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OPERATIONAL CHARACTERISTICS OF A RADIAL EXTRACTION ION SOURCE WITH AN INJECTED ELECTRON BEAM

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Summary

An RF ion source of the radial extraction type is modified by introducing an electron gun to supply electrons which interact radially with the source's plasma, thereby increasing ionization density. A tungsten filament is used with an accelerating electrode, under the influence of axial magnetic field. Two plasma tubes have been tested with the same tube length (12 cms) and diameters 4&5 cms respectively. Glass-coated tungsten wires are immersed in the plasma as electrical probes. Two extraction electrodes of apertures 4 and 8 mm are used. The extraction characteristics indicate 15% increase in the extracted ion beam.

Introduction

In the low pressure electrodeless discharge[1] the mean free path of the primary electrons is large with respect to the tube dimensions. In this case the electrons collide with the tube walls before its collision with gas molecules. These primary electrons possess high energy that could release secondary electrons from the tube walls. These secondary electrons represent the main source of electrons at such low pressure since the number of electrons produced due to electron collision with gas molecules is so small that it could be neglected. In the new ion source considered here the one-side constricted type[2,3] is used in which a modification is introduced whereby the number of primary electrons is increased by using an additional source of primary electrons. Electrons from an electron gun are accelerated and injected into the RF plasma. The increase of the number of oscillating electrons inside the source by this way increases the probability of electron collision with gas molecules which produces larger ion beam current and increases the percentage of the highly charged ions. The aim of this work is to investigate the extracted ion current under the influence of the filament power with the discharge parameters in the low pressure range.

Apparatus

The ion source is an improved one-side radial constricted RF type (Fig.1). Compared with the normal radial constricted RF source this type is featured by the use of hot filament with an accelerating electrode. The filament is heated by using a transformer (6V-10A) and the accelerating potential is furnished from a d.c+300 V power supply. Around the filament there is an electromagnet similar in its construction to that of the duoplasmatron ion source[4]. This electromagnet serves to confine the electron beam while injecting it in the plasma. The increase of electron density inside the source increases the cross-section of ionization. Two plasma tubes having the same length of 12 cms and of diameters 4&5cms respectively are tested. An extraction electrode of aperture 4mm is used with the first

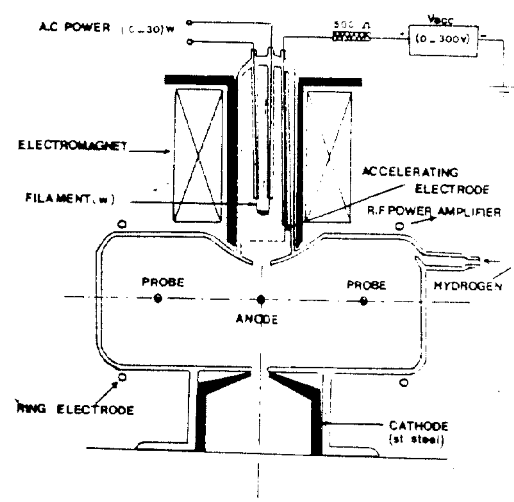

FIG.1 THE SOURCE

tube (of diameter 4 cm) and another electrode of aperture 8 mm is used with the second tube. The two tubes have constriction 13 mm from the upper side (Fig.1). Three tungsten wires of dia 1 mm are used as electrical probes. They are situated near the walls and covered with glass. The middle probe is immersed 2 mm inside the tube . The other probes are situated at distance 3 cm from both sides of the middle probe and immersed 2 mm inside the tube.

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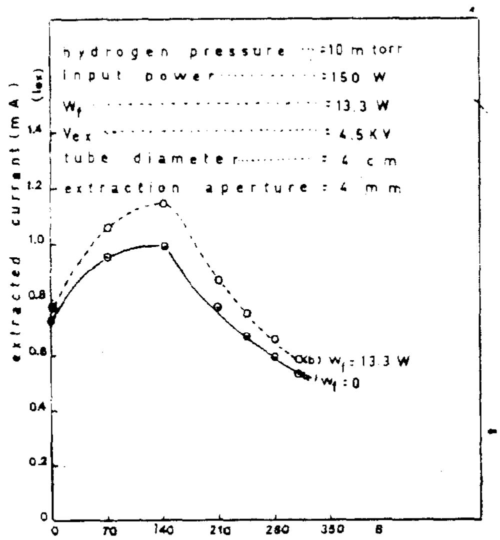
In this work the middle probe is used as anode. Its length is 5 cms. The RF power is supplied to the source across two ring electrodes from a 15 MHZ oscillator with a classC power amplifier. A complete vacuum unit with a 220 l/s mercury diffusion pump, a liquid nitrogen trap and a 150 l/min rotary pump provide vacuum down to 10^{-5}mm Hg. Pure hydrogen is supplied from palladium tube. The extracted current is measured by a Faraday cup at distance 2.5 cm from the base of the cathode. More details about the apparatus are given in previous papers[3,5].

