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Particle Recycling at Carbon Deposited Tungsten Surfaces Facing TEXTOR-94 Plasmas

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Abstract

The W poloidal limiter was placed beyond the LCFS determined by the carbon toroidal limiter ALT-II to form a C layer on the W surface. The formed C layer could be removed by plasma radiation about 1.5×10^{19} cm^{-2} deuteron fluence when the limiter was kept in the shadow of ALT-II for about 60 discharges. When the surface was kept in the shadow for about 1600 discharges, the C layer became stable against plasma exposures and the intensity ratio of the line spectrum emission of WI to Dγ was reduced by one order of magnitude, while the e-folding lengths of spectrum intensities toward the plasma center for Dγ, WI, CII and OII were unchanged. The surface showed an increase in intensity of CD band spectrum as the limiter was exposed to plasma heated by a 5 s NBI pulse.

Keywords:

tungsten, particle recycling, TEXTOR-94

1. Introduction

There is the possibility that both low-Z and high-Z materials are used as first wall materials for a future fusion experiment device. When both low and high-Z materials are present in the inner surface of the confinement device, they are removed from the wall, penetrate into the edge plasma, and are deposited on other parts of the wall made of different materials. The deposition layer of a low-Z element on high-Z material or vice versa should show particle recycling different from the pure material, and affect the condition of the edge plasma.

To see the change in the characteristics of particle reemission from the surface due to a mutual contamination between C and W, a test limiter half made of C and another half made of W had been put into the edge plasma of TEXTOR-94 beyond the LCFS [1]. The change in the impurity emission from the part directly exposed to an edge plasma radiation had been observed after several tens of shots. The post-mortem analysis had shown the formation of W implanted C, and C implanted W layers on the limiter surface [2].

Meanwhile, the amount of impurity C-flux in the TEXTOR edge plasma can be up to 2 to 3% of deuteron flux because of C released from the toroidal belt limiter

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ALT-II. The poloidal limiter made of vacuum plasma sprayed (VPS) W deposited on graphite with a Re interlayer was installed to study its impact upon the TEXTOR plasma [3]. After the experiment the limiter had been withdrawn from the plasma, and kept outside of the LCFS. At the time of vacuum opening the limiter was taken out of TEXTOR, and the surface was confirmed coated with C layer in the postmortem analysis [2]. The thickness of the C layer on the poloidal limiter was larger than that of a twin limiter, and the particle recycling can be completely different between two limiters. To investigate the change in impurity emission due to the formation of this C layer, a series of experiments has been conducted by installing new blocks of W poloidal limiter, and coat it with C by keeping in the shadow region of the ALT-II belt limiter for specified numbers of shots.

2. Experimental Arrangement

TEXTOR-94 was operated with the standard discharge conditions of I_p~350 kA and B_T~2.24 T. Core plasma parameters were obtained from the routine diagnostics, while the edge electron temperature and density were obtained from He atomic beam diagnostic method [4]. The ALT-II main limiter fixed the plasma minor radius to be 46 cm. The poloidal limiter was moved further into the plasma beyond 46 cm minor radius to be exposed to TEXTOR plasmas.

The experimental set up for the local particle emission measurement from the poloidal limiter surface is schematically illustrated in Fig. 1. The surface of the poloidal limiter was observed from the toroidal tangential direction through an optical spectrometer that covered the wavelength range from 415 to 437 nm. A CCD camera observing the W poloidal limiter surface through a 1.5 nm bandwidth interference filter at 400.9 nm was used to monitor a two dimensional spatial distribution of WI neutral line spectrum emission. There was another CCD camera installed to observe the optical image of the limiter.

