Influx of metal impurities from toroidal and poloidal limiter in FTU

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Introduction

Poloidal limiters made with different materials (inconel, W and Mo) and a Molybdenum toroidal limiter have been used on the Frascati Tokamak Upgrade (FTU) to define the last closed magnetic surface.

The study of the plasma contamination due to the inflow of metallic impurities, which occurs as a consequence of the plasma limiter interaction, is of importance in view of the possibility of using high Z materials in some region of the ITER divertor. Such a study can be conveniently performed on FTU since, in this device, the limiter thermal loads are comparable to those predicted for the ITER divertor.

Visible spectroscopy is an important diagnostic tool for studying the fluxes of impurities emitted by materials facing the plasma. In fact, it is generally possible to infer the flux of particles released by those surfaces by measuring, in the visible range, the brightness of spectral lines in the cold plasma periphery where they are mostly neutral or weakly ionised.

In this paper, the impurity influxes have been measured and compared in different operating conditions with both limiters, either in ohmic and in RF discharge.

Experimental data analysis with poloidal and toroidal limiters

The impurity flux is derived from the measurements of absolute line intensity obtained by a calibrated Optical Multichannel Analyzer spectrometer [1].

The most careful analysis is done for the molybdenum limiter since, at the moment, FTU is operating with a toroidal TZM limiter [2]. A visible spectrum, in the range of 3700-7000 è, for a typical FTU discharge (plasma current I_p=500 kA, toroidal field B_t=6 T and line averaged electron density $<n_e>=0.9\times10^{20}$ m^{-3}) is shown in fig.1. The wavelenghts of MoI lines are: 3798.3 è, 3864.1 è, 3903.0 è corresponding to the transitions from the level z^7P^o to the ground state a^7S, and 5506.5 è, 5533.0 è, 5570.4 è corresponding to the transitions from the level z^5P^o to the metastable state a^5S.

To obtain the flux from the limiter, the brightness of the lines are multiplied by the ratio S/XB, i.e. the MoI number of ionisations per photon emitted (S being the ionisation rate, X the excitation rate and B the branching ratio of the observed lines). The values of S/XB are taken from the Atomic Data and Analysis Structure (ADAS) database [3]. The uncertainties on evaluating the fluxes are due, mainly, to the uncertainties on electron density and temperature: in our case, T_e = 30 eV and $n_e=0.2<n_e>$ are taken. The total MoI flux is composed of atoms

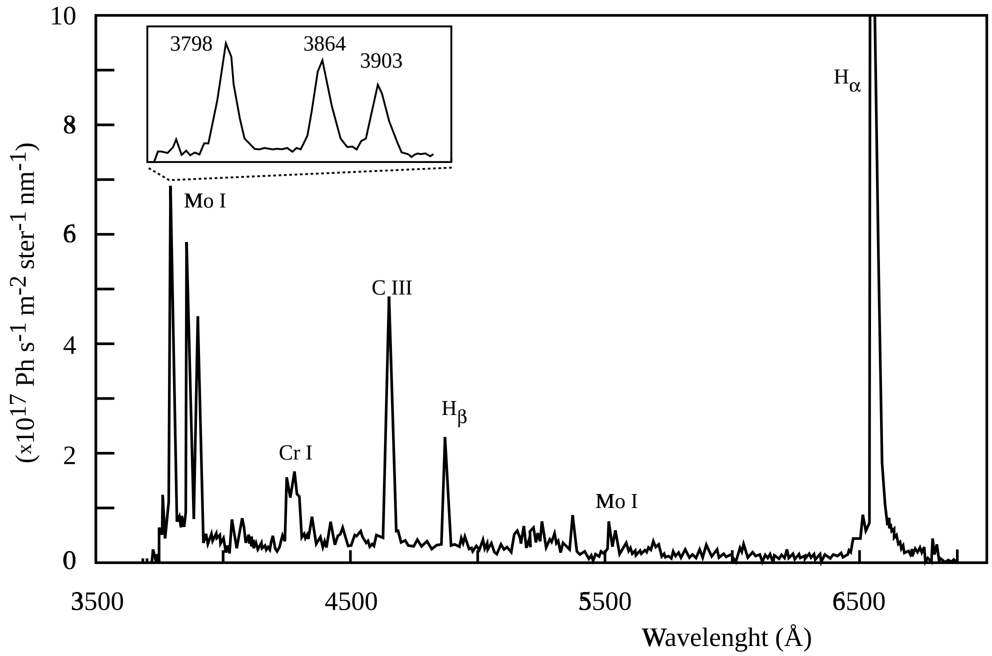

Fig. 1

Fig.1 - Visible spectrum for a typical FTU discharge.