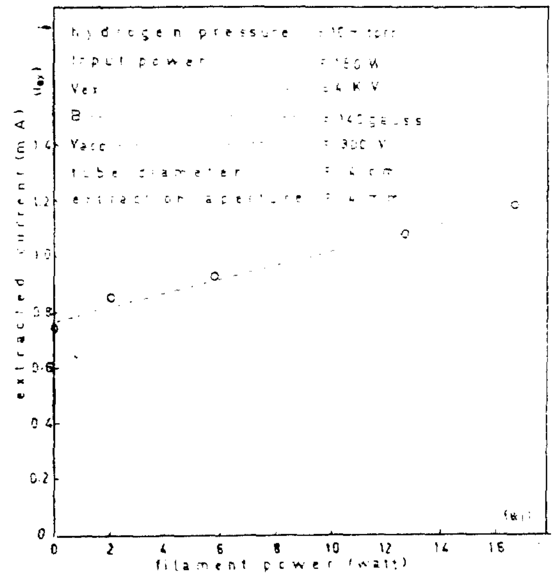
Results and Discussions

This study deals with the influence of the filament electrons on the operational characteristics of the (one-side)radial constricted RF ion source with radial extraction at low pressure. The variation in ioncurrent due to change in magnetic field is shown in Fig.(2). Curve (2.a) represents the ion current without using the filament. Curve (2.b) represents the change of ion current when using the filament at power W_F=13.3 watts. The two curves show maximum ion current at the resonance value[6] of the magnetic field which appear when the electron gyrofrequency ω_H equals the excitation frequency ω.The decrease in ion current at larger magnetic field ($B > Br$) is due to presence of plasma instabilities[5].



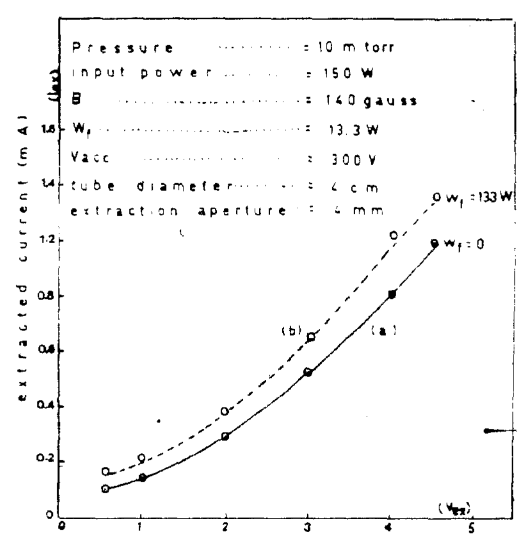
FIG(2) INFLUENCE OF MAGNETIC FIELD & FILAMENT POWER ON THE EXTRACTED CURRENT.

Fig.(3) shows the increase of ion current with the change in filament power at pressure of 10 m.Torr and extraction potential of 4KV.It is clear that the increase of electron density inside the plasma due to filament electrons could increase the percentage of ion density which is represented by the extracted



FIG(3) INFLUENCE OF FILAMENT POWER ON EXTRACTED CURRENT.

current. The ion current is measured at the resonance value of the magnetic field (B_r=140 gauss) which leads to maximum current Fig.(4) shows the variation in ion current with the extraction potential at pressure of 10 m. Torr. The ion source used in this text has internal diameter 4 cm and extraction electrode with aperture 4mm. The maximum ion current reaches 1175 µA when using the filament with power W_F= 13.3 watt and extraction potential Vex=4.5 kV. Fig (5) shows the extraction characteristics for another ion source bottle with internal diameter 5 cm and extra-



FIG(4) EXTRACTION CHARACTERISTICS AT PRESSURE 10mTORR ction electrode with aperture 8 mm. The maximum extracted current reaches 2.8 m.A on using the filament with power 15 watt and extraction potential $V_{ex} = 4kV$ at pressure of 5.10^{-2} mm Hg. This value of ion current is greater than the current obtained under the experimental conditions given at fig. (4).

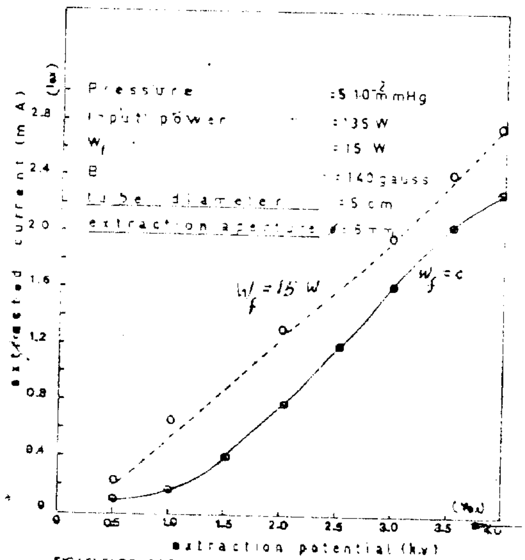


FIG.(5) EXTRACTION CHARACTERISTICS AT PRESSURE 5.10^{-2} m.m Hg

Conclusion

In this ion source the accelerating electrode of the electron gun has two important features:

1- It accelerates the electrons (emitted from the filament) and injects them in the RF plasma to increase the electron density.

2- Its positive potential retards the positive ions and causes an increase in the extracted current in addition to the effect of the filament.

The ion current has maximum value at the resonance magnetic field and increases with the increase in filament power, extraction potential and pressure. This ion source is characterized by the following:

1- The physical changes in the discharge colour could be easily visualized indicating ion density increase with electron injection from the electron gun.

2- The plasma diagnostics could be easily studied by the electrical probes(Fig.1)

3- Large possibility for the production of highly charged ions due to presence of electron beam-plasma interaction [7,8] and the oscillation of the electrons in the RF field.

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