ARC CHARACTERISTICS OF THE SELF HEATED PIG ION SOURCE

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Summary

In order to find out the better condition for the production of the higher charge state of ions, the arc characteristics of the self heated PIG ion source are investigated. The arc voltage, current and sputtering yield are measured for cathodes made of tungsten, tantulum, niobium and molybdenum alloys (TZM). Of these materials, tungsten cathode can be operated in the highest arc voltage. The two types of cathode holder, that is, fixed and loosely fixed ones are compared in its impedance of the arc. The fixed type shows the higher impedance than the case of the loosely fixed one.

Introduction

It passed about 30 years since the PIG ion source was used in the regions of fundamental researches or industrial usage. In spite of the great success of ECR ion source to produce the highly charged ions, there have been continued many improvements on the PIG ion sources. The advantages of the PIG ion source are its simple structure and its low cost to produce the highly ionized ions for light heavy elements.

In this report, we introduce the fundamental study to find out the better characteristics of the PIG source with the several materials of the cathode. The special attention is paid to the arc voltage which depends not only on the material but also on the structure to fix the cathode to its holder. As stated in another paper[1], the performance on the heavy ions of the RCNP cyclotron, has been near the limit obtained with the PIG ion source. The recent problems which confront us are to produce 8^+ ions of argon and calcium, and 9^+ or 10^+ ions of kripton at a high production yield. These characteristics investigated in this study will make a good result in these problems.

Apparatus

Structure of the heavy ion source

The comparison of the arc characteristics has been studied with the two types of cathode as shown in Fig. 1.

The first is the type of the heat insulated cathode and its lower tuntalum cathode is located on the small tungsten stage which is indirectly cooled with the cupper body of the cathode holder. The upper tuntalum cathode is hang from the small tungsten holder connected to the cooling pipe. The loose contacts between the cathodes and their holders help the cathodes at higher temperature than the case of the fixed connection. The second is the type of the well cooled cathode and its lower cathode is fixed to the holder with cupper rings and screws. The upper tuntalum cathode is also fixed to the cooling pipe with screws through its cupper holder.