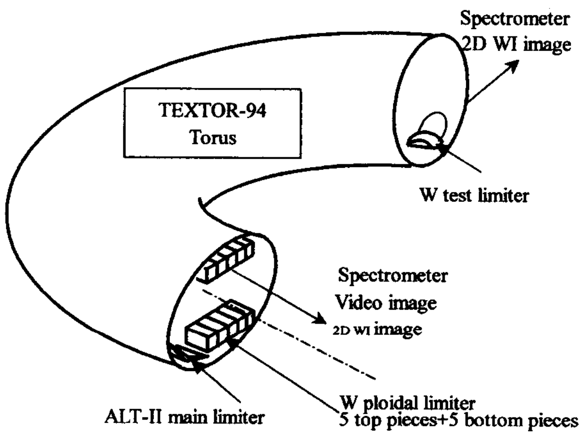

Fig. 1 Experimental arrangement.

3. Results and Discussion

3.1 Short term accumulation of C on W surface

The top 5 blocks of the W-poloidal limiter were replaced to new ones during the vacuum opening of TEXTOR. Before the exposure of the W-poloidal limiter to the plasma, 53 discharges had been made for other research missions by keeping the limiter position at 49 cm minor radius.

Prior to the experiment a He glow discharge was sustained for 40 minutes to reduce oxygen. After the glow discharge treatment, four ohmic discharges were made keeping the limiter position at 49 cm. Then the poloidal limiter was positioned at 48 cm minor radius for shot No. 81679 and at 47 cm minor radius for shot No. 81680. No line radiation of WI was observed on the limiter surface for these shots, but the CD band spectrum was observed indicating the presence of C on the surface. Toward the end of the shot No. 81681 when the limiter was located at 46 cm minor radius, a noticeable signal of WI was recorded on the limiter surface.

The peak of the line spectrum intensity of WI became comparable to those of CrI and OII, as the limiter was moved up to 45.5 cm minor radius in shot 81682. During shots 81682 and 81683, the intensity of WI had slowly increased. In Fig. 2, the spectrum for the final stage of the shot 81683 with the poloidal limiter positioned at 45 cm minor radius, is shown to compare it with the spectrum for the beginning stage of the shot 81682. As shown in the figure, the intensities of the WI lines became larger, and the intensity of the CD band spectrum became smaller. The CD band spectrum had been reduced to less than a half of the original value after shot 81683.

The deuteron fluence onto the limiter integrated over the toroidal direction by shots 81681, 81682, and 81683 was estimated to be 4.3×10^{19} cm^{-1}. If the geometrical length of the limiter in the toroidal direction, which is 3 cm for the poloidal limiter is assumed to be the total length in the line-of-site for the particle emission, the deuteron fluence can be roughly

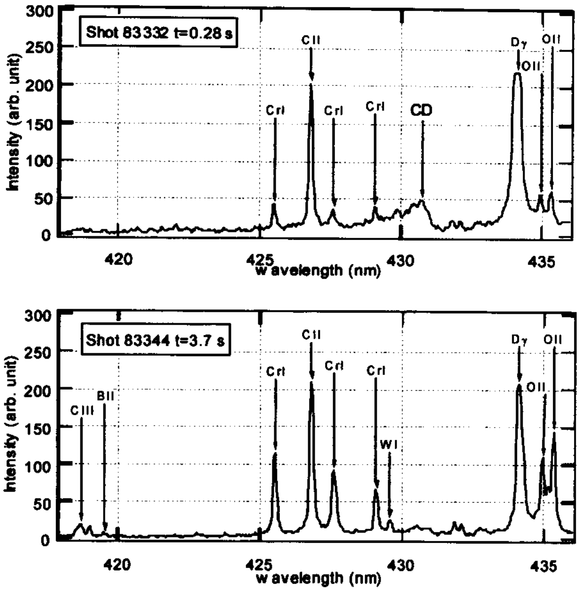

Fig. 2 Comparison of the spectra between shots 81682 and 81683.

