THE PROTOTYPE OF RADIOACTIVE ION SOURCE

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Abstract

The design and experimental results of the RIB source prototype are presented. A source will have the container of ^{235}U compounds heated up to 2200-2500^{0}C. Vapors of uranium fission obtained when the ion source is irradiated by the high energy neutron flux, are then ionized and extracted from the source. In the experiments with the prototype loaded by ^{12}C the source working temperature 2700^{0}C was reached, the carbon ion current 10 nA was obtained. The total operation time of more than 100 hours with no performance degradation was demonstrated.

1 INTRODUCTION

The radioactive ion source (RIS) which is under development for SPES project [1] will consist of the container made of heat-resistant material (Ta, W), filled by disks made of ^{235}U compounds 1 mm in thickness. The container heated up to the temperature 2500^0 C is irradiated by the neutron flux 10^{10} sec^{-1}·cm^{-2}. When neutrons interact with ^{235}U, the radioactive ions of various masses are produced. Ions being diffused towards the disk surface are evaporated into the container's free vacuum space.

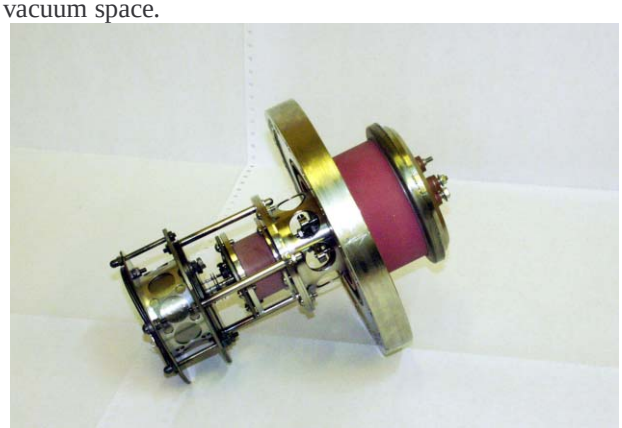

Figure. 1: *Picture of ion source prototype (side view)*

The produced vapor which contains radioactive ions gets thermally ionized on the internal walls of a container. The flux of a mix of atoms and ions of radioactive elements is directed to the accelerating space via the container's emission hole, where then accelerated up to 20 keV/u.

To verify the possibility of RIS production the prototype (Fig.1,2) with graphite as the working agent was developed and tested. During the experiments on a prototype the reliability of the selected design was confirmed, the evaluation of power consumption required to maintain a given temperature inside the prototype was done as well as the study of vacuum conditions required.

Figure. **2:** *Picture of ion source prototype (rear view)*

2 PROTOTYPE DESCRIPTION

The prototype of RIS consists of tantalum container (7, see Fig.3) 20 mm in diameter and 30 mm in length, which is positioned on the tungsten holder 4mm in diameter. Graphite is placed inside the container. The container is surrounded by 5 thermal screens (5) made of sheet tantalum 0.1 mm in thickness. To reduce the thermal flux from the high temperature volume, additional thermal screens are set on the technological apertures (10). One of the container wall has the emission hole 0.5 mm in diameter.

Between the external cylindrical surface of the container and the internal cylindrical surface of the thermal screen, the cathode (3) is placed.

