NUKLEONIKA 2003;48(Supplement 2):S89–S92

PROCEEDINGS

Role of a biased electrode in the production of highly charged ions using the DECRIS 14-3 ion source

Marek Leporis,
Sergei L. Bogomolov,
Andrei A. Efremov,
Vladimir N. Loginov,
Vladimir E. Mironov

Abstract ECR ion sources are used for the production of highly charged ions in various accelerator facilities. In most of them biased electrodes are normally used to increase the ion yield. Physical processes in the plasma of an ion source are quite complicated and the role of a biased electrode is not clear. To investigate the effect of a biased electrode on the intensity of extracted highly charged ions, an axially movable electrode was placed into the plasma chamber of the DECRIS 14-3 ion source. It was found that the intensity of Ar ions depends on the position of the biased electrode and negative bias voltage. The optimal position of the biased electrode was found near the maximum of the magnetic field. Experiments with a pulsed biased electrode were also carried out. The influence of the negative pulse on the ion yield depends on the ion charge state.

Key words ECR ion source • plasma • biased electrode

M. Leporis✉
Flerov Laboratory of Nuclear Reaction,
Joint Institute for Nuclear Research,
Dubna, Moscow region, 141980, Russia,
Tel.: +7/ 096 21 62992, Fax: +7/ 09621 650 83,
e-mail: leporis@nrsun.jinr.ru
and FEI STU,
3 Ilkovicova Str., Bratislava, Slovakia

S. L. Bogomolov, A. A. Efremov, V. N. Loginov
Flerov Laboratory of Nuclear Reaction,
Joint Institute for Nuclear Research,
Dubna, Moscow region, 141980, Russia

V. E. Mironov
Laboratory of Particle Physics,
Joint Institute for Nuclear Research,
Dubna, Moscow region, 141980, Russia

Received: 8 November 2002, Accepted: 10 February 2003

Introduction

An appreciably fast development of the ECR type ion sources has been observed within the past decade. In many research centers, ECR ion sources have been widely used as reliable sources of intense beams of middle- and highly-charged ions. However, some of the physical phenomena and their mechanisms are not completely understood. For example, the role of biased electrodes used in most ECR ion sources is of special interest. This problem was intensively investigated at RIKEN [2] and Frankfurt [3]. One of the primary tasks of these experiments was to consider the influence of a biased electrode on the extraction current aiming at an increase in the intensity of highly charged ion beams. Meantime, the study of these effects is not only of practical interest, but could also assist in better understanding of the processes in ECR plasma.

Description of experiment

The experiment was carried out with the ion source DECRIS 14-3. A detailed description of the ion source can be found in Ref. [1]. The cross-sectional view of the DECRIS 14-3 and the mechanism of the bias electrode movement are shown in Fig. 1. The range of movement is about 30 mm. An aluminum disk, 15 mm in diameter and 3 mm in thickness, was used as a biased electrode. It is possible to apply the negative bias voltage between the electrode and plasma chamber or to use the electrode at

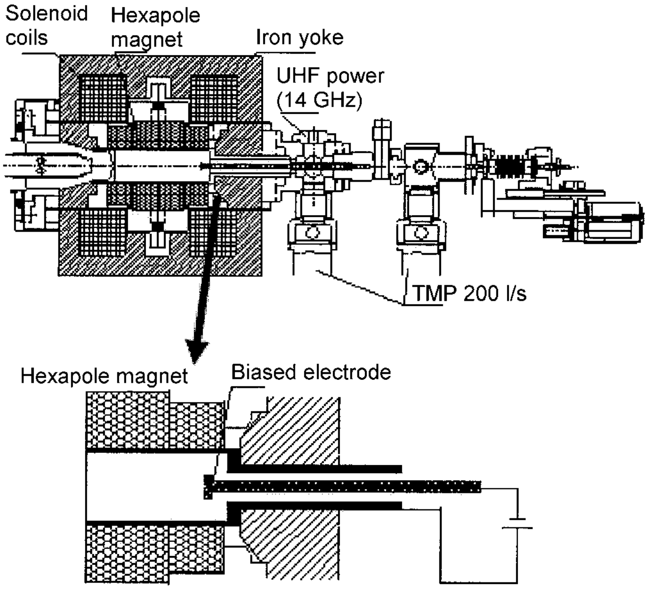

Fig. 1. Cross-sectional view of DECRIS 14-3.

a floating potential by disconnecting it from the electric power supply. In our case we determined the optimal position of the electrode adjusting it to the maximum current of Ar^{8+}. Furthermore, the reflected power was also optimized in each point of measurements. He or O were used as support gases. The extraction voltage was 16 kV.

