§10. Long-pulsed Operation of a Negative Hydrogen Ion Source

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Neutral beam injection (NBI) system is one of the powerful and fruitful heating tools in fusion researches. A high power hydrogen negative-ion (H^-) source has been successfully developed for a beam source and operated as a major heating device in LHD.[1),2)] For a long pulse or continuous operation, it is requisite to develop radio-frequency (RF)-driven H^- sources. They have no electrode like a filament, usually used in arc-discharge-driven sources, which limits a source lifetime by its erosion and fragility.

Our purpose of this research is to develop a compact RF-driven H^- ion source by using a FET-switching inverter power supply with a frequency of 0.3-0.5MHz as a RF source and to operate it for long time duration. The small ion source consists of a cylindrical driver region and an expansion region. In the driver region a multi-turn loop antenna was wound around a cylindrical ceramic tube (inner diameter: 70 mm, outer diameter: 80 mm, length: 170 mm). Axial magnetic field can be applied in order to enhance plasma production. Electron density attains to 10^{19}cm^{-3} at the driver region and to more than 10^{18}cm^{-3} at the expansion region.[3),4)] Cesium vapor can be injected to enhance the H^- production. It is necessary to clarify temporal behavior of heat influx to electrodes, cesium behavior in the plasma and beam currents during long pulse operation.

Figure 1 shows temporal evolution of ion saturation current density (j_{is}) during a 100 sec operation of the RF source. As temperature of ceramic tube at plasma production region increased, it was operated with lower RF power during the long time operation. Electron density and temperature were nearly constant in the operation.

H^- beam current was measured using a calorimeter set at downstream of the acceleration grids. In order to clarify the effect of cesium vapor injection and plasma grid temperature we measured temporal behavior of optical line emission of cesium and calorimeter current with gradual increase of plasma grid temperature as shown in Fig. 2.

With using a cesium oven, a small amount of cesium vapor was injected into the chamber and plasma was operated with short pulse length in constant repetition rate during the long duration. After injection of the cesium vapor, we increase the grid temperature gradually up to 260 deg.

Firstly, cesium line emission increased and decreased when the grid temperature increased more than 200 deg. Then H^- beam current measured by a calorimeter gradually increased as shown in the figure. This behavior was related with surface production of H^- ions on the plasma grid. With an increase of the grid temperature cesium atoms accumulated on the grid escaped into the chamber, and thin atomic layer (hopefully half monolayer) covered on the grid surface, which was adequate for H^- ion production.

We are going to investigate the relationship of cesium behavior in the plasma chamber and H^- ion production during a long pulse operation.

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2) K.Tsumori, et.al., Rev. Sci. Instrum., **79** (2008) 02C107.
3) A.Ando, et al., Rev. Sci. Instrum., **81** (2010) 02B107.
4) A.Ando, et al., AIP conf. Proc. **1390** (2011) 322.

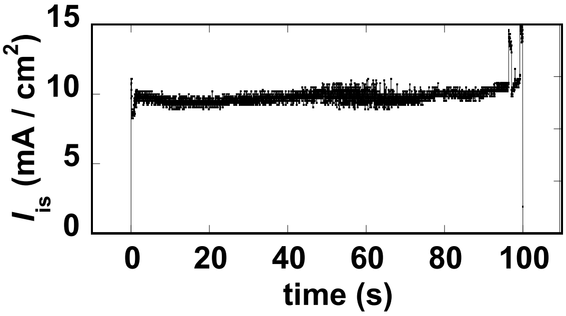

Fig.1 Temporal evolution of ion saturation current density (j_{is}). P_{RF}～2.2kW. f=0.34MHz. B_z=0mT. p=1.9Pa. T_e～3eV, n_e～4.4×10^{16}m^{-3}.

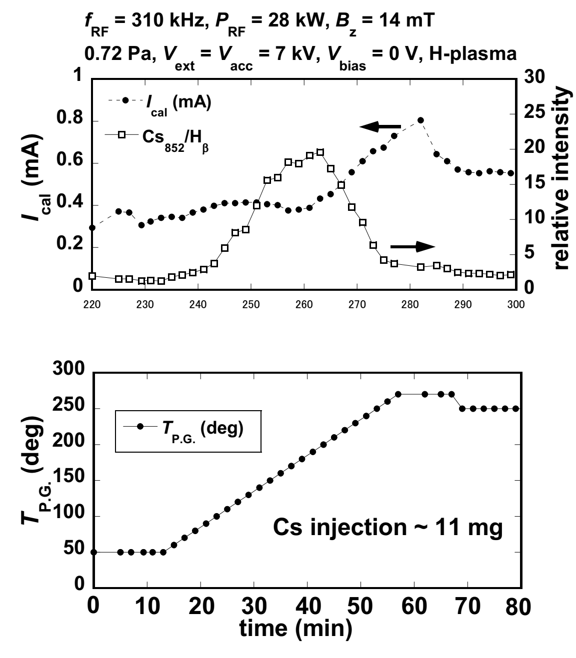

Fig. 2 Temporal behavior of optical emission of cesium line, calorimeter current and temperature of plasma grid. V_{ext}=V_{acc}=7kV, P_{RF}=28kW. P=0.72Pa, f=0.31MHz, B_z=14mT.