§7. Characteristics of Cs Atom and Cs+ Ion in Beam Extraction Region of NIFS R&D Ion Source

Tsumori, K., Nakano, H., Kisaki, M., Geng, S. (Grad. Univ. Advanced Studies), Ikeda, K., Nagaoka, K., Osakabe, M., Takeiri, Y., Kaneko, O., NBI Group

Stability of beam injection power of negative-ion-based NBI depends on the production yield of hydrogen negative ion (H^-) in negative ion sources. The yield is a function of caesium (Cs) vapor pressure as well as plasma-grid (PG) temperature. In order to investigate time-dependent characteristics of Cs vapor pressure, we have prepared Cs ionization gauge, laser absorption spectroscopy for Cs atoms and optical emission spectroscopy (OES). The OES has been carried out to measure the Cs vapor pressure in a LHD-NBI negative ion source [1]. Recently, a multi-diagnostic system has been installed to an R&D source at NIFS teststand [2], and OES has been measured to investigate the H^--ion rich plasmas generated in the R&D source to analyze the data obtained with the multi-diagnostic system.

The experimental setup is described elsewhere [3] and the line-of-sight of OES are set to observe the beam extraction region of the ion source as the other diagnostic devices. Whole the spectra in the detectable range of spectrometer are shown in Fig. 1. The discharge power is

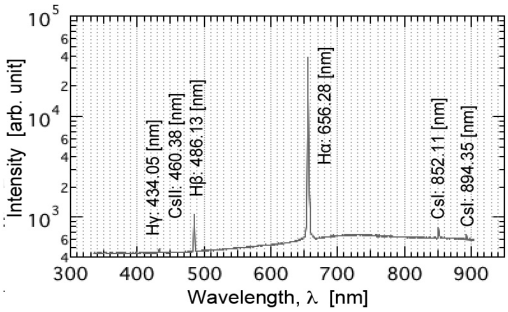

Fig. 1. Typical full-range spectra obtained with Cs-seeded arc-discharge plasma with the discharge power of 50 kW.

50 kW in the H_2 operational pressure of 0.44 Pa and Cs is injected in the ion source in this case. In the spectra, Cs I line originated with emission from excited electronic state of Cs atom and hydrogen Balmer lines are clearly observed, while Cs II line due to Cs^+ ion has not been obviously detected through the experiment as same as the previous experiment. The electron temperature is less than 0.8 eV in the extraction region and is much lower than the excitation energy to emit the Cs II light with ~2.7 eV.

Bias voltage (V_{bias}), which is applied to PG with respect to arc chamber, is one of the effective parameter to change a density ratio of H^- ion to electron. Bias dependence of two Cs I and hydrogen Balmer line intensities in logarithmic scales are shown in Fig. 2 (a) and (b). Both of those spectra show monotonous decrease with increasing the V_{bias} from -10 V to ~4 V and then they

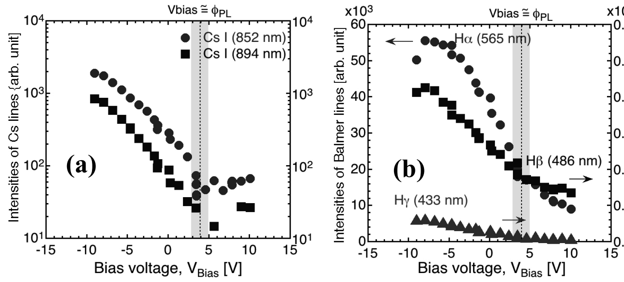

Fig. 2. Bias dependence of (a) Cs I and (b) hydrogen Balmer line intensities in extraction region. Notice that vertical axis is indicted with logarithmic scales.

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. Although the flips of the slopes at the V_{bias} of 4 V are smoother, similar characteristics are indicated in Balmer series in Fig. 2. 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 mainly emitted via recombination processes of electrons

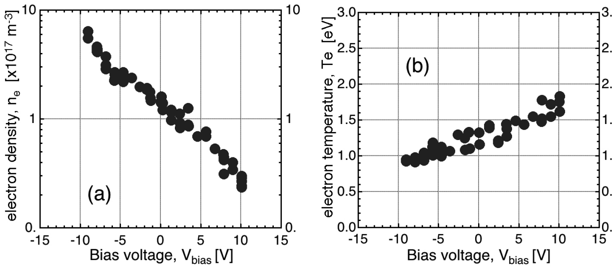

Fig. 3. (a) Electron density and (b) temperature in the extraction region with respect to bias voltage, V_{bias}.

and H_2^+ ions in the condition of low electron energy.

Electron density and temperature in the extraction region are shown in Fig. 3 (a) and 3 (b), 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. The electron temperature linearly increases as a function of the V_{bias}. Even by combining those data, it is impossible to explain the slope changes in Cs I lines at the bias voltage more than ~ 4 V. In that bias region, the electron density becomes less than 1 % of H^- ion density. Electronic excited levels of the Cs I are 2.44 (852 nm) and 2.51 eV (894 nm), and they are close to the affinity level of H^- ion (0.75 eV), and following mutual neutralization is possible:

$$Cs^+ + H^- \rightarrow Cs^* + H \rightarrow Cs + H + h\nu\ (\mathrm{Cs\ I})$$

This work is supported with KAKENHI Grant No. 25249134 and NIFSULRR-702.

1) Ikeda, K. et al.: Rev. Sci. Instrum. **79**, 02A518 (2008).
2) Tsumori, K. et al.: Rev. Sci. Instrum. **83**, (2012) 02B116.
3) Tsumori, K. et al.: *AIP conference proceedings*, **1515** (2012) pp.149-156.