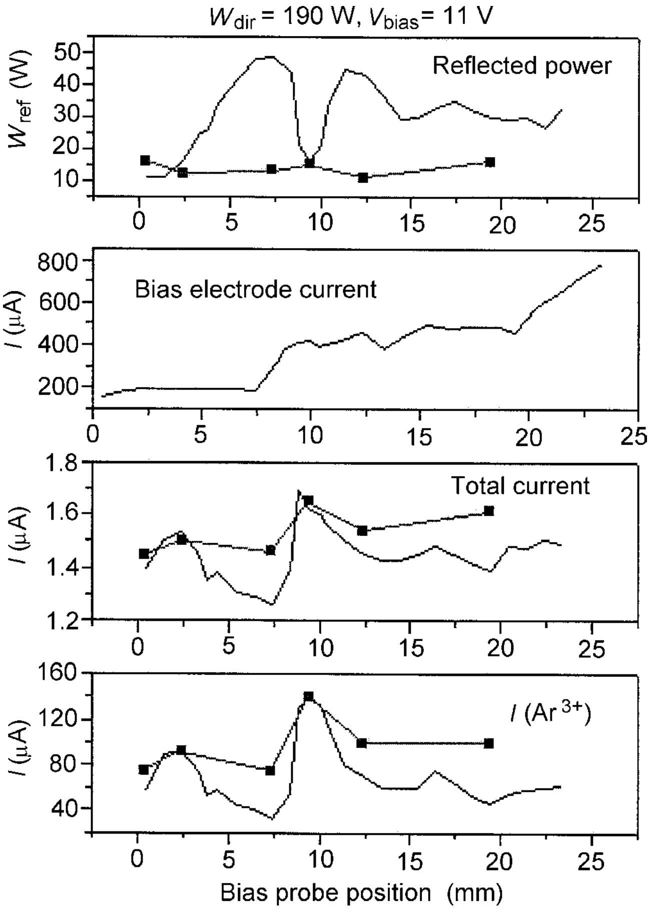

Fig. 2. Dependencies of the reflected power, bias electrode current, total current and I (Ar^{8+}) on the bias probe position.

Experimental results and discussion

First of all, the source was adjusted to the maximal ion yield of Ar^{8+} at the initial position of the electrode. Then, the bias electrode was moved inside the plasma chamber. Thus such parameters as the Ar^{8+} ion current, the reflected power, the current on the bias electrode and the total extracted current were measured. As it is shown in Fig. 2, there is an appreciable effect of the electrode position on the extracted ion current. It is necessary to pay attention to the reflected power of the UHF generator. It is evident that the increase of the Ar^{8+} current corresponds to the minimal reflected power and, on the contrary, at the maximal reflected power the current of Ar^{8+} considerably falls. A possible explanation of this effect is as follows. In the case of our ion source a bias electrode is simultaneously a part of the UHF coupling system. In the course of the electrode movement the matching of the UHF transport line and plasma chamber also take place. This assumption has been proved to be true in the next series of experiments when in each measuring point the adjustment of the reflected power was made. As it is shown in Fig. 2 the total extracted current and current Ar^{8+} change smoothly with the position of the biased electrode if the reflected power is adjusted to the minimum in each point of measurements. The growth of a current at the biased electrode at the movement inside the plasma chamber after passing the maximum of the magnetic field can be explained by the fact that the electrode is immersed in the area of more dense plasma.

In the second part of the experiment, three points were chosen for taking measurements. The first one corresponds to the position of the bias electrode in the maximum of the magnetic field and two others are situated before and after the maximum. For each position dependences of some parameters of the source on the potential of the biased electrode were measured. The results of the measurements are presented in Figs. 3, 4 and 5. It is necessary to note, that at the position of the electrode near the maximum of the magnetic field the optimal potential at the biased electrode does not exceed 10–15 V, which is in good agreement with the results given in Ref. [2]. In all the cases the maximal current at the bias electrode corresponds to the minimal current of Ar^{8+}.

