THE POSSIBLE VARIANT OF PULSED RF-DISCHARGE CLEANING MODE OF THE URAGAN-3M TORSATRON

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The cleaning regime with the use of pulsed RF-discharges in hydrogen-nitrogen mixture was examined over the nitrogen concentration range from 4 at.% to 96 at.% at the same parameters of RF-generator as for pure hydrogen. The analysis of obtained preliminary data has shown that even about $2x10^3$ discharge pulses in H_2-N_2 mixture causes drastic decrease of partial hydrogen pressure and ultimate base pressure. But, in contrast, to revert initial high hydrogen partial pressure in the U-3M torsatron vacuum chamber, it is needed more than $2x10^4$ pulsed discharges in pure hydrogen. The possible reasons of effective hydrogen removing in RF-discharges in hydrogen-nitrogen mixtures are discussed.
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1. INTRODUCTION

The usual regime of pulsed RF-discharge cleaning under wall conditioning in the Uragan-3M (U-3M) torsatron [1, 2] includes long time plasma machine operation at high hydrogen pressure of about 10^{-4} Torr. The interaction of low temperature hydrogen plasmas with plasma facing components (in the U-3M they are, mainly, stainless steel housing of helical windings of magnetic coils and TiN-coated stainless steel RF-antennas) and the intensive molecular hydrogen flow, passed through U-3M vacuum chamber [3], result in the increase of hydrogen concentration on the surface and in the bulk of the PFM and walls of vacuum chamber. As the consequence, hydrogen partial pressure in the U-3M vacuum chamber increases to about $5x10^{-7}$ Torr (instead of $2\text{-}3x10^{-7}$ Torr ultimate base pressure) and desorbed hydrogen becomes the main gas in the mass-spectrum of residual gases. It lets to carry out plasma experiments under sufficiently clean conditions in spite of the unbaked variant of U-3M vacuum chamber construction. Moreover, the possible activated state of desorbed hydrogen similar, as it had been shown for metal hydrides [4], could play the positive role on the initial stage of pulsed plasma discharges. But, when the mode of operation with low hydrogen recycling is needed, it is necessary to revert system in the state with low hydrogen isotope concentration in the materials and low hydrogen partial pressure. It is possible, using rare gases during discharge cleaning, e.g., helium or helium-oxygen mixture [5]. Such researches are also of a great interest from the point of view to improve methods of minimization of hydrogen isotope contamination of constructional materials.

2. EXPERIMENTAL RESULTS

As shown earlier [6-8], the small amount (about 0.5-4%) of hydrogen admixed in N_2 (or N_2 admixed in H_2) leads to a significant change of discharge characteristics in high frequency discharges and in dc glow discharges. Therefore, before experiments in the U-3M some imitating examinations had been carried out in abnormal glow discharge plasmas of an axial configuration [9], when hydrogen came through hot Pd-cathode into nitrogen plasma, and in mirror Penning discharge plasmas in DSM-1 device [10]. The current-voltage characteristics were measured with and without hydrogen admixture (≈ 1-8 at.%). In the case of glow discharge plasmas it had been founded really strong influence of hydrogen admixture to nitrogen on discharge current (as seen in Fig.1, discharge current at the same voltage for H_2-N_2 mixture is in 5-8 times higher than for pure nitrogen). In the contrary, in the case of Penning discharges it had not been founded of significant influence of the hydrogen admixture in the working gas (nitrogen) on voltage-current plasma performances (Fig.2). A similar situation was observed for discharges when nitrogen was admixed in hydrogen. Such behavior can be explained by the fact that the plasma column of Penning discharge due to magnetic field has no direct contact with the wall surface, so surface reactions influencing recombination rate do not play an essential

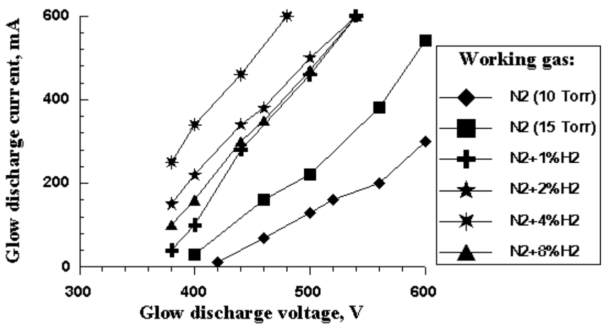

Fig. 1. I-V characteristics for abnormal GD in pure nitrogen and in nitrogen with hydrogen admixture

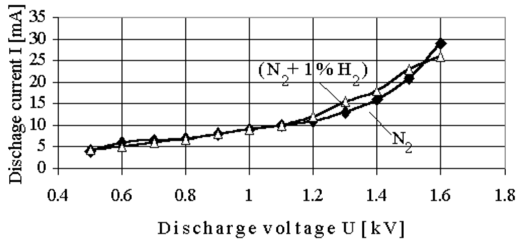

Fig.2. Current-voltage characteristics for N_2- and (N_2 + 1%H_2) – Penning discharges at pressure 0.266Pa.

role. It has to be noted only, that discharge current instability takes place in Penning discharges during of a few minutes on an initial stage of discharge caused by impurity flow from cathodes. In this time discharge current decreased on 30-50% from the current value in the initial stage of discharge.

