THE INFLUENCE OF WALL CONDITIONING PROCEDURES ON OUTGASSING RATE OF STAINLESS-STEEL IN THE “URAGAN-2M” TORSATRON

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Using the thermal desorption method the investigations were carried out of stainless steel probe outgassing rate in a vacuum and estimation of the number of monolayers on its surface in the Uragan-2M torsatron in situ. The decrease of surface impurity by more than one order of magnitude was measured at the vacuum improvement from $1.6{\cdot}10^{-6}$ Torr up to $6.5{\cdot}10^{-7}$ Torr after pumping and RF discharge cleaning. Mass-spectrometric measurements has shown H_2O (18 m/e), Co_2 (44 m/e) and 28 m/e ($CO+N_2$), as the main gases desorbed from probe surface during its heating. Heavy hydrocarbon masses (58 m/e) were also registered. Some practical conclusions were made for the U-2M wall conditioning procedure improvement.

PACS: 52.40.Hf

INTRODUCTION

The wall conditioning procedure in the present thermonuclear plasma devices is necessary technological process of their preparing for plasma experiments. The impurity level of the wall surfaces (number of impurity gases monolayers, outgassing rate in a vacuum) mainly determines the ultimate vacuum in the device and the impurity flows to plasma during work discharges. This problem is especially important for non heated plasma devices. In the Uragan-2M (U-2M) and Uragan-3M (U-3M) torsatrons the cleaning of plasma facing surfaces (mainly stainless steel 12KH18N10T) is carried out usually with RF discharges in hydrogen atmosphere [1-4]. The control of cleaning procedure efficiency was realized on the change of CIII, CIV spectral lines intensity. Besides, the mass spectrometric analysis and ultimate vacuum pressure measurements were carried out. These control methods gives the information on the impurity concentration in the vacuum chamber volume. But it is very important for plasma experiments to know not only ultimate pressure and partial impurity pressures, but impurity concentration on the surfaces of the vacuum chamber, too. Just the latter determines the intensity of impurity flows to plasma during work discharges. From the other hand it is known the sufficiently simple method for surface impurity level estimation with the use of thermal desorption phenomenon [5, 6]. The essence of the method is in the providing of metal probe placing in the investigated vacuum chamber and its heating by directly running the electric current. The pressure increase, caused by the gas desorption from the probe surface, is proportional to monolayer number, i.e., impurity level. So it was interest to study the outgasing behavior of stainless steel (SS) surface and level of its impurity on the wall conditioning procedure in the U-2M torsatron with the use of above mentioned method.

EXPERIMENTAL, RESULTS, DISCUSSION

The scheme of the experiment is shown in Fig. 1. The strip-like probe (2) was made of stainless steel 12KH18N10T (SS), similar to U-2M vacuum chamber (1) material. The probe dimensions were 10 mm x 190 mm x 0.3 mm.

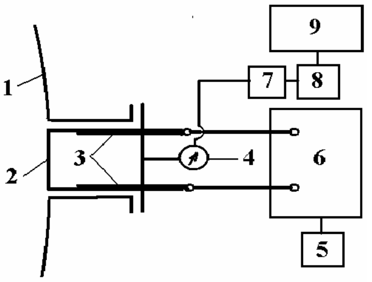

Fig. 1. The scheme of the experiment:
1 – U-2M vacuum chamber wall; 2 – stainless steel probe; 3 – current contacts; 4 – PMI-2 lamp;
5 – time relay; 6 – electric power unit;
7– VIT-2 device; 8 – analog divider module WAD-AIK-BUS; 9 – computer

Probe was connected with help of massive copper contacts (3) to electric power unit (6) providing pulsed heating of probe to given temperature. High bound of the temperature range was 300 ºC because the diffusion gas release from SS was started at the higher temperatures. The measured characteristic was specific outgassing rate q (Torr·l/s·cm^2·) under probe heating in a vacuum.

Before SS probe placing in the U-2M chamber it was calibrated on the heating voltage and specific outgassing rate at the temperatures of 200…300 ºC in the special stand “Block of the U-2M gas-analyzer”. In these experiments the probe heating time and voltage was determined with the using of chromel-copel thermocouple placed on the probe.