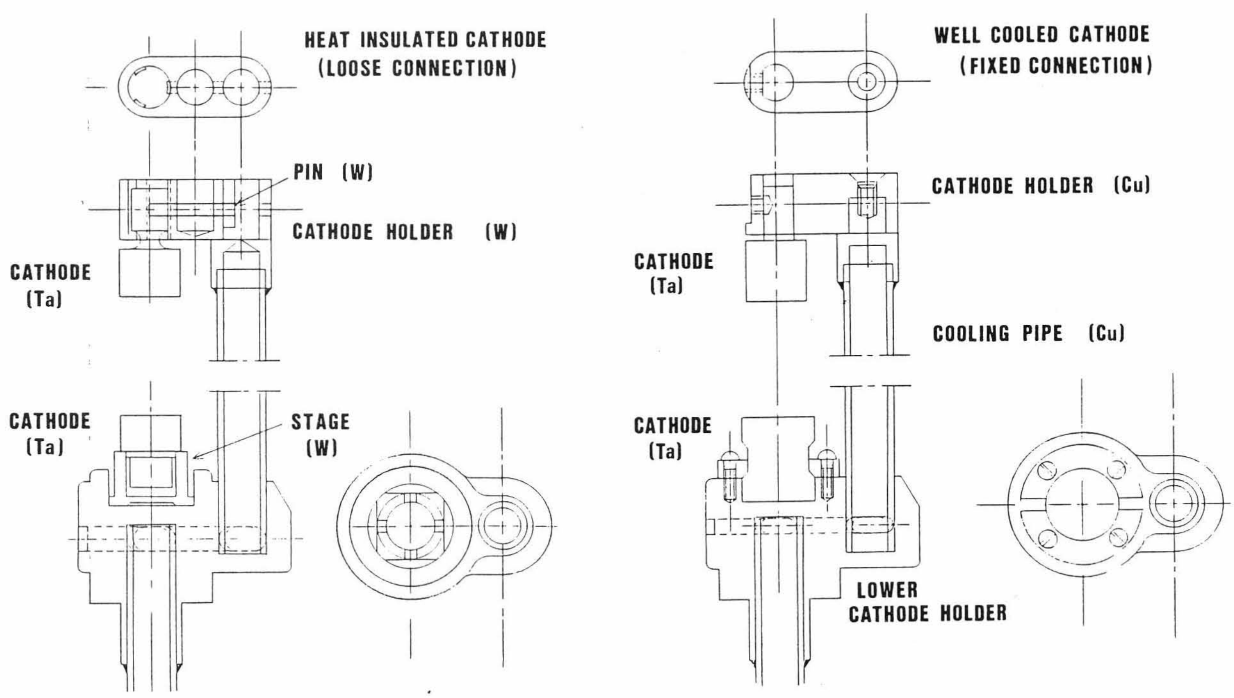

Fig. 1. Sectional view of two types of cathode.

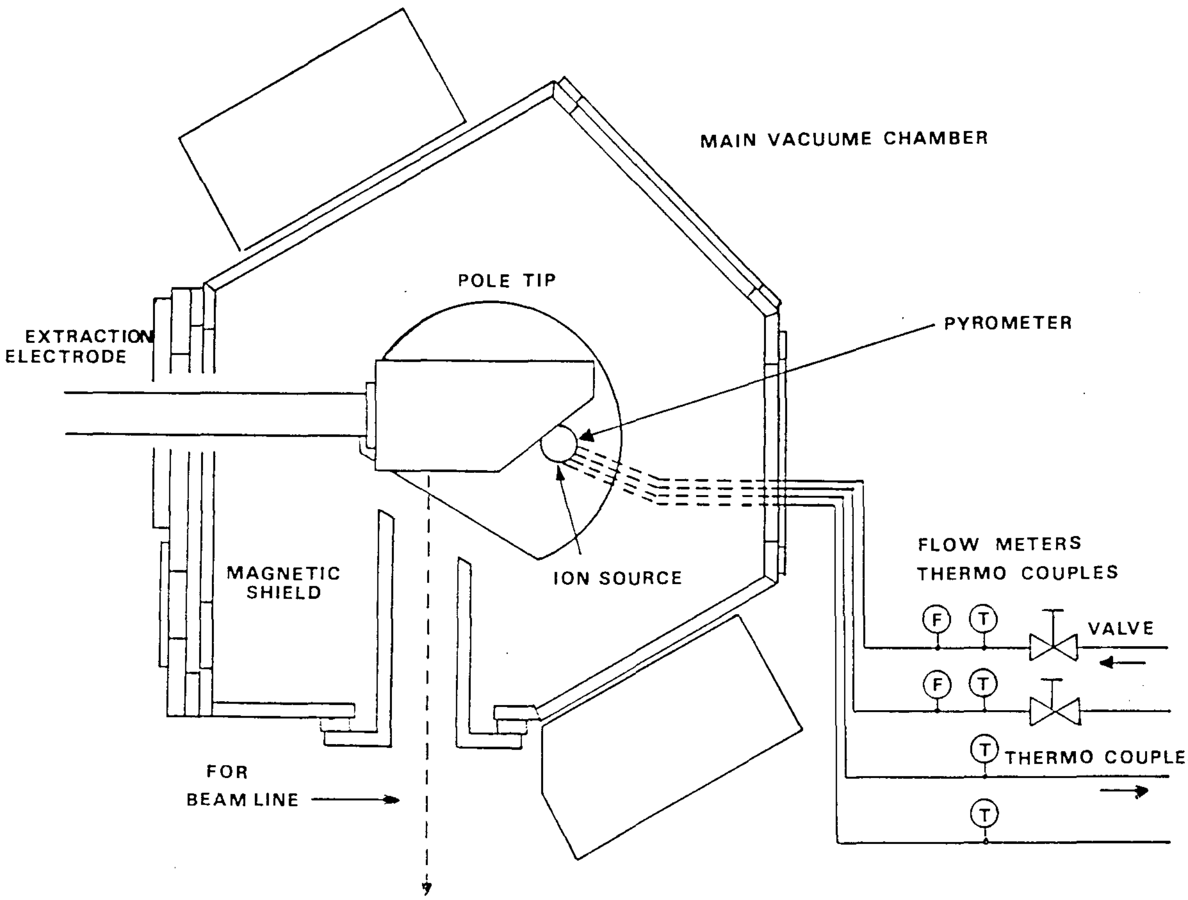

Fig. 2. Test bench.