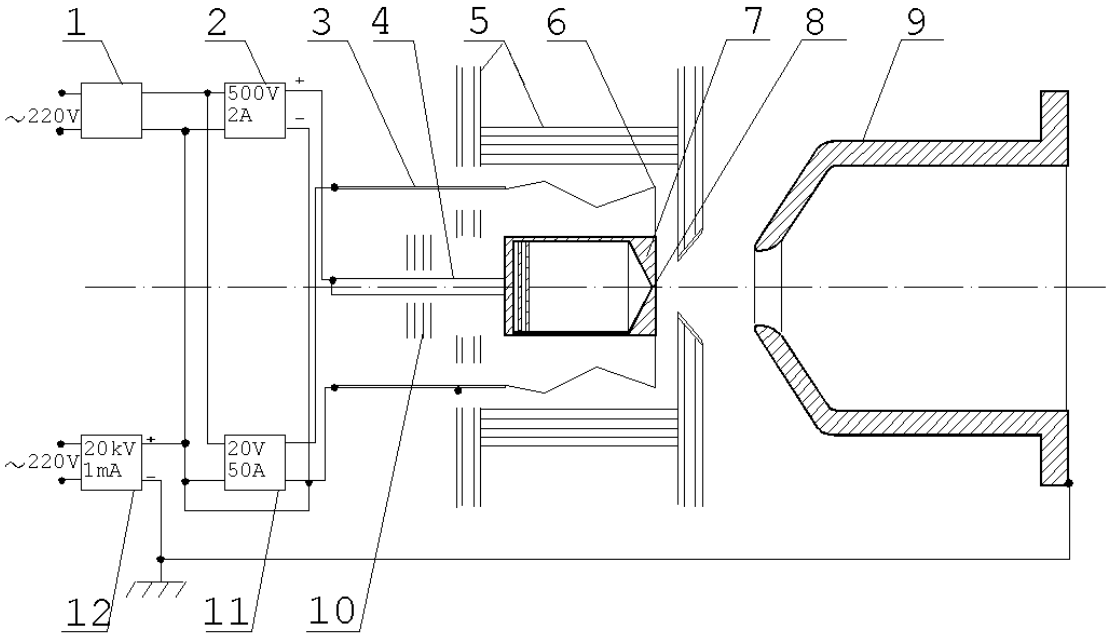

Figure 3: *Ion source prototype schematic view. 1 - isolation transformer; 2 - direct current supply; 3 - cathode holder; 4 - container holder; 5 - thermal screens; 6 - cathode; 7 - container with graphite; 8 - emission hole; 9 - anode; 10 - additional thermal screen; 11 - cathode heater; 12 - accelerating voltage source.*

It is made of tungsten 1 mm in diameter and 280 mm in length. To provide the cathode stability at high temperature, the cathode holders are performed as three parallel tungsten rods, each 1 mm in diameter. One of it acts as the extension of the cathode wire, and all of them are joined by the tungsten bands performed as 0.25 mm wire. It reduces the operational temperature and increases the hardness of cathode holders. For cathode heating up to the electron emission temperature, the power supply of 700 - 800 W is used. The container is electrically insulated from a thermal screen and could be shifted up to 500 V. While heating the thermal screen internal surfaces, they also emit electrons to the container. Upon the achievement of the container's steady-state temperature 2500^0 C, the total power consumption in the source reaches 1750 W. The external surface of the thermal screen is around 125 cm^2, so ensures the heat flux around 140 W/cm^2.

The anode (9) is positioned at a distance of 10 mm from a thermal screen coaxial with the emission hole. The voltage between the anode and the source is 20 kV. The prototype of the RIS is mounted on the metal flange welded with the butt-end of the ceramic vacuum pipe, and placed into the cooling vacuum chamber under a pressure around 10^{-5} Torr. The body of a RIS prototype has a potential of +20 kV relative to the ground, so the isolation transformer is used for power supply.

3 EXPERIMENTS WITH PROTOTYPE

When the prototype was tested, the working agent inside the container was graphite due to appropriate level of its vapor pressure at the required temperature (~ 2500^0 C). The container temperature around the emission hole was measured by the pirometer, taking into account the thermal radiation ratio for tantalum ε_{Ta}= 0.29. Temperature measured by pirometer was $T_p=2050^0$ K, and temperature of the container was calculated as:

$$T_c = \frac{T_p}{\sqrt[4]{\varepsilon_{Ta}}} = 2820^0 K$$

This temperature measurement was confirmed by the carbon vapor pressure in the jet that flew out from the emission hole. In three hours at temperature 2050^0 K the carbon layer 0.05 mm in thickness was formed on the anode surface. It defined the pressure value in the carbon vapor jet ~ $5 \cdot 10^{-2}$ Torr, and graphite temperature at this vapor pressure was 2800^0 K.

