THE EFFECT OF THE AXIAL MAGNETIC FIELD ON THE DUOPLASMATRON ELECTRON SOURCE

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Abstract

In this study the influence of the discharge parameters on an electron beam extracted from the duoplasmatron source is given. The effect of the magnetic field on the electron beam is found to be more significant with the decrease in pressure, and the increase of collector potential. With arc current 7A, filament current = 15 A, pressure = 3 X 10^{-3} Torr, magnetic field = 5600 gauss and collector potential= 10 KV the maximum recorded current reaches 91 mA.

Introduction

In the duoplasmatron source a hot cathode low pressure gas discharge is run under confinement by an intermediate electrode and by an axial magnetic field[1] in the anode region. According to this magnetic field, the electrons cover a longer path by its circulation in helical orbit.

The pressure P due to the increase in magnetic field[2] B is given by

$$P = - \frac{B^2}{8\pi} \qquad \text{.....(1)}$$

The electron and ion losses from the plasma are reduced by the axial magnetic field due to the decrease of the diffusion coefficient[3] D_B where

$$D_B = \frac{D_{B=0}}{B^2} \qquad \text{.....(2)}$$

At strong magnetic field the radius of the spiral motion of the electrons is so small that the electrons could not ionize large number of atoms. Also, at this magnetic field many kinds of plasma instabilities[4] appear and cause an increase in the diffusion losses.

Probe measurements[5] show that a double sheath exists in the plasma region of the intermediate electrode dividing the discharge into the cathode plasma and the anode plasma. Electrons emitted from the cathode pass through the cathode plasma ,and are accelerated across the double sheath to form a beam in the anode volume which is focused by the magnetic mirror. This electron beam is responsible for the ionization and the arc forms around it.
This paper includes the influence of the discharge parameters on the electron beam extraction in the presence of the axial magnetic field under pressure $\simeq 10^{-3}$ Torr in the High vacuum region.

Apparatus

The Duoplasmatron source is fitted with an expansion cup with a diaphragm (Fig. 1) . It consists of cathode (tungsten filament of 1 mm diameter) and an anode with aperture 2 mm . An intermediate electrode with an electromagnet is used to cause constriction to the arc discharge. The arc discharge is initiated between the cathode and the anode by an arc supply 500 V/20 A. The filament is heated by a d.c. power supply 6 V/50A.
For electron beam extraction a H.T. supply 20 KV/50mA is used. Its positive terminal is connected to the collector. This electron collector is made of graphite and is situated at a distance of 4 cm from the source. By using vacuum system the ultimate pressure before helium gas injection in about 10^{-4} Torr and reaches 10^{-3} Torr after gas injection.

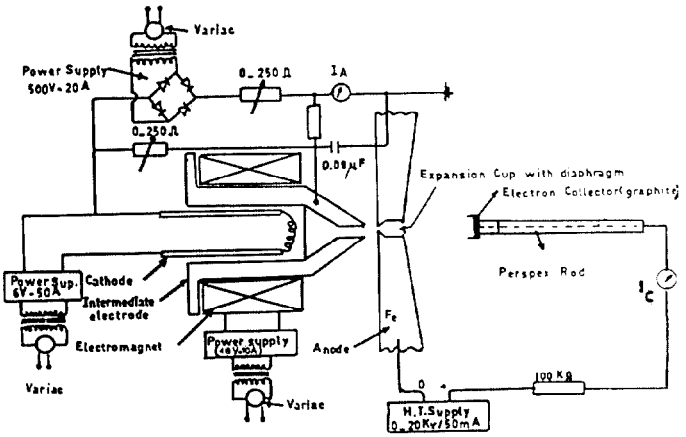

Fig.(1) The Electrical Circuit of The Duoplasmatron for The Electron Beam Extraction.

The gas is injected by a needle valve through the ionization region between the intermediate electrode and the anode.

Results and Discussion

On investigating the effect of gas pressure(Fig.2) it is found that it is of significance in the operation of the source. It is noticed that the influence of the axial magnetic field on the collector electron current is greater at lower pressures, while at larger pressure ($\simeq 10^{-2}$ Torr) the increase of neutral particles tends to cancel the influence of the magnetic field. It is clear in Fig. 2 that at constant collector voltage, the electron current decreases with the decrease in pressure while the magnetic confinement is equivalent to an increase in pressure as given by equation (1).