Test bench

A simple H-shaped magnet and vacuum chamber is constructed. The pole gap of this magnet is determined as the ion source used in the RCNP cyclotron could be installed vertically. Thus, its height and diameter are 200mm and 400 mmϕ respectively. The magnet excitation is supplied by the stabilized DC power supply (420A, 110V) which can sweep the field manually or automatically. The range of its field is between 3.5 KGauss and 8.0 KGauss. The vacuum chamber is evacuated by a turbo-molecular pump with a pumping speed of 3000ℓ/s and it is kept less than 10^{-5} Torr with gas flow of 1cc/min.

The ion source is set into the median plane of the magnet via vertical stem of 60mmϕ. This magnet plays roles both for the magnetic field to held the plasma and for the analysis of charge to mass ratio of produced ions.

The arc power is fed from the same arc power supply used at the routine operation. The maximum arc current is 30A at 30% duty. It is regulated with series tube (4CW 50000E). The flow rates both of anode and cathode cooling water can be controlled with manual valves and their temperature at inlets and outlets are measured respectively.

The temperature of the upper cathode can be observed with a pyrometer from the outside of the vacuum chamber. The layout of these is shown in Fig. 2.

Arc Characteristics

Increase of the cooling water temperature for the arc power

The temperature increase between the inlet and the outlet of the cooling water for cathode and anode has been measured. For two types of cathode they are almost independent of their arc power as shown in Fig. 3. It indicates that the plasma power mainly dissipates in the anode region even though the cathode heat-up partly irradiates the power to their surrounding. Special feature observed in this measurement is the large difference of the temperature increase for two types of cathode. At the 2KW input, about 8 degree in difference is observed at a flow rate of 1.0ℓ/min. It shows experimentally the effectiveness of heat insulated cathode and it may expect the higher cathode temperature than the other type.

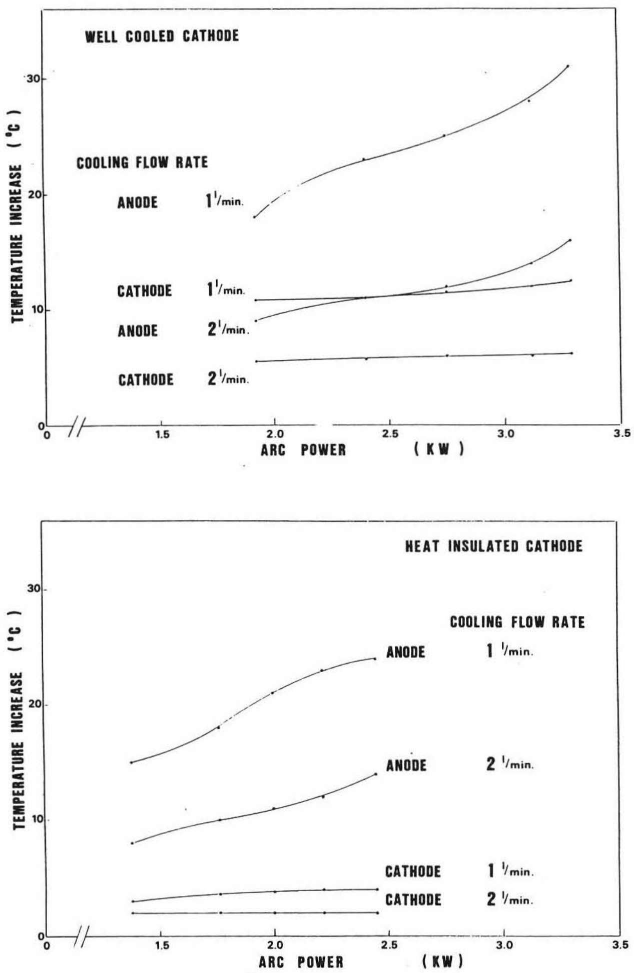

Fig. 3. Temperature increase with arc power for two types of cathode.

