3.28 Formation time of the plasma in crossed fields in millisecond region

D. Đ. TOŠIĆ and V. I. MILJEVIĆ, *Institute of Nuclear Sciences "Boris Kidrič", Beograd, Yugoslavia*

Abstract

The problem of the plasma formation in crossed electric and magnetic fields at low pressure has been studied. By measuring of the formation time it was shown that an intense gas discharge initiates in the magnetron diode with considerable delay of the order of a few milliseconds, with respect to the anode voltage establishment. It was observed that the formation time increases as the square of the magnetic field and decreases with pressure.

3.29 Influence of the cathode heating current on the plasma formation time in crossed fields

D. Đ. TOŠIĆ and V. I. MILJEVIĆ, *Institute of Nuclear Sciences "Boris Kidrič", Beograd, Yugoslavia*

Abstract

The influence of the cathode on the plasma formation time in the gas magnetron diode with hot cathode has been investigated. It was shown that the parasitic electric and magnetic fields due to the heating current flow lead to an increase in the plasma formation time.

3.30 Gas ionisation in crossed electric and magnetic fields

P. K. CIBIN, *Institute of Nuclear Sciences "Boris Kidrič", Beograd, Yugoslavia*

In the present paper we report preliminary calculations which attempt to explain the behaviour of the gas magnetron diode with hot cathode (as a system of crossed fields) near the cutoff. For weak magnetic fields (smaller than the cutoff magnetic field B_c) the gas magnetron diode at low pressures behaves like a simple diode without magnetic field. Paths of emitted electrons lengthen with magnetic field reaching the maximum at B_c. With lengthenning of electron paths the number of produced ions increases. At critical magnetic field the electrons graze the anode and come back to the cathode, so we could expect a jump in the ion production. Since the number of ions N_i depends also on the ionisation cross-section, i. e. on the electron energy, which changes with magnetic field, it was of interest to obtain the shape of the function $N_i = f(B)$.

The number of ions created on the path dl is

$$dN_i = N_e n_g \sigma_i \, dl, \qquad (1)$$

where σ_i is the ionisation cross-section, N_i the number of electrons, n_g density of neutrals.

Since at low pressure the mean free path of electrons and ions is much larger than the interelectrode distance d, the number of electrons N_e was assumed to be constant. Besides, we can neglect all secondary processes caused by ion-neutral and electron-ion collisions. Therefore, the number of ions can be derived by the intergration of Eq. (1) along an electron path, i. e.

$$N_i = N_e n_g \int_l \sigma_i \, \mathrm{d}l.$$

The plane magnetron diode was chosen as the simplest crossed fields system. The potential distribution is then $U = (U_a/d)\, x$.

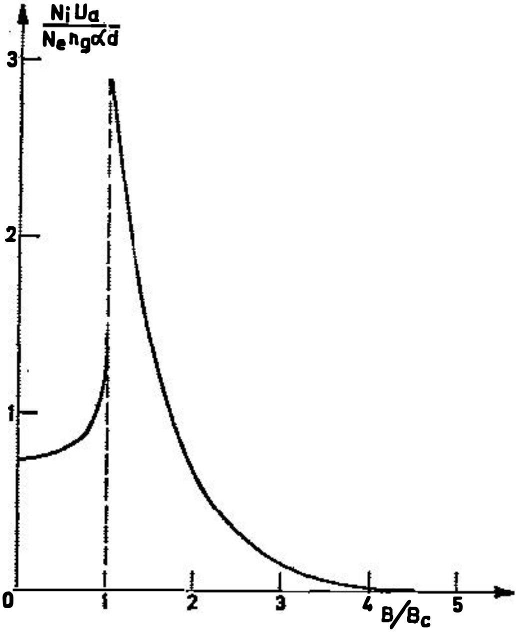

Fig. 1

The ionisation cross-section was taken in the approximation form

$$\sigma_i = \frac{a\,(U - U_i)}{(U - U_i + \beta)^2}, \quad (U > U_i); \qquad \sigma_i = 0, \quad (U < U_i),$$

where U_i is the ionisation potential, a and β constants depending on the type of gas [1,2].

For the magnetic field B orthogonal to the electric field E, the cycloidal path of emitted electron is determined by

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \frac{E}{B} \sin \omega_c t, \quad \frac{\mathrm{d}y}{\mathrm{d}t} = \frac{E}{B} (1 - \cos \omega_c t).$$

Combining the aforesaid equations we can derive the final expression for the number of ions produced along a cycloidal path. Since at B_c there is the discontinuity in the length of the electron path, this expression is separated into two ranges, depending on magnetic field:

1° for $B<B_c$

$$N_i = N_e n_g a \frac{d}{U_a} a \left\{ \frac{2a^2+b-2c}{2(a^2+b-c)^{3/2}} \log \left[\frac{(\sqrt{a^2+b-c}+(\sqrt{a^2-c})^2}{b} \times \right. \right.$$

$$\left. \left. \times \frac{(\sqrt{a^2+b-c}-\sqrt{a^2-1})^2}{1+b-c} \right] - \frac{b}{a^2+b-c} \left(\frac{\sqrt{a^2-c}}{b} - \frac{\sqrt{a^2-1}}{1+b-c} \right) \right\};$$

2° for $B>B_c$

$$N_i = N_e n_g a \frac{d}{U_a} a \left\{ \frac{2a^2+b-2c}{(a^2+b-c)^{3/2}} \log \frac{(\sqrt{a^2+b-c}+\sqrt{a^2-c})^2}{b} - 2 \frac{\sqrt{a^2-c}}{a^2+b-c} \right\},$$

where $a=B_c/B$, $b=\beta/U_a$, $c=U_i/U_a$, $B_c=\left(\frac{2m}{e}U_a\right)^{1/2}/d$.

The numerical example was calculated by digital computer for $U=300$ V and nitrogen (Fig. 1).

These calculations show that the gas ionisation was enhanced about four times and reaches the maximum at critical magnetic field, which was observed in many experiments[4].

The above analysis is valid only for primary electrons. The complete analysis must take into account the ionisation processes caused by secondary electrons, as well as the influence of the space charge on the electron dynamics.

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3.31 Characteristic magnetic field in a gas magnetron diode

P. K. CIBIN and D. Đ. TOŠIĆ, *Institute of Nuclear Sciences "Boris Kidrič", Beograd, Yugoslavia*

The fundamental characteristic of the vacuum magnetron diode is the switching action of the magnetic field (cutoff). In the gas magnetron diode cutoff occurs at much higher magnetic fields, than in vacuum conditions, because the electron