# §11. Negative Hydrogen Ion Diagnostics by Using the Cavity-Ring-Down Technique

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Negative hydrogen or deuterium ($H^-$ or $D^-$) beams are required for Neutral Beam Injection heating in fusion reactors, and negative ion sources has been successfully developed. It is known that $H^-$ ions are produced near the plasma grid by (1) volume production from vibrationally excited hydrogen molecules and (2) surface production on a low work function surface (e.g. cesium seeded plasma grid surface). However detailed $H^-$ production mechanism is not clarified yet. Furthermore, because the production mechanisms are different in source operations with and without Cs seeding, comparison of $H^-$ behaviors is important. Thus, negative hydrogen ion diagnostics in the ion source, especially near the plasma grid, is essential. Recently Cavity-Ring-Down (CRD) technique has been used for $H^-$ diagnostics utilizing photodetachment process of $H^-$ ions ($H^- + h\nu \rightarrow H^0 + e^-$) [1]. This technique has been applied for $H^-$ diagnostics in a filament-arc negative NBI ion source at National Institute for Fusion Science [2]. This study aims to apply the CRD technique to a Radio Frequency (RF) ion source and study the characteristics of $H^-$ ions especially effect of Cs seeding.

The CRD diagnostic system was installed in a FET (Field-Emission-Transistor) based RF ion source driven by RF power with a frequency of <1 MHz, which is much lower than that of conventional vacuum tube based RF power supplies [3]. Figure 1 shows Cs seeding effect on $H^-$ ion production. Line intensity of Cs spectrum increased gradually as the Cs oven temperature was increased. The $H^-$ density was measured by CRD and electron density was measured by Langmuir probe. The particle density ratio increased drastically around 180 degrees of oven temperature attaining one order of increase at 190 degrees. Source parameter dependences of the $H^-$ density and $H^-$ to electron density ratio were measured. Laser photo-detachment was used for Cs operation because the CRD mirrors might be contaminated by Cs particles and measurement accuracy might be reduced. The RF power dependence of particle density ratio stayed almost constant with and without Cs seeding, however it was 3 times larger with Cs seeding than without Cs seeding attaining more than 10% of ratio. The pressure dependence of the particle density ratio is shown in Fig. 2. As the source pressure went down, the density ratio showed an increase without Cs seeding. On the other hand, it showed an increase as the source pressure went up. It is assumed that the electron temperature in the driver of ion source affects on the $H^-$ production and low pressure suppresses destruction of $H^-$ when Cs is not seeded. However, when Cs is seeded, Cs dynamics, which depends on the source and plasma conditions, seems to strongly affect on the $H^-$ population.

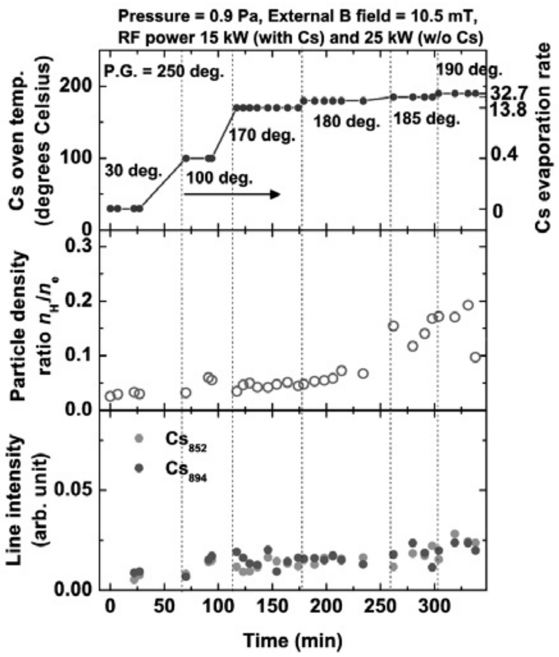


Fig. 1. Cs seeding effect on negative hydrogen ion to electron ratio.

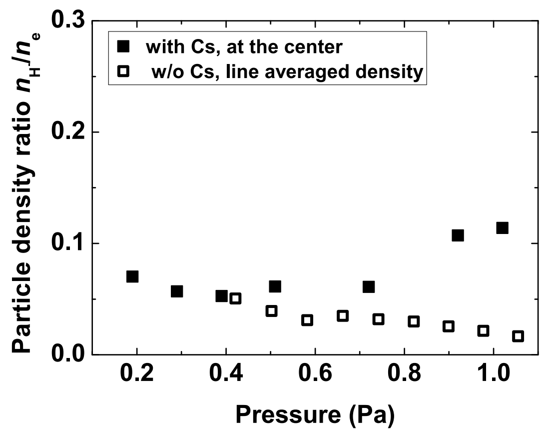


Fig. 2. Pressure dependence of the negative hydrogen ion to electron ratio. Filled plot: with Cs seeding. Open plot: without Cs seeding.

1) M. Berger, U. Fantz, S. Christ-Koch, and NNBI team, Plasma Sources Sci, Technol. **18**, 025004 (2009)
2) H. Nakano et al., AIP Conf. Proc. **1515** 273 (2013)
3) N. Tanaka et al., AIP Conf. Proc. **1515** 263 (2013)