§6. Characteristics of rf-based Hydrogen Negative Ion Source with Cs Additive

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Neutral beam injection (NBI) system is one of the powerful and fruitful heating tools in fusion researches. A hydrogen negative-ion (H-) source was developed for a beam source with beam energy more than 100keV, and a large H- source has been successfully operated as a major heating device in LHD.[1),2)] For a long life operation, it is requisite to develop radio- frequency (rf)-driven H- sources. They have no electrode like a filament, usually used in DC-arc driven sources, which limits a source lifetime by its erosion and fragility.

Our purpose of this research is to develop an H- ion source by using a FET-switching inverter power supply as an rf source and an improvement of the rf-driven H- ion source. We have investigated a small ion source with a cylindrical driver region and an expansion region. In the driver region a multi-turn loop antenna was wound around a cylindrical tube made of Al_2O_3 ceramic (inner diameter: 70 mm, outer diameter: 80 mm, length: 170 mm). Turn number of the antenna was changed to adjust optimal coupling. Axial magnetic field can be applied in order to enhance plasma production. An rf-driven hydrogen plasma produced by the FET-based rf source with a frequency of 0.3-0.5MHz.[3),4)] The produced plasma expanded into the expansion region with 10cm in depth. Electron density and temperature were measured at the driver region (Z=70mm from the end of the driver region) and the expansion region (Z=255mm).

Figure 1 shows the dependencies of measured electron density n_e and temperature T_e on the applied axial magnetic field. As the axial magnetic field increased, n_e increased more than twice in the driver region and more than one order of magnitude in the expansion region. In a lower magnetic field below 100G, n_e increased both in the driver and expansion region due to the increase of plasma production rate and reduction of wall loss. In a higher magnetic field, n_e increased only in the expansion region, which indicates the increase of diffusion rate from the driver to the expansion region.

Figure 2 shows dependencies of n_e on the input RF power. In the both regions n_e increased linearly to the input power and attained to nearly $5\times10^{18}m^{-3}$ in the expansion region.

Although the high density plasma was produced at more than 1 Pa, the density decreased at lower pressure around 0.5 Pa. As the RF frequency increased from 0.27 to 0.45MHz, the density increased at lower pressure around 0.5Pa. Further investigation is necessary for more efficient rf plasma production in the low pressure region.

We are going to measure H^- density by the photo-detachment method and to extract H^- beam with Cs vapor injection.

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4) A.Ando, et al., Frontier of Applied Plasma Technology, 2, 67 (2009).
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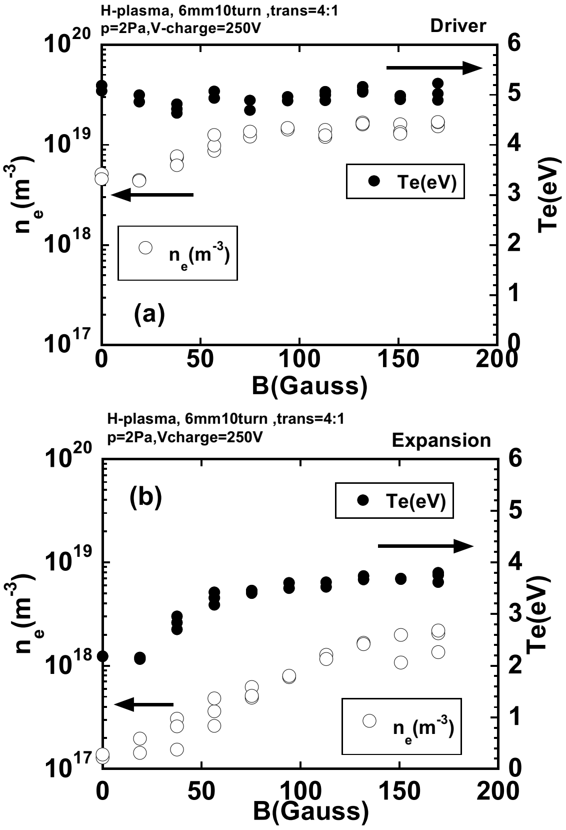

Fig.1 Dependences of electron density and temperature on axial magnetic field in (a) driver and (b) expansion regions. P_{RF}=13kW, p=2Pa.

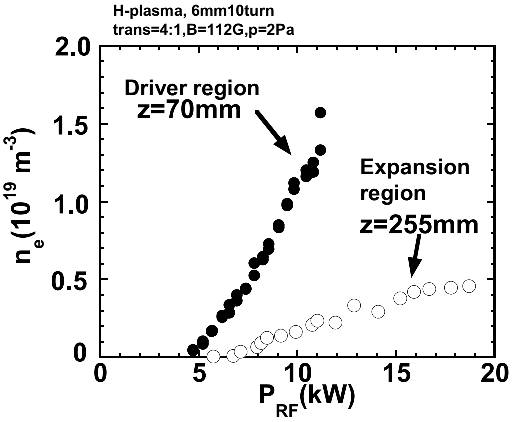

Fig. 2 Dependences of electron density on RF power in the driver and expansion regions. B=112G, p=2Pa.