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A PROTOTYPE GLOW DISCHARGE SYSTEM FOR THE SPHERICAL TOKAMAK ETE – INPE/LAP

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Abstract

To specify a glow discharge cleaning system to be used in the conditioning of the ETE tokamak vacuum vessel, a simple system was constructed and tested in a small chamber . This system works with a DC source (300 or 600 V) together with a high voltage pulse generator to trigger the discharge. The discharge tests were performed with argon, nitrogen and helium at several pressures.

1. Introduction

Glow discharge has been used for substrate preparation and to cleanup vessel surfaces following atmospheric exposure where ultrahigh vacuum is necessary or in fusion devices where particle bombardment can desorb the adsorbed species and contaminate the plasma[1,2,3]. The glow discharge cleaning system consists basically on the installation of one or more electrodes in the chamber that serves as the discharge anode. The number of electrodes depends on the dimensions and geometry of the vessel. The anode can be a bar-shaped stainless-steel rod sized to take the full current of the discharge without overheating. The vessel wall working as the cathode is subjected to the bombardment of the ions which removes surface and near-surface impurities from the vessel. The main outgassing species from these wall surfaces are normally water vapor, CO and CO_2 .

The gases normally used for glow discharge cleaning are argon, oxygen, hydrogen, helium and in some cases, a combination of them. Since the radiation losses in high temperature fusion plasma devices is strongly dependent on Z_{eff} of the plasma, H_2 or He are preferable for cleaning these devices. Gas pressures spanning from 0.5 to 30 mTorr have been used in several experiments[1].

The glow excitation can be performed by an AC or DC (200 - 1000 V) source, a microwave source (1 - 3 GHz), a RF source (200 kHz or 13.6 MHz) or a combination of them. The simple one is a DC source that keeps the current densities in the range of 10 to 100 $\mu A/cm^2$ at the vessel surface [1].

To specify a glow discharge cleaning system for the ETE[4] tokamak which is under construction at the LAP/INPE, a simple prototype system for tests was constructed.

2. Experiment

Figure 1 shows the schematic drawing of the test apparatus. The vessel is a stainless-steel cylindrical chamber with 135 mm radius and 380 mm length. The anode is a stainless-steel cylindrical rod (ϕ = 7 mm, l = 30 cm) isolated from the chamber by a nylon insulator feed-through. To evacuate the vessel it was used a difusion and mechanical pump system to reach a base pressure of 6×10^{-6} Torr.

The power source (figure 2) consists on a simple DC power supply used to sustain the glow and a high voltage pulse generator that is used to trigger the glow. The DC source can supply rectified 300 V or 600 V through a bridge of diodes and with a filter of 100μF capacitor. The maximum current is limited by a 1.4 kΩ

resistor to less then 400 mA. To isolate the pulse generator from DC current a 125 pF (20 KV) ceramic capacitor is used. The high voltage pulse generator is operated by discharging a 220 μF capacitor charged by a retified 110 V source, through a common automobile spark coil. To trigger the system a SCR (TIC 116) electronic switch is used. This pulse generator can provide 5 - 10 kV pulses with duration of about 100 μs. To isolate the DC power supply from the pulse generator a high voltage diode (SKHE 10000) is used. It is then possible to use only one electrode to trigger and keep the discharge.

To operate the system, the chamber is firstly evacuated until reaching the mentioned base pressure and then a constant flux of the gas is supplied keeping the pressure at the required value. A DC voltage is applied to the anode and the glow is triggered by the pulse generator. The total current is measured on the 1.4 kΩ output DC resistor.

