EXPERIMENTAL RESULTS OF THE GAS MIXING EFFECT ON DECRIS-14-2

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The gas mixing effect has been studied experimentally on DECRIS-14-2 with the first stage, with negatively biased electrode (no first stage), and with the first stage together with negatively biased potential. Different support gases (helium, oxygen, neon) were tested in combination with different main gases (oxygen, argon, xenon). The main gas consumption and the mixing ratios were measured for the conrresponding experiments. The results indicate that the gas mixing effect is restrained by the negatively biased potential compared with the first stage. The main gas consumption is decreased by more than 60 % due to the gas mixing effect. By means of the gas mixing effect, the beam intensity of the optimized ions are typically improved averagely by more than 30 % with the negatively biased electrode, and by more than 50 % with the first stage.

1 Introduction

The gas mixing effect in ECR ion sources is very effective to increase beam intensity of highly charged ions when a second lighter gas is mixed into the plasma. The gas mixing effect has been used widely in many ECR ion sources over the world [1,2]. But its mechanism has not been very clear. In order to improve the highly charged ion production on DECRIS-14-2 [3] (Dubna Electron Cyclotron Resonance Ion Source at 14 GHz), and study the gas mixing effect experimentally, a set of experiments were performed on DECRIS-14-2 with the first stage, with negatively biased electrode [3] (no first stage), and with the first stage together with negatively biased potential. Different support gases (helium, oxygen, neon) were tested to the different main gases (oxygen, argon, xenon). Here we report our main experimental results.

2 Experimental Procedures

DECRIS-14-2 is a 14 GHz compact ECR ion source (CAPRICE or GANIL ECR4 type) particularly developed for the multiply charged ion production. This source has been put into operation for the FLNR cyclotron U-400M. The structure of this source is shown in Fig.1. The details of DECRIS-14-2 were described in Ref.[3].

All experiments about the gas mixing effect were done on DECRIS-14-2 with 10 KV extraction voltage and 8 mm extraction hole. The source was optimized at a constant rf power-level of 200 W for all the highest available charge states. The main gas (beam-gas) and support gas (mixing-gas) are fed by two seperated piezo valves. The main gas is mixed up with the support gas at the common exit of the piezo valves from where the mixed gas is fed into the source through the coaxial line. The gas consumption and flow rate can be estimated by the two calibrated valves which are controled by the high voltage around 1 KV. The typical gas pressure for the bottle of the main gas and support gas is approximately 200 ~ 300 mbar. All the ion currents were measured by a Faraday-cup situated about 90 cm downstream the exit of a 90 degree analyzing magnet, no any slits in the beam line.

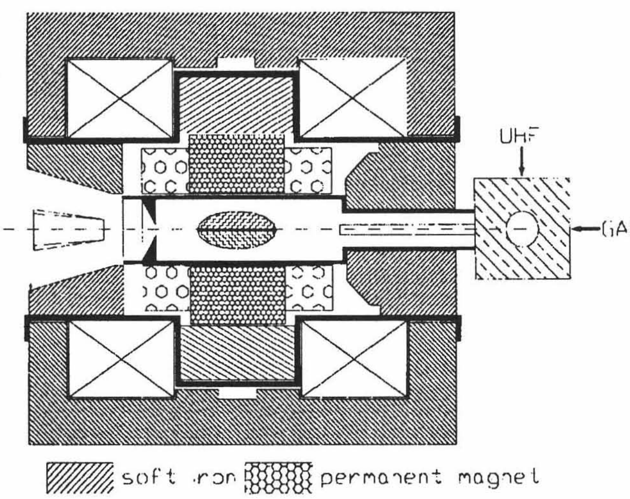

Figure 1: Schematic form of DECRIS-14-2.

The experimental procedures are always same no matter what kind of ions are optimized, and no matter with the first stage and the negatively biased electrode. The source always begins to be tuned with pure gas

Table 1. Comparison of the gas mixing effect with the first stage and the negatively biased electrode for the typically optimized ions (μA).

	The First Stage			Negatively Biased Electrode		
	no gas mixing	with gas mixing	f	no gas mixing	with gas mixing	f
O_{16}^{6+}	60	90	1.5	116	135	1.16
Ar_{40}^{11+}	11	16.5	1.5	17	25	1.47
Xe_{132}^{17+}	15	23	1.53	23	28.5	1.24
Xe_{132}^{18+}	14	23.5	1.68	22	31	1.4
Xe_{132}^{19+}	14	22	1.57	20	28	1.4

*: Helium was used as support gas for O_{16}^{6+} . The support gas of the others was oxygen.

f means enhancement factor

by optimizing certain high charge state, and then the support gas is injected and the ion with the same charge state is optimized. All the results compared between the gas mixing effect and no gas mixing were obtained at the best optimization regime of the source so that we could understand the real and practical effect of the gas mixing. We usually do the experiments like the following procedure.

