Beam Current Increase and Cathode Lifetime Improvement of KOTRON-13 Ion Source

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1. Introduction

Technology of cyclotron has been actively developed to meet the increasing requirement output of medical radioactive isotopes for PET.

KOTRON-13 is produced with low negative hydrogen ion beam current owing to the low efficiency of proton beam current compared with foreign cyclotron. In the defect there from, the lifetime of cathode is around 5,000min, which requires frequent maintenance period, and the target beam current is maximum 50uA at a poor efficiency compared with the inflow quantity of hydrogen gas and that of inflicting arc current.

Considering above affairs, we have to improve the PIG ion source extraction efficiency of KOTRON-13 in order to lift beam current.

Mostly the ion source of cyclotron less than 30Mev comes from the use of PIG ion source mainly with the method of cold cathode or hot cathode [1].

However, the cyclotron of 30Mev grade of EBCO or IBA uses the external ion source and uses ion source with cusp type of good withdrawal efficiency.

This type requires high voltage, and transports ion from ion source to cyclotron, which requires precise transportation equipment. And entering cyclotron requires a high quality of inflictor with a high defect rate, but high current cyclotron has no choice but to use ion source of such a method. But the cyclotron using PET with the beam current less than 100uA uses PIG ion source of KOTRON-13 with a reasonable maintenance cost [2].

2. NEW DESIGN OF KOTRON-13 ION SOURCE

In the negative hydrogen ion beam extraction condition of KOTRON-13, center magnet field is 1.3T, extraction radio frequency 77.3MHz, the voltage licensed in Dee center DC 45kV.

And hydrogen gas injection into the ion source is 1~6sccm, arc power voltage -2.5kV, and arc current can be injected up to 0.1~3A with a variable state [3].

In the PIG ion source inside of KOTRON-13, the tube to transmit ARC current with cathode is designed to do ionization water cooling simultaneously, and enlarged cooling efficiency with the external diameter 6.35mm [4]. And it isolated all the remaining part saving cathode to isolate Anode and cathode.

We designed the structure of new single tail rather than the structure of original double tail to increase the efficiency of plasma.

To increase the efficiency between cathode and anode, we reduced the depth of tail from 2mm to 0.5mm, and fixed the length between the cathodes to 3.3mm.

We changed and designed the plasma hole of anode by increasing its size by 3.0mm~9.0mm for low hydrogen gas and low arc current to generate a high density of plasma.

We also designed anode by changing inside diameter 6.4mm~9.0mm for the generation of enough electron density and high plasma. And we designed the slit size to be 0.6mm*4mm in negative hydrogen ion beam extraction considering Dee gap and extraction spread angle, optimizing 0.15mm thickness of slit, 0.65mm of expansion gap.

And in the design we optimized the position of hydrogen gas injected in the PIG ion source of KOTRON-13.

Fig.1 shows the structure of the original PIG ion source of KOTRON-13 is left figure and right figure is the structure of the new PIG ion source of KOTRON-13.

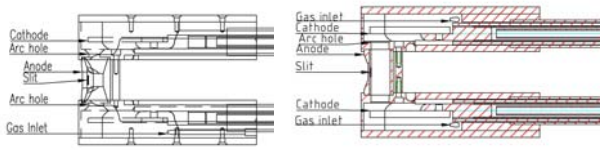

Fig.1. Negative hydrogen PIG(Panning Ion Gauge) ion source of KOTRON-13 and New ion source of KOTRON-13

3. EXPERIMENTAL RESULTS

It could be known that in the result of the change of arc hole to decide the size generating and creating plasma, the bigger the size of arc hole gets in the inflict condition of RF power (1~20KW), hydrogen gas (1~6Sccm), arc voltage(-2.5kV) and arc current (0.1~3A), the longer the extraction quantity of beam current becomes. And the method to inflect hydrogen gas in the upper and lower parts drew more beam current than the method to inflect it in the lower part, and that the method to inflect hydrogen gas only in the upper part drew more beam current than the method to inflect it in the upper and lower parts.

