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CHEMICAL EROSION MEASUREMENTS AND MODELLING IN TORE-SUPRA

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I. Introduction

In the Tore-Supra Outboard Pump Limiter (OPL), the *in-situ* chemical sputtering yield of the carbon neutralizer plate has been studied. Investigation of methane and heavier hydrocarbons (C_2D_X and C_3D_Y) emission has been performed in ohmic and low hybrid (LH) heated discharges, by means of mass spectrometry and optical spectroscopy. In this study we will first focus on the variation of hydrocarbons production versus incident D^+ flux, as well as the variation of the emission yield of CD_4. Then, we will study the dependence of the emission yield of CD_4 versus surface temperature. In parallel, simulation of plasma wall interaction in the OPL throat, have been performed with a Monte Carlo code (BBQ), in order to compare the experimental results with modelling. In the last part we will compare the experimental measurements of the CD band emission obtained during the last experimental campaign in Tore-Supra (2001) on the CIEL new actively cooled limiter, the toroidal pump limiter, with the CD emission simulated by the BBQ code.

II. Chemical sputtering yield variation versus deuterium flux

This study has been performed on the Tore-Supra Limiter (OPL). To get more information on this element and on the diagnostics used in the experiment see reference [3].

It has been found that for ohmic discharges, the production of chemical impurities (CD_4, C_2D_X and C_3D_Y) increase with the deuterium ion flux. The CD_4 production versus deuterium flux follow the same relation that one established by Ruggieri [4] and is comparable to what is found on JT-60 [5]. This relation is : $P_{CD4} \propto \varphi^{0.73}$ where P_{CD4} is the partial pressure of methane and φ is the deuterium ions flux.

For heavier hydrocarbons, the production is less important compared to the CD_4 production. It is two times lower for the C_2D_X and five to eight times lower for the C_3D_Y.

The C_2D_X production has almost the same flux dependence than CD_4 and the relation is also close to the one found on JT-60 [5]. The flux dependence is defined by : $P_{C2Dx} \propto \varphi^{0.68}$, where P_{C2Dx} is given by the signal of mass 30. The increase of C_3D_Y is lower than CD_4 and C_2D_X hydrocarbons and shows the following flux dependence : $P_{C3Dy} \propto \varphi^{0.5}$, where P_{C3Dy} is given by the signal of mass 42.

From these results and taking into account only the CD_4 emission, we have investigated the variation of the chemical sputtering yield Y_{CD4} versus the incident deuterium ion flux. Y_{CD4} decreases when the deuterium flux increases (Fig. 1), with the following flux dependence : $Y_{CD4} \propto \varphi^{-0.23}$. These results are similar to those found on JT-60 [5], and in another hand are far away from theoretical model that presents a φ^{-1} flux dependence [6].

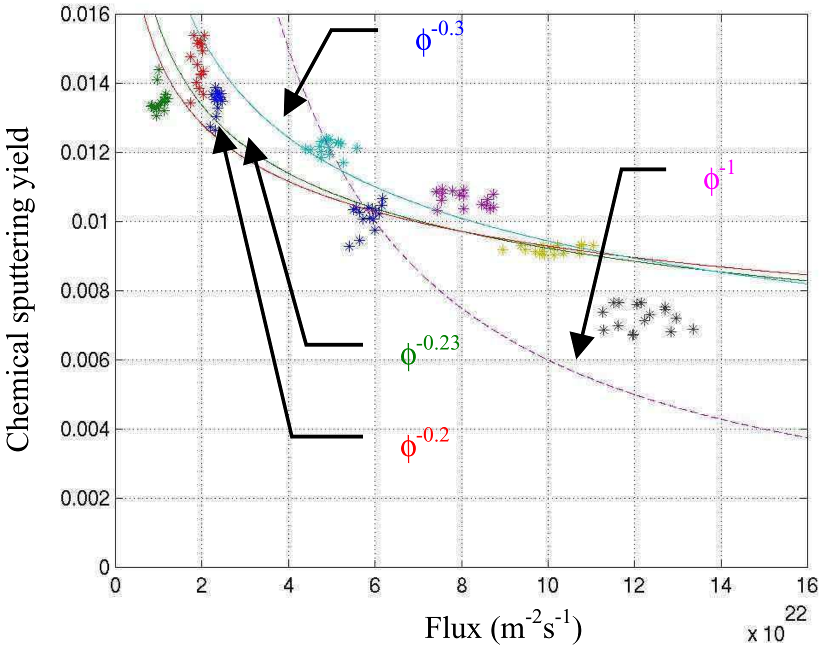

Fig. 1 : CD_4 emission yield variation versus incident deuterium ions flux.

