Application of E×B Field to a Side-Extracting PIG Ion Source

By

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Abstract

Results are given of a preliminary experiment on the application of an $\boldsymbol{E}\times\boldsymbol{B}$ field to the side-extraction PIG ion source. With an $\boldsymbol{E}\times\boldsymbol{B}$ field a significant increase in the extracted ion current was obtained even at a constant PIG discharge current.

I. Introduction

It is well known that a charged particle in the electric field $\boldsymbol{E}$ and the magnetic field $\boldsymbol{B}$ drifts with the velocity of $\boldsymbol{E}\times\boldsymbol{B}/\boldsymbol{B}^2$. Application of $\boldsymbol{E}\times\boldsymbol{B}$ field to the plasma of the PIG discharge would enhance the ion density in the vicinity of the exit aperture, if the drift velocity is directed to the exit aperture. This paper describes a preliminary experimental test on this possibility.

II. Experimentals

A sectional view of the discharge chamber is shown in Fig. 1. The gaps between the cathodes and the anode were enclosed with insulating pipes of BN to

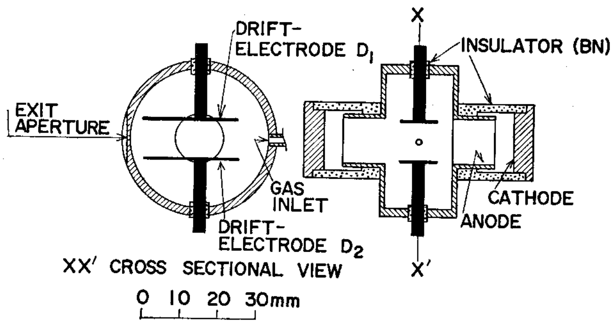

Fig. 1. Sectional view of the discharge chamber.

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prevent the leakage of the supporting gas. The electric field for drift is applied between the electrodes D_1 and D_2 whose distance of separation is 1 cm. (We will call them "drift electrodes" hereafter.) The electric potential of two drift-electrodes were controlled independently. For the measurement of extracted ion current, a copper plate was placed at a distance of 1 mm apart from the exit aperture (1 mm in diameter) of the discharge chamber. The discharge chamber was set in the magnetic field (0.3 Wb/m^2) such that the magnetic and the electric fields crossed perpendicularly. The discharge was supported by neon gas.

III. Results and Discussion

In Table I are listed the relations between the extracted ion current and the potentials of the drift electrodes. In all cases listed, the ion collector had an equal potential with the anode. With the exception of one case where the discharge was unstable, Table I shows that the ions were detected only when the two

Table 1. The relation between the extracted ion current and the potentials of drift-electrodes.

Applied Voltage (with respect to Anode)							
	Electrode D_1	−	+	−	0	−	+
	Electrode D_2	+	−	0	+	−	+
Is the drift velocity directed to the exit aperture?		Yes	No	Yes	Yes	Yes	Yes
Was the ion current detected by the collector plate?		Yes	No	No	Yes	No	(Yes)

( ) means that the discharge becomes unstable.

conditions were fulfilled: the drift velocity was directed to the exit aperture, and the drift-electrode D_2 had a positive potential with respect to the anode. The latter condition means that the electric field between the anode and the drift electrode is necessary to push out the positive ions through the exit aperture. In order to confirm this interpretation, the energy spectra of the extracted ions were studied by means of the retardation-potential method. The intensity of extracted ion current was measured as a function of the retarding potential on the collector plate. The differentiation of this function immediately gives the energy distribution of the extracted ions. In Fig. 2, the results are shown for three different potentials of the drift-electrode D_2, keeping the potential of drift-electrode D_1 as zero with respect to that of the anode. The energy distributions have rather narrow peaks corresponding to the potentials of the electrode D_2. It is noted that the widths of all the peaks are almost the same (50 eV FWHM). The peak energy of ions T can be approximately expressed as a function of the potential V_{D_2} as,

$$T = V_{D_2} - 110 \quad (\text{eV}) .$$

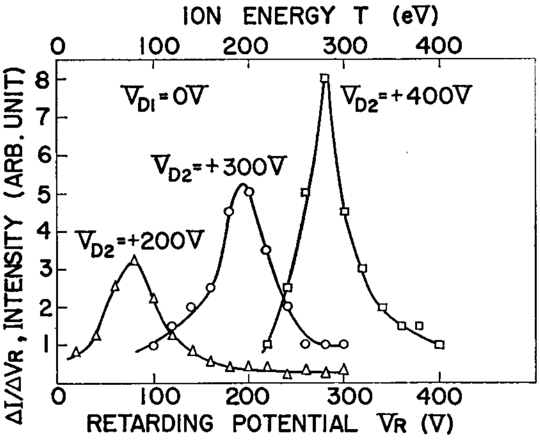

Fig. 2. Energy spectra of extracted ions.