The obtained ion current was then studied in the magnetic spectrometer. Fig.4 shows the dependence of the ion current on the atomic mass and the power fed the container. The prototype stood around 100 hours with no performance degradation, then electric break-downs were detected on the ceramic insulators. After insulators were cleaned, break-downs were stopped.

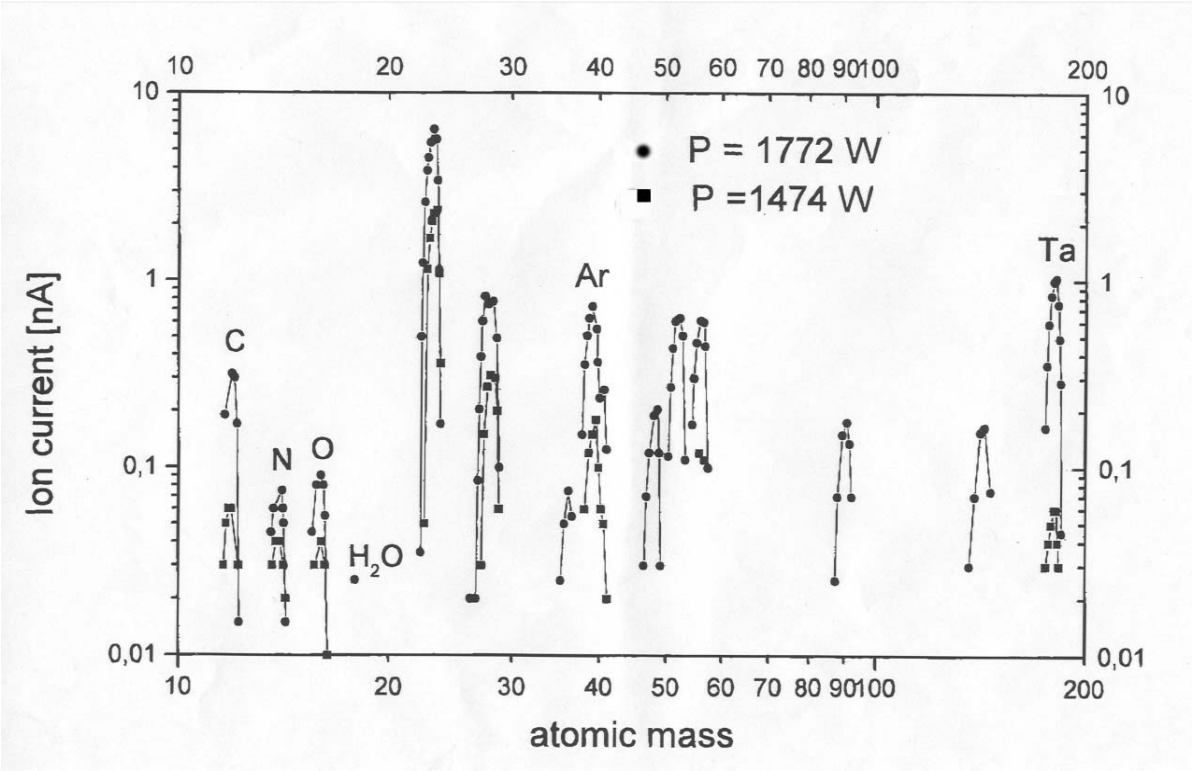

Figure 4: *Ion current vs. atomic mass for various container's power supplies.*

4 CONCLUSION

To increase the prototype lifetime without break-down, the vacuum condition improvement is required, and protection screens should be set before ceramic surfaces to reduce the spraying.

The prototype of ion source with vacuum chamber was manufactured at BINP, Novosibirsk, and then tested in LNL INFN, Legnaro. During the upcoming series of experiments it is planned to test the prototype with uranium carbide as the operational substance.

REFERENCES

[1] LNL-INFN (REP) 145/99, June 1999.