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A Study on Diffusion Loss Mechanism for Plasma Particles (Electrons) at Breakdown Threshold Voltage Developed within Different Toroidal Chambers in Presence of Magnetic Field with Nitrogen

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ABSTRACT
Diffusion loss phenomenon of plasma particles on breakdown threshold voltage of a toroidal discharge has been studied using H type solenoidal coil excited by a 13.56 MHZ radio frequency power source with different pressures, toroidal magnetic fields and aspect ratios for nitrogen. In this paper we have discussed that the threshold breakdown voltage controlled by diffusion phenomenon on filling pressures, toroidal magnetic fields and minor radius of the designed models[1]. The detailed experimental setup is also presented.

Key words: Diffusion loss, threshold breakdown, aspect ratio, minor radius, toroidal magnetic field

1. Introduction:

This work uses a set of simple and easy to make torii. Many such torii can be used with wide variation in all geometrical parameters [major radius (R), minor radius(r) and the aspect ratios ($\sigma = R/r$)].Working gases, pressure and magnetic field can also be varied within the available limits. It is hoped that this set of experiment will answer to several questions relating to the start-up phase of tokamak machine [2]. A modelling of the start-up phase of a tokamak discharge was performed by Papoular [3] in which an analysis was made of the breakdown and ionisation of the filling gas in Toroidal devices like TA 2000 and TFR tokamak when it has been shown that the discharge can be developed. The pressure of the gas affects the electrons to pick up energy from the electric field due to collision with ions and other electrons. This phenomenon happens in straight and simple way in the DC field but takes place in a more complicated manner for an RF field. Gas pressure also controls the diffusion losses since it invariably helps to restrict perpendicular diffusion of charged particles to the wall of the torus. Then there is a host of atomic parameters which come into play even in a simplified model of the start-up phase of a toroidal machine and for the development of discharge in a toroidal machine[2,3,4,5,6].

The purpose of our work is to expand the observation space and to draw the possible logical conclusion on diffusion los mechanism.

2. Experiment

2.1 Experimental Set Up

The experiment was carried out in pyrex glass toroidal chambers with minor radius (r) varying from 0.0222m to 0.0477m [Table 1]. Each torus has its own pumping port, gas inlet and a pre-ionisation window. The chambers are mobile and can be mounted on the same experimental table and pumped by the same pumping system, here in this case, an oil diffusion pump backed up by a rotary pump.

The rf coils were mounted on each torus. They consist of four parallel connected and inductively coupled coils, with same number of turns and wound at equal intervals around the torus. A fifth parallel coil of 28 gauge copper wire of hundred turns is wound around a chamber for primary tuned circuit.

The schematic representation of the experiment is shown in Fig. 1

2.2 Experimental Procedure

Our primary objective for the experiment and the analysis of the data obtained is to get a trend of the variation of different parameters concerned.

Initially the Toroidal chamber is evacuated to about 10^{-3} torr and was filled with different gases at different pressures varying from 0.001 to 0.1 torr. The pressure was measured with a calibrated pirani gauge.

An magnetic field was supplied and was varied from 0 G to 80 G. for a constant value of magnetic field, the pressure is raised and the threshold breakdown voltage is determined.

3. Results And Discussions :

3.1 The Diffusion Loss

The diffusion loses can be expressed as uniform rates (per second), per electron. In a confined plasma there will be generally a density or pressure gradient from the interior to the outside which will cause charged particles to diffuse and eventually escape to the walls of the torus. As the motion of electrons and ions are affected by a magnetic field, it is natural that the diffusion of electrons and ions change by the application of the magnetic field. Diffusion of electron due to elastic collision with molecules in presence of magnetic field is characterized by the coefficient [7]

$D_H = D / (1+ \omega_H{}^2 \tau^2)$ ……..(1)

Where D is the diffusion coefficient in absence of magnetic field [2] = 1/3 $V_r \lambda_e$,Where V_r is the random velocity of an electron and λ_e is the mean free path of an electron =L/P, ω_H = eH/m, H is the toroidal field in Gauss, τ is the time between successive collisions between the electron and the neutral gas molecules known as mean free time

$\tau = \lambda_e / V_r$

$= L / P V_r$ …….(2)

$D_H = (1/3\ V_r L/P)/(e^2H^2/m^2.L^2/P^2\ V_r{}^2)$

$D_H = Pm^2/ 3Le^2H^2\ (KT/m)^{3/2}$

$=PC/H^2$

Where $C = m^2/ 3Le^2\ (KT/m)^{3/2}$ …….(3)

Diffusion loss rate (D_{lr}) can then be defined as [3]

$D_{lr} = PC / H^2 r^2 = D_H /r^2$ …….(4)

Where r is the minor radius of a torus.

Using equation (4) we may see the variation of Diffusion loss rate (D_{lr}) with magnetic field (H) in different torii at a constant filling pressure (P) and also with different filling pressures (P) in different torii at constant magnetic field (H).

In figure 2 shows the variation of the Diffusion loss rate (D_{lr} **)** with magnetic field (H) at a constant pressure of 0.1 torr was plotted for different torii [minor radius (0.0222m to 0.0477m)]. It is observed that Diffusion loss rate (D_{lr}) decreases with increase in magnetic field almost exponentially and beyond the magnetic field of 27.3 Gauss the D_{lr} gets almost saturated. Thus we may define this as a critical magnetic field (H_c), which also comes different for different torii.