Then SS probe (without thermocouple to provide minimum parasitic outgassing) has been placed in the one of the U-2M ports. The measurements method was in detail described in works [7, 8]. The experiments were carried out during U-2M wall conditioning procedure: pumping, RF discharge cleaning, heating. After U-2M chamber pumping to pressure up to $1.6{\cdot}10^{-6}$ Torr the probe heating switched on the time of 4…5 s. The probe temperature increased up to 250…300 ºC and the pressure increase in the adjutage caused by desorbed gases was measured with help of ionized gage (4), vacuum apparatus (7), analog module WAD-AIK-BUS (8), computer (9). The typical apparatus curve of pressure increase on the time is shown in Fig. 2. Specific outgassing rate (Torr·l/s·cm^2) was determined from the eqution $q = (p-p_o)S/F$, где p_o и p – initial and final pressure; S – adjutage vacuum conductance; F – effective surface area of the probe. Data-processing operation of the curves (see Fig. 2), measured at the various pressures in the U-2M vacuum chamber (up to $6{,}4{\cdot}10^{-7}$ Torr) gives the dynamics of decreasing of outgassing rate from the vacuum chamber walls on the duration of U-2M chamber pumping (Fig. 3).

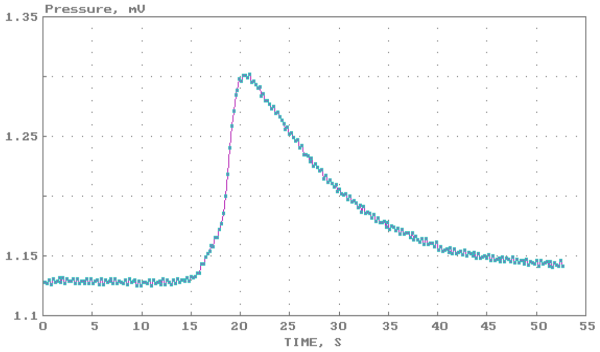

Fig. 2. Apparatus curve of pressure increase in the U-2M adjutage on the time (probe temperature is 250 ºC, initial pressure $1.13{\cdot}10^{-6}$ Torr)

It is seen that during vacuum pressure improvement from $6{\cdot}10^{-6}$ to $6{,}4{\cdot}10^{-7}$ Torr outgassing from the heated SS probe decreases in more than one order of magnitude (red color data in Fig. 3). Note, if to measure SS outgassing just after RF discharge cleaning (blue color date in Fig. 3) the SS outgassing rates are essentially higher. Note, in this experiment RF discharge cleaning was carried out only two hours. It is the evidence that very high impurity flow desorbs under RF plasma impact on the plasma facing surfaces and that the pumping facilities does not cope with a task of impurity pumping. As the result these impurities redeposit on the walls after switching off the discharge. The subsequent pumping of the U-2M vacuum chamber during 24 hours leads to obtaining good ultimate vacuum pressure of $6.4{\cdot}10^{-7}$ Torr and to decreasing of the number of monolayers on SS probe surface up to 2 instead of ~ 30 for a vacuum of $1.6{\cdot}10^{-6}$ Torr. The estimation of monolayer number on the probe surface was carried out with the use of the equation: $N=V{\cdot}L/N_w$, where V (N см^3)= qt – amount of gas desorbed from the unit of the probe surface; t (s) – time of the gas desorption; L – number of molecules in the gas volume of the 1 cm^3 (Loshmidt's number); N_w – number of molecules in monolayer. In the calculations it was supposed the water vapor as the main adsorbed gas and so $N_w \approx 5{\cdot}10^{14}$ cm^{-2} (according to Ref. [9] data). Really, the additional mass-spectrometric experiments in the U-2M vacuum chamber, made during SS probe heating to 300 ºC temperature, had shown the water vapor as the main desorbed gas (Table). The essential increasing of desorbed CO_2 (44 m/e), 28 m/e and hydrocarbons (58 m/e) was observed, too.

