Production of ions of metals with an ECR ion sources at FLNR (JINR) cyclotrons.

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Two ECR ion sources: DECRIS-14-2 and ECR4M are presently in permanent operation at the FLNR cyclotrons U400M and U400, correspondingly.

During last two years the major effort were made in production of high current stable ion beams of solids with the relatively low melting point in the mass range from Li to Bi. Both the evaporator and MIVOC methods were used.

Among the solids such an exotic beam as ^{48}Ca was produced at the U400 cyclotron with high efficiency.

Introduction.

Many of the elements required for acceleration at the FLNR cyclotrons are available in the solid state. The method of solid materials feed into an ECR ion sources strongly depend on the specific properties of materials.

According to FLNR scientific program the key ions required for acceleration at the cyclotrons were $^{7}Li^{2+}$ at the U-400M cyclotron for generation of ^{6}He secondary beam and $^{48}Ca^{5+}$ at the U400 cyclotron for experiments on synthesis of new super heavy nuclei.

At the last ECR Workshop we have reported on the new method of production of ions of solids with relatively low melting point [1]. This paper presents the results obtained with this methods at the cyclotrons.

I. The evaporator method.

The above mentioned method consists of the use of microoven with the maximal temperature of 900 °C and thin cylindrical Ta sheet placed inside the discharge chamber to prevent the condensation of metal at the chamber wall. For the first time this method was successfully used for production of Li ions at the U400M cyclotron.

One of the Li ion spectrum is shown in Fig.1. The material consumption (metallic Li) measured at 100 eμA current of Li^{2+} during 5 hours constitutes about 2 mg/h, in long term (up to 2 months) operation with the injected current of Li^{2+} in the range of 50 – 70 eμA the material consumption was about 0,7 mg/h.

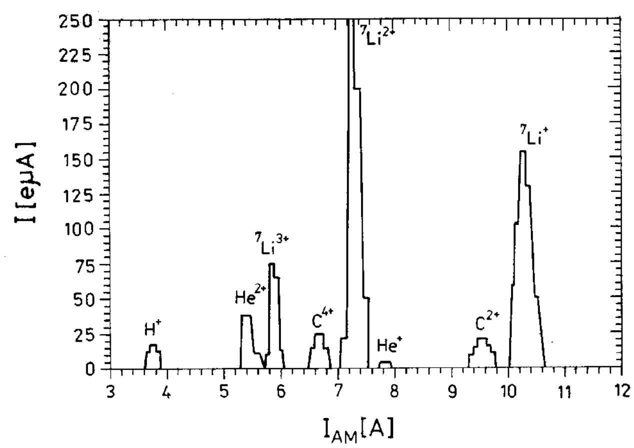

Fig.1 Li ion spectrum optimized for Li^{2+} production. He is used as a support gas.

The design of the microoven allows one to use the crucible with the length of 30 mm and useful volume of about 0,1 cm^3. Due to this fact the continuous time of the source operation was limited to about 40 –50 hours.

The same technique was used for production of $^{24}Mg^{3+}$ ions from the ECR4M ion source at the U400 cyclotron. The material consumption was about 2,5 mg/h and the continuous time of the source operation did not exceed 40 hours.

To increase the amount of the working substance the new crucible was designed (Fig.2), and the amount of Mg which was possible to load in the crucible was more than 1 g. In this case we have used the combined heating of the crucible – by the microoven and by plasma. Different gases – He, Ne and Kr were tested as a support gas. The best results from the point of view of stable operation were obtained with Kr. The spectrum of Mg ions is shown in Fig.3.

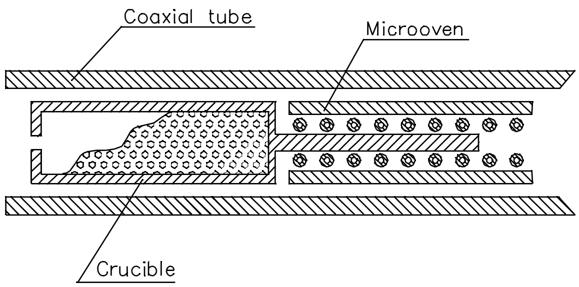

Fig.2 Schematic view of the large volume crucible for Mg ion production.