According to estimations made in [10], it could be about 75 % impurity content (mainly H_2O, CO, CO_2,) on the initial stage of discharges, if to suppose only one impurity monolayer on cathodes surfaces before discharge. So really, on the initial stage, the discharge characteristics are presented for mixture of gases. The second fact needed to be noted is the essential ultimate pressure improvement, observed after pure nitrogen throughput and discharge cleaning in nitrogen of Penning discharge device DSM-1, which long time worked with hydrogen work gas before.

In this work the cleaning regime of U-3M with the use of pulsed RF-discharges in hydrogen-nitrogen mixtures was examined under the nitrogen concentrations 4 at.% and 96 at.% at the same parameters as for pure hydrogen: 1 pulse per 6 seconds, RF input power was about 50 kW, discharge duration was 60 ms, the stationary magnetic field was varied from 250Gs to 270 Gs. The comparison measurements of plasma density, voltage-current characteristics of Langmuir probe, current and voltage of RF-antenna, mass-spectra were made in discharges at the different nitrogen concentration and in pure hydrogen. It is seen in Fig.3 that plasma density decreases with nitrogen concentration increase, and the essential rise of the antenna voltage is observed (Fig. 4). Note, that at this time the breakdown voltages for H_2-N_2 mixtures were essentially lower than for pure hydrogen. To provide the increase of plasma density and low antenna voltage one can using of the raising of the magnetic field value from 250 Gs (pure hydrogen) to 270 Gs and what is more (for H_2-N_2 mixtures).

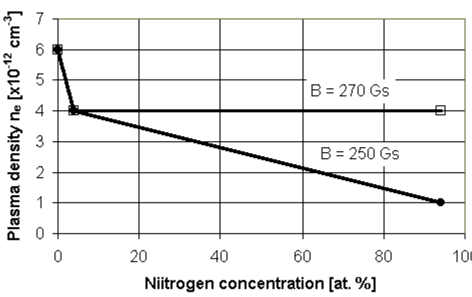

Fig.3. Plasma density vs nitrogen concentration in hydrogen under different magnetic fields.

At the same time voltage-current characteristics of Langmuir probe are near for both the pure hydrogen and mixtures (Fig.5). This fact confirms that in the case of the magnetic confined plasmas there are not essential influence of the surface recombination reactions, as it was observed for Penning discharges [10].

It is seen in Fig.6 that even about 2-5x10^3 discharge pulses in H_2-N_2 mixture causes drastic decrease of partial hydrogen pressure. It should be noted that ultimate base pressure also decreased from 2.5x10-7 Torr to 1.5x10-7 Torr. But, in contrast, to revert initial high hydrogen partial pressure in the U-3M vacuum chamber, it is needed more than 2x10^4 pulsed discharges in pure hydrogen. What could be the reasons of such hydrogen effective removing?

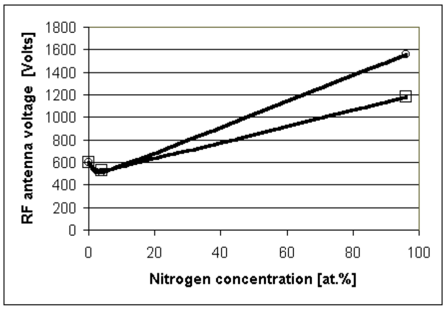

Fig.4. Influence of magnetic field on RF antenna voltage for different nitrogen admixtures: ○ - 250Gs,□ - 270Gs

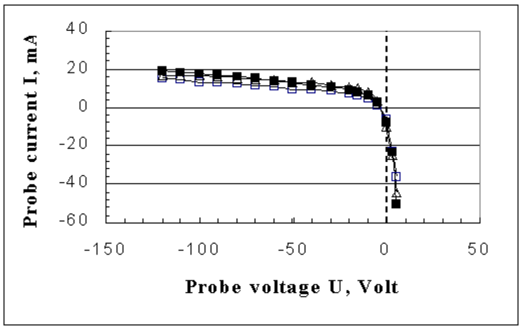

Fig.5. I-V characteristics of Langmuir probe under cleaning discharges in pure hydrogen (closed squares), in ($4\%N_2+96\%H_2$)-mixture (open triangles) and in ($96\%N_2+4\%H_2$) mixture (open squares).