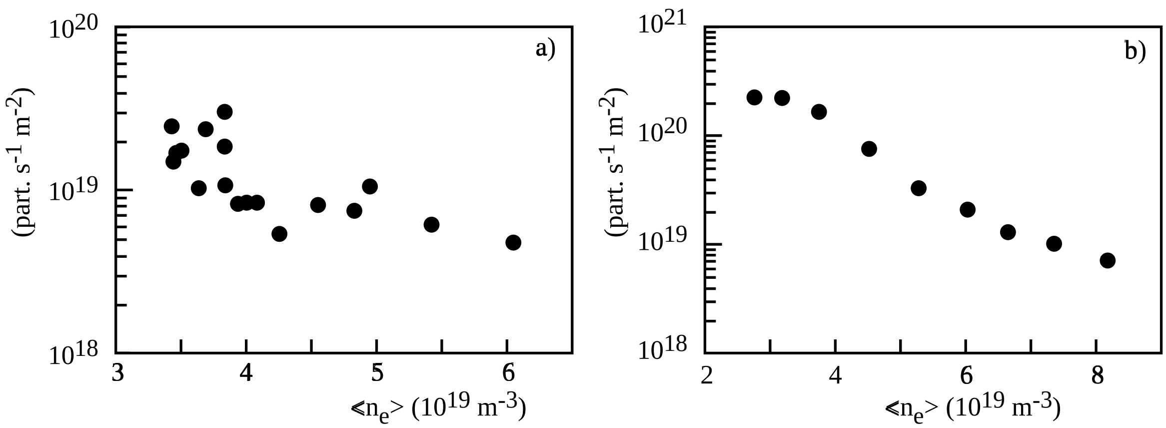

Fig. 2

Fig.2 - Neutral Mo influx , in toroidal limiter configuration (a) and in poloidal limiter configuration (b).

released both in the ground state and in the metastable state (about 10% of the total). The first contribution to the flux is derived by the line intensity of transitions $z^7P^o \rightarrow a^7S$ and the second by the line intensity of transitions $z^5P^o \rightarrow a^5S$. In the last case, to evaluate the population of the excited level z^5P^o only from the metastable state a^5S, corrections are taken into account, as suggested by [3].

Figure 2 shows the MoI flux as a function of the electron density for a discharge with B_t=6 T and I_p=0.6 MA, in configuration of toroidal limiter and H_2 fuel (a) and in configuration of poloidal limiter and D_2 fuel (b). In both cases, the MoI flux decreases with the density until the detection limit. The MoI flux is 10 times smaller with the toroidal limiter, as expected by the ratio between the limiters' emitting surfaces. Figure 3 shows the ratio of MoI flux to the fuel flux, derived by the brightness of H_β line intensity for case (a) and of D_γ line intensity for case (b). This ratio can be considered as an effective sputtering yield of Mo due to the hydrogen/deuterium ions impinging on the limiter surface and self-sputtering. In toroidal limiter configuration, this ratio is of the same order of magnitude as that obtained in poloidal limiter configuration.

Under certain operating conditions, at low plasma current or at high electron density, expecially during the plateau phase, the Mo flux in the discharge becomes smaller than the detection limit. The presence of Mo is observed in the stationary phase of the discharge only at very high plasma current, Ip>900 kA.

In the FTU discharges obtained with both toroidal Mo limiter and external poloidal inconel limiter, significant quantities of Cr are observed. For typical FTU discharges, the Cr behaviour is similar to that of Mo both in magnitude $\Gamma_{Cr} = 1\times10^{19}$ part. s^{-1} m^{-2}, and in temporal

