WALL CONDITIONING DISCHARGES DRIVEN BY T-SHAPED ANTENNA IN URAGAN-2M

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New VHF antenna was introduced at Uragan-2M for VHF vacuum chamber wall conditioning without and with weak magnetic field. It was made as a T-shaped ¼ wavelength double rod. The T-shaped antenna is capable for slow waves generation due to its longitudinal currents. This new wall conditioning tool was studied analyzing vacuum chamber wall conditions and achieved plasma parameters.

PACS: 52.50.Sw

INTRODUCTION

New non-shielded T-shaped antenna, proposed by one of the authors (V.E.M.) is used for Uragan-2M (U-2M) vacuum chamber inner surfaces conditioning. It creates plasma with VHF discharge. The previous small frame antenna was grounded and non-resonant, which means it couldn't be very effective option for long wall conditioning.

Present work aims to determine optimal regimes for continuous conditioning plasma discharge creation and maintenance without magnetic field [1] and in weak magnetic field [2]. Optimal conditions were searched through changing magnetic field, pressure and RF power. First experiments were about tuning all systems, adjusting diagnostics, hunting proper RF system functioning scenarios, neutral gas pressure and magnetic field strength. Plasma electrons temperature and density were measured with movable Langmuir probes and validated with spectral diagnostics. Evaluation and comparison of two regimes (with and without magnetic field) were made with cryogenic nitrogen trap diagnostic and thermo-desorption diagnostic.

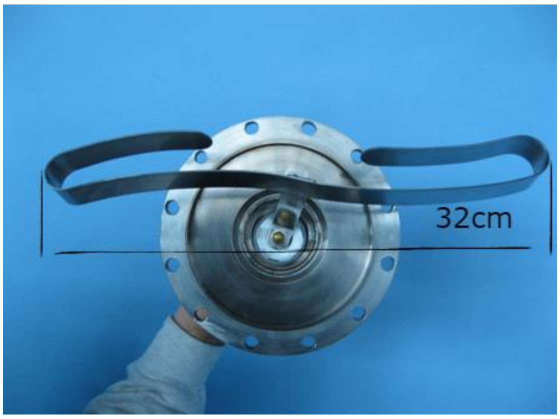

Fig. 1. T-shaped antenna mounted on 160 mm flange

EXPERIMENTAL SETUP

The T-shaped antenna is made from a stainless strap 20 mm wide, 2 mm thick and 500 mm in long. The length of each sholder plus the feed-through is ¼ wave length. Antenna is shaped according to plasma column surface. Distance from the outward part of antenna to the last closed magnetic surface doesn't exceed 15 mm. Antenna is placed from outside of plasma column between toroidal magnetic coils 1 and 16. The main antenna conductor is oriented along magnetic field and excites the slow wave.

Fig. 2. T-shaped antenna RF-discharge in conditioning regime without magnetic field

EXPERIMENT

Conditioning regimes with the T-shaped antenna were implemented and researched at Uragan-2M device. U-2M is a torsatron ($l = 2$, $m = 4$) which has the additional toroidal and compensating vertical magnetic fields.

The T-shaped antenna created RF discharges at U-2M being fed from VHF generator. The generator functions at 130 MHz frequency and continuously puts out 3 kW of power. Magnetic field at the axis was equal to 0.01 T or 0 depending on a conditioning regime. Initial continuous power was 3 kW in both regimes. Initial plasma in the conditioning regime with weak magnetic field was created with RF generator Kaskad-2 (K2) at working pressure of the neutral hydrogen $P \sim 1\cdot10^{-4}$ Torr. The frame antenna of the Kaskad-2 generator has a wide toroidal wave excitation spectrum ($\lambda = 80...1068$ cm). This antenna breakdowns the gas and creates hydrogen plasma with density up to $1\cdot10^{12}$cm^{-3}. Then VHF generator sustains the plasma discharge and maintains it all 150 minutes of the experiment. The RF generator K2 was turned off after it created plasma and the wall conditioning was carried out only by the VHF generator.

It was enough for T-shaped antenna to get 3 kW from VHF generator to maintain plasma discharge in regime without magnetic field and working gas pressure $P \sim 1\cdot10^{-2}$ Torr.

DIAGNOSTICS

Local characteristics of plasma discharge were measured with solitary Langmuir probes which are placed in different points of the device torus.

The vacuum chamber conditioning effectiveness was analysed using the diagnostic complex with the cryogenic trap and the thermo-desorption diagnostic data.

The cryogenic trap method. The gases generated inside the vacuum chamber during wall conditioning are pumped out through cryogenic trap which is placed between outlet fitting and vacuum pump. Some amount of the gases is condensed on cooled surface of the trap. To make measurements, the trap is cut off the vacuum chamber and the pump closing the corresponding vacuum valves after fixed period of operation. Then it is heated. As a result, the condensed gases are evaporated inside the cutted volume. Then the pressure P_g of evaporated gases is measured. The pressure allows one to estimate the amount of adsorbed gas and, hence, the amount of gas generated during conditioning [3].

