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Hydrogen and helium removal retained in stainless steel by neon glow discharge

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ABSTRACT

In order to examine the effect of neon glow discharge on hydrogen or helium removal, neon glow discharge was conducted for the stainless steel after the exposure to hydrogen or helium glow discharge, and then the amount of desorbed hydrogen or helium and retained neon were evaluated. Large hydrogen desorption was observed at the initial period of the neon discharge following the hydrogen discharge. The removal ratio of retained hydrogen by the neon discharge with 2 h was 1.3 times larger than that by the argon discharge, and a half of that by the helium discharge. In the case of the neon discharge following the helium discharge, the removal ratio of retained helium was 4 times larger than that by the argon discharge. The amount of retained neon was an order of magnitude smaller than that of helium retained in the stainless steel.

1. Introduction

Hydrogen isotope retention in plasma-facing material is one of the important issues concerning with the safety and the density control of fusion reactor [1]. The helium glow discharge cleaning has been widely employed in order to remove the hydrogen isotope and impurities from the first wall [2,3]. The large helium desorption from the first wall, however, was observed during the main discharge in the Large Helical Device (LHD) [4], resulting in the deterioration of the plasma confinement. So, the alternative or additional conditioning method might be necessary for the reduction of hydrogen isotope and/or helium retention. The neon glow discharge might be attractive cleaning method for the removal of retained hydrogen isotope and/or helium. However, the effect of neon glow discharge cleaning on the removal of retained hydrogen and helium has not been evaluated sufficiently so far. In the present study, neon glow discharge experiment was conducted for the stainless steel which has already retained hydrogen or helium, and then the amount of desorbed hydrogen or helium and retained neon was evaluated by residual gas analysis and thermal desorption spectroscopy using a sample probe system. The results of neon glow discharge cleaning were compared with those of argon glow discharge obtained in the previous study [5]. The current density dependence of the discharge gas retention and the removal ratio of gas retention were also investigated.

2. Experiments

The schematic diagram of the glow discharge device used in the present study was shown in Fig. 1. The cylindrical liner made of 316L SS, which was the same material of plasma-facing wall in LHD, was installed in the device. Introducing a constant flow of discharge gas using mass flow controllers, the glow discharges were conducted between a copper anode and the liner at room temperature. The discharge pressure was 8 Pa. The discharge duration was 2 h. The discharge voltage was 200–300 V. During the discharge, the desorbed or retained amount of gases for the liner was quantitatively measured by a residual gas analysis using a quadrupole mass spectrometer in the differential pumping system. The desorbed or retained amount was obtained from the pressure decrease or increase during the discharge. These amounts were normalized by the surface area of the liner (7700 cm^2).

In order to evaluate the hydrogen removal by glow discharge, helium, argon or neon glow discharge was conducted to the liner in which hydrogen have been already retained by the hydrogen glow discharge. In addition, in order to evaluate the effect of glow discharge on the reduction of helium retained in the liner, the argon or neon glow discharge was also conducted to the liner in which helium have been already retained by the helium glow discharge.

In addition, the 316LSS probe samples were set on the sample station in the device, and then the probes were exposed to the several glow discharges. After the plasma exposure, the probes were analyzed by thermal desorption spectroscopy [6] in order to evaluate the amount of retained or desorbed discharged gas during the discharge.

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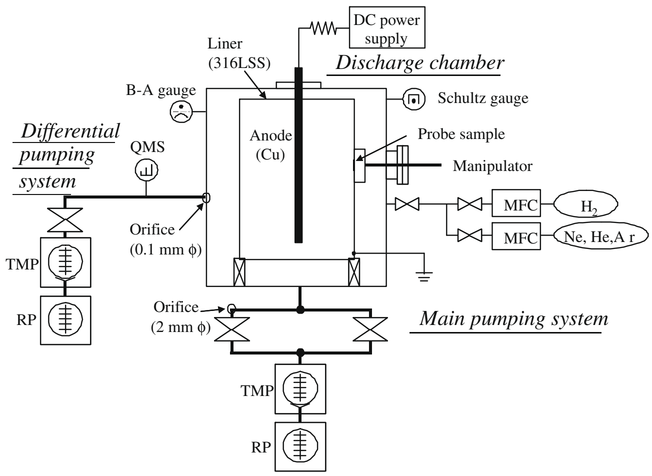

Fig. 1. Schematic diagram of the glow discharge device.

In order to investigate the current density dependence of the discharge gas retention and the removal ratio of gas retention, the helium, argon and neon glow discharge experiments were carried out by changing the current density.

