An innovative method for $^{12}C^{4+}$ suppression in $^{18}O^{6+}$ beam production in an electron cyclotron resonance ion source†

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It is a major and complex task to accelerate an ion that has the same charge to mass ratio with strong contaminant ions, such as $^{12}C^{4+}$ in the $^{18}O^{6+}$ beam. An innovative method has been developed to suppress the contaminant ions in the Electron Cyclotron Resonance (ECR) ion source by introducing Li vapor. The ion distribution inside the ECR zone was obtained by the optical analysis of ions inside the ECR ion source. The $^{12}C^{4+}$ ions were suppressed as much as by a factor of 10, whereas the $^{18}O^{6+}$ beam changed little with the use of this technique.

A 14 GHz Hyper-Electron Cyclotron Resonance (Hyper-ECR) ion source has been successfully used as an injector for the RIKEN Azimuthal Varying Field (AVF) cyclotron.[1] A grating monochromator was installed at the Hyper-ECR ion source, and the emitted light intensities of gaseous and metal ions were observed during ion beam tuning.[2,3] Recently, the $^{18}O^{6+}$ beam was produced at the Hyper-ECR ion source and injected into the RIKEN AVF cyclotron. After the beam time was started, the users noticed a significant contamination of the $^{18}O^{6+}$ beam with the $^{12}C^{4+}$ ions. The plasma chamber is not hydrocarbon free, and a counter-flow of rotary oil is also suspected for the presence of the carbon atoms. During the beam tuning process, the charge distribution of ions extracted from ECR plasma was measured by a magnetic beam analyzer and a Faraday cup. However, the charge to mass ratio (q/m) of $^{18}O^{6+}$ is 0.33335, and that of $^{12}C^{4+}$ is 0.33333. Even our high-resolution AVF cyclotron (Δm/m =1/12000) is unable to separate these two ions.

During the experiment a total beam current of the q/m =1/3 ranged from 30 to 50 μA. Although the $^{12}C^{4+}$ beam current contaminating the main beam had to be measured, a direct measurement was impossible. Therefore, we measured the light intensity of the C IV line spectrum during the beam experiment.[4,5] The strength of the light intensity measured by a photomultiplier and a digital voltmeter constantly showed 2.5 mV throughout the experiment. Figure 1 shows the light intensity of the C IV line spectrum from the residual gas plasma as a function of the analyzed $^{12}C^{4+}$ beam intensity. From this result, the 2.5 mV light intensity corresponded to the 12 μA of $^{12}C^{4+}$ beam intensity. Therefore, the contamination ratio of the $^{12}C^{4+}$ ions in the total beam was 24∼40%.

When an $^{7}Li^{2+}$ beam was produced and extracted from the Hyper-ECR ion source, there was no C IV light intensity present.

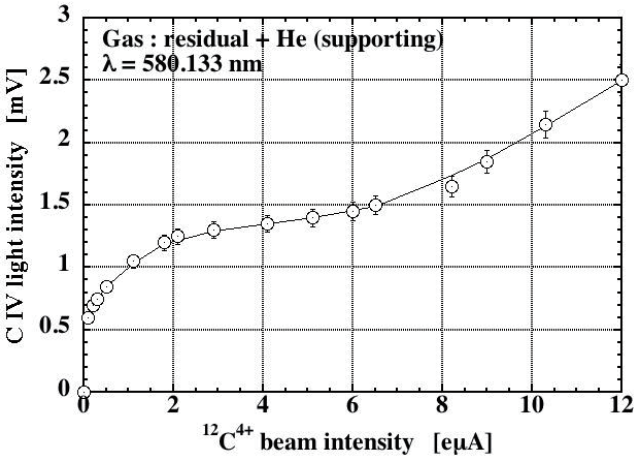

Fig. 1. Light intensity of C IV line spectrum as a function of an analyzed $^{12}C^{4+}$ beam intensity.

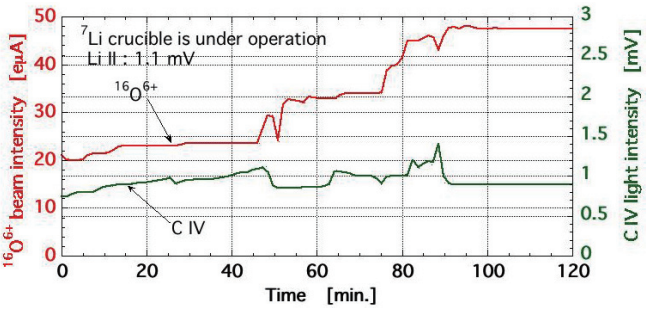

Fig. 2. Time chart of $^{16}O^{6+}$ beam intensity and C IV light intensity with ^{7}Li crucible in operation.

Then, we attempted to tune the $^{16}O^{6+}$ ion beam while vaporizing a small quantity of Li atoms in the plasma chamber. Figure 2 shows a time chart of $^{16}O^{6+}$ ion beam current and C IV light intensity under $^{16}O^{6+}$ ion beam tuning with Li evaporation.

By adjusting the distance between the Li crucible and plasma, the brightness of the Li II light intensity was kept at 1.1 mV. To prevent excessive Li crucible heating, the C IV light intensity was kept at less than 0.9 mV, and the beam current was controlled at 48 μA of $^{16}O^{6+}$. The $^{12}C^{4+}$ beam current became ∼1.0 μA when this C IV brightness was converted into the beam current as shown in Fig. 1. The amount of impurities was drastically improved to around 2% from 40% by the Li ion pumping effect.

References

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