

Experimental Investigation of Negative Ion Production Mechanisms on Cs-Deposited Metal Surfaces

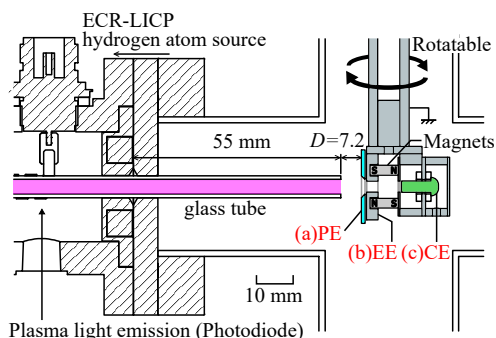
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Abstract

Surface production of negative hydrogen (H^-) ions on Cs-deposited low-work-function materials plays a key role for high-current ion sources used in neutral beam injection. The contribution of atomic hydrogen on surface-produced H^- ion current is difficult to isolate from that of positive ions in conventional ion-source plasmas. In this study, a compact electrode assembly was installed downstream of an ECR-LICP (Electron Cyclotron Resonance Locally Inductively Coupled Plasma) hydrogen atom source to evaluate background signals before Cs deposition. The assembly can be rotated between hydrogen-irradiation and Cs-deposition positions, enabling both Cs deposition and optical diagnostics. Background signals were measured as functions of electrode distance from the atom flux exit, electrode bias, and H_2 flow rate. Shortening the distance to the production electrode and applying a positive collector bias suppressed background components, clarifying conditions for future Cs-assisted H^- measurements.

Experimental setup

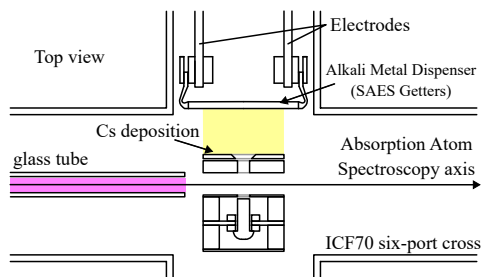
Negative-ion (H^-) detection system



Schematic of the negative-ion detection electrode assembly consisting of:

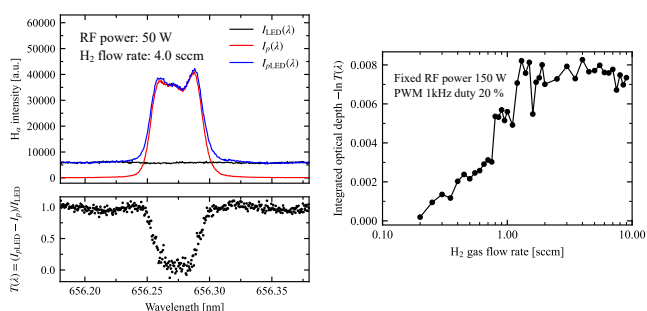
- (a) Production electrode (PE) ← Negative bias for H^- extraction
- (b) Extraction electrode (EE) ← GND
- (c) Collector electrode (CE) ← Positive bias for noise suppression

Cs-deposition system



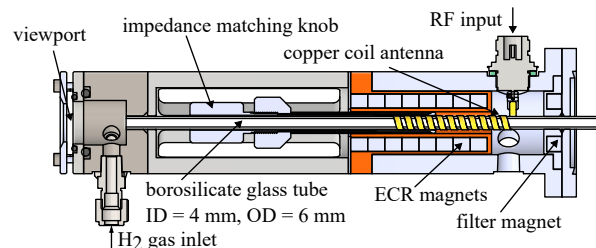
Top-view schematic of the Cs-deposition and spectroscopy arrangement. The electrode assembly can be rotated between the hydrogen-irradiation position and Cs-deposition position that keeps the spectroscopy axis unobstructed enabling optical diagnostics during the experiment.

Atomic Hydrogen Absorption Spectroscopy (Cs deposition position)



Representative Balmer- α emission/absorption spectra and H_2 flow-rate dependence of the wavelength-integrated optical depth. The spectra show strong atomic-hydrogen absorption, and the optical depth indicates a threshold-like increase with H_2 flow rate. The flow-rate dependence was measured at 150 W, 1 kHz, and 20% duty factor.

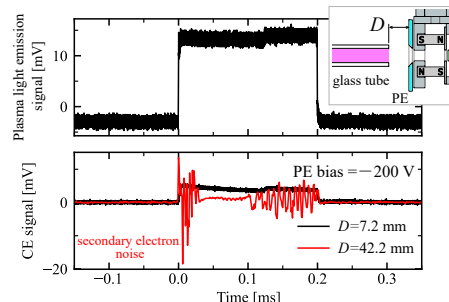
ECR-LICP hydrogen atom source



Validation of the measurement system function

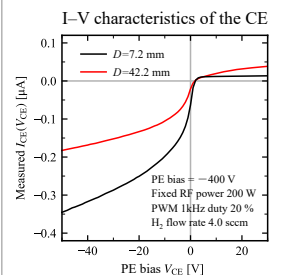
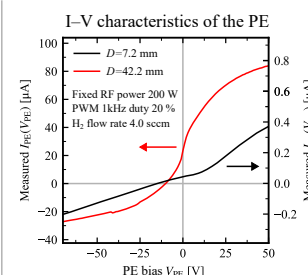
Effect of the distance between the glass-tube end and PE

Temporal evolution of the detected voltage during a PWM pulse



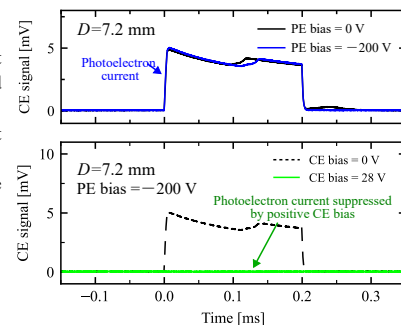
- At $D = 42.2$ mm, charged particles from the atom-source plasma reached the electrode assembly, producing positive-current and electron-noise components in the CE signal.
- Reducing the distance suppressed the electron-noise component and clarified the positive CE signal synchronized with plasma emission.
- The positive CE current increased as the plasma was brought closer, probably because photoelectron current became dominant under stronger local plasma emission.

Shorter distance suppresses charged-particle noise and makes the photoelectron-related signal dominant.



Effect of collector bias

Temporal evolution of the detected voltage during a PWM pulse



The result suggests that the positive signal was mainly a background photoelectron current rather than an extracted ion current.

Dependence on hydrogen flow rate

- The CE signal depended on the H_2 flow rate under the positive CE-bias condition.
- At low flow rate, a short positive CE pulse appeared just after the plasma emission decayed.
- The positive pulse became smaller as the H_2 flow rate increased.
- The signal polarity during RF power induction also changed slightly with flow rate, suggesting that the balance of transient charged-particle and photoelectron-related background components depends on the plasma condition.