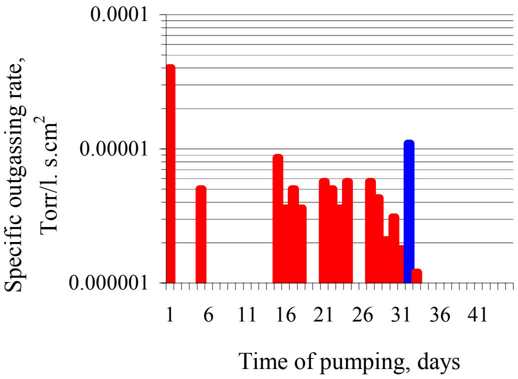

Fig. 3. Dependence of SS outgassing rate (250 ºC) in the U-2M on the duration of pumping (red color) and just after RF discharge cleaning (blue color)

Desorbed impurity gases partial pressures in the U-2M vacuum chamber during outgassing experiment

Desorbed gas, mass	Initial pressure P_o, Torr	Maximum pressure P, Torr	ΔP, Torr
H_2O (18 m/e)	$3.3{\cdot}10^{-7}$	$3.9{\cdot}10^{-7}$	$6{\cdot}10^{-8}$
$CO+N_2$ (28 m/e)	$8.18{\cdot}10^{-9}$	$1.87{\cdot}10^{-8}$	$1.6{\cdot}10^{-8}$
CO_2 (44 m/e)	$4.9{\cdot}10^{-9}$	$1.68{\cdot}10^{-8}$	$1.19{\cdot}10^{-8}$
58 m/e	$7.72{\cdot}10^{-10}$	$1.4{\cdot}10^{-9}$	$6.28{\cdot}10^{-9}$

The second series of the experiments was carried out during wall cleaning with stationary RF discharges in the warm (60 ºC) chamber (Fig. 4). Two RF generators with frequencies 5.6 MHz (~1 kW) and 132 MHz (~1 kW) generated stationary cleaning discharge during 12 hours. Then discharge was switched off and the U-2M vacuum camber was pumped during 12 hours. Then SS outgassing rate was measured at the probe temperature of 300 ºC (see Fig. 4, blue color data). Note, these outgassing rate values are essentially higher than in the case when outgassing rate was measured 1 hour later the additional RF discharge cleaning during 0.5…1 hour (yellow color data). This shows once more that pumping speed in the U-2M is not enough to evacuate effectively the desorbed impurity gases, the significant amount of which condensates on the vacuum chamber walls. So, the quasi-stationary RF discharge cleaning regime with short (0.5…2 hour) duration and with long time pumping, could be more effective for impurities evacuation.

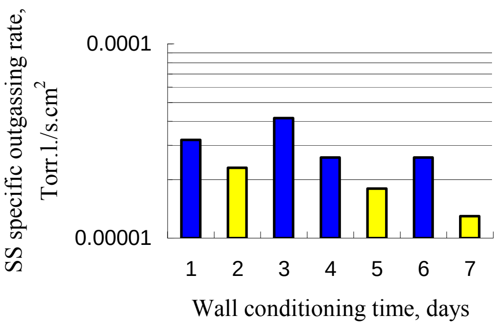

Fig. 4. Dependence of SS outgassing rate (300 ºC) in the U-2M on the duration of pumping and RF discharge cleaning

CONCLUSIONS

The investigations were carried out of SS probe outgassing rate and estimation of the number of monolayers on its surface in the “Uragan-2M” torsatron in situ. After preliminary pumping and RF discharge cleaning the decrease of surface impurity by more than one order of magnitude was measured at the vacuum improvement from $1.6\cdot10^{-6}$ Torr up to $6.4\cdot10^{-7}$ Torr. According with estimations the number of monolayers on the SS probe surface had decreased from ≈30 to ≈2. Mass-spectrometric measurements has shown H_2O (18 m/e), Co_2 (44 m/e) and 28 m/e, as the main gases desorbed from SS probe surface during its heating. Heavy hydrocarbon masses (58 m/e) were also registered. The analysis of the obtained data allows to say that the quasi-stationary RF discharge cleaning regime with short (0.5…1 hour) duration and with long time pumping, could be more favorable for impurities evacuation but to provide more correct estimation of efficiency of various scenarios of wall conditioning process in the U-2M torsatron the additional experiments will be provided.

