Development of Magnetic Hollow Cold Cathode for Ion Source

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Abstract: The research presented in this work focuses on the development of ion source with hollow cold cathodes which supplies low –power and high ion-current density applications. The theoretical and experimental results were used to design a second-generation laboratory model, low-current hollow cathode. Our experiment is to design a hollow cold cathode with two application possibilities. [The Journal Of American Science. 2007;3(4):15-19]. (ISSN: 1545-1003).

Key words: hollow cold cathode, magnetic hollow cathode, ion source, plasma.

1. Introduction

The magnetic hollow cathode is an element for the construction of discharge arrangements for different purposes, which are still functional with relatively low gas pressures.

It can be widely used for the ionization of gas flows, the production of high plasma densities, Magnetron arrangements for thin films deposition (Pessoa at al., 2006), spectra light sources, low-vacuum electron beam sources and gas lasers.

The construction by plasma beams for the material denudation or to the building by cold cathode ion source.

Hollow cathodes discharge, in their various forms, are very suitable in a large variety of applications where high current densities, low cathode-fall voltages, and extended lifetimes are required (Rawlin, at al. 1968, Kirkici, at al. 1995, Fradkin, at al.1970, Ferreira, at al. 1978). They are capable of operation at a fraction of an Ampere up to several hundred Amperes, all in arc discharge.

Although there could be various technical applications of the magnetic hollow cathode, essentially two application possibilities were tested in this work:

- Sputtering plant with magnetic hollow cathode for layer demolition.
- Cold cathode ion source with magnetic hollow cathode.

2. Experiment

Two differently ion source types were developed and their characteristics are examined (Boubetra, 2007). The description of the sources is represented in figures 1 and 2.

COLD CATHODE SOURCE IN CATHODE CIRCUIT

The ion source is similar to a Penning ion source in its structure (Kerkow, at al. 1992). But, the cathode is replaced by the magnetic hollow cathode as shown in Fig.1. A high magnetic field with similar characteristics to that used in Penning ion source is applied to the anode region.

At low pressure the gas enhancement in the hollow cathode is not sufficient for the maintenance of discharge.

In this case, only the pendulum effect of electrons ensures low discharge current of about 1 mA.

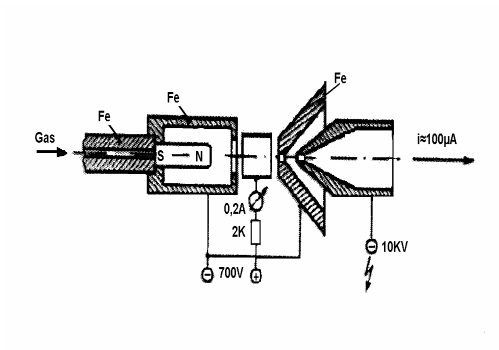

Figure 1: The cold cathode Ion source with magnetic hollow cathode in cathode circuit.

Increasing the pressure to around 0,1Pa leads to the enhancement of gas, and discharge current with the magnitude of about 2 within the range of some 100mA.

Under these pressure conditions, the discharge is better collimated as that observed in Penning-arrangement where discharge is distributed over the entire cathode surface. According to higher unloading pressure the current density is therefore higher in a discharge with magnetic hollow cathode than in the Penning ion source.

Bethge and Baumann (1974) tried to limit discharge by the reduction of the cross sections and by drillings in the magnetic pole with small surface ranges. However the volume of the small hollow cathode is not sufficient to ensure the necessary Gas reinforcement for discharge. The importance of the developed ion source is not only apparent in the production of ions using the oscillating electrons but it raises in directing plasma through an inhomogeneous magnetic field towards the counter cathode so that the appearance of ions opening takes place .

With following reflection the electrons and the plasma become in opposite directions by the magnetic field absent-minded. The pendulum effect of the electrons is small thereby. The ion source reacts very flexibly to pressure changes, i.e. the discharge current can be adjusted over a pressure control between the smallest and the greatest possible river continuously. A substantial advantage is that discharge in the Penning arrangement themselves with vacuums of 0,01Pa still burns.

A special execution of the source for a 350kV-Ion accelerator was tested. Typical ion stream, which were based on the target system of the 350kV-Ion accelerator, are arranged in table.1 for different feed gases.