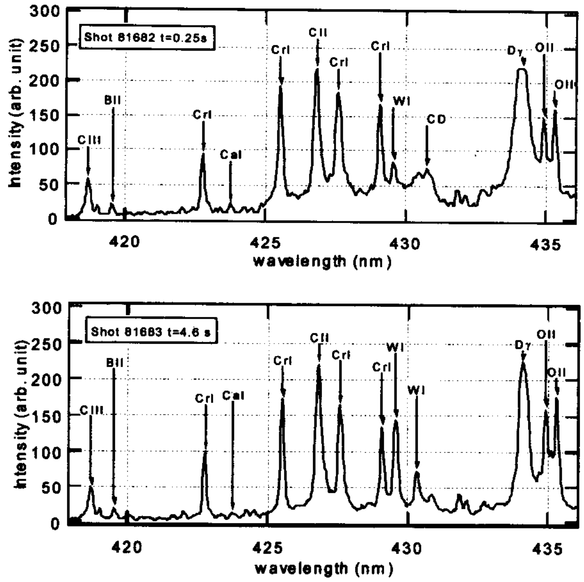

Fig. 3 Comparison of the spectra between shots 83332 and 83344.

estimated to be 1.5×10^{19} cm^{-2}. The C layer on the W poloidal limiter could been removed with this magnitude of deuteron fluence when the C layer on the W surface was formed by about 60 shots.

3.2 Long-term accumulation of C on W surface

After shot 81739, the W poloidal limiter was kept at 49 cm minor radius. It was moved up to 45.5 cm minor radius in shot 83332. This means that the poloidal limiter was kept in the shadow region of the ALT-II limiter for about 1600 shots. As shown in Fig. 3, the peak of WI could never be identified, but a clear CD band spectrum was observed. After 10 shots with the poloidal limiter positioned deeper than the ALT-II, the WI peak was recognized on the spectrum at shot 83344. The line integrated deuteron fluence for these 10 shots was about 6.5×10^{19} cm^{-1}. However, the intensity of WI did not become as strong as that observed after the removal of C layer formed on the newly installed W limiter block like the case of shot 81683.

The intensity ratio of WI to CII was about 0.06 for shot 83344, while it was 0.208 for shot 81705 before the long-term surface accumulation of C. The plasma exposure was continued until the line integrated D fluence exceeded 4.4×10^{20} cm^{-1}, but no apparent sign of enhancement in WI intensity was observed. The flux ratio of C to D of shot 83344 estimated from the line spectrum intensities was about 1.2% and was smaller

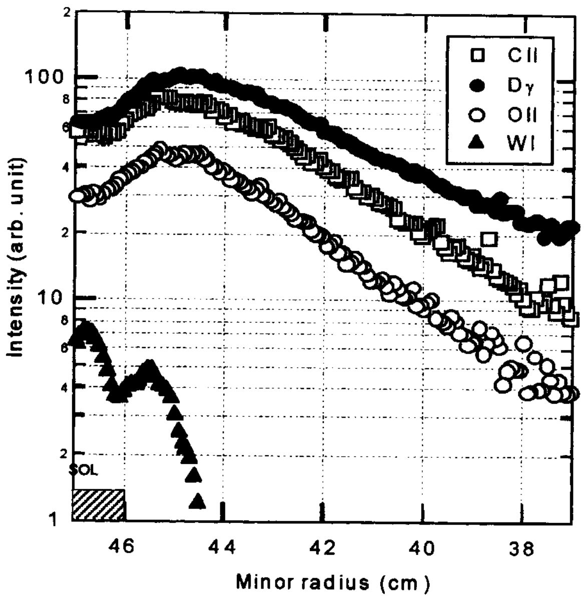

Fig. 4 The intensity distributions of line spectra near the surface of the C covered W poloidal limiter.

than that of shot 81683. Meanwhile the intensity ratio of WI to Dγ of shot 83344 was smaller than that of 81683 by an order of magnitude. (See also Fig. 4.)