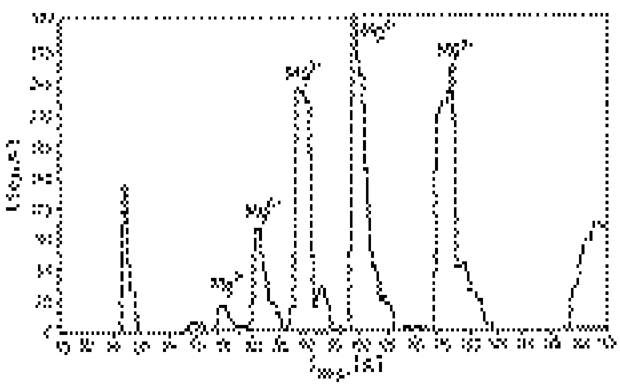

Fig.3 Mg ion spectrum. Kr is used as a support gas.

During 92 hours of operation 225,4 mg of Mg was consumed, giving the consumption of 2,45 mg/h.

At the U400 cyclotron the main efforts were made to produce a ^{48}Ca ion beam for experiments on synthesizing of new super heavy nuclei. Preliminary tests were performed with natural metallic Ca. About 200 eμA of $^{40}Ca^{6+}$ were produced.

For production of ^{48}Ca beam two methods were employed. According to the first one, reduction of calcium from calcium oxide was performed directly in the vacuum volume of the ECR source [2]. A mixture of CaO and Al with a weight ratio of 3:1,2 was loaded in the crucible and heated in the microoven. Up to 100 eμA of $^{48}Ca^{5+}$ were produced at a Ca consumption of about 0,6 mg/h. This method requires the temperature close to the thermal limit of the heater of the microoven and therefore the operation of the source was not reliable. Therefore, in the subsequent experiments the metallic ^{48}Ca was used which was reduced from calcium oxide in a separate vacuum volume with the use of the oven with higher temperature. The spectrum of ^{48}Ca ions is shown in Fig.4.

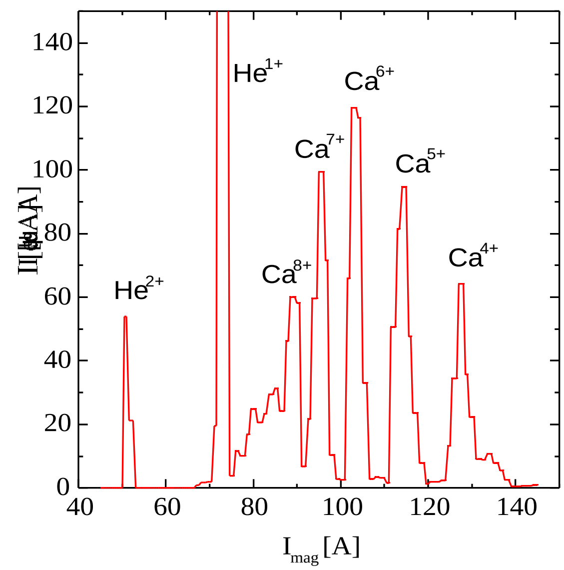

Fig.4. ^{48}Ca ion spectrum produced from the metallic calcium. He is used as a support gas.

In a long-term operation an average consumption of calcium was about 0,4 mg/h. The ratio between the physical target current and the quantity of calcium fed into the source (with a single gap buncher in the axial injection system) constitutes $1{,}7\times10^{-3}$. The detailed analysis of Ca ion balance in the source will be presented at the ICIS’99.