3. Results and discussion

3.1. Reduction of hydrogen retention by neon glow discharge

Before the glow discharge cleaning using neon gas, the hydrogen glow discharge was conducted in order to retain the hydrogen in the liner. The amount of retained hydrogen by the hydrogen discharge was estimated as 5.2×10^{16} H/cm^2 by the residual gas analysis. Fig. 2 shows the time evolution of hydrogen and neon partial pressure during the neon glow discharge after the hydrogen glow discharge. The ion current density was 1.5×10^{-5} A/cm^2. Large desorption of hydrogen from the liner in addition to the neon retention was observed at the initial period of the glow discharge. The hydrogen desorption rate was almost constant above 2000 s in the discharge time. The amount of desorbed hydrogen during the neon glow discharge was 2.4×10^{16} H/cm^2, which corresponded to 47% of the amount of retained hydrogen before the neon glow discharge.

Thermal desorption spectrum of the probe exposed to the hydrogen discharge followed by the neon glow discharge is shown in Fig. 3. The spectrum of the probe exposed only to the hydrogen discharge was also shown. The spectrum of the probe exposed only to the hydrogen discharge had two large peaks at 680 and 1200 K. These peaks almost disappeared after the neon glow discharge. This result clearly indicates that the hydrogen retention in the SS probe can be significantly removed by the neon glow discharge.

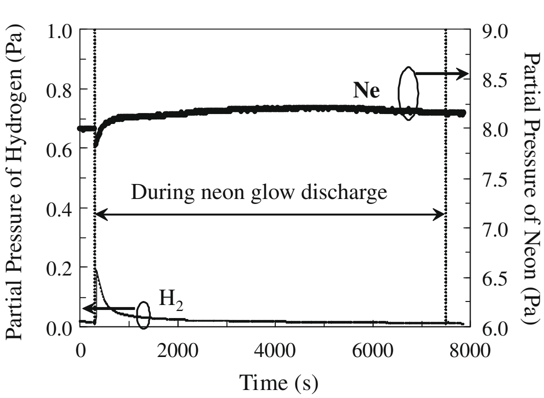

Fig. 2. Time evolutions of hydrogen and neon partial pressures during the neon glow discharge after the hydrogen discharge.

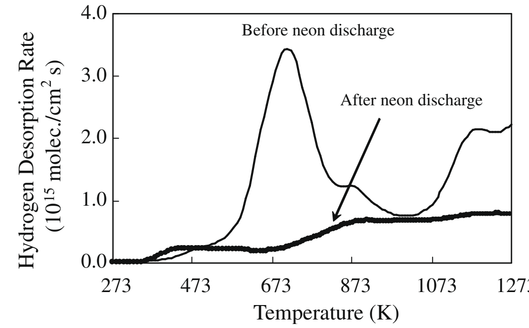

Fig. 3. Thermal desorption spectra of the probes exposed only to the hydrogen discharge and to the hydrogen discharge followed by the neon glow discharge.

3.2. Reduction of helium retention by neon glow discharge

The amount of retained helium after the helium glow discharge was estimated as 2.1×10^{14} He/cm^2. Fig. 4 shows time evolution of helium and neon partial pressure during the neon glow discharge after the helium glow discharge. Helium desorption with relatively long period was observed during the neon glow discharge. This long desorption behavior might be owing to the small diffusion coefficient of helium atom, compared with that of hydrogen atom. The amount of desorbed helium was 1.1×10^{14} He/cm^2, which cor-

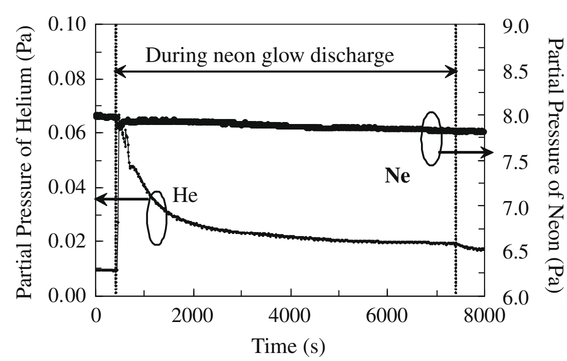

Fig. 4. Time evolutions of helium and neon partial pressures during the neon glow discharge after the helium glow discharge.