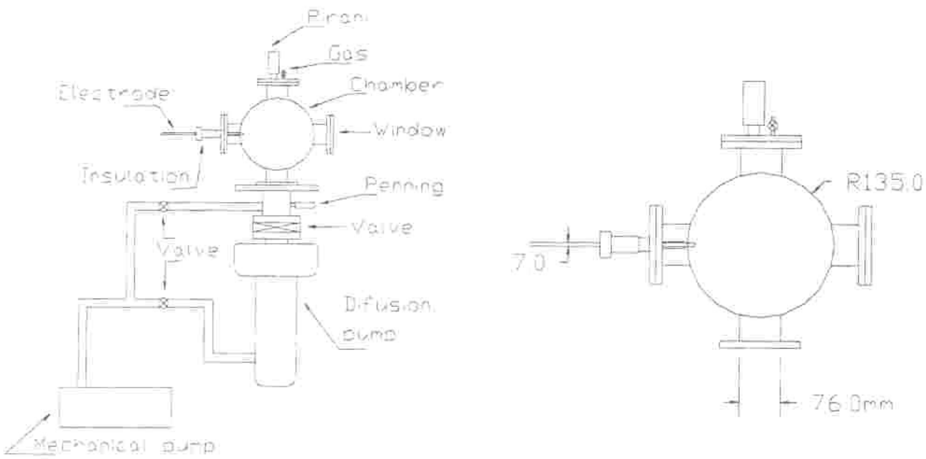


Figure 1 : Schematic drawings of the glow discharge test chamber.

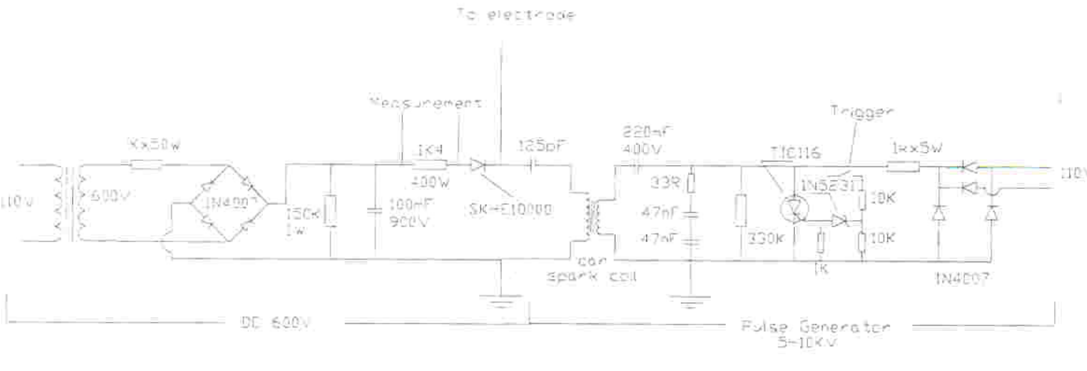


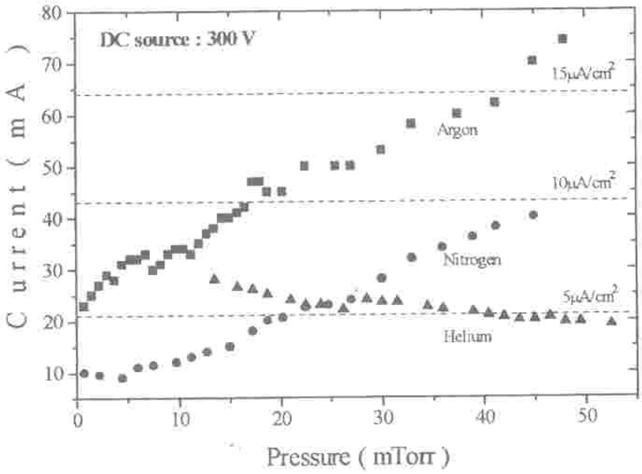
Figure 2 : Circuit for the power supply and the high voltage pulse generator.

3. Results

The discharge was performed at several pressures for three different gases at two anode voltages, as shown in figure 3. The horizontal dashed lines in the graphs represent the wall chamber current density for a given total current (vertical axis), considering a homogeneous discharge.

Since nitrogen and argon have lower ionization potential compared to helium, it was possible to start the discharge at lower pressures (1 mTorr), when using 300 V anode voltage. For this voltage, it was only possible to have a helium glow discharge above 10 mTorr, and it was not possible to reach the minimum current density (10 $\mu A/cm^2$) normally required in discharge cleaning experiments.

For 600 V anode voltage, it was possible to keep the discharge at low pressure range (down to ~ 1 mTorr) for the three tested gases. For helium the largest wall current density was reached between 10 - 20 mTorr.



