Effects of Boronization in LHD

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Abstract

Boronization (boron coating) using diborane was carried out in the Large Helical Device (LHD) for wall conditioning. Using three nozzles for the diborane supply, about 60 % area of the vacuum chamber was covered by boron film. Oxygen impurity radiation was strongly reduced by gettering, and radiation from carbon and metals were reduced about 30 – 40 % by coverage with boron film. As a result, radiation loss was reduced and the operational density exceeded 1×10^{20} cm^{-3}, which is about twice of that before boronization.

Keywords:
boronization, diborane, wall conditioning, impurity, radiation loss, operational density regime, LHD

It is well known that a good wall condition is essential to obtain good plasma performance. Various boron compounds are using for boronization; B_2H_6 in TEXTOR [1], B_2D_6 in DIII-D [2] and Alcator C-Mod [3], $B_{10}D_{14}$ in JT-60 [4], and $B(CD_3)_3$ in MAST [5] and NSTX [6]. To reduce impurity release from the chamber wall, boronization (boron coating) using diborane (B_2H_6) at room temperature without wall baking was started from FY2001 (5th experimental campaign) in the Large Helical Device (LHD) for wall conditioning. One nozzle at a diborane supply unit was used to supply diborane into the LHD vacuum chamber. In FY2002 (6th experimental campaign), two more nozzles were installed to increase the coated area.

During boronization, the exhaust gas from the pumping system was led to the diborane filter unit and the residual diborane was changed into a nontoxic oxidized gas by catalysis. In order to detect any leaking diborane, 6 diborane detectors were installed around this system.

Diborane was introduced into a helium glow discharge plasma without wall baking. The introduced diborane was easily decomposed into boron and hydrogen by the glow discharge. Most of the hydrogen was exhausted and boron was coated on the vacuum chamber wall with residual hydrogen. After boronization, the helium glow discharge was continued for three hours to reduce decomposed hydrogen in the boron film. H_α emission from the glow discharge plasma was reduced by one order of magnitude by this three hours of glow discharge. It needed 1.5 days to reduce the next one order of magnitude. By this coating, oxygen was trapped into the boron film by a gettering effect and kept in the form of boron oxide [7]. Other impurities on the chamber wall were covered by the boron film and their releases from the wall were suppressed.

During the 5th experimental campaign, boronizations with one nozzle were carried out two times in LHD. The boronization durations were 6 and 7 hours, respectively, and the supplied volumes of diborane were 7.2 normal liter (NL) and 14.4 NL, respectively. The thicknesses of the boron films estimated from the supplied boron volume were 20 nm and 40 nm, respectively. It was estimated that about 2 sectors (20 – 25 % of LHD chamber wall) were coated with boron.

During the 6th experimental campaign, boronizations were carried out three times using three nozzles. The durations of the boronizations were 5, 7 and 7 hours

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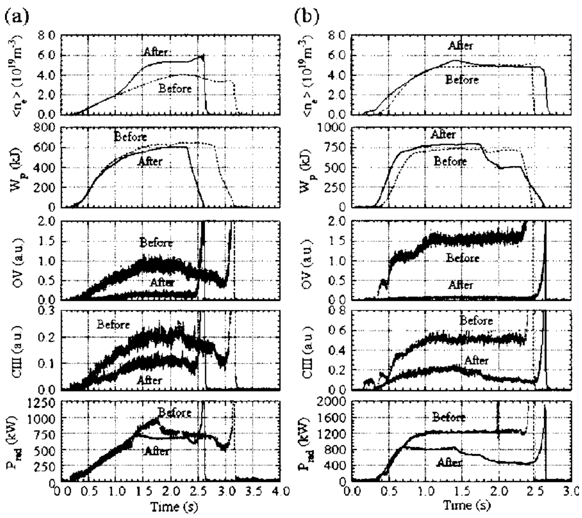

Fig. 1 Comparison of plasma parameters between before and after boronization.
(a) results of 5th campaign (one nozzle),
(b) results of 6th campaign (three nozzles).

and the supplied volumes of diborane were about 14, 22 and 22 NL, respectively. The averaged thickness of the coated boron film estimated from the supplied diborane volume was 30 – 55 nm , and the coated area was about 60 % of the vacuum chamber. In this estimation, we used the boron film density of about 1.2 g/cm^3 [8].

Figure 1 shows a comparison of plasma parameters before and after boronization in the cases of (a) one nozzle and (b) three nozzles for the diborane supply. Neutral beam injection powers were about 5 MW in the case of (a) and about 6 MW in the case of (b). The decrease of carbon (CIII) was roughly proportional to the coated area. Metal impurities also showed similar results. This indicates that the sources of carbon and metal impurities are covered with the boron film and prevented their release. The oxygen (OV) was reduced to less than 10 % in the case of (a) and to less than 1 % in the case of (b). It means that the reduction of the oxygen is caused by the strong gettering effect other than the covering effect. Comparison of the reduction rate of the radiation loss (P_{rad}) with the oxygen indicates that the contribution of the oxygen to the radiation loss is not significant in the LHD plasma.

Figure 2 shows an operational regime of density and stored energy before and after boronization. As shown in Fig. 1, Figs 2 (a) and (b) are the results of one nozzle and three nozzles, respectively. The solid

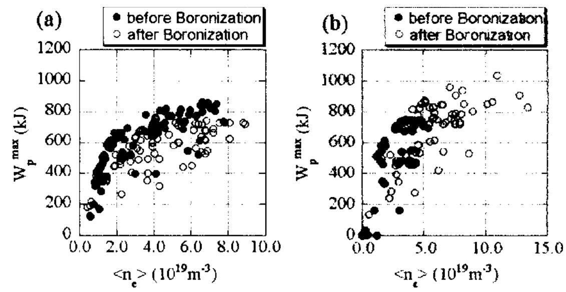

Fig. 2 Comparison of operational regime for density and stored energy before and after boronization.
(a) results of 5th campaign (one nozzle),
(b) results of 6th campaign (three nozzles).

symbols and the open symbols show the data before and after boronization, respectively. Although hydrogen pellets were a useful tool to increase density, it was hard to keep the high density for an extended time. For this reason, these figures do not contain the pellet data. An operational regime of the electron density was extended to the higher density regime after the boronization in both (a) and (b) cases. The rate of increase in the density was close to the rate of decrease in the radiation loss. Since the boronization incorporated the hydrogen in the boron films, recycling of the hydrogen and difficulty of low density operation were concerns [9]. However, as shown in Fig. 2, low-density operation was possible after boronization just as before boronization.

To investigate the details of the boronization, many sample probes were installed at various positions of the LHD vacuum chamber. The analyzed results of these samples will be reported in another paper.

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