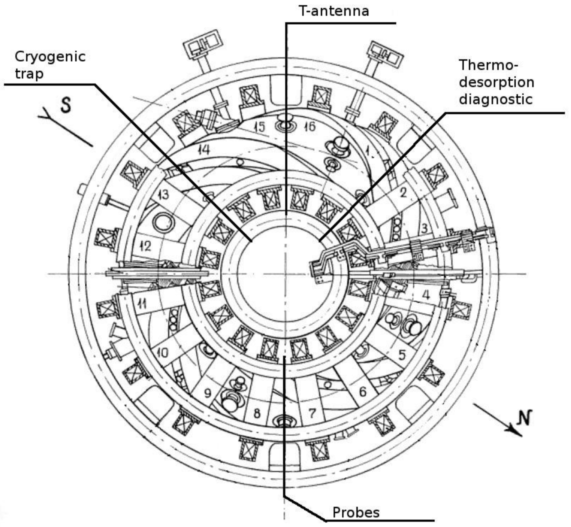

Fig. 3. Position of T-shaped antenna, cryogenic trap outlet, thermo-desorption diagnostic and Langmuir probes at U-2M

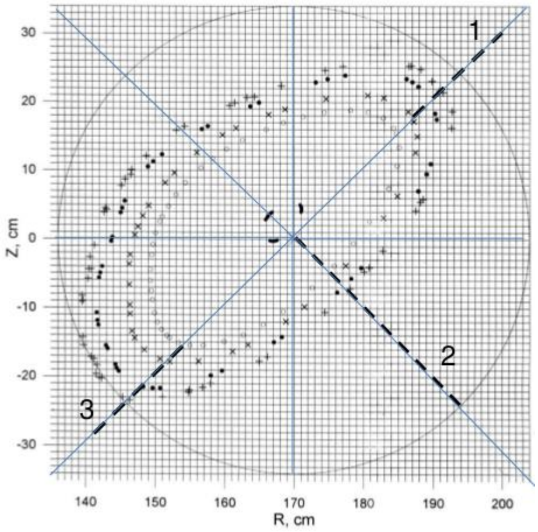

Fig. 4. Position of long, bottom, upper and distant Langmuir probes relative to closed magnetic surfaces. Cross section is taken between coils 7 and 8: long probe (1), bottom probe (2), upper probe (3)

The thermo-desorption diagnostic is based on measurement of gas prerssure increase which is caused by thermo desorption from stainless steel (12X18H10T) sample heated to 250...300ºC [4] in situ.

CONDITIONING WITHOUT MAGNETIC FIELD

Without the magnetic field plasma created with VHF generator existed only near antenna. The size of such plasma cloud increased with RF power. At maximum power (3 kW) its luminosity decreased for an order at 1 m from antenna along the torus. The whole research time was about 40 hours, that is 2+2 hours during two experimental weeks.

Fig. 5. Cryogenic trap diagnostics

The plasma parameters in conditioning regime without magnetic field were measured with the nearest Langmuir probe which is situated near antenna at small radius of 22 cm. The distant probe measurements were carried out in a single spatial point at the most distant technically achievable position from chamber wall. The measured electron temperature was up to 5 eV while the average electron density was $\sim 1\times10^{9}$ cm^{-3}. The signal from the long probe at the opposite side of the chamber torus relatively to the T-shaped antenna at small radius r = 14 cm was recorded at rather low level $I_s \sim 0.03$ mA. Nevertheless, this is an evidence of discharge existence far enough from the main plasma cloud.

Then analysis of hydrogen and nitrogen mixtures showed the best results for H_2/N_2 = 80/20%. The amount of condensed gas inside the trap in atmosphere of pure hydrogen is 1.5 times less than during other gases mixtures conditioning. Each measurement was made during a single day.

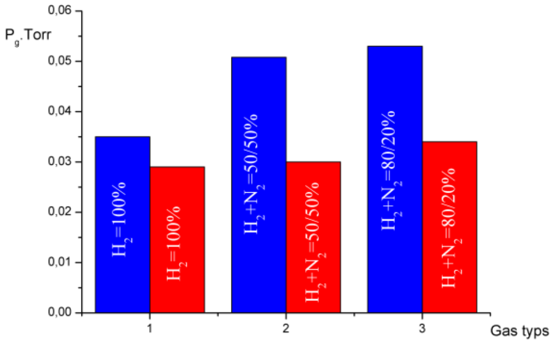

Fig. 6. Amount of gas condensed inside cryogenic nitrogen trap during one day with different conditioning mixtures

The analysis of thermo-desorption diagnostic results in the vacuum chamber conditioning regime without magnetic field showed significant decrease of gas monolayers amount at measurement plate surface during the first experimental day. Then the process speed decreases and gradually reaches almost quasi-stationary state with 10...20 monolayers of light impurities [4].

