International Journal of Pure and Applied Physics
ISSN 0973-1776 Volume 4, Number 2 (2008), pp. 151–156

http://www.ripublication.com/ijpap.htm

# Plasma Compression in a Hollow Cathode Gas Discharges (HCGD)

**Dj. Boubetra[1], H. Kerkow[2] and M. Bouafia[3]**

[1] LMSE, C.U. B.B.Arreridj 34000 Algeria.
[2] Humboldt University Berlin, Germany.
[3] Setif University 19000 Algeria.
E-Mail: boubetra@gmail.com

**Abstract**

The gas discharges plasma compression is necessary to increase the ion yield of. In this work we show the possibility to compressing column plasmas resulting from a gas discharges. The applicability of the the method can be reached in two different ways: by inhomogeneous magnetic field and by geometrical restricting of discharge.

**Key Words:** Plasma, magnetic field, gas discharge

## Introduction

According to the theory, the mean impact number δ of gas atoms on a wall with a gas pressure P can be defined as:

$$\delta = \frac{p}{\sqrt{2mKT}} \tag{1}$$

Where m is the mass of the atom, K the Boltzman constant, and T the absolute temperature. If all atoms would be ionized, the current density would amount to $j = e_0 \cdot \delta$. What was shown in reference [1]. The given relation can be expected to recognize clearly that the ionization degrees in a cold cathode ion source amounts to only little per cent. The reason for the fact lies above all in the fact that discharge cannot be arbitrarily highly increased, since otherwise the power losses at the electrons would not to be controlled, if one sinks on the other hand the gas pressure, then the discharge geometry changes, because the mean free path of the discharge particles grows. if it reaches discharge geometry, then the discharge expires. The plasma of a gas discharge is therefore a small disturbance of the essentially neutral gas, which is intending for the impact-kinetic processes of the energy transmission.

## Materials and Methods

### Plasma compression by magnetic Field

So far it was accepted that the charge carriers moves in a homogeneous magnetic field, from the free charge carriers the course radius of the electron is smallest in accordance with equation

$$r = \frac{m.v}{q.B} \tag{2}$$

If it concerns however inhomogeneous magnetic fields, then the electrons follow also this field process and their course radius is reduced in a convergent magnetic field[2]. to the ions applies this in far smaller mass. As is recognized in figure. 2 and 3, one can affect the shape and density of the plasma clearly by inhomogeneous magnetic fields. For the demonstration of this connection was used a hollow cathode discharge, because the source point of discharge (the hole in the hollow cathode) is fixed and the fuel conditions at the cathode will be little affected by the magnetic field , Without magnetic field the plasma steps out in bundles form more from the opening as figure.1 shows. The anode geometry has hardly influence on the shape of the plasma, which spreads generally in the area.

As in figure. 3, one place a permanent magnet on the anode, thus the plasma pulls together on one point on the anode. The charge carriers follow the scattering field of the permanent magnet, which collected the quasi charge carriers. As in figure . 2 one places a horseshoe magnet on the anode, thus the scattering field is made visible by the plasma. One receives one point of focusing for the plasma on the North Pole and another on the south pole of a magnet, between them forms a circular envelope of the trajectory of the plasma, since the ions are hardly affected by the magnetic field, must be still clarified,

The magnetic scattering field of the horseshoe magnet causes an allocation of the plasma current to the anode. The electrons, and concomitantly the plasma, follow similarly the iron filings the scattering field of the horseshoe magnet.

By a permanent magnet the electrons are bundled from the cathode area toward anode