For the experiments in applied physics the beam of Bi^{19+} was produced from the ECR4M ion source and accelerated in the U400 cyclotron. The spectrum of Bi ions is shown in Fig.5. Production of Bi ions did not cause any troubles and the source operated very stable with He as the support gas. The material consumption constituted 0,36 mg/h.

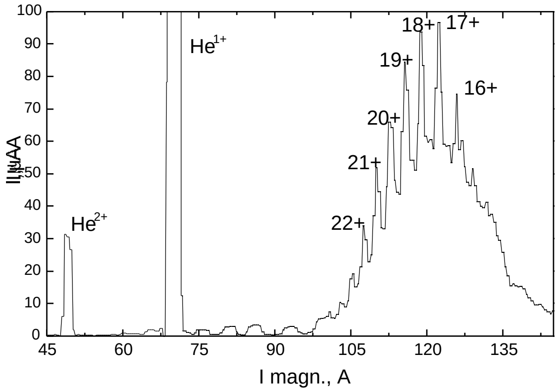

Fig.5. Bi ion spectrum. He is used as a support gas.

II. The MIVOC method.

For generation of secondary beam of ^{8}He at the U400M cyclotron the intense beam of $^{11}B^{3+}$ was required from the DECRIS-14-2 source.

For production of B ions the volatile compound $C_2B_{10}H_{12}$ which has the vapor pressure of about 1-2 Torr at the room temperature has been used. The compound was loaded into the glass volume and fed into the source through the standard piezoelectric valve. The ion source operated stable without addition of support gas.

The maximal current of $^{11}B^{3+}$ up to 200 eμA was produced. The spectrum of boron ions is shown in the Fig.5. The material consumption measured at 100 eμA current of $^{11}B^{3+}$ constitutes 2,2 – 2,8 mg/h.

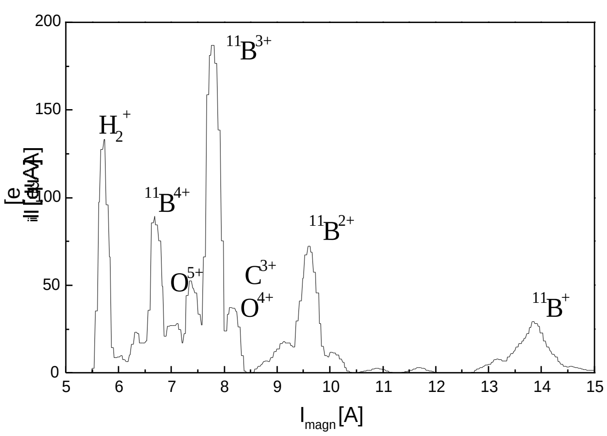

Fig.5 The spectrum of boron ions produced from $C_2B_{10}H_{12}$ compound.

Conclusion.

The use of the hot screen inside the discharge chamber allows one to produce the intense beams of medium charged ions of solids with relatively low melting point. The results obtained with this method at the cyclotrons are summarized in the Table.

To provide the recycling of the solid material condensed at the chamber wall the level of u.h.f. power more than 300 – 400 W is required. With this power level the charge state distribution is shifted to the higher charges from the desired charge state.. The preliminary tests with ^{48}Ca have shown that the use of Xe as a support gas instead of He leads to the shift of the charge state distribution to lower charges. This method requires further investigations and optimization of the source operating mode. The another possibility is the use of independently heated screen that will allow one to optimize the u.h.f. power and screen temperature independently.

Table.

Ion	Maximal current, eμA	Average material consumption, mg/h
Li^{2+}	290	0,7 - 2
Mg^{4+}	300	2,45
$^{48}Ca^{6+}$	120	0,4
Bi^{19+}	90	0,36

Acknowledgement.

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References.

1. Efremov A.A. et al. Proc. of the 13th Intern. Workshop on ECR ion sources. p.128
   Texas A&M University, 26-28 Febr. 1997, College Station, Texas, USA.
2. Lukyanov S.M. et al. GANIL A89-07.