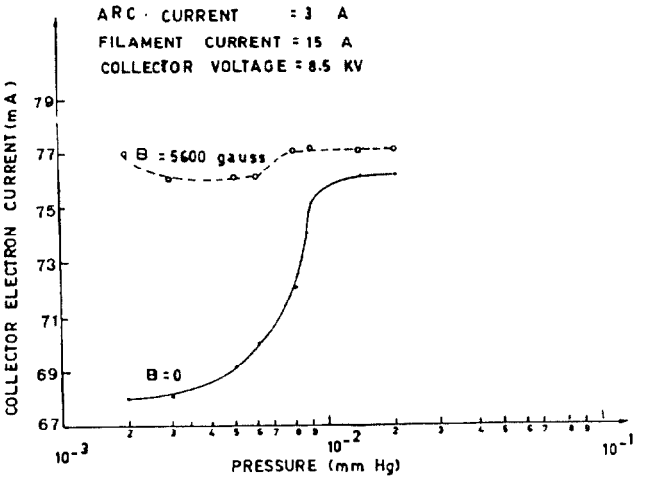

Fig. (2) Influence of Pressure in The H.Vacuum Region on The Collector Electron Current.

On investigating the influence of the axial magnetic field ,(Fig.3) , at collector voltage 10 KV and at the lowest possible pressure of 2 X 10^{-3}Torr , it is found that the maximum electron current reaches 85 mA at B_{max} = 5600 gauss.

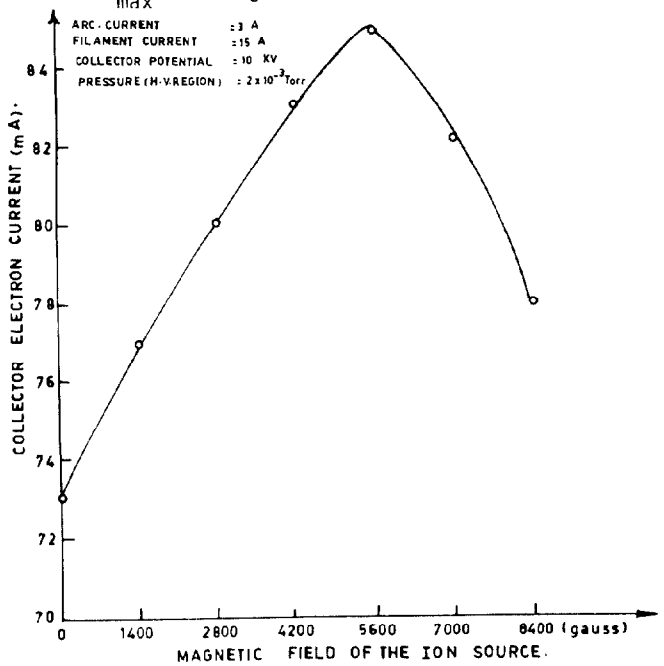

Fig.(3) Change of Collector Electron Current With The Axial Magnetic Field.

At B > B_{max} a decrease in electron current occurs. This could be due to the increase in diffusion losses across the magnetic field by the appearance of plasma instabilities[4] . Also , at the strong magnetic field the radius of the circular motion is so small that the electron could not ionize gas atoms as given before . On investigating the influence of the arc current on the collector current (Fig.4) , it is found that at arc current larger than 5 A the electron current could be increased with the arc current. This could be due to the increase in the ionization cross section[6]

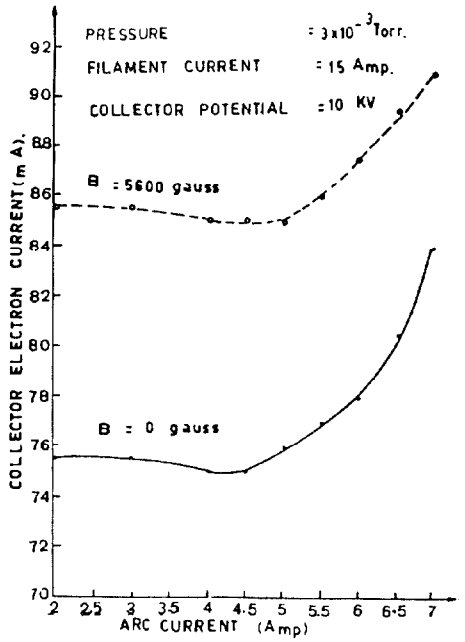

FIG.(4) EFFECT OF ARC CURRENT ON COLLECTOR ELECTRON CURRENT.

at this value of arc current . The application of the magnetic field at V_{coll} = 10 KV could change the electron current to large values. At arc current 7A the electron current could be increased to 91 mA.

