A NEW MODIFICATION OF PIG-TYPE H^- ION SOURCE FOR THE COMPACT CYCLOTRON.

D.I.Yartsev, V.E.Yarosh, A.Ya.Pisman
Russian Research Centre "Kurchatov Institute"
Moscow, 123182, Russia

Abstract

A directly heated cathode ion source has been developed to produced negative ions for use in the MPC-10 cyclotron. In operation with hydrogen, the ion beam current is 5.6mA, with energy 15kV and gas flow about 10cm^3/min, at the H^- ion beam current density equal to 92mA/cm^2. Using electrocondactive ceramics for cathode and reflector permits to increasing life-time of the ion source. The Mo converter is installed in the discharged chamber for increasing H^- ion yield. It's allows to vary the beam current in a wide range and to decrease a cyclotron gas load.

1.INTRODUCTION

In development of a small-size cyclotron intended for production of ultrashort-lived isotopes, wear problem studies and neutron radiography some specific requirements are imposed on the H^- ion source. At high ion beam current the ion source must be very compact, perform at small working gas flow, have a sufficiently long life-time, and not contaminate the accelerating system of the cyclotron.

2. H^- ION SOURCE WITH SELF-HEATED CATHODS

For a compact cyclotron MPC-10 the internal PIG-type negative ion source was design [1]. Tests this source with self-heated cathodes made of different materials was provide on the control bench and it was shown that a beam of accelerated H^- ions with current I = 1mA can be obtained at the following parameters:

arc voltage, V	200 - 250 V
arc current, I	1.5 - 2.5 A
extraction voltage, V	13 kV
gas flow (hydrogen), Q	10cm^3/min
magnetic field, B	0.6 T
extraction slit size, S	1*6 mm^2

Unfortunately, this ion source version had three main disadvantages besides the beam current which we desired to rise too:

- high discharge ignition voltage (higher than 2 kV) and, accordingly, frequent break-downs insulators,
- high gas flow,
- short life-time.

3.ION SOURCE WITH DIRECTLY HEATED CATHODE

To avoid the mentioned disadvantages a hot-cathode ion source version with a directly heated cathode has been developed [2].

The cathode of this ion source was made of electro-conductive ceramics having cathode sputtering coefficient essentially low (by an order of magnitude) than those of tantalum and tungsten commonly used as cathode materials. In particular, use of zirconium carbide to manufacturring of the directly heated cathode and reflector permitted the ion source life time to be increased by several times and the ignition voltage reduced to 150 - 200 V.

The cathode heating current usually was equal to 80-100 A (for initial heating of masive cathodes with cross sections of 25 - 30 mm^2 a current as high as 150 A is required).

At the parameters which was mentioned above and hydrogen gas flow was equal to 8 cm^3/min the negative ion beam current equal to 1.3 mA can be obtained. An increasing of the ion beam current was related obviously with more precise tune performance of the ion source in optimum mode.

4.ION SOURCE WITH CONVERTOR

In order to increase the H^- ion beam current molybdenum noncooled converter is installed on the rear wall of the discharge chamber used as the anod. The convertor was set in the middle (by height) part of the discharge chamber near opposite the extraction slit. No impurities, including alkaline metals, were introduced into the discharge. The discharge-faced surface of the convertor had a cylindrical shape with radius equal to that of the inner part of the discharge chamber. It should be pointed out that the hydrogen could be delivered directly to the extraction slit space. The converter was electrically isolated from the discharge chamber and one had a separated electrical terminal. An independent controlled potential of any polarity can be applied to it from an independent power source. The other terminal of this power source was connected with the discharge chamber (anode). The sheme of the source power supply is shown in Fig.1.

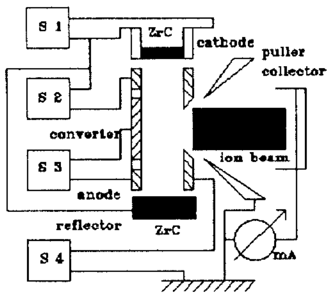

Figure 1. Experimental arrangement for the modified negative ion source.