As the production of heavier hydrocarbons seems to be important for low incident energies [7], we have studied the contribution of different hydrocarbons (CD_4, C_2D_X and C_3D_Y) to the carbon production. It appears that the carbon amount produced by the C_2D_X in this range of incident D^+ flux is equal to that produced by CD_4. Additionally, the carbon produced by the C_3D_Y molecules is not negligible since it is only a factor 3 lower than the carbon produced by CD_4. In that way, C_2D_X and C_3D_Y contribute significantly to the total chemical erosion yield and cannot be neglected. The carbon production versus incident flux is plotted in Fig. 2.

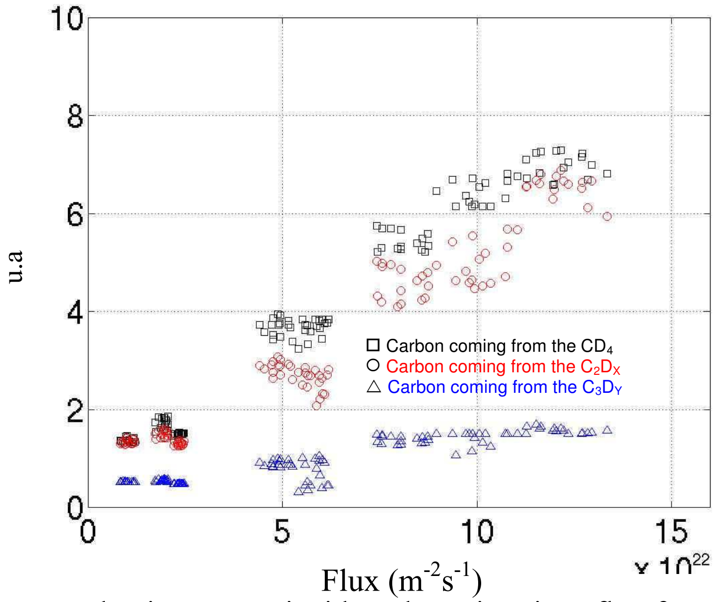

Fig. 2 : carbon production versus incident deuterium ions flux for each ohmic shot.

III. Chemical erosion yield variation versus surface temperature

The CD_4, C_2D_x, C_3D_y partial pressures and the total pressure increase with surface temperature and particularly when the temperature exceeds 450 °C. The experimental chemical sputtering yield, as predicted by the model [8], increases with the surface temperature. This result is confirmed by the simulations performed by the Monte Carlo code BBQ described in detail in [9].

IV. CD emission

In order to increase the duration of the plasma discharges, new plasma facing component have been installed in Tore-Supra, particularly, a new actively cooled limiter, the toroidal pumped limiter (CIEL project). During the last experimental campaign (2001), we have observed the CD emission of a part of a section of the limiter. Thus, we compare a CCD camera image of CD emission obtained using a CD filter, with simulations of CD emission given by the BBQ 3-D Monte Carlo scrape-off layer impurity transport code [9] [10]. The incident D^+ and heat flux deposition profile on the limiter surface is calculated, starting with the geometry obtained from the CASTEM-2000 finite elements code [11]. The scrape-off layer electron density (n_e), temperature (T_e) and spatial decay lengths are used in a physics-based model to calculate local distributions of density and temperature. These values are used, with CASTEM maps of magnetic field line angle of incidence and with the calculated sheath-accelerated incident energy, to provide the incident deposition profiles. The local limiter temperature profile, which is needed to evaluate chemical sputtering yield, is calculated using the heat flux deposition map and can be checked against direct infra-red measurements.

