§ 20. Simulation Study on Interactions of Walls with Plasmas Including Carbon Impurity

Kawakami, R. (Fac. Engin., Tokushima Univ.)

In the future fusion plasma device, ITER, simultaneous use of Carbon (C) and Tungsten (W) materials has been planned as plasma-facing materials (PFMs) at the divertor plates.[1] However, the simultaneous use causes a problem with mutual contaminations of the PFMs, such as C-contaminated W material and W-contaminated C material. The contamination is due to deposition of impurity transported by the core plasma or by the SOL plasma from other material. How the contamination affects plasma-wall interactions such as impurity emissions is an open question.

Regarding this problem, an exposure experiment of a W-C twin test limiter composed of W and C materials has been performed in TEXTOR-94.[2] In ref. 2, a result that a CII emission profile from a C-side of the test limiter to the core plasma is similar to that from a W-side of the test limiter has been reported. In this study, in order to understanding the experimental result, ionization distributions of C^+ to C^{2+} for C atoms and CD_4 molecules emitted from C and W materials exposed to D^+ plasmas including C^{4+} impurity have been calculated by the EDDY code. A comparison of the calculated results with the experimental results has been described.

The simulation code for plasma-wall interactions, EDDY, is composed of 4 models: (*a*) transport of bombarding ions in a pre-sheath plasma, (*b*) emission of impurity from PFMs due to the bombarding ions, (*c*) the resultant mixing of the PFMs, and (*d*) transport of the emitted impurity in the plasma. Especially, in the (*d*) model, ionization and dissociation processes of chemically sputtered CD_4 due to electron collisions in the plasma are taken into account together with the ionization of physically sputtered C. Based on a feature of the TEXTOR-94 plasma, the plasma temperature is assumed to be decreased from 72.4 eV to 12.6 eV with increasing minor radius r (r = 41 cm – 51.3 cm). The plasma density is also assumed to be decreased from 8.03×10^{12} cm^{-3} to 0.79×10^{12} cm^{-3}. In contrast, the CD flux ratio defined by the ratio of C impurity flux to D fuel flux is assumed to be increased from 2.2% to 6.7%.

The simulation results obtained by the EDDY code are similar qualitatively to the measured CII emission profiles from the W-and C-sides. In particular, the similarity presents a difference between C impurity emitted from W-contaminated C material and that from pure C material. If the chemical sputtering yield Y_{CD4} is $Y_{CD4} = 0.006$, C impurity emitted from the W-side is reproduced. This shows that there is little contribution of the chemical sputtering to the C impurity emission from the W-side. Thus, the C impurity emission from the W-side is caused by reflection of C^{4+} impurity in the bombarding ions and by physical sputtering of C deposited on the W-side. This result is the same as that for C impurity emitted from a W-mono test limiter exposed to the TEXTOR-94 plasma.

If $Y_{CD4} = 0.01$, C impurity emitted from the C-side is reproduced as shown in Fig. 1 (a). This figure shows that there occurs the weak contribution of the chemical sputtering at a distance of less than 1.5 cm from the C-side. Thus, the C impurity emission from the C-side is found to be due to the same emission process as that for the W-side. This result is in disagreement with that for C impurity emitted from a C-mono test limiter exposed to the TEXTOR-94 plasma. For the C-mono test limiter, if $Y_{CD4} = 0.03$ (which is higher than that for the C-side), the simulation reproduces the experimental data, as shown in Fig. 1 (b). There is the significant contribution of the chemical sputtering at a distance of less than 0.5 cm from the C-mono test limiter. The decay length of the CII emission profile is quite similar to that for the chemical sputtering. Thus, the C impurity emission from the C-mono test limiter is caused mainly by chemical sputtering of CD_4 molecules from the C target.

Eventually, a comparison between the C impurity emission from the C-side and that from the C-mono test limiter shows that, for the C-side, the contribution of the chemical sputtering is significantly suppressed. The suppression of the chemical sputtering from the C-side is due to redeposition of W atoms, which are physically sputtered from the W-side and locally back onto the C-side. In the W-C twin test limiter experiment, the redeposition of the W atoms on the C-side has been actually observed. For chemical sputtering of CD_4 due to D^+ bombardment of C, an other experimental result shows that the chemical sputtering from W-contaminated C material is suppressed compared with that from pure C.[3] This experiment result also supports the explanation for the suppression of the chemical sputtering from the C-side.

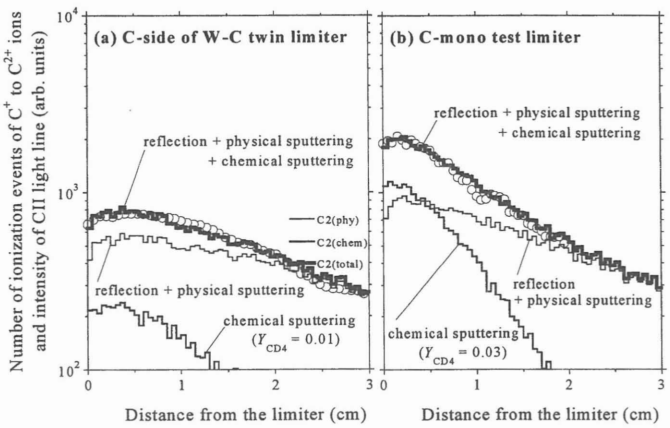

Fig. 1. (a) Ionization event number of C^+ to C^{2+} for C atoms and CD_4 molecules emitted from a C-side of a W-C twin test limiter exposed to the TEXTOR-94 plasma (thick curve) and the measured CII emission profile from the C-side (open circles).[2] **(b)** Ionization event number of C^+ to C^{2+} for C atoms and CD_4 molecules emitted from a C-mono test limiter exposed to the TEXTOR-94 plasma (thick curve) and the measured CII emission profile from the C-mono test limiter (open circles).[2] In these figures, Y_{CD4} is the chemical sputtering yield of CD_4 due to D^+ bombardment of C. The thin curves correspond to the simulated results for reflection and physical sputtering. The others correspond to the simulated results for chemical sputtering.

References:
1) ITER Physics Basis Editors : Nucl. Furion **39,** (1997).
2) Huber, A. *et al.* : J. Nucl. Mater. **290-293,** (2001) 276.
3) Wang, W. *et al.* : J. Nucl. Mater. **241-243,** (1997) 1087.