

WALL CONDITIONING IN T-15
INVESTIGATION OF WALL SURFACE STATE BY WASA II

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The carbon is practically the unavoidable plasma impurity in tokamak with graphite limiters like T-15. To diminish a carbon flux into plasma different methods are used such as boronisation, usage of composites and so on. A decrease of the influx of another light impurity - oxygen - can be reached by long term backing of vacuum vessel and discharge cleaning (DC). The temperature of T-15 vacuum chamber walls at backing is not homogeneous - it can be 200-230° C in toroidal part of vessel (total area equals 75 m²) and only 40-50° C in far parts of ports (total area of ports equals 75 m² also). Therefore optimization of discharge cleaning procedure is rather important to reduce T-15 plasma contamination by oxygen. Three types of discharges are used in T-15 for this aim: inductive discharge in hydrogen (IDCH₂) and glow discharges in hydrogen (GDCH₂) and helium (GDCH_e). These methods are widely used for wall conditioning in other tokomaks and usually RGA gives some information about wall purity. Because of the big temperature differences in the T-15 vessel, the RGA spectra didn't represent the condition of the first wall. The diagnostic station WASA II (Wall Analysis with SIMS and Auger) on T-15 was used for in situ measuring of the impurity content on probe surface (PS) exposed to cleaning and tokamak discharges (TD). Description of this diagnostic was given in [1] and first results were published in [2,3]. In this work different cylindrical probes made from copper and stainless steel with a tantalum foil on the lateral surface of probe were used for measurements. In special experiments with Faraday cylinders it was shown that ion current densities on analyzed lateral and plasma facing surfaces are equal each other and therefore processes of deposition and desorption of impurity atoms and molecules are the same on both surfaces. Measurements with biased and floating probes had shown that chemical composition of PS was almost the same in both cases though the desorption of main impurity - carbon - is a little lower at floating potential. The usual position of probe in all experiments was on the minor radius 76 cm what is larger than inner radius of unmovable limiters (70 cm). Extraction of probe from the discharge chamber into analysis chamber of WASA II and measurements of AES and SIMS on PS were made every 1,5-2 hours in discharge cleaning or after a number of TD.

During the DC the content of oxygen on the wall surface is probably the result of the deposition of oxygen escaping weakly backed and poorly outgassed parts of the vessel (ports) and desorption of oxygen from the wall surface due to generation of volatile molecules and impact sputtering. The same processes have to be observed on the PS. In fig.1 one can see that more rapid desorption of carbides leads to appearance of foil material line in AES which afterwards disappears due to deposition of oxygen and iron. Using this figure data one can calculate initial values of carbon desorption rate ($\sim 10^{15}$ at $\text{cm}^{-2} \text{s}^{-1}$) and deposition rate of oxygen ($\sim 6 \cdot 10^{14}$ at $\text{cm}^{-2} \text{s}^{-1}$), equilibrium concentrations of these impurities at which deposition and desorption are equal each other ($\sim 8 \cdot 10^{15}$ at cm^{-2}) and rather roughly a characteristic time of deposition-desorption balance ($\sim 2\text{-}3 \cdot 10^3$ s). Assuming that a total concentration of impurities on PS is about of one monolayer (a short term appearance of Ta line shows that we have a rather like case) we can use a simple equation for some impurity concentration neglecting overlapping with other impurities. According to solution of this equation the characteristic time gives an estimation of an effective cross-section of desorption process ($\sigma \sim 7\text{-}1 \cdot 10^{-17} \text{cm}^2$).

Practically the same value of desorption cross-section can be obtained using the initial desorption rate of carbon and a balance condition for oxygen. Then the total desorption rate of some impurity "m" is σCI where I - current of glow discharge and C - average concentration of impurity "m" on the wall surface. A pumping speed must be high enough to remove this flux of impurities at their pressure much lower then a pressure of working gas.

The highest concentration of oxygen on PS (up to 50%) was measured in GDCH2 at low wall temperature ($T=40\text{-}100^\circ \text{C}$). It is seen in fig.2 that it did not practically changed in almost 40 hours discharge. The partial pressure of water was constant during this time also. In GDCHc the oxygen content fell down to less than 20% at the same wall temperature. The change in chemical composition of PS at transition from GDCH2 to GDCHc can be seen in fig.2 where two last hours of cleaning were performed with helium discharge. Another example of impurity contents on PS is shown in fig.3. The special feature of this case is the very high concentration of nitrogen on PS what may be due to a nitrogen contamination of the helium used. It is worth to notice that after this event traces of nitrogen were observed in AES during the month of intense tokamak operation though part of nitrogen was released from PS as ammonia in the first following IDCH2. This means that during GDC impurity atoms (in this case nitrogen) were implanted in near surface layer of PS where they had a wide spectrum of binding energy with surface. Therefore the usage of GDC at high level of impurities on chamber walls is undesirable. The lowest oxygen content (<10%) was observed in IDCH2 ($T=40\text{-}230^\circ \text{C}$) what can be seen in fig.4. So the

measurements don't contradict to assumption that contamination of chamber walls by oxygen is the consequence of port wall cleaning. Glow discharges penetrate deeper into ports than inductive one and produce the higher flux of oxygen into toroidal part of chamber (GDCH2 higher than GDCHe). According to these results one can expect that contamination of T-15 plasma by oxygen will be lowest in TD after IDCH2.