The principal characteristics of the studied ohmic shot are the following : n_e and T_e at the last closed magnetic surface (LCMF) are respectively $\sim 7\times 10^{18}$ m^{-3} ~50 eV. The scrape-off layer decay lengths for density (λ_N) and temperature (λ_T) are 4 cm and 5 cm, respectively. The surface temperature is estimated to be low, ~150 °C. Thus, all contributions to chemical sputtering (the source of the CD emission) will arise from athermal chemical sputtering. The similarity of the measured and simulated CD emission patterns in Fig. 3 is a consequence of the strongly modulated toroidal distribution of incident flux (and hence impurity emission) due to the Tore Supra toroidal field ripple. This comparison is made at t=8.9s. The selected time slice for the CCD image, occurs at a time when the radiated power from the core plasma has increased and the heat flux to the limiter is dropping.

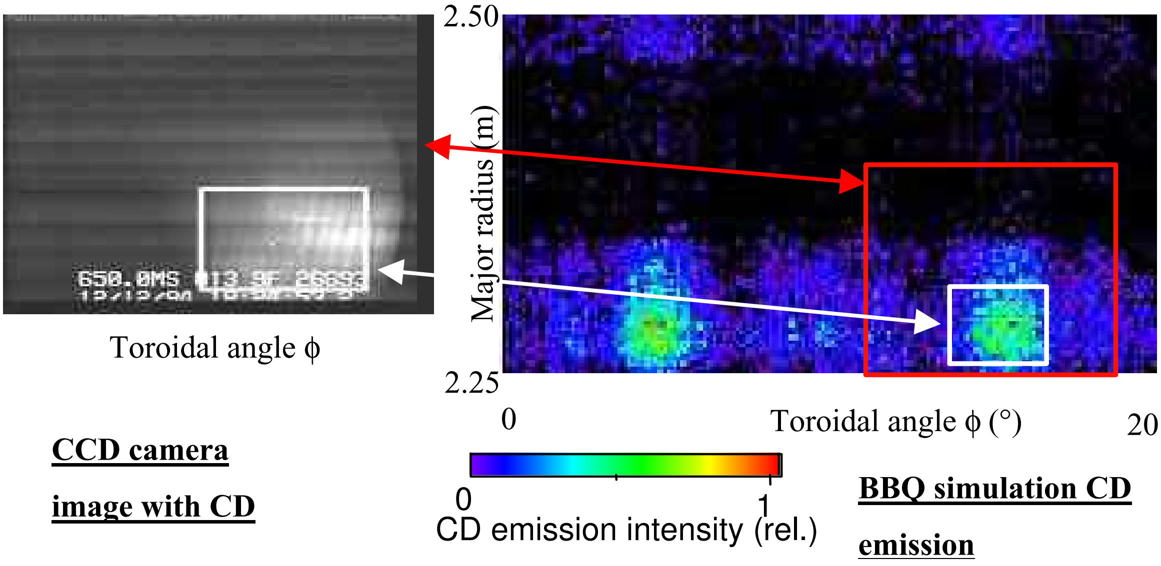

Fig. 3 : Comparison of the BBQ simulation of CD emission from a segment of the toroidal pumped limiter, with a CCD camera image of CD emission

Bibliography

[1] B. Meslin et al., J. Nucl. Mater, 266-269 (1999) 318-323
[2] C.S. Pitcher and P.C. Stangeby, Plasma Phys. Control. Fusion 39 (1997) 779-930
[3] A. Cambe, E. Gauthier, J. Hogan, J.M. Layet, to be published
[4] R. Ruggiéri, E. Gauthier, J. Hogan, J.M. Layet, T. Loarer, J. Nucl. Mater. 266-269 (1999) 660
[5] N. Hosogane et al., J. Nucl. Mater. 220-222 (1995) 415
[6] J. Roth, J. Nucl. Mater. 266-269 (1999) 51
[7] A.A. Haasz, J. W. Davis, J. Nucl. Mater. 175 (1990) 84
[8] J. Roth, C. Garcia-Rosales, Nucl. Fusion, Vol. 36 No. 12 (1996) 1647-1659
[9] J. Hogan, C. Klepper, J. harris et al, Proc 16th Intern. Conf on Plasma Physics and Controll. Fusion, Montreal, 1996. (IAEA, Vienna)
[10] R. Gianella, Y. Corre, J. Hogan et al, Plasma Phys. Control. Fusion 43 (2000) 271
[11] R. Mitteau, A. Moal, J. Schlosser et al, J. Nucl. Mater. 266-269 (1999) 798