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POSITIVE COLUMN CONSTRICTION IN CESIUM PLASMA DISCHARGE

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A lot of papers were published by different authors on positive column with the purpose to explain the constriction phenomena.

There are many proposed mechanisms to explain surprisingly well one and the same phenomenon - the positive column constriction.

One of the most popular explanation of the constriction is the inhomogeneous heating of the gas in the discharge tube, with the subsequent change in the radial charge density distribution /1/.

This thermal effect is considered in /2/ to be not important. Indeed, the measured pressure at which the column constriction appears for various noble gases is smaller for pulsed discharge than for the steady discharge, in spite of the fact that the thermal effects are smaller in the former.

In a previous paper /3/ we have theoretically considered the possible contribution of the atomic to molecular ion conversion process, on the radial charge density distribution in the positive column. According to our paper, due to the higher mobility of the molecular ions than that of atomic ones, the radial charge density decreases faster than Schottky distribution. The solution for the distribution of the radial charge density \( n \) is:

\[
\frac{\partial n}{\partial t} = \frac{\partial}{\partial r} \left( \frac{\partial n}{\partial r} \right) + \frac{\pi}{2} \int \left( \frac{\partial n}{\partial r} \right) \left( \frac{\partial n}{\partial r} \right) + \ldots
\]

which is a fast convergent series for small values of the coefficient \( 2 \pi \). In eq.1, \( n_r \) is the charge density at the positive column axis, \( r \) is the radial distance from the axis and \( \frac{\partial n}{\partial r} \). Coefficients \( \beta, \gamma \) and \( \delta \) are given by the relations:

\[
\beta = e(\mu_a + \mu_m) \ln \frac{1}{(A_e + \mu_m)} \]

\[
\gamma = e \alpha \left( \frac{1}{(A_e + \mu_m)(A_e - A_m)} \right)
\]

\[
\delta = \rho \left( \frac{1}{e} \right) \left( \frac{\partial n}{\partial r} \right)
\]

where \( \mu \) and \( D \) are the mobility and the diffusion coefficient, respectively, indices \( e, p_1 \) and \( p_2 \) referring to the values concerning electrons, atomic and molecular ions, respectively. The conversion frequency \( \alpha \) is defined as \( \alpha = k_c N^n \), where \( N \) is the neutral atoms density and \( k_c \) the transformation coefficient of atomic ions into molecular ions. The parameter \( \alpha_i \) is the ionization frequency for atomic ions.

The conversion effect is strongly dependent on the cesium pressure and is described by the equation:

\[
\frac{dN_{mol}^+}{dt} = k_c N_{at}^+ N_{at}^2
\]

where \( N_{at}^+, N_{mol}^+ \) and \( N_{at} \) are respectively the densities of the atomic ions, molecular ions and neutral atoms.

In the TABLE I the values of \( k_c \) for some gases and vapours are given /4/.

<table>
<thead>
<tr>
<th>( k_c ) (10^-31 cm^6/s)</th>
<th>( p_c ) (torr)</th>
<th>( \sqrt{k_c p_c} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>He</td>
<td>.9</td>
<td>100</td>
</tr>
<tr>
<td>Ne</td>
<td>.7</td>
<td>75</td>
</tr>
<tr>
<td>Ar</td>
<td>2.0</td>
<td>13.5</td>
</tr>
<tr>
<td>Kr</td>
<td>2.7</td>
<td>9.0</td>
</tr>
<tr>
<td>Xe</td>
<td>3.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Cs</td>
<td>150.0</td>
<td>2.8 x 10^-2</td>
</tr>
</tbody>
</table>

with \( p_c \) the pressure above which the constriction appears, its values being taken from /2/.

We can introduce now the empirical coefficient \( C = k_c \sqrt{p_c} \), which can be considered as a constant of the positive column constriction phenomena. Indeed, \( C \) has prac-
tically the same value for all gases con-
tidered. Using the value of $C=8.0$ and tak-
ing into account the value of $k_c$ for ces-
ium vapours, we computed the value of the 
expected cesium vapour pressure for the 
positive column constriction.

This expected value for cesium is: 
$$k_c = 2.8 \times 10^{-2} \text{ torr}.$$ 

**EXPERIMENTAL SET-UP AND RESULTS.**

The experimental device is shown sche-
matically in Fig. 1. The cathode is a moli-
denum disc of 25 mm diameter heated by e-
lectron bombardment. The cathode is sur-
rounded by a ceramic insulator, except the 
front planar surface. The anode is a stain-
less-steel disc at a distance of 300 mm 
from the cathode. The experimental tube is 
provided with a number of movable double 
probes. The positions of the probes were 
measured optically from the distance of 
1.5 m from the tube.

The whole device is mounted inside an 
oven, which insures the necessary tempera-
ture to obtain the needed cesium vapour 
pressure.

In Fig. 2 are given some of the obtained 
values for the normalized charge density 
versus the normalized distance $r/R$ from 
the axis of the tube (where $R$ is the radi-
us of the tube). The charge density at the 
axis is $n_0$. The experimental points were 
taken for two values of the cesium pres-
Sure: $p_1 = 2.8 \times 10^{-2}$ and $p_2 = 9 \times 10^{-2}$ torr, corresponding to the temperature of the cesium reservoir of 175 and 240°C, respectively. On the same figure are given two more cur-
ves: the Schottky curve and the computed 
curve for the radial charge density dis-
tribution using the equation inferred by 
us in /3/, but for a small conversion coef-
icient (low pressure of the cesium va-
our).

The obtained results can be compared 
with the value obtained for $P_c$ (Cesium), ac-
cording to the empirical relation $C = k_c \sqrt{P_c}$. 
The agreement is quite good.

We may conclude, as it has been 
pointed out in our previous paper too, the 
ion conversion effect has to be taken into-
account in the explanation of the positive 
column constriction.

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