MASS SPECTRUM OF IONS EXTRACTED FROM RF ION SOURCE WITH INJECTED ELECTRONS

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ABSTRACT

The influence of injected electrons into the RF plasma and the discharge parameters on the production of hydrogen and nitrogen ions has been studied experimentally with the use of magnetic analyser. For hydrogen ions, it is found that the injected electrons change the ion beam composition by an increase of H_1^+, H_3^+ % age. Also for nitrogen ions it increase the cross-section for multiple ionization process which allows an increase of N^{+2}, N^{+3} % age

INTRODUCTION

Hydrogen ions are formed in the discharge by two main types of collision processes[1]:

1. Single collision process :

The production of H_2^+ by single collision process is represented by the interaction (1), while H_1^+ is formed by the interaction (2).

$$e + H_2 \xrightarrow{\text{ionization}} H_2^+ + 2e \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$e + H_2 \xrightarrow{\text{dissociation}} H_1 + H_1^+ + 2e \quad \ldots\ldots\ldots\ldots(2)$$

2. Multiple collision process :

In this process H_1^+ and H_3^+ are formed as follows

$$\left.\begin{array}{l} e + H_2 \xrightarrow{\text{dissociation}} H_1 + H_1 + e \text{ then} \\ e + H_1 \xrightarrow{\text{ionization}} H_1^+ + 2e \end{array}\right\} \ldots\ldots\ldots(3)$$

$$\left.\begin{array}{l} e + H_2 \xrightarrow{\text{ionization}} H_2^+ + 2e \\ e + H_2^+ \xrightarrow[\text{+recombination}]{\text{dissociation}} H_1 + H_1 \\ e + H_1 \xrightarrow{\text{ionization}} H_1^+ + 2e \\ H_1^+ + H_2 \xrightarrow{\text{recombination}} H_3^+ \end{array}\right\} \ldots\ldots(4)$$

The production of multiply charged ions from nitrogen could be produced in multiple collision process. Thus, ions which are ionized to higher degrees ($n = 3$, ...10) can be most conveniently obtained from sources with high electron and ion concentrations .

The influence of electron beam injection in RF plasma on the production of different ion species from hydrogen and nitrogen gases will be studied in this paper.

Apparatus

The source [2] is of radial extraction type (Fig.1), having a hot filament and accelerating electrode, surrounded by an electromagnet to confine both the injected electrons and the plasma. The measurement of the ion beam composition is made by making the ion beam passes through an orifice (Ø = 8 mm) before entering a sector magnet (Fig. 2) with angle of deviation 27° . The ion current is measured by connecting the Faraday cage to an electrometer DC amplifier (Fig.3) . The pressure reaches 10^{-5} mmHg at the target region.

From the equations, $mv^2/R = ev\,B$, and $v=\sqrt{2e\,V/m}$ (where B = magnetic field, v= velocity, V=extraction voltage, R= radius of the central circular path in the sector magnet), we could deduce the value of magnetic field required for ion beam selection. For R= 10 cm and V= 3 kV, we get the following data:

$\frac{m}{e}$ $\frac{kg}{coul.}$	B(gauss)	$\frac{m}{e}$ $\frac{kg}{coul.}$	B(gauss)
H_1^+ = 1.043	791	N^{+1}= 14.602	2959
H_2^+ = 2.086	1180	N^{+2}= 7.301	2093
H_3^+ = 3.129	1370	N^{+3}= 4.867	1710

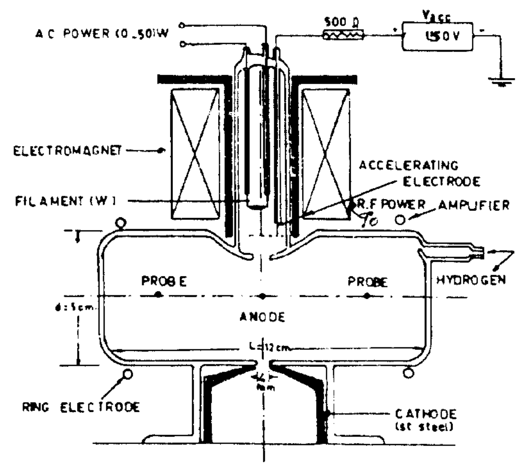

Fig. (1) RF ion source with injected electrons .