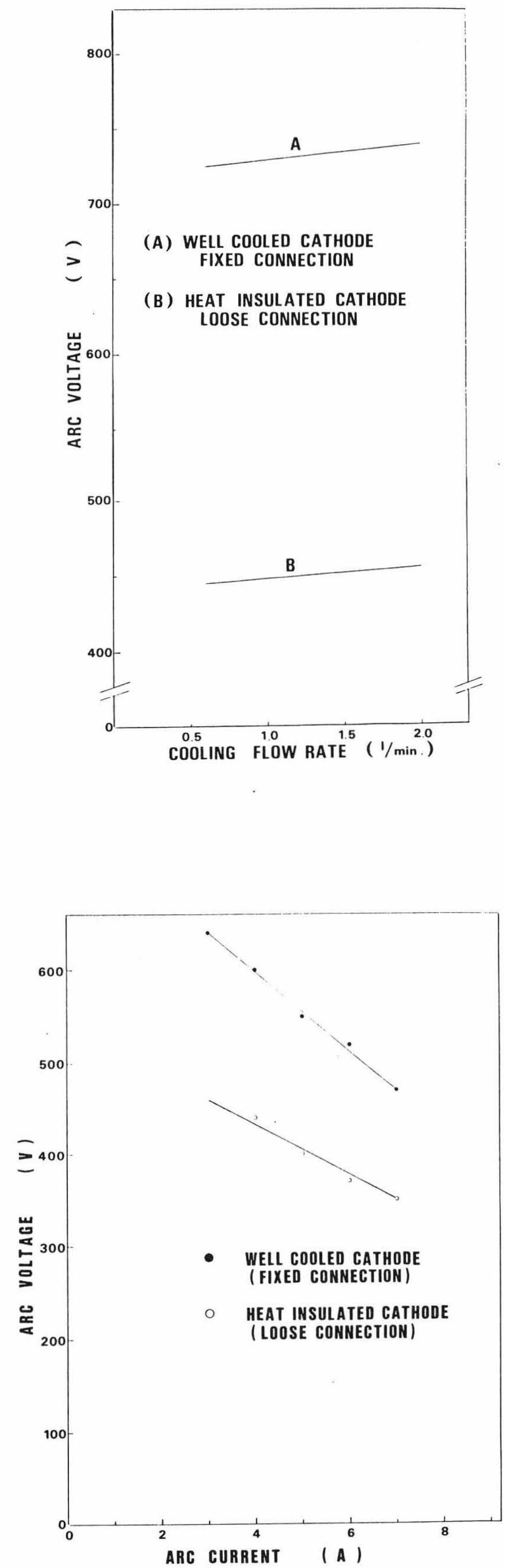

Fig. 4. The arc voltage for the rate of cooling water and for the arc current.

Arc voltage

The arc voltage and the current for two types of cathode are measured with varing the flow rate of cathode cooling as shown in Fig. 4. The arc voltage in the case of the cathode at fixed connection becomes higher than the case at loose connection. These dependences are taken at the two flow rates of cooling water and its reproducibility is fairly good. With more attention to these experiments, we can observe the slight signs for the voltage increase by the change of the flow rate from 0.6ℓ/min to 2.0ℓ/min. It may suggest that much flow rate results in higher arc voltage than ever. Another manifest feature is the higher impedance of the fixed type cathode than the loose type by about 50%. Due to these results, this type of cathode is relatively suitable to produce highly stripped ions.[2]

Cathode materials

The arc voltage dependence on its cathode material in loose connection is measured. As shown in Fig. 5 several materials for cathode, that is, tungsten, tantulum, niobium, and molybdenum are tested with nitrogen gas flow rates form 0.5cc/min to 2.0cc/min. Of these materials, the cathode of tungsten has the highest arc

