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Side extraction duoPIGatron-type ion source

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Abstract – We have designed and constructed a compact duoPIGatron-type ion source, for possible use in ion implanters, in such the ion can be extracted from side aperture in contrast to conventional duoPIGatron sources with axial ion extraction. The size of the side extraction aperture is 1×40 mm. The ion source was developed to study physical and technological aspects relevant to an industrial ion source. The side extraction duoPIGatron has stable arc, uniformly bright illumination, and dense plasma. The present work describes some of preliminary operating parameters of the ion source using Argon, BF_3. The total unanalyzed beam currents are 23 mA using Ar at an arc current 5 A and 13 mA using BF_3 gas at an arc current 6 A.

1. Introduction

Reliability is of paramount importance for industrial ion-beam systems. However, manufacturing processes often involve the operation of ion sources at elevated temperatures also as with corrosive and erosive feeds. Under these conditions, the durability of various components, and especially cathodes, may be reduced by physical sputtering and chemical erosion.

The duoPIGatron ion source,[1] having two chambers, is well suited to minimizing this problem. The first chamber houses the cathode and serves as an electron generator for the second PIGing, or reflex arc, chamber where most of the extracted ions are created. It is essentially a tandem discharge with a cathode plasma and an anode plasma separated by a double sheath boundary, arising owing to presence of the small size aperture in the intermediate anode. The cathode plasma acts as a buffer zone between the main body of the discharge and the real cathode and supplies ionizing electrons to the anode plasma. The concave double sheath defocuses the ion towards the first chamber thus reducing ion current density. This minimizes the cathode erosion resulting from ion bombardment. Moreover, the first chamber can be operated on an inert gaseous feed chosen to maximize filament lifetime, while the second chamber is fed a noxious gas or vapor that gives rise to the ion of interest.

The present paper reports on the operation of a constructed duoPIGatron with transverse extraction of ions.

2. Ion source description

The design drawing of duoPIGatron ion source is given on fig.1. The ion source consists from plasma generator and extraction column.

The plasma generator comprises three subsystems: the electron generator, the PIGing chamber, and the oven. The cathode is a non-inductive spiral fashioned from 1.5 mm diameter tungsten wire. The filament length can be various and depends on size of a discharge current. Inside the PIGing chamber the electrons are, as usual, confined axially by an electrostatic mirror consisting of the anticathode and the intermediate electrode. However, radial confinement is provided longitudinal magnet field. The peak field at the centre of the PIGing chamber is about 400 mT. The entire PIGing chamber has been cut out from dense graphite and lined inside with molybdenum plates. The intermediate electrode is turned from mild steel. Heat removal from the intermediate anode is provided with high heat conductivity of the copper cylinder hardly dressed on this anode and mounted on a flange cooled by oil. DC arc voltage is applied between the anode and filament, while the intermediate electrode is self-biased through high resistance (about 300 Omh) connections to the anode. The intermediate electrode serves as the magnetic screen to weaken a field inside cathode area and so a magnetic pole, to provide a homogeneous axial magnetic field in anode area. The anticathode can be electrically allowed to float.

The primary electrons emitted from the filament produce a cathode plasma in the first chamber. Some of these electrons are accelerated through the intermediate electrode channel and into the PIGing region. These energetic electrons are constrained by the magnetic field and oscillate between the cathode plasma and anticathode. They initiate and maintain a so-called PIG discharge or a reflex discharge. Because of their high energy and long path length, they

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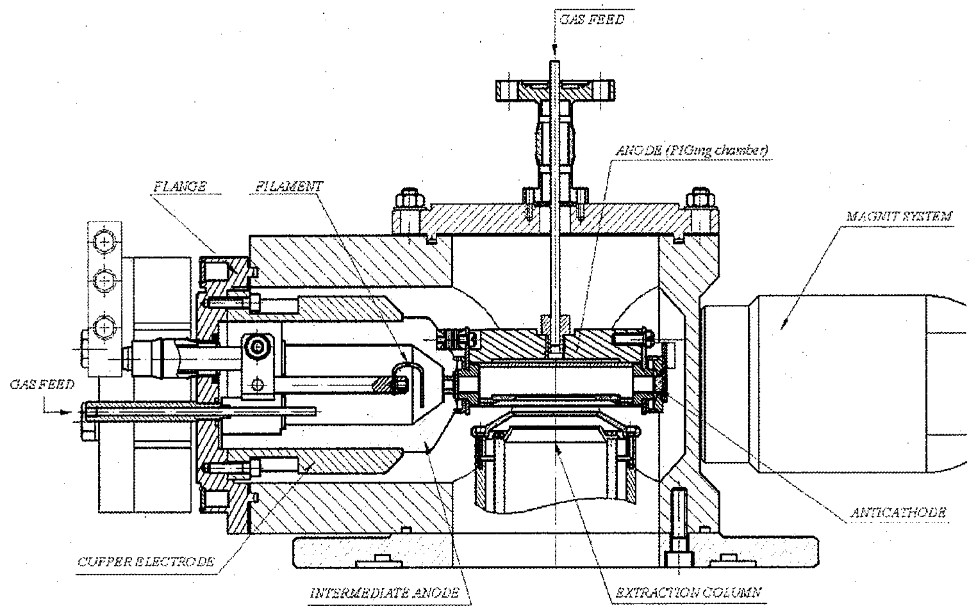

