§12. Overview of Physics-based Investigation of Behaviors of Charged Particles in Caesium Seeded Negative Ion Source for NBI

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Caesium (Cs) seeded negative ion source is the key component of Neutral Beam Injector (NBI) based on negative hydrogen ions (H^-). So far, the maximum injection power of ~6.9 MW has been achieved per oin source and 16 MW of the total power is injected to LHD using three negative-NBIs. Deuterium beam injection is scheduled in the next LHD experiment. In extracting deuterium negative (D^-) ion, it is reported that the current density becomes ~√2 times lower than that in the case of H^- and co-extracted electron current increases in the same accelerating configuration[1]. To obtain deuterium injection power comparable to hydrogen one, further improvement is required. For this reason, we have stared to investigate the mechanism from production through extraction of H^- in a NIFS R&D negative ion source (NIFS-RNIS), whose details and configuration of diagnostic devices are shown elsewhere[2].

By seeding sufficient Cs in the NIFS-RNIS, ion-ion plasma including quite low electron density (less than 1 % of H^- density) is formed in the beam extraction region between so-called plasma grid (PG) and filter magnet. This plasma consists of positive and negative ions with similar masses and the shielding characteristics are considered different from electron plasma. Distributions of plasma potential measured with a Langmuir probe are shown in Fig. 1 in the cases of (a) electron plasma, H_2 plasma, and (b) negative-ion rich one, Cs-seeded plasma. Each plot is obtained with different bias voltage applied for PG to the source plasma. The farmer distribution has almost constant slopes and larger potential difference is located near PG. On the other hand, the latter changes the slope as increasing the bias voltage. Acceptance to the potential difference is lower than the electron plasma and bias electric field penetrates inside plasma due to poor electrostatic shielding in the negative-ion rich plasma.

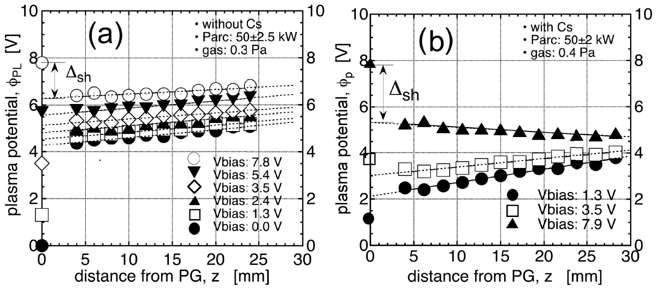

Fig. 1. Distributions of plasma potentials in (a) electron plasma, H_2 discharge, and in (b) negative-ion rich plasma, Cs-seeded plasma.

Beam extraction field is considered to affects to the charged-particle motions as well as bias field, and flows of charged particles, electron, positive and negative hydrogenous ions have been measured before and during beam extraction. A combination of multi-pin directional Langmuir probe and photodetachment probe is applied for the measurement[3]. Flow distributions of electron and positive ion are indicated in Fig. 2(a). Flow vectors of these particles at any points move toward PG. They are very similar in the extraction region and show ambipolar characteristics. Distribution of H^- flow is in Fig. 2(b). As shown in the figure, the flow directs from PG to extraction region. The flow is can explain the flat H^- distribution measured with cavity ring-down[4] and widely expanded distribution of extracted H^- obtained with Ha-filtered CCD method[5]. The H- should turn the direction to be extracted and details of the flow is described in another report in this issue[6].

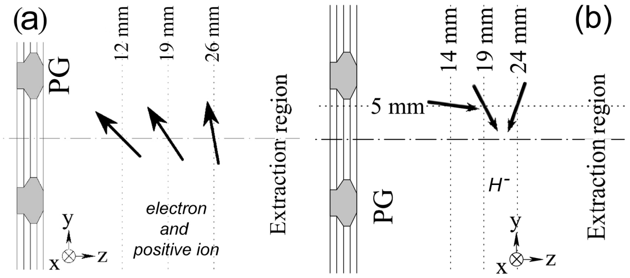

Fig. 2. Flow vectors of (a) electron and positive ion, and (b) H^- near PG.

Incoming parent particles of H^-, such as Flank-Condon hydrogen atom and/or proton, and H^- should satisfy following energy relation.

$$e(\phi - U_{aff}) \geqq \varepsilon_{H^-} - \varepsilon_{in}$$

Here ε_{H^-}, ε_{in}, ϕ and U_{aff} represent outgoing H^- energy, incoming energy of the parent particle, the work function of Cs-covered PG surface and affinity energy of H^-, respectively. In our experiment, ε_{H^-} is 0.10 ± 0.05 eV[3,4] and U_{aff} is 0.75 eV. The value of ϕ is assumed ~ 1.45 eV and ε_{in} should be larger than 0.8 eV. In our experiment, only proton has sufficient energy, ~ 1.0 eV, in this condition[7].

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2) Tsumori, K. et al.: Rev. Sci. Instrum. **83** (2012) 02B116 and Takeiri, Y. et al.: AIP conference proceedings **1655** (2015) 060004.
3) Geng, S. et al.: Rev. Sci. Instrum. **87** (2016) 02B103.
4) Nakano, H. et al.: J. Inst. **11** (2016) C03018.
5) Ikeda, K. et al.: New Journal of Phys. **15** (2013) 103026.
6) Geng, S. et al.: NIFS annual report on 2016 (in this report).
7) Wada, M. et al.: Rev. Sci. Instrum. **87** (2016) 02B107.