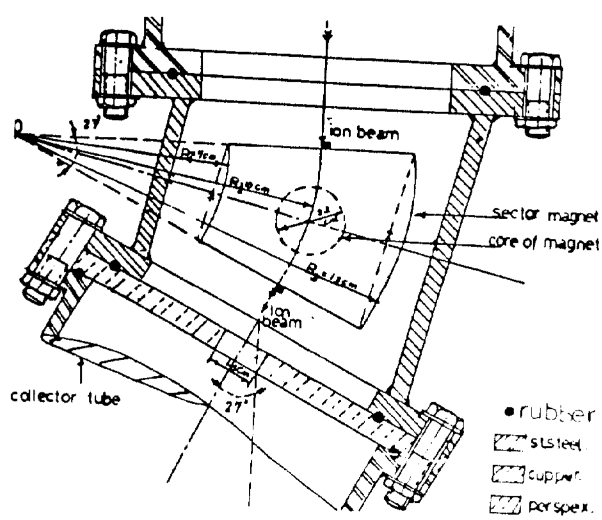

Fig. (2) The magnetic analyser

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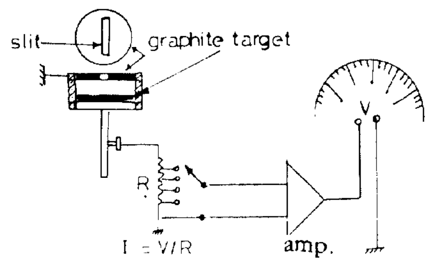

Fig.(3) Measurement of Analyzed ion current .

RESULTS AND DISCUSSIONS

From Fig. (4) and Fig.(5) the hydrogen ions percentage are as follows :

At low discharge pressure (P_r= 3 X 10^{-3} mm Hg) the ions % age without injection are (H_1^+= 81% ,H_2^+=13%, H_3^+ = 6) and the ions % age with injection are (H_1^+ = 85%, H_2^+ = 6 %, H_3^+= 9%).

At high discharge pressure (P_r= 10^{-2} mm Hg) the ions %age without injection are(H_1^+ = 20% ,H_2^+= 8% , H_3^+ = 72%) and the ions % age with injection are (H_1^+ = 18 % , H_2^+ = 6% , H_3^+ = 76 %) .

It is clear that the multiple collision process yielding H_1^+ atomic ions have the highest probability at low pressure[3,4] while at high pressure the atomic ion H_1^+ recombines with the molecule H_2 producing large percentage of the molecular ion H_3^+

The electron injection increases the % age of H_1^+ at low pressure and the % age of H_3^+ at high pressure (2 X 10^{-2} mm Hg) . This is due to the increase of the electron concentration under the action of the magnetic field which leads to a higher probability of multiple collisions.

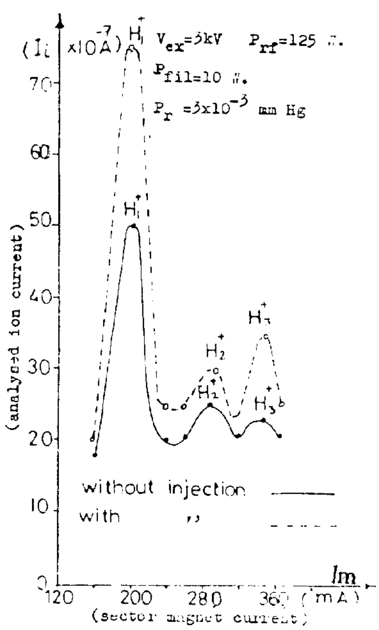

Fig.(4) Mass spectrum of Hydrogen Ions at low pressure .

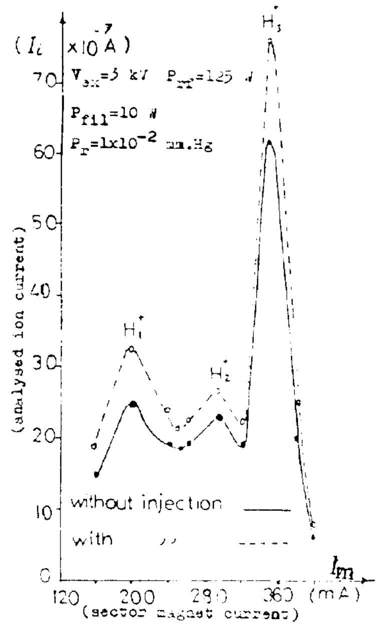

Fig.(5) Mass spectrum of Hydrogen Ions at High pressure.

