Mg ion pumping effect during $^{24}Mg^{8+}$ ion beam production at the Hyper-ECR ion source

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A grating monochromator with a photomultiplier has been used for beam tuning at the Center for Nuclear Study Hyper-Electron Cyclotron Resonance (ECR) ion source.[1,2] The Hyper-ECR ion source has been successfully used as an injector of the multi-charged ion beams of high intensity for the RIKEN AVF cyclotron.[3] $^{24}Mg^{8+}$ ions have been produced in the 14.2-GHz Hyper-ECR ion source. At the beginning of the chamber baking an RF power of 100 W was fed to the residual gas of the plasma chamber. The extraction voltage was set to 10 kV. Then the vacuum gauge reading rapidly dropped to less than 10^{-4} Pa from the order of 10^{-5} Pa and a brakedown of the high-voltage power supply occured because of the huge drain current. A few hours later the extraction voltage was recovered and the vacuum gauge reading was restored to the order of 10^{-5} Pa. The RF power was gradually increased to 600 W until a good vacuum condition ($1\sim5 \times 10^{-5}$ Pa) and low drain current of less than 2 mA were obtained. After baking the plasma chamber an MgO rod was gradually inserted into the chamber without excessive heat. The RF power ranges from 500 to 600 W for $^{24}Mg^{8+}$ ion production. A grating monochromator (JASCO CT-25C) and a photomultiplier (Photosensor module H11462-031, Hamamatsu Photonics) were used for light intensity observation during chamber baking and beam operation.[3] The wavelengths of the observed lines were determined in accordance with the NIST Atomic Spectra Database.[4] Figure 1 shows the optical line spectrum of the Hyper-ECR ion source under plasma chamber baking. This spectrum was taken three hours from baking start. The vacuum gauge reading was 5.7×10^{-5} Pa. The drain current was 12 mA. The RF power was 100 W. In this figure most of the peaks were from Fe I and Fe II. The relative intensities of those Fe I and Fe II peaks are quite high. Figure 2 shows an optical line spectrum of the ECR plasma during $^{24}Mg^{8+}$ ion beam tuning. The vacuum gauge reading was 1.7×10^{-5} Pa. The drain current was 1.8 mA. The RF power was 611 W. The line intensities of Fe I and Fe II almost decreased to zero and Mg line intensities appeared. Especially, the Mg VIII line spectrum (λ=279.64 nm) was clearly obtained to identify the existence of $^{24}Mg^{8+}$ ions in the ECR plasma. The ion source was tuned for the production of the $^{24}Mg^{8+}$ ions. The H^+ ions were also reduced during $^{24}Mg^{8+}$ ion beam operation. From these results the ion pumping effect of Mg ions was visually demonstrated by the optical grating monochromator with a photomultiplier.

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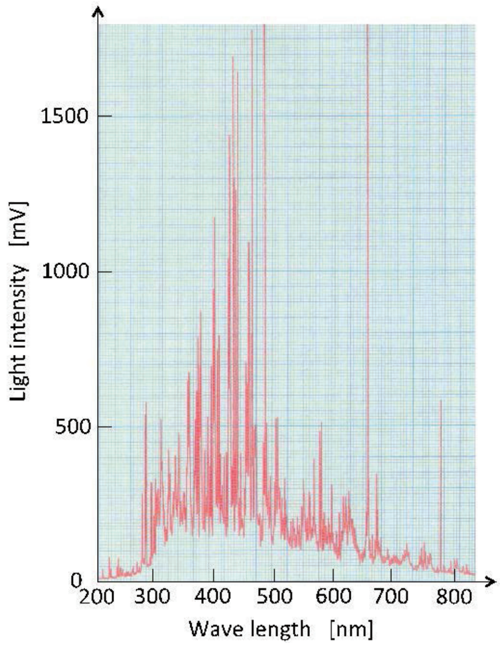

Figure 1. Light intensity spectrum of the residual gas ions during baking for three hours.

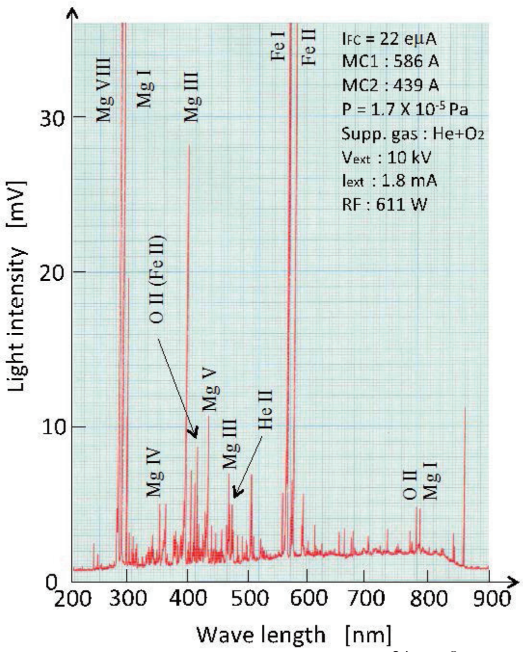

Figure 2. Optical line spectrum during $^{24}Mg^{8+}$ ion beam tuning.

References
1) H. Muto et al., Rev. Sci. Instrum. **84**, 073304 (2013).
2) H. Muto et al., Rev. Sci. Instrum. **85**, 02A905 (2014).
3) H. Muto et al., Physics Procedia **66**, 140 (2015).
4) www.nist.gov/pml/data/asd.cfm for NIST atomic spectrum data base.