The third part of our experiment was carried out with the bias electrode in pulse mode. As is shown in Fig. 6,

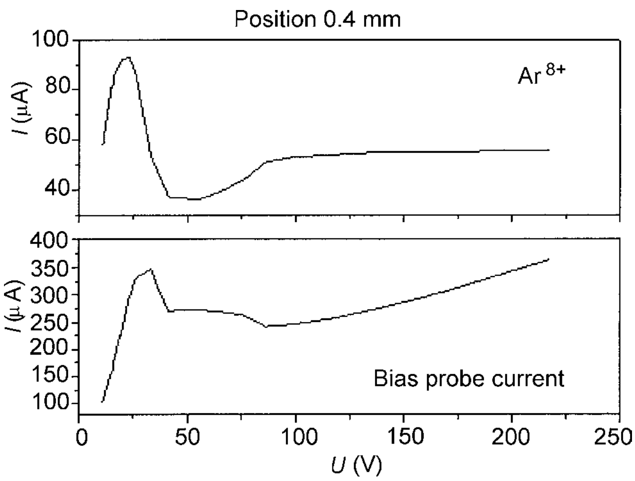

Fig. 3. Position before the maximum of the magnetic field.

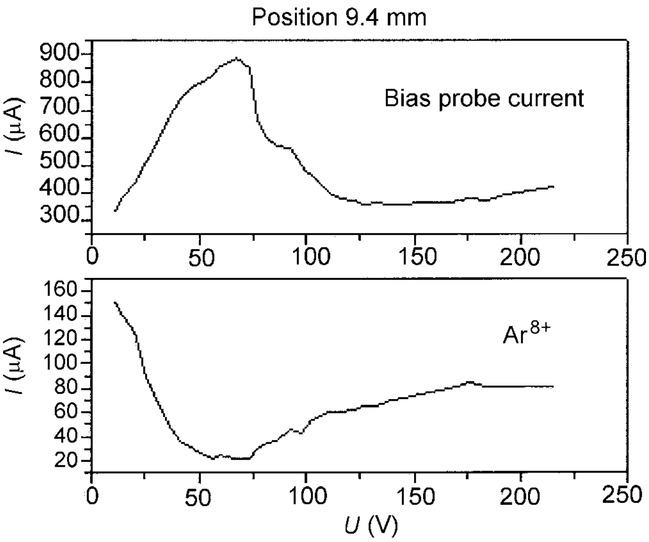

Fig. 4. Position of the electrode near the maximum of the magnetic field.

a negative pulse applied to the bias electrode strongly influences the extracted ion current. The rise (or drop) time at the front of the extracted current does not exceed about 100 µs. It is also important to note that the response of the extracted current at the bias disk pulse depends on the ion charge state. In the case of the low charge states (Ar^{3+} in Fig. 6a) the current decreases, for the medium charge states (Ar^{5+} in Fig. 6b) it practically does not change, and for the high charge states (Ar^{8+} in Fig. 6c) the current grows. Therefore, it is possible to deduce that a negative voltage at the bias electrode does not influence the ionization processes in plasma. It can only change the potential distribution in the extraction region and, as a result, effect on the ion diffusion process in a very complicated combination of magnetic and electric fields.

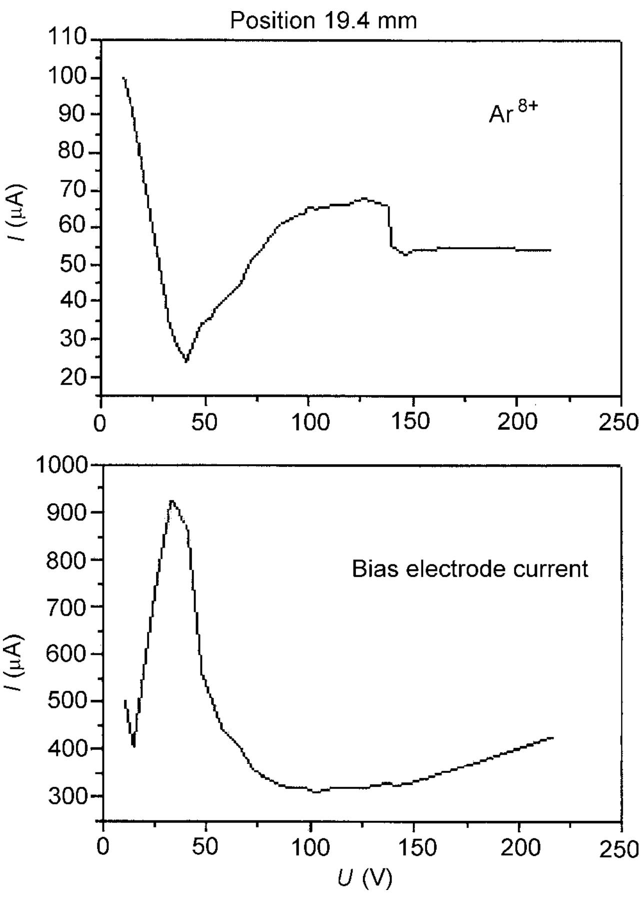

Fig. 5. Position of the electrode after the maximum of the magnetic field.

