§11. Development of Cesium-Free Deuterium/ Hydrogen Negative-Ion Source with Metal Catalectic-Ionization Method

Oohara, W., Tauchi, Y., Fujimoto, S., Nakano, T., Tashima, S. (Dept. Electronic Device Eng., Yamaguchi Univ.),
Fukumasa, O. (Ube National Col. Technol.),
Takeiri, Y., Tsumori, K.

Development of deuterium/hydrogen negative-ion source without cesium admixture is performed upon surface production of atomic ions on porous catalysts with discharged-plasma irradiation. First of all, the production property of hydrogen ions is investigated.

Experimental setup of a dc arc-discharge negative ion source is shown in Fig. 1. The rectangular chamber with line cusp magnetic fields is 25 cm x 25 cm in cross section and 19 cm in axial length. U-shaped tungsten filaments with 0.5 mm diam and 15 cm long are set in the arc discharge region. A commercially available porous plate (Celmet, Sumitomo Electric Toyama Co., Ltd.) made of Ni is set at an external magnetic filter composed of a pair of permanent magnets, and a parallel magnetic field along the porous surface is applied. The porous plate acts a catalyst with a porous body of 47-53 cells/inch, a pore size of 0.55 mm, a thickness of 3 mm, a specific surface area of 2,800 m^2/m^3, and a porosity of 95 %. The porous catalyst can be biased at dc voltage V_{pc} and the chamber wall is grounded. Plasma parameters are measured by Langmuir probes, and an extracted current of negative ions can be analyzed by a magnetic-deflection-type ion analyzer behind an end plate.

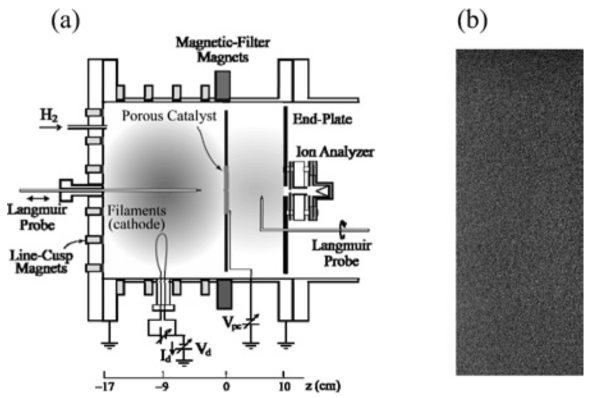

Fig. 1. (a) Experimental setup. Hydrogen plasma is generated by dc arc discharge and irradiated to Ni porous catalyst. Atomic ions are produced from the back side of the irradiation plane. (b) Photo of the porous plate.

A plasma potential at z = −5 cm is almost +4 V independent of the discharged power P_d and the bias voltage V_{pc}. Positive ions in the discharged plasma are irradiated to the porous catalyst at $V_{pc} < 0$ V and an ionic plasma is observed at $z > 0$ cm. The irradiation energy of positive ions is $e(\phi_s - V_{pc})$. The properties of ion production $I_\pm$ and irradiation current I_{ir+} to the porous catalyst as a function of P_d are shown in Fig. 2 (a) at the filter magnetic field of B_{MF} = 12 mT, where $e(\phi_s - V_{pc})$ is almost fixed at 110 eV. $I_\pm$ are positive and negative saturation currents of the probe, proportional to the production flux of ions. The amount of ions produced from the catalyst surface increases in proportion to I_{ir+} under the irradiation energy fixed. On the other hand, the properties of $I_\pm$ as a function of $e(\phi_s - V_{pc})$ are shown in Fig. 2 (b) at P_d = 300 W, where I_{ir+} is almost fixed at 6 mA. The amount of ions produced increases at several specific energies of irradiated ions. The peak energies are clarified to decrease in proportion to B_{MF}.

The production mechanism of the ions is considered to be completely different from conventional production mechanisms of converter type and cesium-seeded type, which is based on an electronic transition of metals with low work functions. Hydrogen atoms, produced by dissociative adsorption, are covalently bound with the surface-metal atoms, and can easily move along the surface, i.e., surface migration occurs. Surface migration on catalysts such as Ni and Pt is a well-known fundamental phenomenon. Hydrogen atoms migrate along the pore surface in the porous catalyst to the back side of the irradiation plane. We consider that an electronic transition occurs between the surface-metal atoms and hydrogen atoms during desorption from the surface. We refer to this process involving dissociative adsorption, surface migration, and desorption ionization as catalectic ionization. The phenomenon of catalectic ionization under plasma irradiation has not been previously reported to the best of our knowledge.

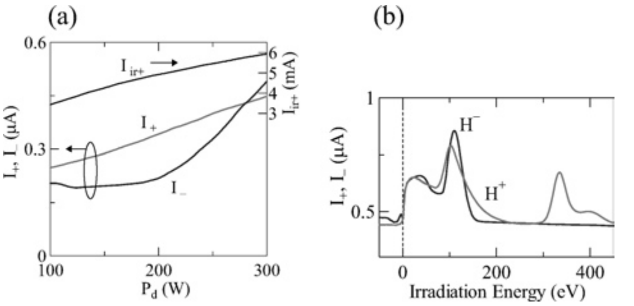

Fig. 2. (a) Properties of ion production and positive-ion irradiation current as a function of discharged power. (b) Production property of ions as a function of irradiation energy, fixed the irradiation current.

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