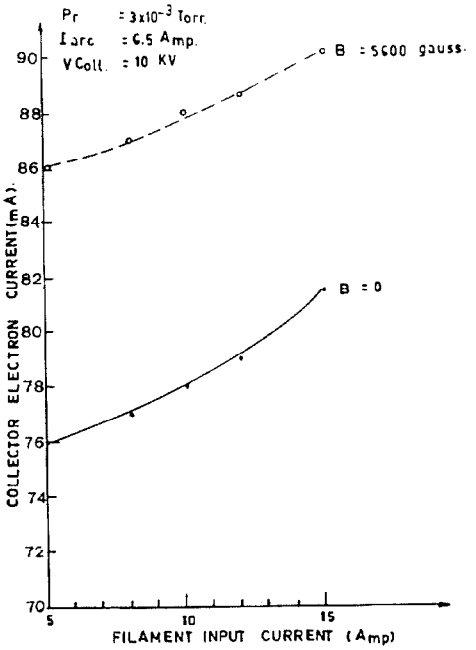

Fig.(5) Effect of Filament Current on The Collector Electron Current.

Fig. 5 shows the increase in the collector electron current with the change in filament current and the application of the peak value of the magnetic field (5600 gauss). The influence decreases at larger pressure. This is due to the larger m.f.p. (at low pressure) at which the electron is capable to

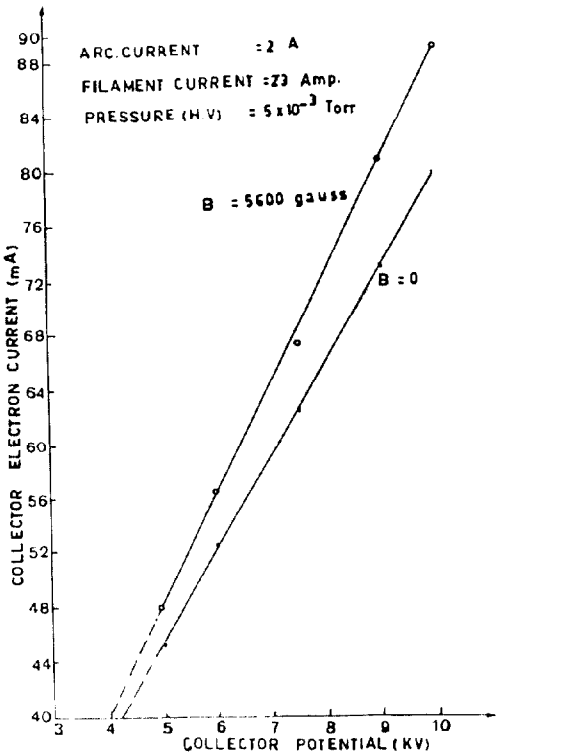

FIG.(6) INFLUENCE OF THE MAGNETIC FIELD ON THE EXTRACTION CHARACTERISTICS.

increase the number of electrons by ionization.

Fig.6 shows an example of the extraction characteristics at pressure 5 X 10^{-3} Torr under the influence of the magnetic field . It is clear that the influence of the magnetic field is larger at larger collector potential.

Conclusion

In this study it is found that the influence of the magnetic field on the electron current is sensitive to the increase in collector potential and the decrease in pressure. Also, the electron current is found to increase with both the arc current and the filament power.

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References

[1] M.Von Ardenne, " Tabellen Für Elektron Und Ionen Physik " Berlin (1956).

[2] L. Spitzer " Physics of Fully Ionized Gases "Interscience Publications, (1962) .

[3] L. Valyi, " Atom And Ion Sources" A Wiley-Interscience Publication, Hungary, P. 168 (1977).

[4] J. Kistemaker, et al., " Nucl. Instr. and Methods" 38, 1, (1965).

[5] C. Lejeune" Symp. Ion Sources " Brookhaven BNL 50310, P. 21, (1971).

[6] T.S. Green " Rep. Prog. Phys. "37, P. 1279, (1974).