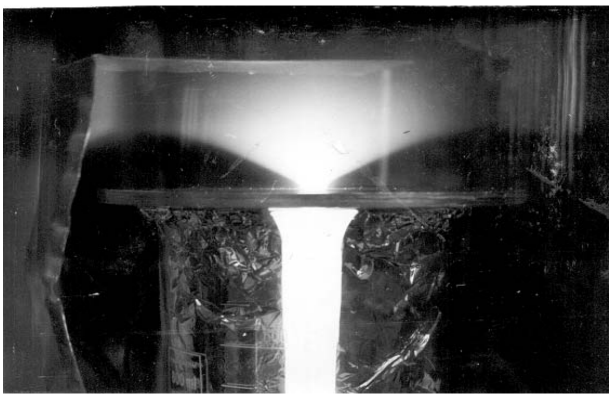

**Figure 1:** Photography of the shining distribution plasmas in an inhomogeneous magnetic field.

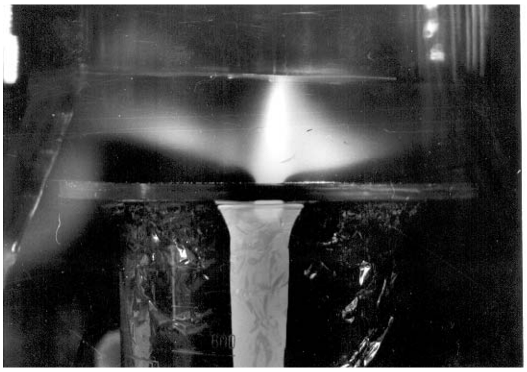

**Figure 2:** Photography of the shining distribution of the plasma under effect of a horseshoe magnet.

**Figure 3:** Photography of a hollow cathode discharge.

A beaker was on the inside deflected up to a slot with aluminium foil. By a metallic cover with a drilling in the center it became the hollow cathode of a discharge. One recognizes clearly, how the plasma drags on into the hollow cathode and the fall-cathodic extends thereby over the entire interior of the hollow cathode.

Why the ions follow the magnetic field circle likewise like the electrons. In the plasma exists a charge carrier density according to the necessary stream?

With a gas pressure of 0,1mbar the particle density of the gas atoms is approximate $10^{15}$ Atoms/cm$^3$. With a discharge current of 100mA and a cross section of 1cm$^2$ at a mean electrons velocity of $5.10^8$ cm/s the space charge density must amount to about $10^{11}$ Elektrons/cm$^3$. Thus less than 0.1% of all particles are ionized[3]. This particle density corresponds to a charge density of $\rho=10^{-2}$As.m$^{-3}$.

According to the Poisson space charge equation [4]:

$$\frac{\Delta E}{\Delta X} = \frac{\rho}{\xi_0} \tag{3}$$

One receives the numerical with $\xi_0$ = 8,8 $10^{-12}$As/Vm ,one receives the numerical value equation $\Delta E/Vm^{-1} = 10^9 \ \Delta X/m$.

Arise shifts of 1mm in the space charge distribution between ions and electrons, thus arise changes of field strength of $10^3$V/mm. These fields are higher, than they are at all possible in discharge. Therefore the ions must follow the electrons because of the high electrostatic forces between the ions and electrons, i.e. the space charge densities must be on the average alike, although small oscillations are possible around the uniform distribution charges in the microscopic range. Therefore the ions would not become the same circulation drive out as the electrons, only provide in the spatial and temporal means for charge equilibrium. Regarding the effect of the magnetic field on free charge carriers must be still marked, that the circulation around the magnetic field lines is a consequence of the induction law, after which the direction of the circle stream runs in such a way, that it tries to weaken the cause, the effective magnetic field is weakened by the circulation of the charge carriers. Thereby the plasma has like all materials, dia.-magnetic characteristics. One can compute the circular frequency charges from the peripheral speed and the course radius, and from this by the Biot-Savart law the amount of the anti fields in the axle will be measured to $B = 10^{-10} Vs/m^2$.

This anti-field prevails inside the circular path of an electron with an outside magnetic induction of 0,1T. However it is always small in relation to from the outside effective field, so that a magnetic screen cannot enter with plasma densities of $10^{11}$ charge carriers/cm$^3$. Only with superconducting materials with charge carrier concentrations around $10^{22}$ particles/cm$^3$ can be achieved a complete magnetic screen of the enclosed volume.

## Geometrical Plasma Compression

If one restricts the discharge area between cathode and anode, then increases here the current density, however one can reach this only if one uses an insulator in place of a metal as material for partition. If the partition is a metal, then it forms a dynode, whereby the partition becomes to the anode for the original cathode and to the cathode for the anode, as is schematically represented in figure 4a).