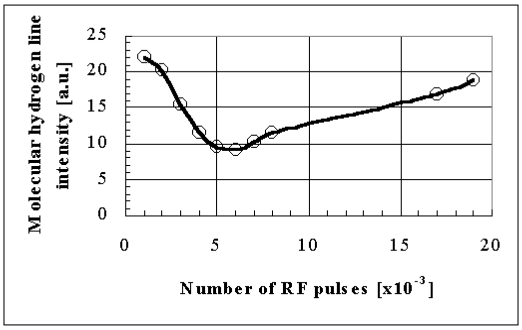

Fig.6. Time evolution of hydrogen concentration in the vacuum chamber of the Uragan-3M torsatron, as measured by IPDO-1 mass-spectrometer.

There are the main three kinds of outgassing surfaces in the U-3M, which specify a vacuum conditions: stainless steel walls of the U-3M vacuum chamber and plasma unfacing surfaces of stainless steel housing of helical windings, plasma facing surfaces of stainless steel housing of helical windings, and TiN-coated stainless steel RF-antennas. For the first, the essential role can play an intensive molecular nitrogen flow, passed through U-3M vacuum chamber under the pressure of discharge cleaning regime similar to effect of essential decrease of TiN and stainless steel outgassing after hydrogen throughflow presented in [3, 11]. It is well known [12] that the interaction between nitrogen and a stainless steel surface is negligible and the exposure to N_2 atmosphere makes possible to short time of pumpdown and to improve an ultimate pressure including hydrogen partial pressure. For the plasma facing surfaces of the U-3M components, behind of nitrogen throughflow, the important role can play interactions of adsorbed particles with neutrals (the production of H and N atoms radically increases in mixtures [12]) and different radicals $NH(NH^+)$, $NH_2(NH_2^+)$. In such conditions the removal of adsorbed hydrogen could be more effective. And, at last, what about TiN-coated surfaces of the RF-antennas. It had been shown in the previous work [13] that long time work of TiN-coated surfaces under exposure to hydrogen plasmas can lead to drastic changes in the TiN outgassing behavior. It is caused by the possibility of selective sputtering of the TiN surface, and the Ti enrichment of the coating nearest surface layer. Titanium, in its turn, activaly adsorbs hydrogen and impurities. So, after the work over a long period of time under hydrogen plasma impact, the TiN-coated RF-antennas could change into significant source of hydrogen and, after exposure to air, of impurities, too. In this situation the exposure of TiN-coated surfaces to nitrogen plasmas or to plasmas of N_2-H_2 mixtures could not only to clean these surfaces, but to repair the faulty parts of antennas forming titanium nitride instead of titanium. Of course, to choose the optimal characteristics of RF-discharge cleaning in the U-3M and to shed light on the real mechanisms of wall conditioning under cleaning in N_2-H_2 mixtures, the additional experiments are needed.

3. CONCLUSION

It had been shown that short time wall conditioning of the U-3M torsatron by RF-discharge cleaning in N_2-H_2 mixtures had resulted in essential decrease of hydrogen partial pressure and in improvement of the base ultimate pressure. Such variant of RF-dischage cleaning mode could be used, but additional experiments are needed before, to choose the optimal discharge characteristics and to understand in detail the real mechanisms of the N_2-H_2 mixed plasma interactions with surfaces of the U-3M torsatron components.

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ВОЗМОЖНЫЙ ВАРИАНТ РЕЖИМА ЧИСТКИ ТОРСАТРОНА УРАГАН-3М ИМПУЛЬСНЫМИ ВЫСОКОЧАСТОТНЫМИ РАЗРЯДАМИ

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Исследовался режим чистки импульсными ВЧ-разрядами в смеси водорода и азота при концентрациях азота от 4 at.% to 96 at.% при тех же параметрах ВЧ-генератора, что и для чистого водорода. Анализ полученных данных показал, что уже около $2x10^3$ импульсов в H_2-N_2 смеси вызывает заметное снижение парциального давления водорода и предельного давления в камере У-3М. Напротив, чтобы вернуть высокое парциальное давление водорода в вакуумной камере У-3М необходимо более чем $2x10^4$ импульсных разрядов в чистом водороде. Обсуждаются возможные причины эффективного удаления водорода разрядами в смеси водорода и азота

МОЖЛИВИЙ ВАРІАНТ РЕЖИМУ ЧИЩЕННЯ ТОРСАТРОНА УРАГАН-3М ІМПУЛЬСНИМИ ВИСОКОЧАСТОТНИМИ РОЗРЯДАМИ

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Досліджувався режим чищення імпульсними ВЧ-розрядами в суміші водню й азоту при концентраціях азоту від 4 at. % to 96 at. % при тих же параметрах ВЧ-генератора, що і для чистого водню. Аналіз отриманих даних показав, що вже близько $2x10^3$ імпульсів у H_2-N_2 суміші викликає помітне зниження парціального тиску водню і граничного тиску в камері У-3М. Навпроти, щоб повернути високий парціальний тиск водню у вакуумній камері У-3М необхідно більш ніж $2x10^4$ імпульсних розрядів у чистому водні. Обговорюються можливі причини ефективного видалення водню розрядами в суміші водню й азоту.