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MODEL FOR CARBON EROSION AND REDEPOSITION FROM THE TORE SUPRA ACTIVELY COOLED LIMITER LDC

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1. Introduction

The creation of an extrapolable model for carbon erosion and redeposition processes is an important task, both for existing (JET) and for planned (ITER) D-T experiments, owing to the potential role of such processes in tritium retention and diagnostic impairment. Experiments have begun on Tore Supra using the Limiter de Demarrage CIEL (LDC), an actively cooled limiter. In order to use available spectroscopic data to relate the global erosion rate to local processes in LDC and CIEL, a simulation model for impurity transport in the edge and scrape-off layer regions of this configuration has been created. The model is based on the BBQ 3-D Monte Carlo scrape-off layer impurity transport code [1, 2]. The model is also based on the CASTEM-2000 finite elements code [3]. Results from a variant of the latter code are used to calculate the starting conditions for impurities in the Monte Carlo calculation. While the present discussion deals mainly with carbon transport, models have also been developed for the recycling (He, Ne, Ar), and chemically active (O, N) impurities. A hydrogenic version has been prepared because of the important effect of impurity charge exchange with edge/SOL impurities. The paper briefly describes the model, and then turns to examples of the comparison with available diagnostic information.

2. Model elements

The incident D^+ and heat flux deposition profiles onto the limiter surface are calculated, and then the applicable surface model is evaluated to provide the starting conditions (**r, v**) of the impurities emitted from the surface. For carbon generation, physical and chemical sputtering and radiation-enhanced sublimation sources are considered. Starting with the 3-D geometry, including the significant effects of toroidal field ripple and magnetic (Shafranov) shift, obtained from TOKAFLU model in CASTEM-2000 [3], scrape-off layer electron density, temperature and spatial decay lengths are used in a physics-based model to calculate 3-D distributions on the limiter surface of density and temperature which, along with CASTEM maps of magnetic field line angle of incidence and the calculated sheath-accelerated incident energy, provide the incident deposition profiles. The local limiter temperature, which is needed to evaluate chemical erosion rates, is calculated using the heat flux deposition map, a process which can be checked against direct infra-red measurements. Using the calculated carbon emission distributions, the Monte Carlo calculation follows the particle evolution in 3-D and calculates the contributions to observed spectral line emission, which are measured in the vicinity of the of the limiter. A high resolution visible spectrometer which is perpendicular to the (horizontal) limiter plane views the impurity emission profiles. In addition to these measurements, a VUV duochromator [4] scans the interface region between the edge and core plasma, measuring the poloidal emissivity profile. Figure 1 shows the geometry of the CIEL / LDC limiter and gives a schematic view of the duochromator and other spectroscopic viewing geometry.. As was done for the Tore Supra ergodic divertor [5], core (MIST impurity transport code [6]) and edge (BBQ code) contributions are combined to match the duochromator profile.

3. Results

Typical results of the model are described. The first application is to calculate the impurity emission characteristics in the region which is seen by the vertical fibre and CCD camera views shown in Fig. 1.. Similarly, a comparison with the VUV duochromator is described.

Typical calculated radial profiles of carbon and hydrocarbon impurities in the edge and SOL region for cases of physical and chemical sputtering, and for radiation-enhanced sublimation, are shown in Fig. 2 (a-c). These calculation are made for the conditions of Tore Supra shots 29313 and 29315, namely, assumed electron density at the last closed magnetic surface (LCMS) is 7. 10^{18} m^{-3} , the LCMS electron temperature is 50 eV, and the scrape-off layer decay lengths for density (λ_N) and temperature (λ_T) are 4 cm and 5 cm, respectively. The 3-D surface temperature from the CASTEM map is scaled with an assumed peak value typical of the processes illustrated: for physical sputtering, T_{surf}^{max} ~ 500 K, for chemical sputtering it is assumed that T_{surf}^{max} ~ 950 K , and for the RES case, T_{surf}^{max} ~ 1250 K. Strongly modulated erosion patterns are calculated by the model for these different sources as a consequence of the modulation due to the spatial modulation of incident flux (and hence impurity emission) by the toroidal field ripple. A comparison of measured CD molecular emission patterns with simulated values is discussed elsewhere (A. Cambe, et al., this meeting).

Simulations of the duochromator poloidal profiles combine the emissivity profiles from the core, calculated with MIST, and the SOL contributions calculated from BBQ. Figure 3 shows a comparison for CIV. The experimental values are reasonably well matched, although the uncertainties in T_e profiles at the edge lead to a broader core profile than is observed. In the SOL region the contribution from the inner and outer leading edges of the limiter are predicted to be significant. Figure 3 distinguishes the total and the BBQ contributions to the simulated emissivity profile. The duochromator comparison is further discussed elsewhere (R. Guirlet et al, this meeting).