Fig. 1. Sketch of the duoPIGatron ion source.

produce a dense PIG plasma and become the chief ionizers in the PIG region.

The ions so created are extracted through 1×40 mm^2 emission slit and formed into an ion beam by the extraction electrodes. The triode extraction system is identical to the one used with Bernas-Calutron ion source.

3. Test results

The schematic drawing of the duoPIGatron experimental set up is shown on Fig. 2. In the first test the ion source have been operated on an inert gas (such as Ar). Gas can be feed into the cathode region or anode region separately or also into both regions simultaneously. From the first experiments we found, that duoPIGatron operates stably with different schemes of the gas feeding including and the gas feed only in anode chamber (PIGing region). Moreover for last case emissive effectiveness (the ratio of an ion emission current to a discharge current) is much higher than at other schemes. It has allowed us at once in experi-

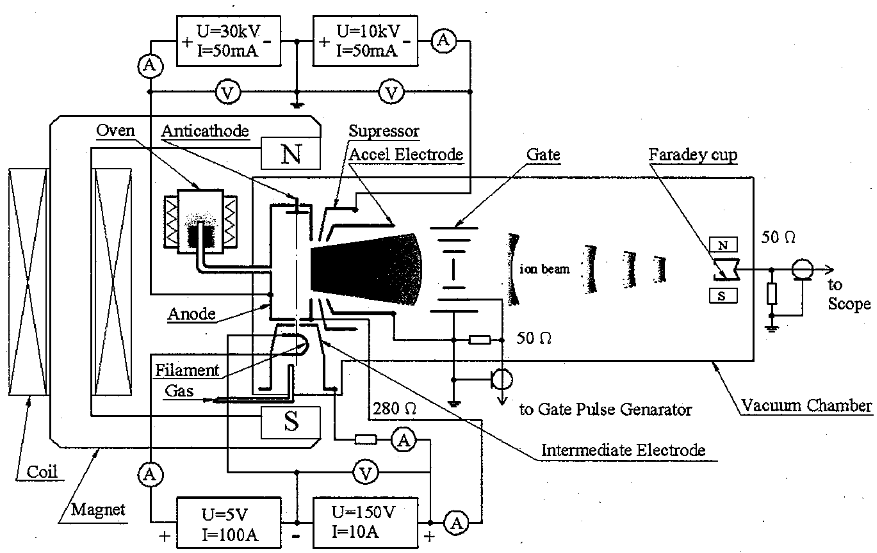

Fig. 2. Schematic drawing of the duoPIGatron experimental set up.

ments with a Boron to proceed with the anode chamber feeding, without use of additional feed of inertial gas in the cathode part of the ion source.

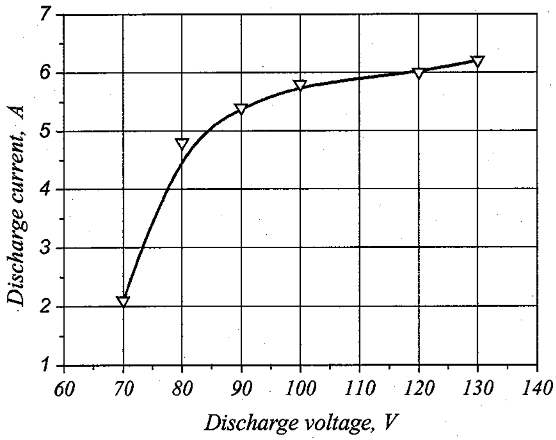

Fig. 3. Discharge current versus discharge voltage for the BF_3 feeding.