A little bit main gas is fed into the source firstly after the currents of the magnetic mirror coils and high voltage of the source are applied to, and then about 50 $\sim$ 100 W rf power is coupled to the source. The plasma is ignited and the ions are extracted from the source which can be seen from the total load current , the profile monitor and the Fraday-cup. The currents of the lens and the analyzing magnet have to be optimized so as to transport and select ions efficiently. After that we increase the rf power little by little up to 200 W and fix it at this level. What is the most important next is to optimize the gas flow rate and the currents of the two magnetic mirror coils in order to get the best optimization regime. The negatively biased potential also has to be optimized if with the negatively biased electrode. We have to pay attention that the axial magnetic field, the gas flow rate and the rf power don't always match very well. Several good regime often occur, but we have to find the best one to make the current of the optimized ion maximum and stable by the best compromise between all those tuned parameters of the source. All the parameters, ion currents and spectrum can be recorded when we are sure that we get the best regime. After completion of a set of charge state measurements we have to check the reproducibility of the beam current for the selected ion. At this moment, the second gas (support gas) can be fed into the source and we begin to tune and optimize the same ion charge state with the gas mixing. The optimization procedures are similar to that mentioned above. The mixing ratio between main gas and support gas plays a very important role and we have to tune it very carefully to get a optimum mixing ratio.

3 Experimental Results

The gas mixing effect to highly charged ions of oxygen, argon and xenon was studied with support gases helium, oxygen and neon. O_{16}^{6+} , Ar_{40}^{11+} and Xe_{132}^{18+} were always as typically optimized ions respectively during all experiments.

The comparison of the gas mixing effect with the first stage and with the negatively biased electrode for the typically optimized ions is presented in Table 1.

We can see from Table 1 that the enhancement factors of the gas mixing effect with the negatively biased electrode are much less than those with the first stage. In other words, the gas mixing effect is restrained by the negatively biased electrode compared with the first stage.

Only argon mixed with oxygen was tested when the first stage together with a negatively biased potential. No any gas mixing effect was found when we optimized Ar^{11+} and Ar^{9+}.

The experiments indicate that helium and oxygen have almost same gas mixing effect to Ar^{11+}. There is no much effect to Ar^{11+} and Ar^{9+} when neon as a support gas. With neon as support gas, the gas mixing effect to the highly charged ions of xenon is obvious, but the effect is less than oxygen (at least $Q \leq 20$).

The consumptions of the main gases oxygen, argon and xenon at different conditions are shown in Fig.2 which were obtained when we optimized O^{6+} , Ar^{11+} and Xe^{18+} respectively. All of the gas consumptions in Fig.2 are estimated from the two calibrated piezo valves.

4 Discussion and Conclusion

By means of the gas mixing effect, the beam intensity of the typically optimized ions (O^{6+} , Ar^{11+} and Xe^{18+}) are improved averagely by more than 30% with the negatively biased electrode and more than 50 % with the first stage. The gas mixing effect not only improves the currents of the highly charged ions, but also decreases the main gas consumption by more than 60% on average

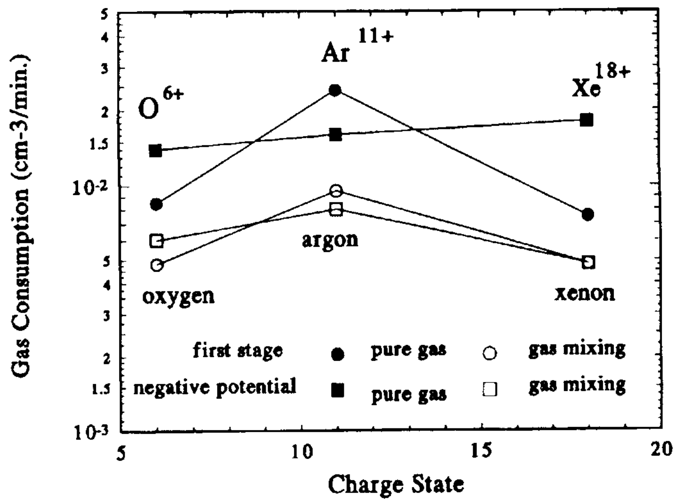

Figure 2: The consumption of the main gases oxygen, argon andxenon with and without the gas mixing.

which is very promising and interesting to the radioactive ion production. Oxygen is the best support gas and very effective to the high charge states of xenon and argon. The mixing ratio between main gas and support gas is different for different ions and different support gas with the first stage and the negatively biased electrode. For DECRIS-14-2 in optimization of Ar_{40}^{11+}, the mixing ratio changes from 20% argon , 80% support gas to 40% argon , 60% support gas with negatively biased potential and with first stage when oxygen and helium are used as support gas.

The experiments indicate that the gas mixing effect is restrained by the negatively biased potential. The negatively biased electrode works as a plasma cathode to collect ions and repel the plasma electrons into the central plasma, meanwhile, it also provides electrons from secondary emission of impinging plasma particles. That means the additional electrons are injected into the ECR plasma with a negatively biased potential. When an ECR ion source works at the best optimum regime, the density of the electrons might reach the value near the cut-off density (a constant value) . when additional electrons are injected into the ECR plasma with a negatively biased potential, the gas mixing effect must be limitted if we think one of functions for the gas mixing effect is the increase of the electron density. If one of mechanisms for the gas mixing effect were not the increase of the electron density, then it would be very difficult to explain this experimental phenomina. It is obvious that this phenomina can not be explained by the previous interpretation to the gas mixing effect (ion cooling). From this interpretation it seems that the increase of the electron density should be one of dominant reasons for the gas mixing effect.

References

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