Current Drive (EC H&CD) Upper Launchers (UL), which have to provide plasma MHD stabilization by localized deposition of high power microwave beams. The structural material foreseen for the UL is the 316L(N)-IG stainless steel. It has to withstand temperatures in the range 120-150°C during normal operation and 240°C during the baking process. One of the preferred manufacturing routes for UL components is Hot Isostatic Pressing (HIP) which is a method to manufacture powder metallurgical structural components of complex geometry with good mechanical properties. The materials for use in the ITER vacuum system have to comply with the outgassing limits given in the ITER vacuum handbook, but no outgassing data for HIPed stainless steel are available in literature, thus they must be obtained by experimental measurements.

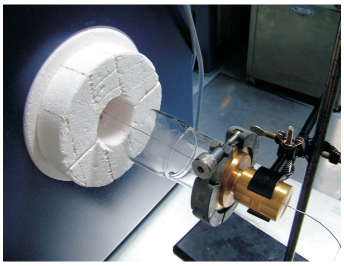
An experimental setup was developed for investigating the partial outgassing rates of stainless steel prototype samples AISI 316LN (on which the 316L(N)-IG is based) and AISI 317LMN, obtained by the powder and solid HIPing methods. A variant of the gas throughput method in vacuum systems was used for the outgassing measurements which were carried out over periods larger than 8 hours and at different temperatures.

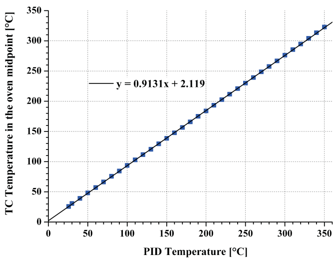
Experimental setup

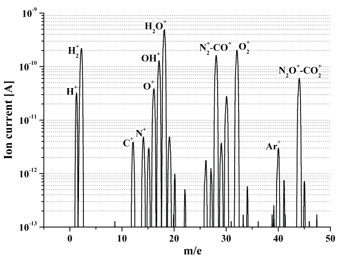


A quartz tube of internal diameter $D \sim 5\times10^{-2}$ m and length $L \sim 8\times10^{-1}$ m is used as vacuum chamber. It is installed in an oven associated to a proportional-integrative-derivative (PID) controller which allows setting the desired temperature. The left side of the chamber is connected to a pumping station formed by a membrane pump (not shown here) and a turbomolecular pump connected in series. Through an equal 4-way cross the chamber right side is attached to a Pirani-cold cathode combination gauge, a quadrupole mass spectrometer, while the last aperture is used for inserting the samples into the quartz tube.

Calibration



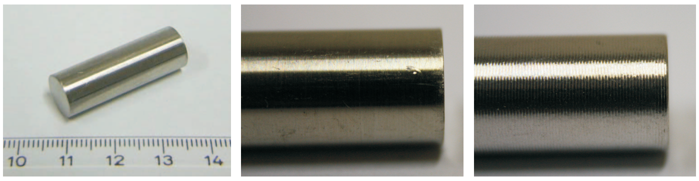


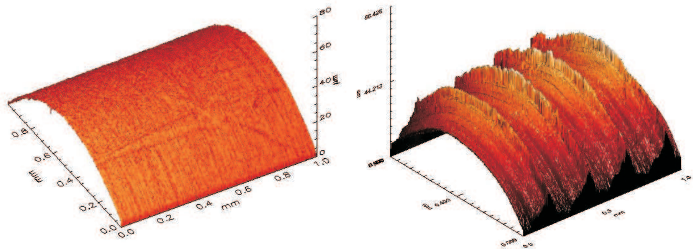


- The outgassing rate of a surface is temperature dependent. The samples are placed at the midpoint of the oven. A temperature calibration was carried out before starting the sample outgassing measurements.
- The specific partial outgassing rate is calculated after comparison between partial pressures in *blank* and *sample* runs, according to the following formula:

$$q = \frac{C\,(P_{sR} - P_{bR})}{A_r}$$

Samples

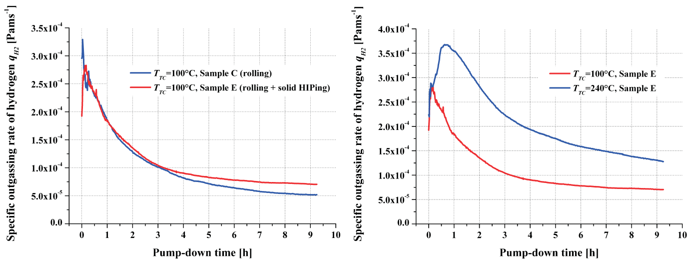




The outgassing rate depends on the surface finish of the material. Its effect can be observed only using the real area of the samples in the outgassing calculations. Roughness measurements were performed in order to calculate the surface factor $f_s = A_r / A_g$ of each sample.

	Material	Fabrication technique	Surface finish	f_s
Sample A	AISI 316LN	Powder HIPing	Polished	1.112
Sample B	AISI 316LN	Powder HIPing	Rills	1.655
Sample C	AISI 317LMN	Rolling	Polished	1.207
Sample D	AISI 317LMN	Rolling	Rills	1.770
Sample E	AISI 317LMN	Rolling and solid HIPing	Polished	1.397
Sample F	AISI 317LMN	Rolling and solid HIPing	Rills	1.943

First results



Conclusions

- Comparing the specific partial outgassing rates between the samples A, C and E or the samples B, D and F, no significant difference due to the HIPing method has been found. A possible reason could be that the samples are too small in order to appreciate the effect of the different fabrication technique. Moreover, because of such small dimensions, the amount of some gases released from the samples has not been appreciated sometimes; so higher sample/chamber volume ratio must be taken into account.
- Comparing for instance the specific partial outgassing rates between the samples A and B which differ only because of the surface finish, it has been observed that in the case of the rills the outgassing value is about 4 times greater than that of the polished sample. The outgassing values are calculated per unit of *real* area of the samples and not geometric, so this increase cannot be explained with a bigger sample area exposed to the vacuum. The explanation for this increase would be the microstructural change close to the surface that the material undergoes when the rills are generated.
- The obtained results are only preliminary and as a consequence cannot be compared yet to the outgassing limits given in the ITER vacuum handbook. Future work aims to further improve the experimental setup considering in particular higher dimensions of the samples, different cleaning methods of their surface and a load-lock system to insert and remove the samples without breaking the vacuum conditions in the setup.

Acknowledgements

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