Diagnostics of Ta Deposited Plasma Electrode for Negative Hydrogen Ion Production with DC Laser Photodetachment Method

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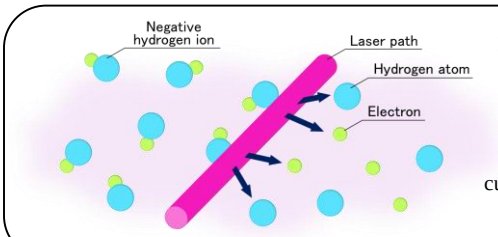
Abstract

Negative hydrogen ion (H^-) density near an extractor depends upon materials which cover plasma electrode (PE) surface. Tungsten and tantalum were compared as adsorbate on a PE using filaments evaporation made of these elements in a H_2 discharge plasma. The difference of the filament material and PE bias voltage showed different characteristics of the intensity of extraction current and that of H^- ion current. For the tantalum filament operation, photodetachment signal showed a similar property of extraction current against the bias voltage while the tungsten filament operation indicated a plateau near the anode potential.

Principle



$H^- + h\nu \rightarrow H + e^-$

Lock-in amplifier detects detached electrons as photodetachment current corresponding laser modulation frequency.

Experimental apparatus

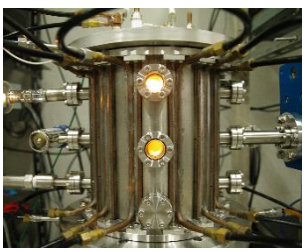


Fig. 1. A picture of the ion source.

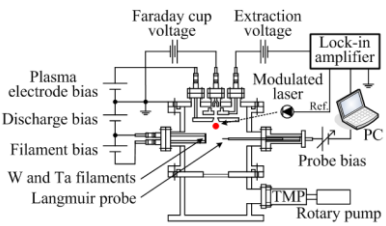


Fig. 2. A schematic diagram of the measuring system.

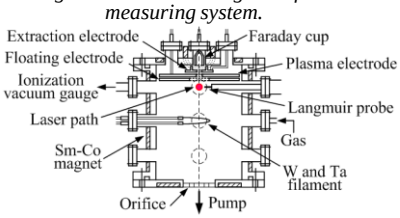


Fig. 3. A schematic diagram of the ion source.

Cylindrical ion source
- 150 mm inner diameter
- 200 mm length
- made of stainless steal
- applying a multicusp magnetic field
- 3.0×10^{-5} Pa of the ultimate pressure

W and Ta filaments
- 0.35 mm diameter
- 90 mm length

Plasma electrode
- 145 mm diameter
- 5 mm hole diameter
- 3 mm distant from EE
  1 mm distant from FE

Semiconductor laser
- 808 nm wavelength
- 0.4 W of beam power
- irradiated at 12 mm distant from the PE
- modulated by a chopper to 683 Hz

Langmuir probe
- 0.35 mm diameter
- 5 mm length
- made of tungsten
- 9 V of probe bias
- located on the laser path

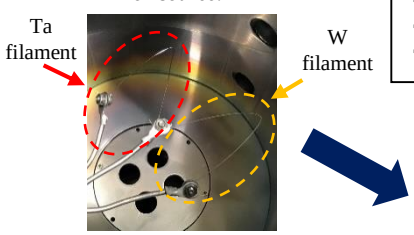


Fig. 4. A picture of the filaments.

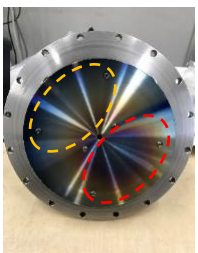


Fig. 5. A picture of the plasma electrode after experiments.

- Both tungsten and tantalum were deposited on the plasma electrode surface due to evaporation from the hot cathode filaments.
- Thicker film was observed on the chamber wall surface of Ta filament side.

Results

Extraction current and Faraday cup current

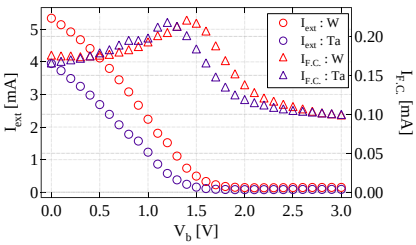


Fig. 6. Extraction current (circles) and Faraday cup current (triangles) against plasma electrode bias voltage.

- Discharge voltage : 80 V
- Discharge current : 1.2 A

W filament
- Filament voltage : 8.7 V
- Filament current : 11.9 A
- Gas pressure : 0.9 Pa

Ta filament
- Filament voltage : 8.5 V
- Filament current : 9.5 A
- Gas pressure : 0.7 Pa

- The W filament operation showed the maximum $I_{F.C.}$ at 1.4 V of V_b.
- The Ta filament operation showed the maximum $I_{F.C.}$ at 1.2 V of V_b.
- I_{ext} of the W filament operation was higher than that of the Ta filament.

Photodetachment current comparing the extraction current

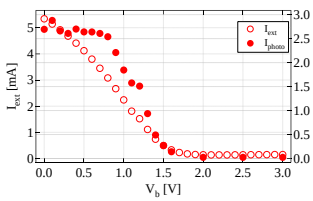


Fig. 7. Photodetachment current against PE bias voltage (W).

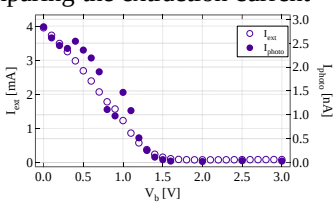


Fig. 8. Photodetachment current against PE bias voltage (Ta).

- Photodetachment current was detected by the extraction electrode.
- Photodetachment current decreased as the bias voltage increased.
- The Ta filament operation followed I_{ext}, while the W filament operation showed a plateau near the anode potential.

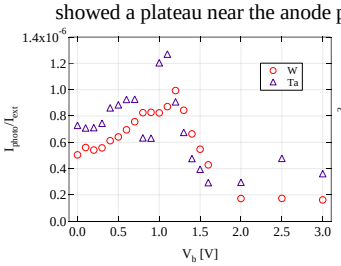


Fig. 9. Ratio of I_{photo} and I_{ext} against plasma electrode bias.

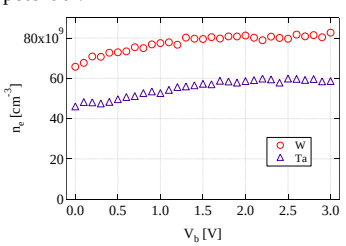


Fig. 10. Electron density against plasma electrode bias.

- The W filament operation showed higher electron density than the Ta filament operation.
- Electron density increased as the bias voltage increased, and saturated over approximately 1.5 V.

Conclusion

- Tungsten operation made the bias potential to draw maximum I_{H^-} higher than the bias for Ta filament operation. For the similar I_{H^-}, I_{ext} of the Ta filament was about 74 % of I_{ext} for the W filament at the anode potential.
- Photodetachment current signal onto the extractor showed a V_b dependence similar to I_{ext}, when Ta was the filament material. When the bias potential to the PE was close to the anode potential, W filament formed the plasma producing constant photodetachment current; *i.e.* I_{photo}/I_{ext} took a maximum at $V_b \fallingdotseq$ 1.2 V before the signal start to decrease.