Fig.(6) shows the change in the percentage ratios of H_1^+ , H_2^+ and H_3^+ with the discharge pressure with electron injection. This figure shows that the change of these percentages with pressure is similar to the change without electron injection and agrees with the result given by Vali et al.[1]

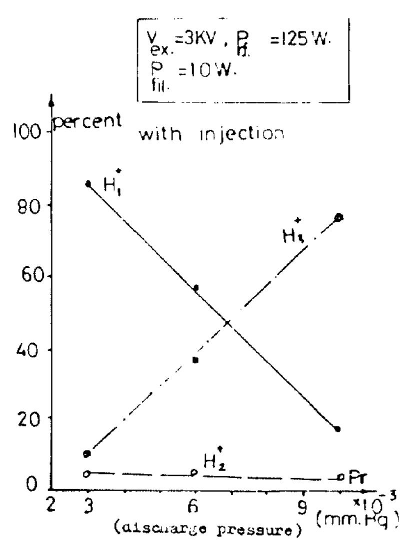

Fig. (6) % variation of H_1^+ , H_2^+ , H_3^+ with the discharge pressure.

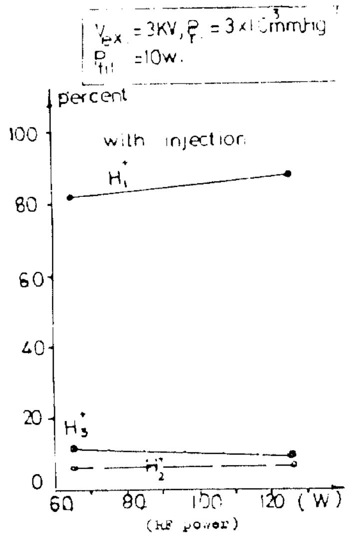

Fig.(7) % variation of H_1^+ , H_2^+ ,H_3^+ with the RF power.

Fig. 7 shows the influence of the increase in RF power on the percentages of the hydrogen ions. It is clear that the atomic ion is relatively more sensitive to the increase of RF power since it increases the electron density .

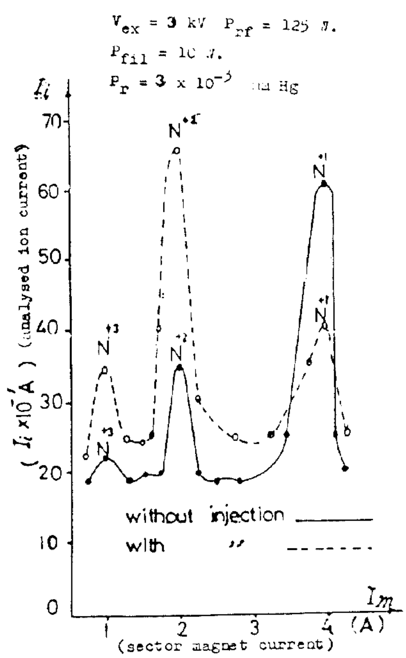

Fig.(8) Distribution of N^{+1},N^{+2}, N^{+3} ions .

For nitrogen ions, from Fig.(8) the ions % age without injection are N^{+1} = 75 % , N^{+2} =20% ,N^{+3}= 5% and the ions % age with injection are N^{+1}= 35%, N^{+2}= 50% , N^{+3}= 15% .

Without injection the % age of these ions decreases with the increase in the degree of ionization. This is due to the increase of the threshold energy as the degree of ionization increases.[5] With injection, both the increase in the number of oscillating electrons and the energy of the injected electrons (=150 eV) increase the cross-section for multiple ionization allowing an increase of the % age of N^{+2} and N^{+3} on the expense of N^{+1} % age .

CONCLUSION

The injected electrons (E =150 eV) increases the number of the oscillating electrons ,thereby enchancing variation of ion composition by an increase of H_1^+ and H_3^+ percentage. Also , it increases the cross-section for multiple ionization process which allows an increase of N^{+2} and N^{+3} percentage on the expense of N^{+1} percentage.

Thus the injection of electrons in the RF plasma could be utilized for increasing the %age of the multiply charged ions in addition to the atomic ions %age from light gases.

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