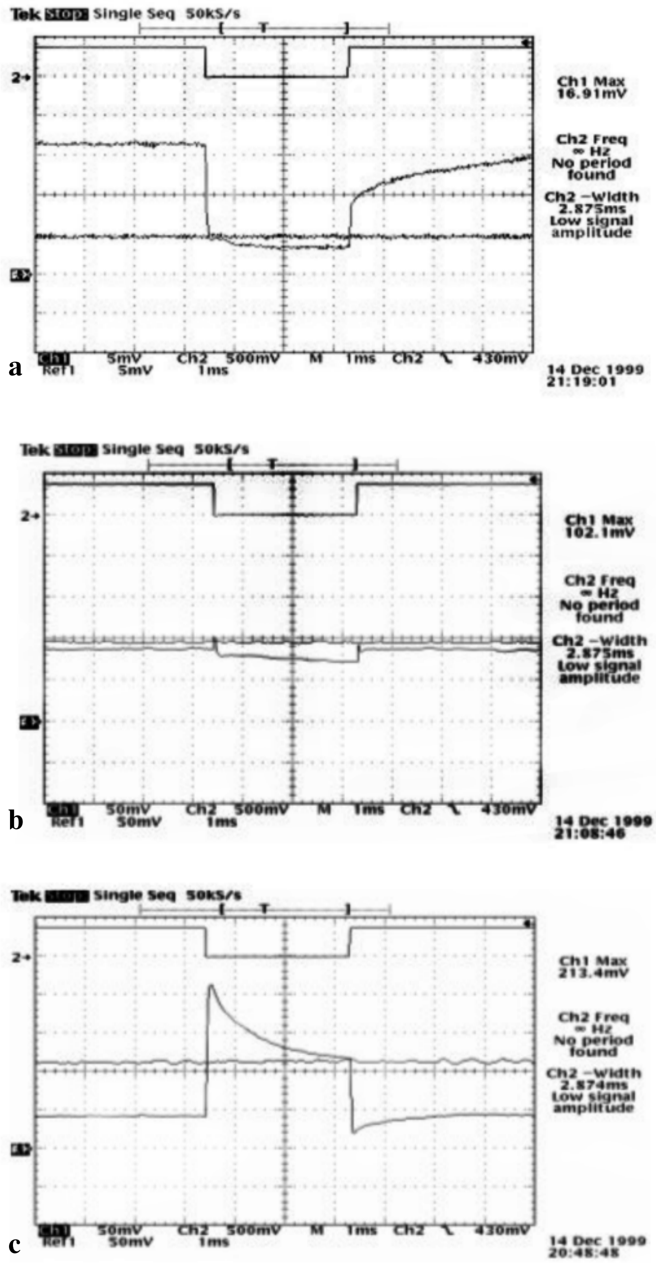

Fig. 6. Negative pulse at the bias electrode (the tops of the panels) and extracted current (the bottoms of the panels) of: a – Ar^{3+}; b – Ar^{5+} + O^{2+}; c – Ar^{8+}.

References

1. Efremov A, Bogomolov SL, Lebedev AN, Loginov VN, Yazvitsky NYu (1999) Ion Source DECRIS 14-3. In: Proc of the 14th ECRIS Workshop, 3–6 May 1999, CERN, Geneva, Switzerland, pp 31–34

2. Nakagawa T, Kidera M, Biri S *et al.* (1999) Recent developments of RIKEN ECRIS's (18 GHz ECRIS and liquid He free SC-ECRIS). In: Proc of the 14th ECRIS Workshop, 3–6 May 1999, CERN, Geneva, Switzerland, pp 1–4

3. Runkel S, Stiebing KE, Hohn O, Mironov V, Shirkov G, Schempp A, Schmidt-Böcking H (1999) Time resolved experiments at the Frankfurt 14 GHz ECR ion source. In: Proc of the 14th ECRIS Workshop, 3–6 May 1999, CERN, Geneva, Switzerland, pp 183–186