From given on Fig.3 current-voltage curve of the discharge it is possible to draw a conclusion, that up to discharge currents of 10 amperes the contribution of the ion bombardment to the heat balance of the cathode is inappreciable. The discharge current moderate increases in a wide range of the discharge voltages. And we did not observe transition from a so-called "free" operation mode of the discharge, wherein the cathode thermal emissivity ability is governed in the main by a filament current, to the "forced" mode or to the mode with a self heated cathode wherein the electron emission of the cathode is determined substan-

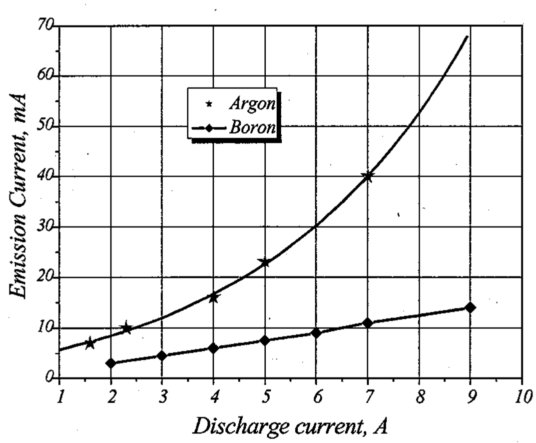

Fig. 4. Ion emission current versus discharge current for the Argon and BF_3 feeding.

tially by the power brought by ion bombardment. In the "forced" mode the discharge current rises sharply. Unfortunately it turned out, that emissive effectiveness of this ion source is appreciably less than for Bernas-Calutron ion source. The emission ion currents depending on the discharge currents measured for Argon and BF_3 are given in Fig. 4. For BF_3 the effec-

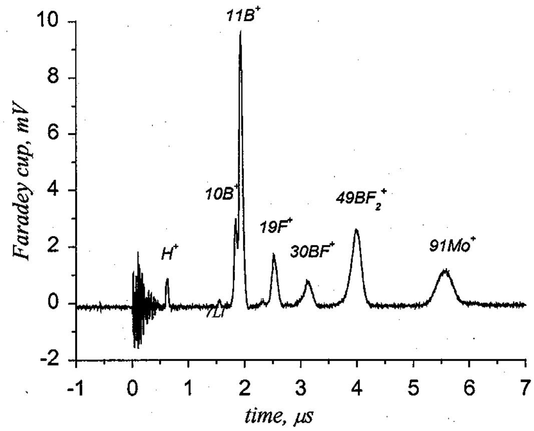

Fig. 5. Spectral distribution of the ion beam emitted from the duoPIGatron ion source.

tiveness is much lower than for Argon. The ion source effectiveness becomes enough high at discharge currents over 6 Amperes and for an Argon feeding only. Except for that the effectiveness depends on gas feed in discharge in the strong degree. It peaks at the rate of a leak about 3 sccm and further is reduced. As it was found out in an aftereffect as a result of the ion bombardment the anticathode diameter has increased, that has brought to short circuit between anticathode and anode. In result of this the discharge has operated without electron oscillation. Fig. 5 shows the spectral distribution of the ion beam for this case. The main characteristics of the discharge and experimentally obtained components the ion beam are cited in Table 1. The analysis of the spectral distribution shows, that ions of hydrogen and molybdenum have appeared in the ion beam. And if the source of molybdenum ions is quite clear, that the origin of hydrogen ions are unknown, through the hydrogen ions can appear or not appear in the same experimental requirements.

Above we mentioned one possible reason of low emissive effectiveness of the ion source. The complete disassembly of the ion source has shown that the discharge filament is displaced aside from the emission slot. In result the plasma density nearby to emission border has decreased, that has given rise to decrease of the ion emission current.

Conclusion

Experimental investigations of the designed duoPIGatron ion source have demonstrated as the positive, and the negative characteristic features of a source assembly.

Positive characteristics of the ion source are the long life time of the cathode filament, the great values of the discharge current (up to 10 A), and ability of the ion source assembly to take a significant thermal load without an appreciable change of geometry of the discharge system. Dissipated power at electrodes of PIGing discharge system has reached 1 кW and more, that has considerably exceeded the dissipated power in a discharge of the Bernas-Calutron ion source.

Negative feature of our duoPIGatron is low effectiveness. The reasons are stated above. The task of the further work will consist in updating the ion source design with the purpose of increase of a ratio of the ion emission current to the discharge current.

References

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