3.3 Particle release from C deposited W surface

Figure 4 shows the intensities of spectral lines of

Dγ, CII, OII and WI plotted as functions of radial position for shot 83344. To find the effect of the long-term deposition of carbon on the surface of the W limiter, data in Fig. 4 are compared with the similar graph obtained for shot 81683. As shown in the figure, the signals fit reasonably well to exponential functions, and e-folding lengths could be determined from the graph.

The obtained e-folding lengths were 3.3 cm for CII, 2.8 cm for OII, 4.7 cm for Dγ, and 0.5 cm for WI, respectively. The local electron density and temperature measured by the atomic beam method at the position of the limiter were 1.2×10^{18} m^{-3} and 60 eV, respectively. When we compare the e-folding length of WI with the data obtained from the solid W test limiter [5], it is slightly larger, but essentially the same within the experimental accuracy.

In shot 81683 the local electron density was 1.2×10^{18} m^{-3} and the electron temperature was slightly higher than that of shot 83344 and was 70 eV. The e-folding lengths under these conditions were 3.3 cm for CII, 2.9 cm for OII, 4.6 cm for Dγ, and 0.5 cm for WI, respectively. Therefore, the e-folding lengths of CII, OII, Dγ and WI were not affected by the formation of the C layer.

3.4 CD release during long NBI pulse

The CD release from the C coated W surface for a discharge with the 1.3 MW, 5 s NBI heating was investigated for shot 83363 by locating the limiter position at 44 cm minor radius. The electron density and temperature at the position of the limiter top was 1.2×10^{19} m^{-3} and 45 eV, respectively. As shown in Fig. 5, the CD band spectrum intensity was strong at the top of the limiter and also at the position about 3 cm away from the top. The intensity had increased at both positions in accordance with the passage of time while the Dγ flux stayed almost constant during the discharge. The increase of CD signal is attributable to the temperature rise of the bulk limiter from 635 K to 725 K, which can cause thermal desorption and/or enhancement in chemical sputtering on C layer.

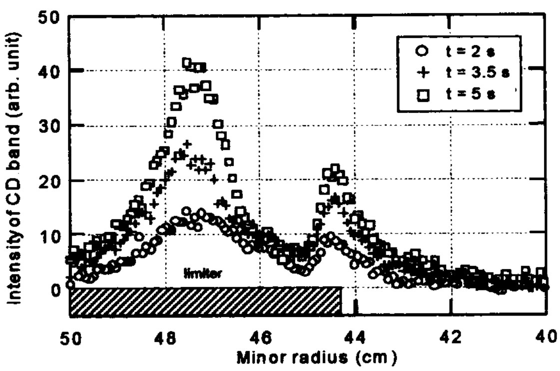

Fig. 5 Change in the spatial intensity distribution of CD band spectrum. Top of the limiter is located at about 44 cm minor radius.

4. Summary

The C layer formed on the W-poloidal limiter surface by 1600 TEXTOR discharges in the shadow of ALT-II could not be removed by D fluence about 1.5×10^{20} cm^{-2}. Due to the formation of the C layer, the ratio of WI intensity to Dγ was reduced by one order of magnitude. Meanwhile, the e-folding length of WI as well as those of OII, CII and Dγ did not change by the layer formation. The C coated limiter surface showed CD emission as the limiter was exposed to plasma heated with NBI for 5 s.

References

[1] A. Huber, V. Philipps *et al.*, *Proc. 26th EPS Conf. Controlled Fusion and Plasma Phys.* (1999).

[2] T. Tanabe, V. Philipps, A. Pospieszczyk *et al.*, To be published in J. Nucl. Mater.

[2] A. Pospieszczyk *et al.*, in these proceedings.

[4] B. Schweer, G. Mank, A. Pospieszczyk *et al.*, J. Nucl. Mater. **196-198**, 174 (1992).

[5] M. Wada, V. Philipps, A. Pospieszczyk *et al.*, J. Nucl. Mater. **241-243**, 1164 (1997).