Figure 3 illustrates the variation of the Diffusion loss rate (D_{lr} **)** with filling pressure (P) at fixed magnetic field (H = 50 Gauss) for different torii. We observed that the D_{lr} (sec $^{-1}$ X 10 ^{4}) increases with increase in pressure. For the torus of minor radius (r = 0.0477 m), the D_{lr} does not vary notably with the increase in pressure where as for the torus of minor radius (r = 0.0222 m) rate of diffusion loss increases more sharply as compared to the other torii. This leads to an investigation on the variation of diffusion loss rate with minor radius of different torii at a constant magnetic field of 50 Gauss and constant filling pressure of 0.1 torr.

This result was depicted in figure 4 which clearly shows a trend of increase of diffusion loss rate with decrease in minor radius of torus.

Table 1: The Characteristics Parameters Of Different Torii

Torus with aspect ratios	Minor radius (r) in m
I (2.10)	0.0477
II (4.14)	0.0318
III (2.83)	0.0280
IV (3.95)	0.0254
V (3.25)	0.0222

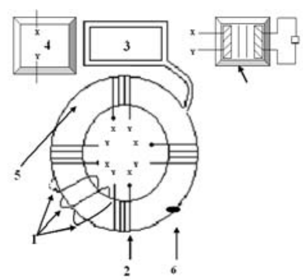

Figure 1. The schematic representation of the experimental set up

1) **Annular coils for axial magnetic field**
2) **Annular H type solenoid coil**
3) **Gas inlet with measurement of filling pressure**
4) **Radio frequency power source**
5) **The toroidal chamber**
6) **The Quartz window for pre-ionisation**
7) **Tunning coil with primary and secondary**
8) **Measurement of breakdown threshold voltage**

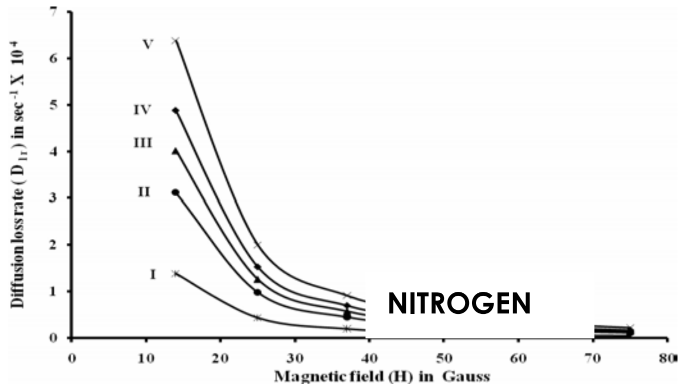

Figure 2. Variation of $\mathbf{D_{l\,r}}$ with **H** at P = 0.1 Torr for nitrogen in different torii **I** : r = 0.0477 m, **II** : r = 0.0318 m, **III** : r = 0.0280 m, **IV** : r = 0.0254 m, **V** : r = 0.0222 m

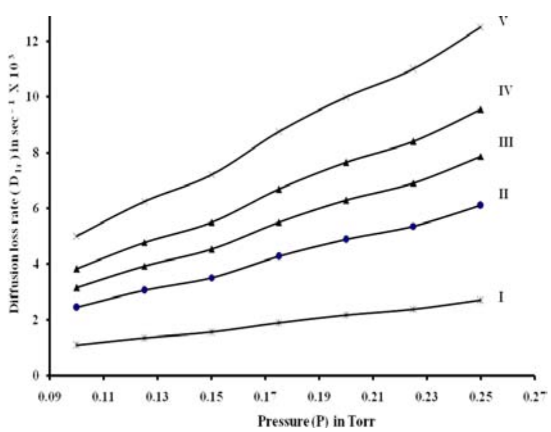

Figure 3. Variation of $D_{l\,r}$ with P at H = 50 G for nitrogen in different torii I : r = 0.0477 m, II : r = 0.0318 m, III : r = 0.0280 m, IV : r = 0.0254 m, V : r = 0.0222 m

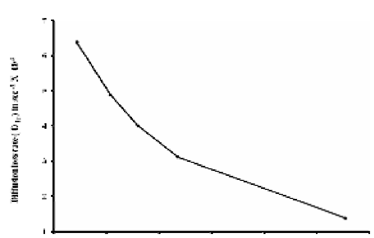

Figure 4. Variation of $D_{l\,r}$ with r at H = 50 G and P = 0.1 torr for nitrogen

4. Conclusion

In the previous report [8] and in this article we have discussed diffusion loss in various toroidal chambers under different pressures and magnetic field for nitrogen. The variation of diffusion loss rate with magnetic field, filling pressures and minor radius of different torii are clearly included. Determination of a critical magnetic field (H_c) gives a scope of further investigation. The variation of diffusion loss rate with minor radii of different torii undoubtedly opens new room of research. It was observed that diffusion loss rate tends to saturate for the torus of minor radius 0.0477 m. therefore this paper provides the further scope of study on the variation of diffusion loss rate with the minor radius beyond 0.0222 m, in which it may be established that there could be such a critical minor radius below which loss of electrons due to diffusion does not take place at the threshold breakdown of plasma development within a toroidal chamber.

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REFERENCES

1. C Das , D C Jana *Journal of Physical Sciences* 11, 68, (2007)
2. Ralf Wilhelm *American Institute of Physics* 21,513,(2003)
3. Papoular R *Nuclear Fusion* 161,5,37(1976)
4. Andre L Rogester *American Institute of Physics*12,5070,(2000)
5. S.C Brown *Basic Data Of Plasma Physics* 157(1959)
6. Smith H.B etal *American Institute of Physics* 20,875,(2003)
7. J S Towsend & E W B Gill *Phil. Mag* 26, 290, (1937)
8. C Das, D C Jana, A K Hui *Proceedings 24th National Symposium on Plasma Science and Technology*, Plasma 2009