This energy T is too small compared with that corresponding to the drift verocity. For example, in the case of $V_{D_1}=0$ and $V_{D_2}=+400$ V, the drift velocity is 1.3×10^5 m/s. For the Ne^+ ion, this drift velocity corresponds to the ion energy of 1.7 keV, which is about six times as large as the observed peak energy of 290 eV. Therefore, it is concluded that the energy of the extracted ion is determined mainly by the acceleration field between the drift electrode D_2 and the exit aperture, and not by the drift velocity.

Fig. 3 shows the variations of I_{D_2} with the cathode current I_c for three different values of V_{D_2} in the case of $V_{D_1}=0$. I_{D_2} is roughly proportional to I_c. Further,

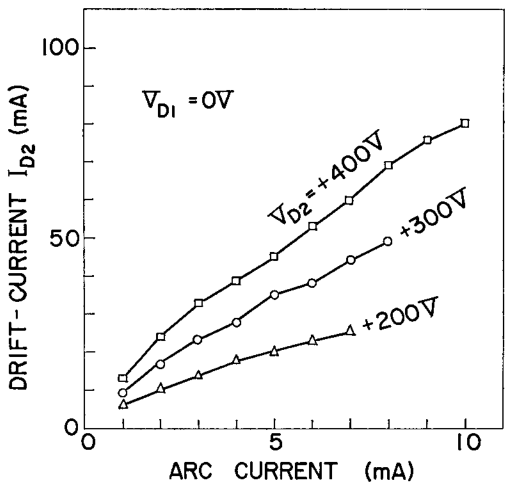

Fig. 3. Variations of drift-currents with arc current. V_{D_1} and V_{D_2} represent voltages of the drift-electrodes D_1 and D_2.

the proportionality constant is larger for the higher potential V_{D_2}. For example, $I_{D_2} \simeq 4 I_c$ for $V_{D_2} = +200$ V, while $I_{D_2} \simeq 10 I_c$ for $V_{D_2} = +400$ V.

In Fig. 4 are shown the extracted ion currents detected by the collector plate

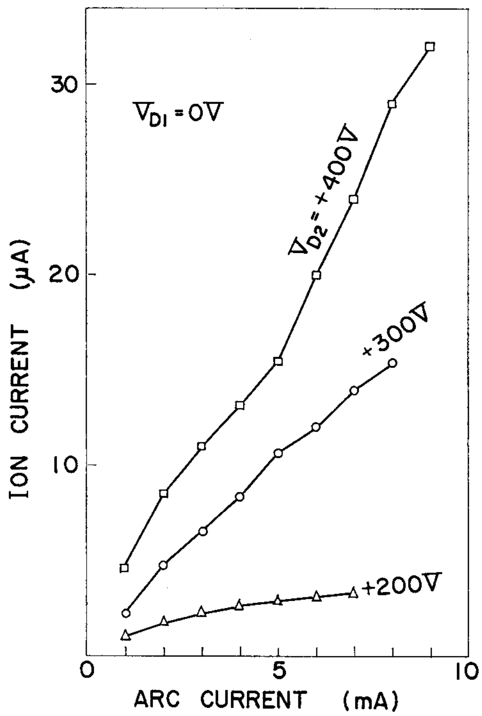

Fig. 4. Variations of extracted ion current with arc current.

as a function of the cathode-current I_c for three different V_{D_2}. The extracted currents are roughly proportional to the arc-current. The proportionality constant is larger for the higher potential V_{D_2}. That is, the application of the higher drift field increases drastically the intensity of the extracted ions, even if the arc-current remains constant. The PIG ion source with an $\boldsymbol{E} \times \boldsymbol{B}$ field can give sufficient side-extracted ion current with a much smaller cathode current than the usual type. Therefore, the lieftime of the cathode, which is roughly in inverse proportion to the intensity of the cathode-current, will become significantly longer if the drift-electrodes are set in the anode cylinder. Since the drift-electrodes are easier for mechanical control than the cathodes, it will be easy to compensate the consumed amount of the electrode material by the mechanical displacement.

The ion source efficiency, that is, the ratio of the extracted ion current to the total power input into the ion source is estimated to be 0.6~0.2 μA/watt for $V_{D_2} = +400$ V~+200 V.