Fig.2 shows the maximum drawing beam current as to the change of arc hole size and that of anode internal diameter according to lower and both, upper hydrogen gas injection.

There occurred the change in extraction beam current according to the change of the inside size of Anode where plasma generated. The result showed that it

increased in proportion to identity as the rise of extraction requirements.

This time it was shown that the extraction beam current increased as the inside diameter increased but the extraction max beam current increased no more when the inside diameter of Anode increased in a certain extent.

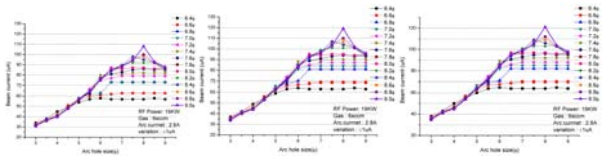

Fig.2. Maximum drawing beam current (at Dummy target) as to the change of arc hole size and that of anode internal diameter according to lower and both, upper hydrogen gas injection

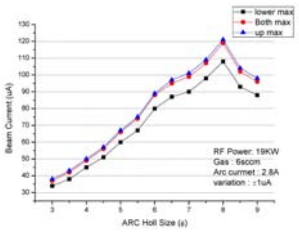

Fig.3. The maximum drawing beam current (at dummy target) in the input of reference conditions as to the change of arc hole size and anode internal diameter according to hydrogen gas injection.

When adjusted the interval between cathode and anode from existing 3.3mm to 3.3±2mm, it didn't show a big difference just with 5uA±1uA.

As the ion source structure of KORTRON-13 is a symmetric structure in the upper and lower position, we gave some influence in extraction beam current against the hydrogen gas injection position of inside.

As a result, it was shown that beam current increased in injecting hydrogen gas both in upper part and lower part rather than in injecting it and extracting beam only in lower part, and beam current also increased when injecting hydrogen gas only in upper part rather than when injecting it both in upper part and lower part simultaneously.

Fig.3 shows the maximum drawing beam current as to the change of arc hole size and anode internal diameter according to hydrogen gas injection.

And we added the change of the thickness of cathode by 2mm and 3mm in the lifetime of cathode according to hydrogen gas injection position.

In each ion source, the lifetime of cathode was measured up to the state where cathode could not be used ant more after using it by mounting the real product. That is, it is the sum with the unit of min of the time used up to the time when the hole occurs in the thickness of cathode in the state where the maximum beam current is not generated.

It could be known in the result of experiment that the lifetime of cathode in new ion source increased 5.1 times in case of 2mm thickness of cathode rather than original ion source, and 6.25 times in case of 3mm of thickness.

Fig.4 shows the cathode lifetime according to hydrogen gas injection position.

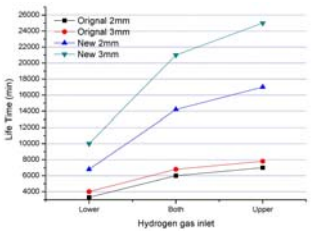

Fig.4. Cathode lifetime according to hydrogen gas injection position

4. CONCLUSION

As the result of the design and test of ion source by changing various parameters, the maximum extracted beam current of 120uA which is 3 times of original value is achieved in the acceleration part of the existing KOTRON-13.

And the amount of ^{18}F production can be increased up to 5,500mCi after the improvement, while that of the original cyclotron is less than 2,000mCi.

In addition, the efficiency of the ion source of KOTRON-13 is increased with the injection direction of hydrogen gas with upper part method rather than lower part method.

The lifetime of cathode is lengthened to 8 times over the existing cathode by increasing the efficiency of the thickness.

In the PIG ion source of existing KOTRON-13, the degree of a vacuum gets lower owing to the influence of the gas occurring in time of hydrogen and Arcing.

More research to extract the beam current of high efficiency in lower RF power, lower hydrogen gas and lower arc current is required in the future.

5. ACKNOWLEDGMENTS

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