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Retention and Desorption of Hydrogen in QUEST (2)
QUESTプラズマ対向壁の水素吸蔵・放出特性(2)

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QUEST in Kyushu University is a medium-sized spherical tokamak aiming steady-state operation. In the experimental campaign in spring/summer, 2014 (2014SS), long pulse operation have improved very much. In order to understand the plasma-wall interaction, which often limits the plasma duration time, characters of the plasma facing surface was measured globally by using color analyzer and many other experimental techniques complementary. Due to strong plasma discharges, entire plasma facing surface were colored more or less by the deposition of impurities such as C, W, Fe and O. Not only the impurity deposition dominant area but also the erosion dominant area original strong retention of hydrogen in 316LSS is suppressed very much by the modification of the surface due to plasma wall interaction. This will be favorable to keep particle balance long under operation.

1. Introduction

One of a major purpose of QUEST is to study on steady-state operation. Long pulse discharges are often terminated due to loss of plasma particle control, namely abruptly desorbed hydrogen from the plasma facing surface (PFS) exceed the pumping power. The reason of the termination was also the loss of particle balance due to uncontrollable increase of hydrogen. Therefore, understanding hydrogen behavior in the plasma facing materials under the long pulse operation is very important to establish steady-state operation.

In the experimental campaign 2014SS long pulse operation have been progressed well by keeping the particle balance well. In the preset work, therefore, modification of plasma facing surface and the characteristics of hydrogen trapping and detraining have been studied to understand the reason for the improvement of long pulse operation and for further progress.

2. Experimental procedures

In the experimental campaign 2014SS, many metal coupons made of 316LSS (material for the wall), W (material for diverter, limiter and wall in future), Mo were placed on the 7 representative points on the PFS. After exposing to the plasmas through the campaign, they were taken out and successively examined by transmission electron microscopy (TEM), scanning electron microscopy (SEM), grow discharge optical emission spectroscopy (GD-OES), X-ray photo-electron spectroscopy (XPS), thermal desorption spectroscopy (TDS). Color of the coupons and also that of the wall was measured by using newly developed potable type color analyzer with an integrating sphere light source (CA).

Microscopic structure of PFS such as impurity deposition and radiation damage were examined by preparing two types of specimens; pre-thinned ones for observation of crystal structure and damage in detail, and cross-sectional ones picked up by first ion beam technique (FIB) for cross-sectional observation of the microstructure.

In order to understand how the PFS retain and desorb hydrogen under the long pulse discharges, 1 keV-D_2^+ were injected 3×10^{21} D_2^+/m^2 into the plasma-exposed coupons of 2014SS, and two hours later, TDS spectrum of D_2, DH and He under constant rate heating with 1 K/s were measured successively.

3. Results and Discussions

A picture of the inner wall after 2014SS and the RGB (red, green and blue) measured by the CA are shown in Fig.1. In the present case the RGB values of white are (1023, 1023, 1023). At the very upper part of the wall (from position 1 to 4 noted in the picture) RGB values are very low (300~400), because the surface is covered by very thick impurity deposition (>200nm) such as C, W and Fe. In contrast, the RGB values between 5 and 14 is quite high. In this area sputtering erosion is dominant, though very thin impurity deposition layer always remains on the surface. The surface at the lower half (from 18 to 30) is very different, namely, it is covered rather homogeneously by an impurity layer. It is remarkable that the deposition of impurities at the equator wall is affected by the large holes for ports.

In order to understand hydrogen behavior at the typical area such as erosion dominant area at the upper half, deposition dominate area at the lower half and the equator, TDS spectrum of D_2 and DH of 316LSS coupons placed at the P16-OE, P16-B and P16-E were measured and their results are shown in Figs. 2 and 3 together that from the virgin 316LSS. Very large thermal desorption of injected D up to 450K from the virgin 316LSS is suppressed two order of magnitude by the deposition of a thick impurity layer (P16-E, P16-B). It should be favorable for the particle control, because the wall temperature of the QUEST is about 373K under the operation. It is worth to note that the retention and desorption of injected D is much small (1.5 order of magnitude lower) at typical erosion dominant area (P16-OE). This result is very different from those of the former campaign, in which suppress by the thin deposition is only 30-50%. Remarkable changes of the 2014SS from the formed campaigns is increasing of hydrogen flux at the wall and remarkable deposition of W. As shown in Fig.3, desorption of HD from P16-E below 600 K is about one order of magnitude higher than that from P16-B coupon. HD desorption is related to the quantity of H retained in the coupon under the plasma discharges. This difference of HD desorption will be important to understanding the flux of the hydrogen at each type of area.

Prominent sputtering erosion and deposition of metallic impurities may change the surface properties of the 316LSS wall. It is considered that strong reduction of D retention, which may contribute to the dynamical retention under plasma discharge, may contribute to the improvement of long pulse operation in the 2014SS campaign.

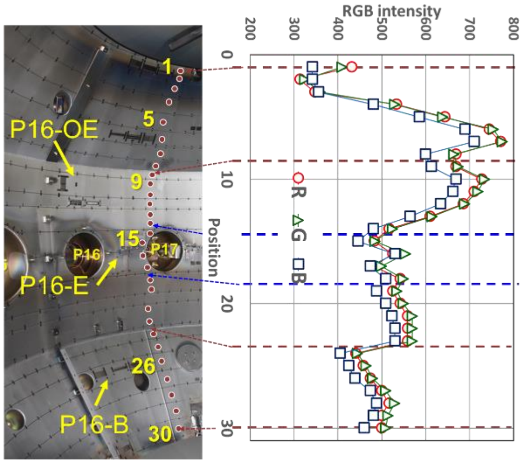

Fig.1 Inner wall surface and its RGB

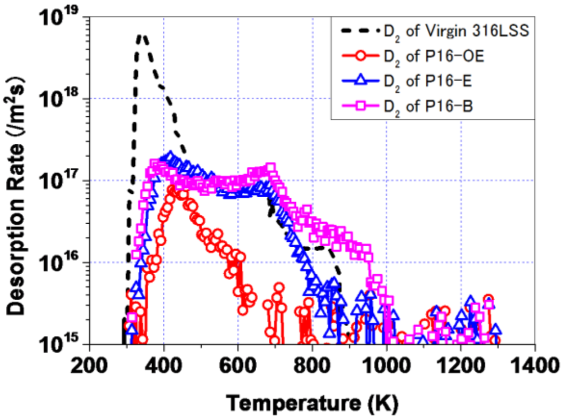

Fig.2 TDS spectrum of D_2

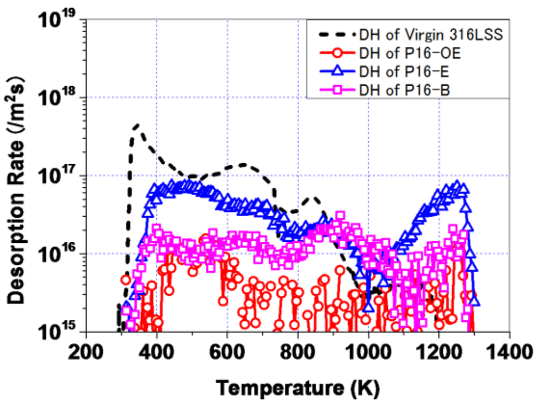

Fig.3 TDS spectrum of HD