Observation of sublimation effect of Mg and Ti ions at the Hyper-Electron Cyclotron Resonance ion source

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INTRODUCTION

A grating monochromator with a photomultiplier has been used for beam tuning at the Center for Nuclear Study Hyper-ECR ion source [4]. Hyper-ECR ion source has been successfully used as an injector of the multi-charged ion beams of high intensities for RIKEN Abeam Cyclotron Field (ACKF) cyclotron [5]. Light intensity observation is an especially useful technique for an identification of the ions of the same charge state and mass ratio in the plasma [4]. These ions are difficult to separate by an analyzer magnet. Before the operation of multi-charged metal ion beams chamber baking (desorption from the plasma wall) must be done to obtain a required vacuum condition. At the beginning low RF power (~100W) is fed to the residual gas in the plasma chamber, and a degassing process is conducted with increasing RF power gradually until the vacuum gauge reading is settled (~1 x 10^-5 Pa order) to start a metal rod insertion into the plasma chamber. In this paper we describe the sublimation pump effect of Mg and Ti ions of ECR ion source during chamber baking and beam tuning.

EXPERIMENTAL

24Mg+ and 26Mg+ ions have been produced in the 14.2 GHz Hyper-ECR ion source. The structure and present operation condition of the ion source are described in Ref. 3. At the beginning of the chamber baking RF power of ~100 W was fed to the residual gas of the plasma chamber. Extraction voltage was set to 10 kV. Then a vacuum gauge reading rapidly dropped down to less than 10^-1 Pa from 10^-3 Pa order, and a break-down of the high voltage power supply happened because of a huge extraction current. Several hours later the extraction voltage was recovered, and vacuum gauge reading also reached 10^-3 Pa order. RF power gradually increased to ~800 W until obtaining a required vacuum condition (~1 x 10^-5 Pa), and a new extraction current of less than 2 mA. After baking of the plasma chamber, a pure metal or an oxidized metal rod was gradually inserted into the chamber without an excessive heat. An excessive heat causes a break-down of the power supply because of a huge extraction current. This RF power was ranging between 500 and 600W for a highly multi-charged ion production. Argon, Neon, Oxygen and Helium gases were used as supporting gases to keep the plasma condition stable. A grating monochromator (JASCO CT-290), and a photomultiplier (Photomultiplier module H11422-031, Hamamatsu Photonics) were used for a light intensity observation. Ni, Fe, Cu, Ti, K, Rubidium, K, Krypton, Rb, and Cs optical lines were used for preventing second and third order light signals. Wavelengths of the observed lines were determined in accordance with the NIST Atomic Spectra Database [5].

RESULTS AND DISCUSSIONS

24Mg+ ion beam tuning

Figure 1 shows the optical line spectrum of the Hyper-ECR ion source under plasma chamber baking after three hours from the start. A vacuum gauge reading was 5.7 x 10^-3 Pa. A drain current (an extraction current) was 12 mA. RF power was 100 W. In this figure most of all peaks were Fe I and Fe II. There were some C, N and O optical lines in the spectrum. However, those lines were all disturbed by Fe I and Fe II strong lights, and therefore it was difficult to separate those. The line intensities of those Fe I and Fe II were almost disappeared, and Mg I light intensities appeared. Especially Mg VIII line spectrum (~279.64 nm) was clearly observed to identify the existence of Mg ions in the ECR plasma. In this figure Ni II (i = 555.7 nm) and Fe II (i = 570.7 nm) light intensities were observed. A non-magnetic stainless steel cover was used for a smooth heat transfer to the tip of the Mg rod from plasma. The edge of the cover was melted by plasma as shown in fig.3. Therefore, a stainless steel front is expected to be present because of the melted stainless cover.

Figure 2: Optical line spectrum during 24Mg+ ion beam tuning. The shape of the peaks of the residual gas ions drastically changed from that of the residual gas plasma. Fe I light intensities of residual gas decreased, and Mg I, II, III, IV, VII and VIII lines were clearly observed.

Figure 3: Mg rod with a stainless steel cover.

CONCLUSIONS

During plasma chamber baking observed light intensities were mostly Fe I and Fe II. Mg ions were relatively heavy and not easy to extract from the plasma chamber. Those atoms were present for a long time in the vacuum chamber. Therefore, stainless steel is thought to be an unsuitable material for a plasma chamber to extract multi-charged ions. Aluminum or Magnesium based light alloy is better for plasma chamber materials for degassing and extraction.

REFERENCES