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Characteristics of Cs^o and Cs^+ in Extraction Region of a Negative Ion Source for NBI

NBI用イオン源引出領域内のCs^oとCs^+の特性

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Characteristics of atomic and ion spectra of caesium atom (Cs^o) and its positive ion (Cs^+) in the beam extraction region of a caesium (Cs) seeded negative ion source have been investigated using optical emission spectroscopy (OES). Emission spectra of Cs^o are clearly observed, while no Cs I emissions are detected in this experiment. By decreasing the bias voltage (V_{bias}) below a specific voltage of ~4 V, the Cs^o emissions increase their intensities. The intensity curves have minimums at ~4 V, and they becomes flat above the voltage. On the other hand, no Cs^+ was identified through this experiment. The specific V_{bias} of ~4 V is close to the plasma potential (ϕ_{PL}) at the boundary of driver and extraction regions, and polarity of ϕ_{PL}-V_{bias} dominates the Cs emission characteristics.

1. Introduction

In Cs seeded negative ion sources adopted for NBI systems, Cs vapor pressure and Cs^+ density in side the sources are one of the important parameter to characterize the source performance. That is because the Cs particles onto heated PG define the work function on the surface as well as a gettering effect to impurity gases such as H_2O and O_2, which pollutes against lowering the work function. Concentrations and energies of charged particles, which are hydrogenous positive ions, hydrogen negative ion (H^-) and electron, affect to the Cs evaporation and Cs ionisation, and they are the parameters of so-called Cs recycling in negative ion source. In beam extraction region, particle concentrations can be drastically changed from electron-rich to H^+-H^- ionic plasmas [1] by varying the bias voltage.

In this paper, we report about the changes of Cs^o and Cs^+ as well as Balmer line intensities measured with OES with respect to V_{bias}, and discuss the result using a difference of ϕ_{PL}-V_{bias}.

2. Experimental Setup

Plasmas generated in an R&D negative ion source at NIFS teststand has been measured using a spectrometer with the focal length of 300 mm.

During the OES measurement, Cs is seeded into the plasmas using filament-arc discharge, and hydrogen negative ions are extracted from the source. The experimental setup is shown in Fig. 1. The optical length of the plasmas is 180 mm in average, and H Balmer lines, Cs^o and Cs^+ lines are measured.

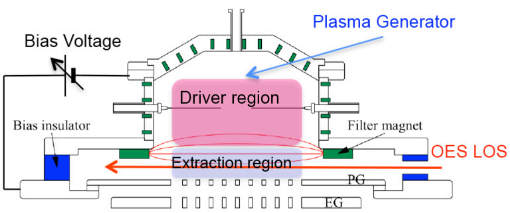

Fig. 1. Schematic of the OES line of sight (LOS) parallel to the PG surface plane.

A cavity ring-down and Langmuir single probe systems are applied to measure H^- density, electron density and temperature, respectively. Those data was simultaneously obtained with OES data to refer the concentrations of the plasma particles. To change the concentrations, V_{bias} applied to the plasma generator and PG is varied from -10 to 10 V.

3. Experimental Results

Typical emission spectra from Cs-seeded plasma are shown in Fig. 2. It is noticeable that Cs II line (at 460.38 nm) corresponding to Cs^+ is comparable to noise level in this experiment, while the clear peaks of Cs I lines (at 852.11 and 894.35 nm) are observed. A spectrum at 777 nm corresponds to O I emission and it is considered coming from H_2O or O_2 molecular in background gas. After a few days' conditioning, the spectrum has disappeared.

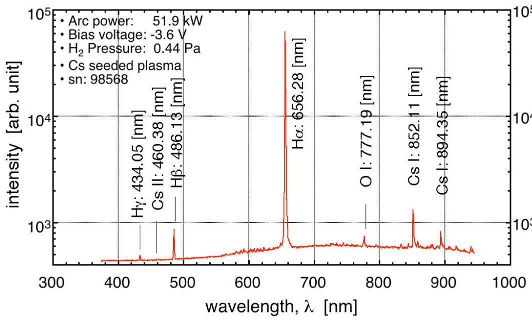

Fig. 2. Typical whole spectra emitted from Cs- seeded source plasma.