The model thus appears to be a useful tool for the further analysis and understanding of the processes of erosion and redeposition.

References

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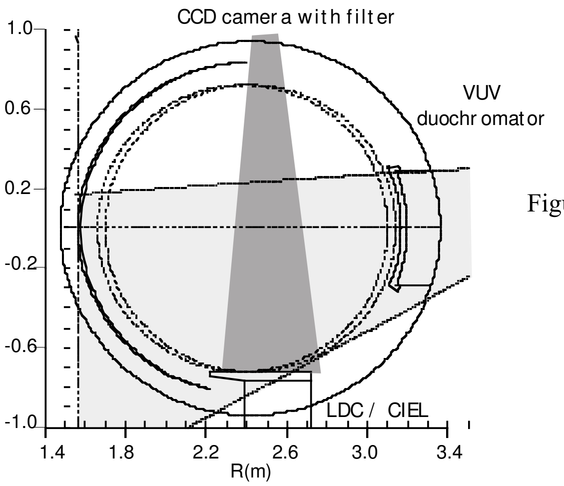

Figure 1.Schematic plan of viewing geometry for wide area CCD and fibre spectroscopy (vertical) and poloidal profiles from the VUV duochromator.

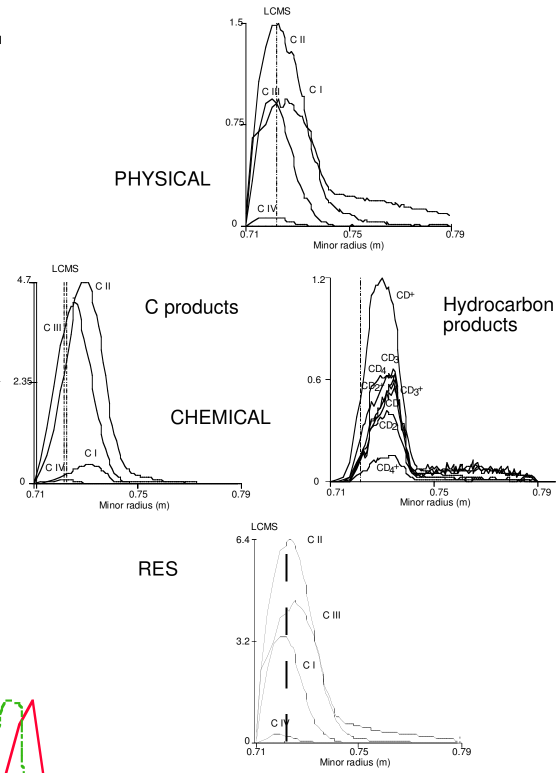

Figure 2. Carbon radial distributions in the edge and SOL calculated from CASTEM-2000 / BBQ model for cases of (a) physical, (b) chemical, and (c) radiation-enhanced sublimation

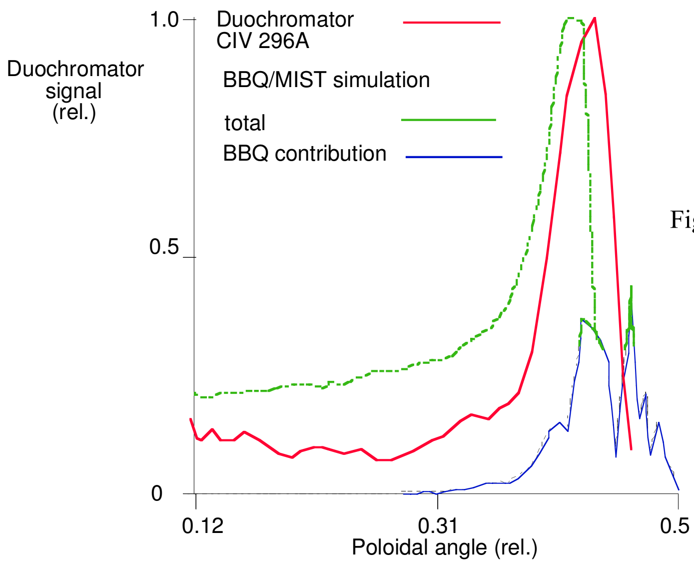

Figure 3. Comparison of measured duochromator profile for CIV with BBQ/MIST profile simulation. Data are compared with the total simulated signal and the BBQ contribution from the edge / SOL.