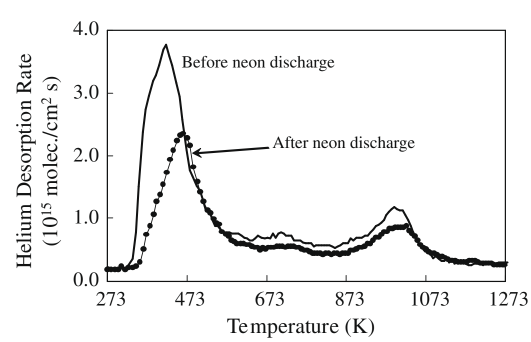

Fig. 5. Thermal desorption spectra of the probes exposed only to the helium discharge and to the helium discharge followed by the neon glow discharge.

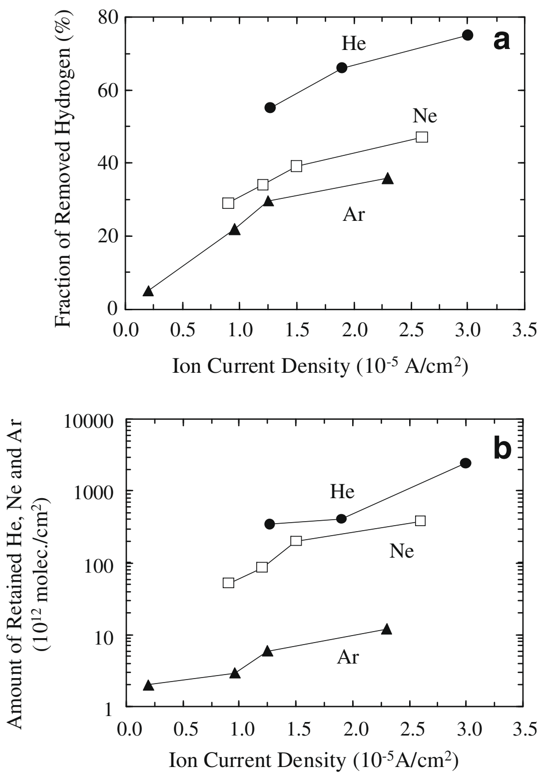

Fig. 6. Ion current density dependences of fraction of removed hydrogen (a), and of retained amount of discharge gases (b).

responded to 51% of the amount of retained helium before the neon glow discharge.

Thermal desorption spectra of the probe exposed only to the helium discharge and to the helium discharge followed by the neon glow discharge is shown in Fig. 5. In the case exposed only to the helium discharge, a large peak appeared at 450 K with a small one at 1000 K. After the neon discharge for the helium-retained SS probe, the peak at 450 K became small.

3.3. Current density dependences of discharge gas retention and discharge cleaning

Ion current density dependence of fraction of removed hydrogen is shown in Fig. 6(a). It was found that the discharge using helium gas was the most effective for the reduction of hydrogen. In the case of the neon discharge with 2 h, maximum fraction of removed hydrogen was 1.3 times larger than that by the argon discharge, and a half of that by the helium discharge in the present study. Large fraction of removed hydrogen in the case of helium discharge was owing to large energy transfer and little sputtering. In the case of argon discharge, it is speculated that significant sputtering occurred and then a thick re-deposited layer was formed on the SS liner. The re-deposited layer may result in small fraction of removed hydrogen in the case of the argon discharge. Ion current density dependence for amounts of retained discharge gases is shown in Fig. 6(b). Large gas retention was observed in the case of the helium discharge. The amount of retained neon was an order of magnitude smaller than that of retained helium, and an order of magnitude larger than that of retained argon for the stainless steel. The large helium retention might be owing to the easy formation of the blister because of its deep projected range. Both the fraction of removed hydrogen and amounts of retained gases increased with the ion current density.

4. Summary

In order to examine the effect of neon glow discharge cleaning on hydrogen or helium removal, neon glow discharge was conducted for the stainless steel after the exposure to hydrogen or helium glow discharge. The removal ratio of retained hydrogen by the neon discharge with 2 h was 1.3 times larger than that by the argon discharge, and a half of that by the helium discharge. In the case of the neon discharge following the helium discharge, the removal ratio of retained helium was 4 times larger than that by the argon discharge. The amount of retained neon was an order of magnitude smaller than that of retained helium in the stainless steel. The effect on hydrogen or helium removal and the retention of discharge gas species is associated with the sputtering of the liner followed by the re-deposition and projected range of ion. These results indicate that the neon glow discharge is more attractive than the argon glow discharge for the reduction of hydrogen isotope retention, although the neon retention in the stainless steel is not negligible.

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