The ion source with the converter produced the H^- ion beam current of 3.4 mA. The mode of the ion source performance was determined by the following parameters:

arc current, I	3 A
arc voltage, U	190 V
gas flow, Q	7.5 cm^3/min
extraction voltage, V	13 kV
magnetic field, B	0.6 T

Increasing of the negative converter potential relatively the discharge chamber from 0 to 50 V permits the beam current to be increased, approximately, by two times. Application of the positive potential leads to suppression of the negative ion yield from the source. The ion beam current dependence on the converter potential is shown in Fig. 2.

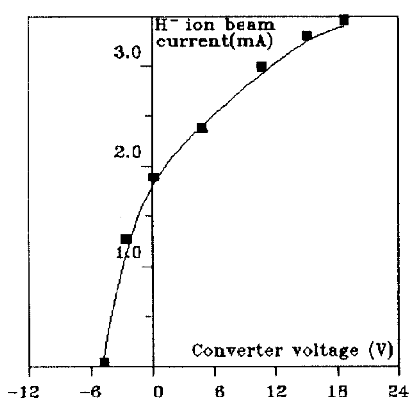

Figure 2. H^- beam current as function of converter potential for constant magnetic field B=0.65T at the discharge power of 210V, 3.5A, gas flow 8 cm^3/min and extraction DC voltage $U_{ext.}$= 13 kV

The density of the H^- ion beam current reached 92 mA/cm^2 , which exceeds by more than twice the data of [3] for these gas flows. Dependences of the H^- ion beam current on the gas flow delivered to the ion source and the extraction voltage are presented in Fig. 3 and 4.

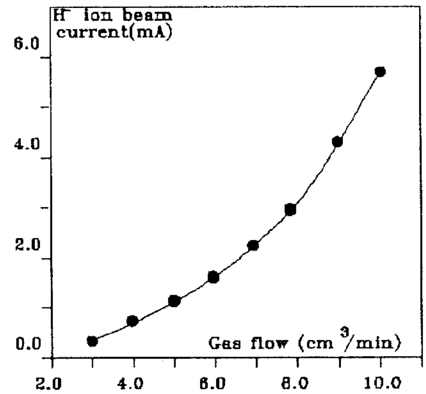

Figure 3. Relation between the extracted H^- ion beam current and the gas flow rate for constant magnetic field B = 0.65 T at the discharge power of 210V, 3.5A, converter potential $U_{conv.}$=20V and extraction DC voltage $U_{ext.}$= 13 kV

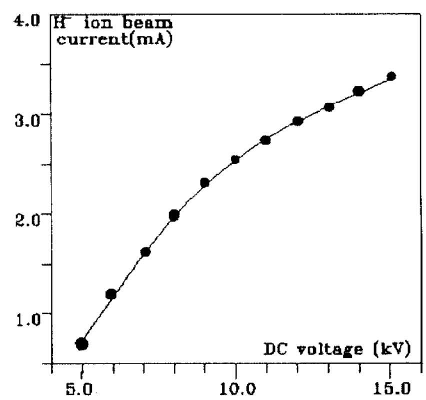

Figure 4. H^- ion beam current as function of extraction DC voltage for constant magnetic field B=0.65T at the discharge power of 210V,3.5A, converter potential $U_{conv.}$= 20V and gas flow Q=8cm^3/min

These dependences are relate to the data of [4].

At present efforts are being made to identify the mechanism of the H^- ion formation in order to determine whether the ions are produced on the converter surface or within the plasma colomb.

5.CONCLUSION

When the negative ions are produced on the converter surface, then material of this surface, it's optimal temperature and geometry must be carefully chosen and, possibly, the place of the hydrogen delivery to the discharge chamber changed. When the negative ions are produced inside the plasma volume then the effect of the converter can be twin:

a) a drift motion of charged plasma particles arisen due to the negative potential applied to the converter enables the H^- ions produced in the plasma column and in the discharge periphery to be carried to the extraction slit area thus increasing the beam current;

b) a drift of charged plasma particles (of both charges) arising in the negative potential of the converter relative to the anode may lead to carrying of vibrationally-excited hydrogen molecules and slow electrons to the extraction slit region where the hydrogen is delivered. Probably the optimal conditions for H^- production create in this space from one these ions are extraction. In this case the material of the converter surface and it's temperature will not affect appreciably on the negative ion beam current. But the choice of the optimal geometry and potential of the converter will become very important.

6. REFERENCES

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