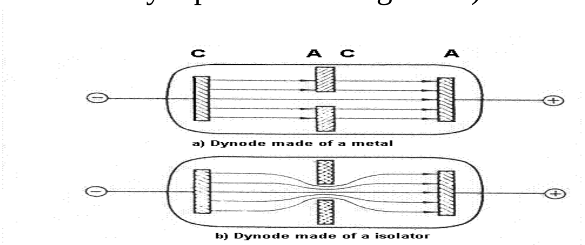


**Figure 4:** Schematic representation of the plasma compression by a screen.

If the dynode consists of a metal, then it takes an intermediate potential between anode and cathode. It does not take place a constriction. If anode and cathode are connected against it by a hole in an isolating wall, then it comes to a plasma compression.

In this case for the maintenance discharges one must only doubling the burnings tension. if against it uses an insulator as partition material, then it comes to a plasma compression in the hole of the wall, as is represented in fig. 4b).

This effect is used for the increase of the brilliance in Geissler tubes or – glasses [5].

Whereby is caused this increase current density?

Since the current density results from the space charge density ρ and the speed of the charge carriers v in accordance with $j = \rho . v$, the current density increase can be attributed to an increase the speed or to the charge carrier density. The speed of the charge carriers will depend on the mean free path λ and the field strength E, because it is valid the connection

$$\frac{1}{2}mv^2 = e_0.E.\lambda = e_0.U \tag{4}$$

For the ions the mean free path is about those of the gas atoms, against for the electrons it depends on the energy of the electrons. Generally the decrease of potential over the plasma is small and amounts to some 10V/cm. With a gas pressure of 0,1Pa the mean free path of the gas atoms is near 1mm. The energy gain between the impacts with gas atoms amounts to for the electrons only some electron volts. These energies are not sufficient for the ionization of the gas atoms, with the impacts, with that gas atoms the electrons are strewn, kept however essentially their kinetic energy, since for a clear energy loss with flexible impacts the mass differences between electrons and atoms are too large. Only if the electrons put several gas-kinetic distances back, they possess a sufficiently high energy for the ionization of gas atoms (inelastic impact procedure). The electrons experienced a strong braking due to the impact process and must again be accelerated. However increases the field strength (potential decrease in the channel of the partition), then shorten also the distances, which are necessary for the acquisition of the ionization energy. Restricting the ionization cross section does not therefore only lead to a noticeable speed increase of the charge carriers, but also for an increase of the space charge density, because the frequency of the ionizing impacts of the electrons increases along the conducting paths. This procedure will continue until finally on the distance of the gas-kinetic impact distances the electrons receive the necessary ionization energy, only by increase of the decrease of potential in the channel then an increase of the ionization degree of the plasma is possible, which leads to multiple ionization gas atoms.

## Conclusion

In summary one can state that depending upon line of flux process one can keep the charge carrier density constant by homogeneous magnetic fields and by inhomogeneous fields can to compress or stretch.

In the case of use a magnetic hollow cathode one can achieve a compression or a homogeneous transfer of discharge by inhomogeneous magnetic fields within the plasma range either up to the anode. The plasma follows the magnetic field lines in its density and direction.

A further possibility of the plasma compression consists in geometrical restricting of an discharge in the plasma range by a hole screen of an insulator than partition.

## References


[1] K. Wasa, M. Kitabake, H. Adachi, in: Thin Films Material Technology: Sputtering of

[2] Compound Materials, Published by William Andrew Inc., (2004).

[3] I.G. Brown, in: The Physics and Technology of Ion Sources: Second, Published by
[4] Wiley-CH, (2004).
[5] H. Kerkow, Dj. Boubetra, Dissertation , H.U. Berlin, (1992).
[6] H. Niedrig, in: Die Grundlagen der Ingenieurwissenschaften, herausgegeben von Horst
[7] Czichos, B121, 29th Auflage, (1991).
[8] Gerthsen-Kneser-Vogel, in: Physik 16.Auflage P.439-443, (1989).