Table1. Ion current in µA with corresponding gas

Ion Gas	H^+	H_2^+	H_3^+	He^+	C^+	N^+	O^+	H_2O^+	F^+	N_2/CO^+	NO^+	O_2^+	Ar^+
H_2	17	65	22	_	_	_	1	8	16	_	_	_	_
He	0,3	0,4	_	65	_	15	2,5	_	_	16	4,5	_	_
N_2	0,2	0,2	_	_	0,4	15	2,5	2	_	55	20	1,7	2,5
O_2	0,3	_	_	_	0,3	0,4	20	2,5	_	3	2,5	55	0,8
Ar	-	1,7	_	_	_	_	_	_	_	_	_	_	75

The ion current were measured with a hole diameter of about 0,7mm at the output slit of the ion source.

More than 100 µA can be reached for all permanent gases according to the surface increase and enlargement of the output slit.

The use of another design for the magnetic hollow cathode, e.g. as shown in Fig. 2, permits to obtain very handy and productively ion source with small dimensions.

This type of particularly ion source should be suitable to produce ions by atomization of difficulty evaporable materials.

By the conversion achievement in the ion source the parts for the magnetic field generation must separate then from the ion source interior. In this case the material in the hollow cathode is sputtered or evaporated by diffusion process into the anode region.

For geometry reasons, the largest part of the steam cloud is condensed on the cathode. While this electrode is also met by ions a sputtering process take place. On the other hand it contributes to the increase of the density within the plasma range. A substantial disadvantage of the ion source is that the ion emission current density is determined by the internal field gradient between plasma and output. It determines the number of the emitted ions. Since the magnetic field hardly affects the ion movement, one must steer the ion emission from the plasma by suitable deformation of the output. In addition, the atomization of the screen material at the output limits the life span of the ion source.

Cold Cathode Ion Source in Anode Circuit

In anode circuit the face with the output of the ions is on anode potential in accordance with Figure 2.

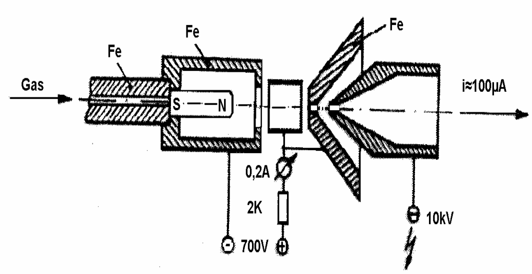

Figure 2. A cold cathode Ion source with magnetic hollow cathode in anode circuit. Held together of the magnetic field in the anode region. Only the anode drop as characteristic of the anode-lateral polarization of the plasma separate the ions at the output slit.

The output slit serves as gas throttle for the neutral gas atom. When it stays before the magnetic disk likewise anode potential, then a part of the plasma is transferred of the ion source by the magnetic field into the outside space.

The ions were aspired and by the electrode and the emission amperage of ion source depends then on the plasma volume, which is seized by the suction electrode, and on the charge carrier density.

Therefore the arrangement of electrode geometry is crucial with this switching type for the ion yield of the ion source. Technically these criteria could be considered with the testing of the ion source in anode circuit only insufficiently, because the cover plate for constructional reasons at cathode potential and be switched only one sheet metal screen with the output had to be put as anode could.

Nevertheless ion current could be obtained, which were comparable with the source in cathode circuit. The advantage of the ion source in anode circuit consists above all of the fact that one can vary the suction conditions independently of the fuel conditions. During the cathode circuit the plasma is separate by an outer zone from the output. The thickness of this outer zone depends on the plasma density, i.e. on the discharge current and on the magnetic focusing conditions. Also still another small portion of a cathode-falls becomes effective; however the source of discharge is the magnetic hollow cathode and not the back plate electrode as with a Penning source. Since the potential difference between plasma and back plate electrode amounts to for instance 300V (Burning tension), the distance between plasma and back plate electrode 1 to 2mm amounts to, field strengths of 10^3V/cm arise, which affects however diverging the emission direction of the ions. In the anode circuit geometry of the suction field is determined by the shape of the suction electrode and the output and can contribute to the focusing of the ion beam. Since the energy distribution of the ions lies within the range of 10eV, a better jet forming should be possible in anode circuit. A disadvantage of the ion source in anode circuit is however that the ion source must be operated with higher gas pressure than in cathode circuit and the combustion behaviour of the ignition characteristic of the magnetic hollow cathode is determined. This disadvantage becomes balanced by the fact that the atomization is small only in the range of the output and can only occur, if negative ions are present in discharge.

Conclusion

We have proposed a simple technological construction of cold cathode in order to compare it with glow cathode or HF-ion sources. The disadvantage is however the high gas pressure for an discharge and the smaller ion yield. By using a magnetic hollow cathode it is well possible to realize an homogeneous transfer of discharge by inhomogeneous magnetic fields within the plasma range to the anode. The plasma follows the magnetic field lines in its density and direction.

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