In contrast to oxygen the carbon content on PS was almost the same in all three types of discharges - 40-60% but the state of carbon films was quite different. The tokamak discharges (TD) with low current (~ 25 MA) performed after IDCH2 were accompanied by continuous density increase and disrupted at the density limit (see fig.5). SIMS analysis showed that after IDCH2 a great part of carbon is bonded on PS as methane or its radicals which could be easily desorbed during TD. Practically the same spectra of secondary ions were observed in intensively deposited carbon after such TD. A content of methane radicals is not constant in these spectra and two examples of them with maximal and minimal population of radicals are shown in fig.6. For both cases (after IDCH2 and after TD) we could not find any correlation between shape of secondary ions spectrum and a type of a foregoing discharge. On the contrary the plasma density of TD with much higher current after GDCHe and foregoing IDCH2 was well controlled by gas puff and the carbon deposition on PS after TD was low (appropriate traces are drawn in fig 5).

Summary. For T-15 it was shown that conditioning of ports walls can be made most effectively by GDCH2. When cleaning the rate of impurity desorption is about $5 \cdot 10^{-3}$ at/ion. Some of impurities are implanted in near surface layer in GD and can be partly released in IDCH2. The wall surface is saturated by hydrocarbons after long term IDCH2. Therefore the optimal cleaning procedure for T-15 is the following.

1. Removal of oxygen from ports by GDCH2.
2. Release of implanted impurities by IDCH2.
3. Desorption of hydrocarbons and CO by GDCHe.

References

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- /2/ A.Herrmann et al., Proc. 18th Europ. Conf. on Contr. Fus. and Plasma Phys., Berlin 1991, Vol. 3, p. 53
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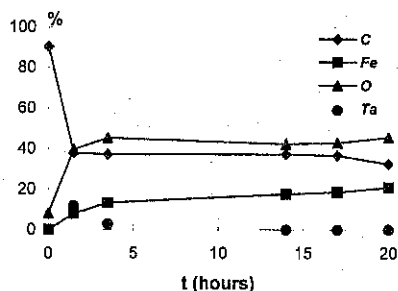


Fig.1 Surface concentration of elements on the Ta foil during GDCH2

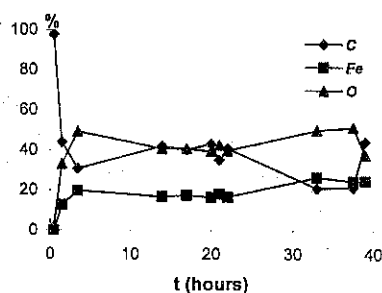


Fig.2 Impurities content on SS PS during GDCH2 and GDCHe (last points)

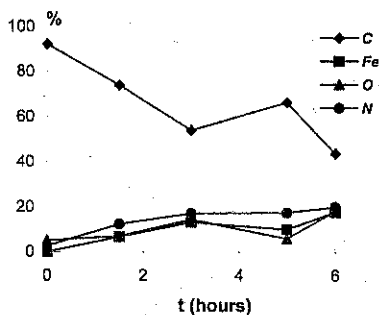


Fig.3 Chemical composition of PS in GDCHe

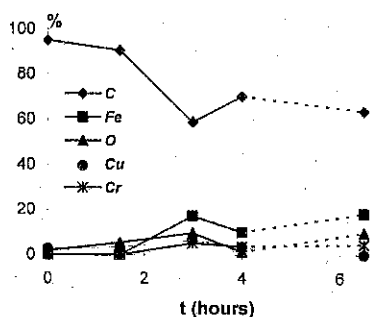


Fig.4 Concentration of impurities on Cu PS during IDCH2

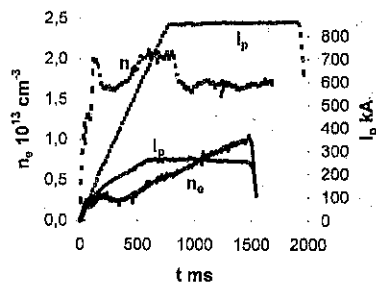


Fig.5 Plasma current and electron density in TD followed after IDCH2 (—) and GDCHe (---).

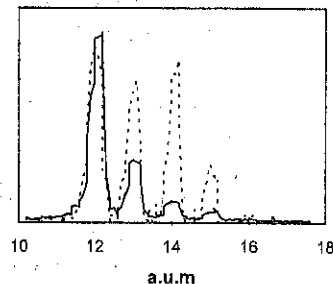


Fig.6 Mass spectra of secondary ions after IDCH2 or following TD