In our previous experiment, Cs II emission was observed [3], and the difference is considered caused by the higher plasma electro-negativity and much lower density of energetic electron in this experiment. Another reason of this lack of Cs II emission could be the difference of their line of sight.

Changes of the emission intensities of two Cs I and Cs II with the wavelength of 852 and 894 nm are indicated in Fig. 3 with logarithmic vertical scale. Both of those spectra show monotonous decrease with increasing the V_{bias} from -10 V to ~4 V, and then they become flat suddenly at ~4 V of the V_{bias}. The V_{bias} of 4 V is close to the ϕ_{PL} at the boundary of driver and extraction regions.

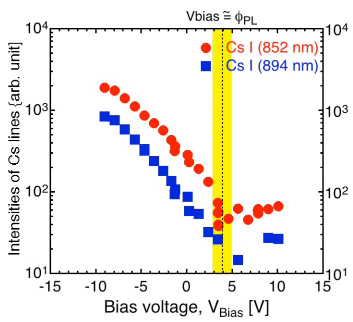

Fig. 3. Changes of Cs I (Cs^0) emission intensities with respect to V_{bias}.

Although the flips of the slopes at the V_{bias} of 4 V are smoother, similar characteristics are indicated in Balmer series in Fig. 4. As is observed in Cs I lines, all the intensities of the Balmer lines bend at the V_{bias} near the ϕ_{PL}. It is natural to think that electrons diffused from driver region induce this phenomenon, because the Balmer lines are emitted via collision processes of electrons and atoms mainly.

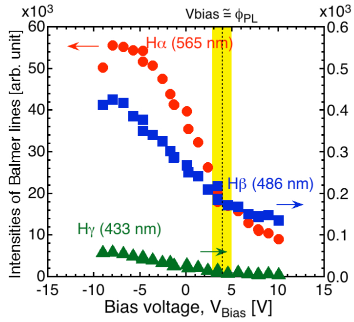

Fig. 4. Changes in Balmer lines as functions of V_{bias}.

Electron density and temperature are shown in Fig. 5a and 5b, respectively. As increasing V_{bias} from -10 to 10 V, electron density decreases about two orders, and the density ratio of electron to H^- ions is ~0.1 at the voltage of 10 V. It is remarkable that the polarity of voltage is opposite to the tendency of the electron density. The electron temperature linearly increases as a function of the V_{bias}.

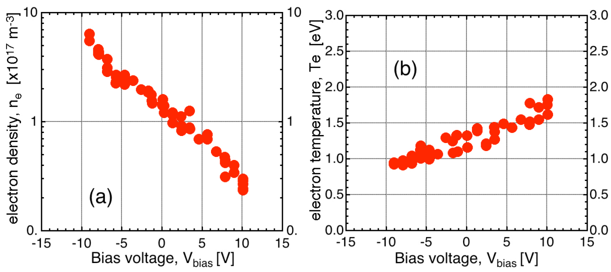

Fig. 5. Electron density (a) and temperature (b) with respect to V_{bias}.

Considering the electron impact is the main excitation process of the optical emission, increase of the electron density shown in Fig. 5(a) is consistent with the features of the atomic emissions. However, it is still impossible to explain the "bends" in the curves of emission intensities at the V_{bias} of ~4 V.

Plasmas in extraction region are diffused plasmas and the electrostatic field penetrates longer distance in the case of electro-negative plasmas [1]. Ignoring the potential drop at sheath potential, the charged-particle flows are strongly affected with a potential difference and its polarity of ϕ_{PL} - V_{bias}.

Acknowledgments

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References

[1] K. Tsumori et al.: Rev. Sci. Instrum, **83** (2012) 02B116.

[2] K. Ikeda et al.: Plasma and Fusion Res, **5** (2010) S2101.