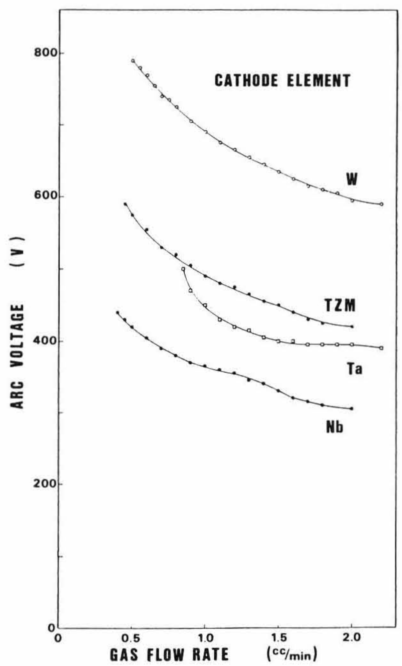

Fig. 5. The arc voltage for the cathode materials.

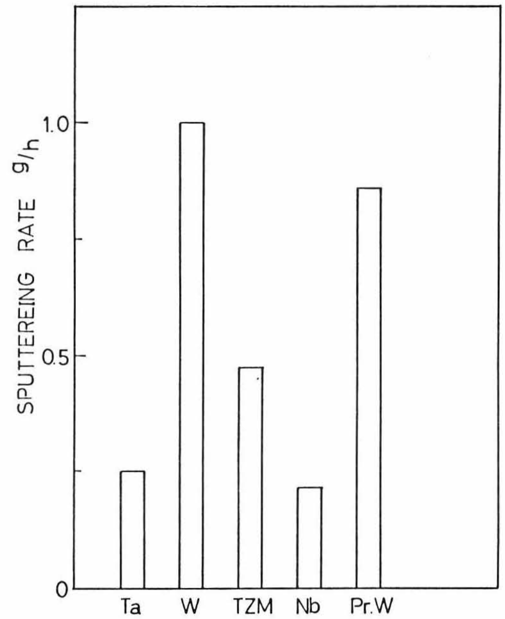

Fig. 6. The sputtering rate for the cathode materials.

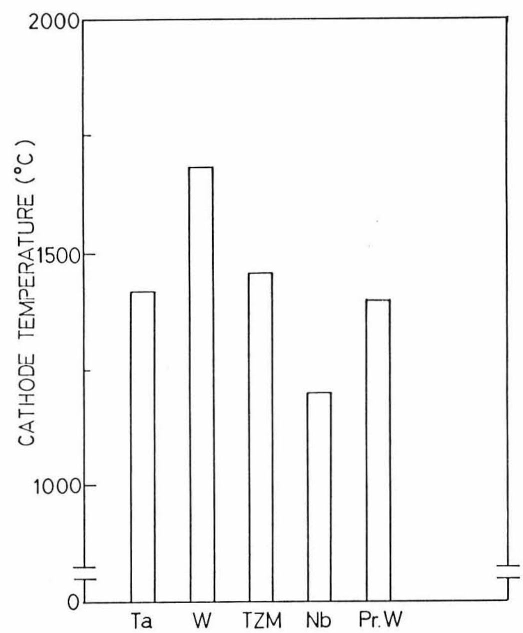

Fig. 7. The cathode temperature for the cathode materials.

voltage at these gas flow rate. Simultaneously, the sputtering rate and the temperature of the cathode with these materials are measured as shown in Fig. 6 and Fig. 7. For example, in the case of tungsten cathode that temperature is 1680°C at the arc power of 4A and 550V, while in the case of niobium that is 1200°C at the arc power of 4A and 360V. In addition, to make a new type of cathode, the porous tungsten for the lower cathode material is tested and it shows nearly the same arc characteristics as tuntalum.

Conclusion

Refering these experimental results for the cathode materials and its structure, the most suitable cathode can be designed to produce the highly charged ions and development with these has been continued in the RCNP cyclotron.

References

1. T. Itahashi et al., RCNP Annual Report (1985) p.175.
2. H. Ogawa, T. Yamada, Y. Kumamoto, Y. Sato and T. Hiramoto, IEEE Trans. on Nucl. Sci. NS-26 1988 (1979).