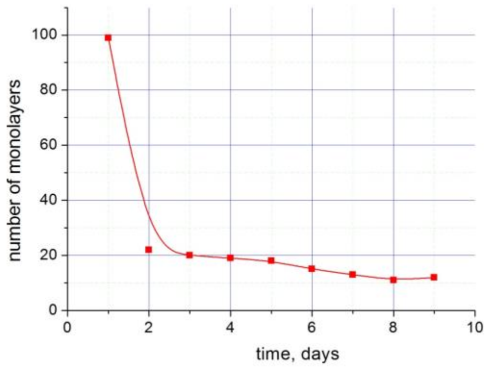

Fig. 7. Evolution of monolayers number during wall conditioning without magnetic field

CONDITIONING IN WEAK MAGNETIC FIELD

The wall conditioning was perfomed in the following conditions: working gas (hydrogen) pressure was $(1\cdot10^{-4}...2\cdot10^{-4})$ Torr and toroidal magnetic field was (0.01...0.012) T. The VHF discharge power was up to 3 kW at 130 MHz working frequency. Total experimental time made 40 hours in 2+2 hours timetable during two research weeks.

Langmuir probe measurement results

Probe	Small radius position	Measurement time	Te (eV)	Density (cm^{-3})
Long	19 cm	10.50...11.50	25	4.7×10^9
Bottom	32 cm	10.50...11.50	38	4.8×10^9
Uppper	32 cm	10.50...11.50	38	2.0×10^{10}
Distant	21 cm	10.50...11.50	40	5.0×10^9

The electron temperature during conditioning with magnetic field is in order higher than without it according to probe measurements.

P_g value comparison for conditioning with 100 Oe magnetic field in hydrogen atmosphere. Measurements show that amount of condesed gas after conditioning regime without magnetic field is 1.5 times higher than after conditioning with magnetic field with the same exposition.

Uragan-2M vacuum chamber wall conditioning with continuous weak magnetic field is the part of the bigger work, the stellarator preparation for experiments with 0.4 T field. That is why these experiments were carried out right after measurements without magnetic field. This is the reason why there are only ~18 initial monolayers at the figure.

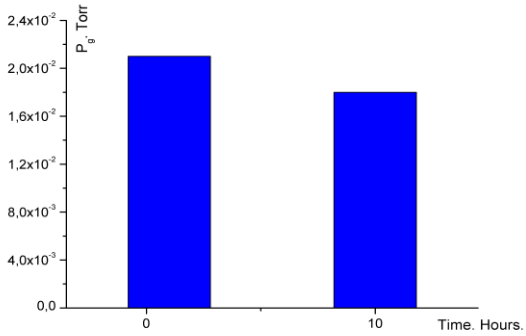

Fig. 8. Cryogenic trap measurement for weak magnetic field conditioning

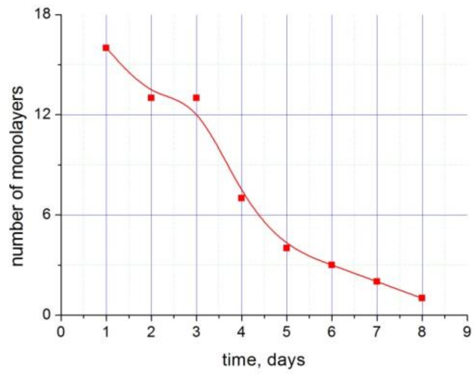

Fig. 9. Progress of weak magnetic field wall conditioning

CONCLUSIONS

The T-shaped antenna can be used during continuous conditioning regimes at toroidal magnetic traps.

Conditioning regime without magnetic field showed plasma existence along the whole device vacuum chamber torus, its characteristics considerably decreased with distance.

The RF conditioning in steady weak magnetic field regime can decrease impurities monolayers amount down to few. The efficiency of this regime can be compared with the impulse conditioning discharges [3].

The cooled feeders allow to input into plasma discharge 3 kW of power during more than 200 minutes.

ISSN 1562-6016. ВАНТ. 2018. №6(118)

Small antenna size allows one to install it into 150 mm fittings.

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Article received 21.10.2018

ОЧИСТКА СТЕНОК УРАГАНА-2М СВЧ-РАЗРЯДАМИ, СОЗДАННЫМИ Т-ОБРАЗНОЙ АНТЕННОЙ

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Для чистки вакуумной камеры Урагана-2М в слабом магнитном поле и без магнитного поля была внедрена новая СВЧ-антенна. Она была выполнена в виде четвертьволнового стержня. Т-образная антенна способна создавать медленные волны с продольными токами. Новый инструмент для чистки стенок изучался посредством состояния вакуумной камеры и достигнутых параметров плазмы.

ОЧИСТКА СТІНОК УРАГАНУ-2М СВЧ-РОЗРЯДАМИ, СТВОРЕНИМИ Т-ПОДІБНОЮ АНТЕНОЮ

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Для чистки вакуумної камери Урагану-2М у слабкому магнітному полі і без магнітного поля було впроваджено нову СВЧ-антену. Її було виконано у вигляді чвертьхвильового стрижня. Т-подібна антена здатна створювати повільні хвилі з повздовжніми струмами. Новий інструмент для чистки стінок вивчався через стан вакуумної камери і досягнутих параметрів плазми.