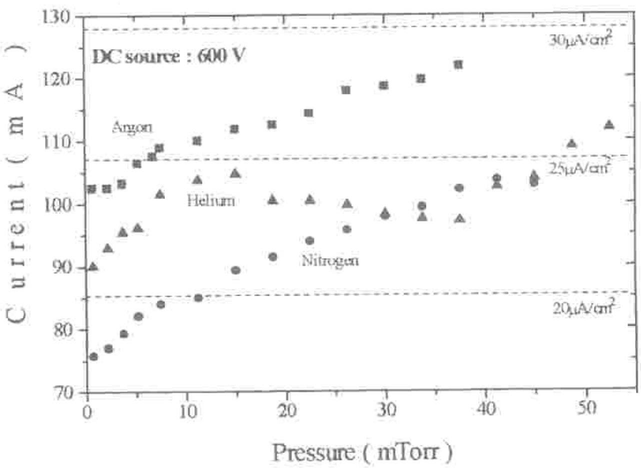


Figure 3 : Glow discharge measurements for 300 V (up) and 600 V (down) anode voltages.

4. Conclusion

A simple power supply was constructed and tested in a small chamber to specify a glow discharge cleaning system for the spherical tokamak ETE.

Since the geometry of the test chamber is simple, the discharge was homogeneous along the inner surface, in contrast with the real case of the ETE vessel, of much a complicated geometry. This problem can be minimized using more than one anode electrode to keep the discharge.

For the reason explained above and because of the big ETE chamber inner area (< $14 m^2$), two or three electrodes will be installed in the lower part of the chamber through CF40 flanges, as shown in figure 4. These stainless-steel electrodes can support currents up to 25 A and temperatures up to 400 °C. The power source must provide 1000 V and supply 5 A to guarantee a current density of 35 $\mu A/cm^2$. Since in our test it was difficult to start the discharge with helium gas (which will be used in ETE cleaning system) it will be necessary to use the high voltage pulse generator apparatus similar to the one described here. From results of figure 3, an optimum work pressure of about 10 mTorr will be used for discharge cleaning of ETE .

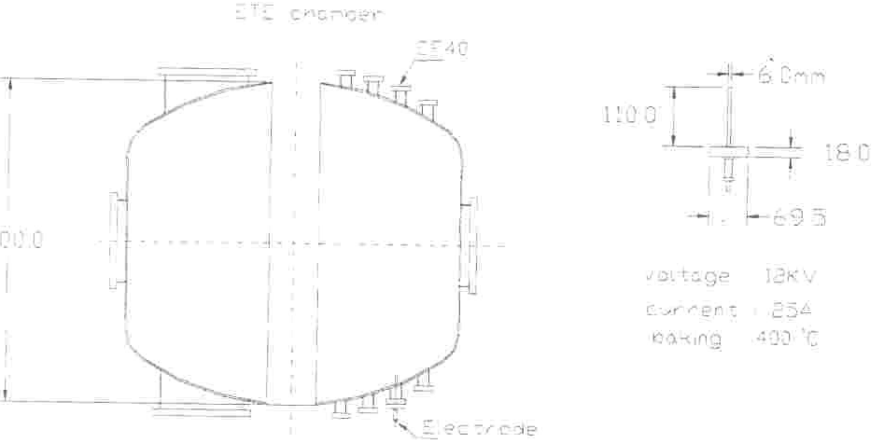


Figure 4 : ETE chamber and electrode details.

References

1. H. F. Dylla; "Glow discharge techniques for conditioning high vacuum systems"; J. Vac. Sci. Technol. A, vol. 6, nº 3, May / Jun 1988

2. R. P. Govier, G. M. McCracken; "Gas discharge cleaning of vacuum surfaces"; J. Vac. Sci. Technol., vol. 7, nº 5, 1970

3. G. Saibene, A. Rossi, at all; "Review of vacuum vessel conditioning procedures at JET and their impact on plasma operation"; Journal of Nuclear Materials, 617 - 622, 1995

4. E. Del Bosco, et all; "The ETE spherical tokamak : present status of construction"; Proc. IV Encontro Brasileiro de Física dos Plasmas, Águas de Lindóia, Set. 1996

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