REFERENCES

1. O.M. Shvets, A.G. Dikij, I.A. Dikij, S.S. Kalinichenko, A.I. Lysoivan, N.I. Nazarov, T.Yu. Ranuk, A.S. Slavnyj, K.N. Stepanov, V.T. Tolok. RF production and heating of plasma in Uragan-3 torsatron // *Proc. Of the 4th Int. symposium on heating in toroidal plasmas. Roma, March 21-28, 1984,* v. 1, p. 513-528.
2. N.I. Nazarov, V.V. Plusnin, T.Yu. Ranuk, et al. Plasma cleaning of the Uragan-3 device surfaces // *Plasma Physics.* 1987, v. 13, p. 1511-1515.
3. E.D. Volkov, N.I. Nazarov, G.P. Glazunov. The cleaning of surfaces and coating deposition with the use of low temperature RF discharge plasmas // *In Proc. of Int. Conf. on Phenomena in Ionized Gases, July, 11-16, 1999, Warsaw, Poland:* Contributed papers. 1999, v. 1, p. 205-206.
4. V.E. Moiseenko, P.Ya. Burchenko, V.V. Chechkin, et al. Wall conditioning RF discharges in Uragan-2M torsatron // *The International Conference-School on Plasma Physics and Controlled Fusion, September 13-18, 2010, Alushta (Crimea), Ukraine:* Book of Abstracts. Kharkov, 2010, p. 6-9.
5. *Sorption processes in vacuum* / Ed. K.N. Myznikov, M.: “Atomizdat”, 1966, 316 p.
6. J.H. Leck. *Pressure measurement in vacuum systems /* Ed. L.P. Khavkin. M: “Mir”, 1966, 208 p.
7. G.P. Glazunov, A.A. Andreev, D.I. Baron, et al. Influence of the method of vacuum-arc TiN coatings deposition on their outgassing in vacuum at high temperatures // *Physical surface engineering.* 2009, v. 7, №4, p. 341-346 (in Russian).
8. G.P. Glazunov, V.K. Pashnev. Method for diagnostics of the Uragan-2M vacuum chamber surface conditions // *Physical surface engineering.* 2012, v. 10, №2, p. 75-79 (in Russian).
9. S. Dushman. *Scientific foundations of vacuum technique.* M.: “Mir”, 1964, 716 p.

Article received 03.10.12

ВЛИЯНИЕ ПРОЦЕДУРЫ ЧИСТКИ ПОВЕРХНОСТИ НА ГАЗОВЫДЕЛЕНИЕ НЕРЖАВЕЮЩЕЙ СТАЛИ В ТОРСАТРОНЕ УРАГАН-2М

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Термодесорбционным методом проведены исследования газовыделения нержавеющей стали и оценка числа монослоев примесей на ее поверхности в торсатроне Ураган-2М. После откачки и чистки ВЧ-разрядами количество примесей снизилось более чем на порядок при улучшении вакуума с $1{,}6\cdot10^{-6}$ до $6{,}4\cdot10^{-7}$ Торр. Масс-спектрометрические измерения показали, что основными примесями, десорбирующимися с поверхности зонда из нержавеющей стали во время его нагрева до температуры 250…300 ºC, являются: H_2O (18 а.е.м.), Co_2 (44 а.е.м.) и 28 а.е.м. ($CO+N_2$). Тяжелые углеводороды (58 а.е.м.) также регистрируются. Сделаны некоторые практические заключения для улучшения процедуры чистки стенок камеры торсатрона Ураган-2М.

ВПЛИВ ПРОЦЕДУРИ ЧИЩЕННЯ ПОВЕРХНІ НА ГАЗОВИДІЛЕННЯ НЕРЖАВІЮЧОЇ СТАЛІ В ТОРСАТРОНІ УРАГАН-2М

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Термодесорбційним методом проведено дослідження газовиділення нержавіючої сталі і оцінка числа моношарів домішок на її поверхні в торсатроні Ураган-2М. Після відкачування і чищення ВЧ-розрядами кількість домішок знизилася більш ніж на порядок при поліпшенні вакууму з $1{,}6\cdot10^{-6}$ до $6{,}4\cdot10^{-7}$ Торр. Мас-спектрометричні вимірювання показали, що основними домішками, що десорбуються з поверхні зонда з нержавіючої сталі під час його нагріву до температури 250…300 ºC, є: H_2O (18 а.е.м.), Co_2 (44 а.е.м.) і 28 а.е.м. ($CO+N_2$). Важкі вуглеводні (58 а.е.м.) також реєструються. Зроблені деякі практичні висновки для поліпшення процедури чищення стінок камери торсатрона Ураган-2М.