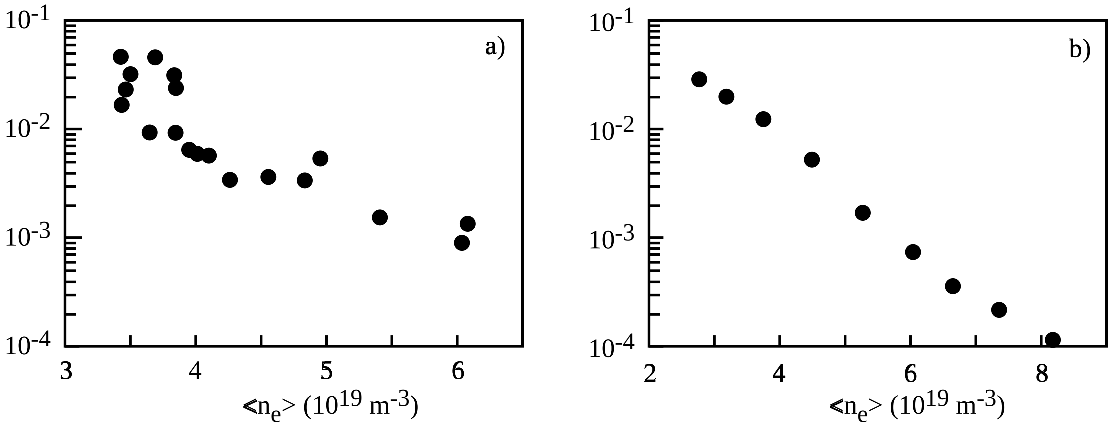

Fig. 3

Fig.3 - The ratio of MoI flux to the fuel flux, in the same cases as fig.2.

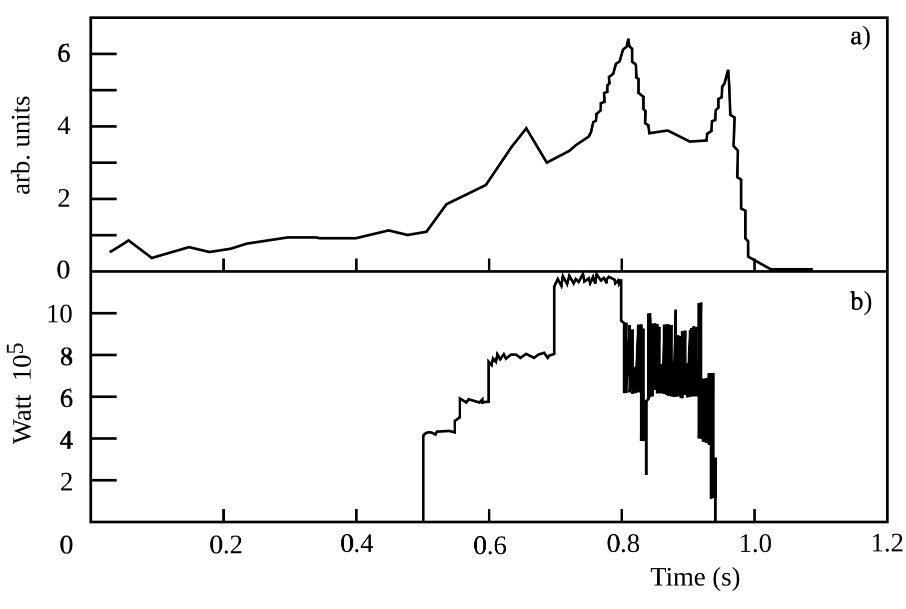

Fig. 4

Fig.4 - Γ_{CIII} (line λ= 4647.4 Å) (a) and the coupled LH power (b) versus time.

behaviour. Cr becomes predominant in run-away discharges when the external limiter plays a fundamental role.

Even if FTU is characterised by metal impurities, there are cases where the light impurity emission becomes predominant. This happens especially during Lower Hybrid Radio Frequency injection [4], where it is observed an increment of the emission of peripherical lines of light impurities. Figure 4 shows the time behaviour of the CIII flux, measured from the visible spectra. During LH phase an increase up to a factor of 4 is observed. This increment is apparently not dependent on total power for coupled LH powers in the range 0.5 to 1.3 MW. The behaviour of carbon is in agreement with that of oxygen as observed in VUV spectra.

Conclusions

The metallic impurity flux, measured on FTU, shows a strong inverse dependence on the electron plasma density. With the poloidal inconel limiter, this dependence for Cr and Ni has been assessed experimentally over a wide range of stationary operating conditions. Mo lines have shown the same behaviour during the density rise, while they are observed in stationary phases only at high plasma current.

The Mo influx is smaller in the toroidal limiter configuration when the interaction of the plasma with the limiter is more uniformly distributed so the thermal load per unit surface is sensibly reduced. The total number of Mo atoms coming from the limiters, in both configurations, is about the same.

When operating with the inconel external poloidal limiter also, significant contribution from other metallic impurities are usually observed even if their emitting surfaces are negligible.

References

[1] I. Condrea, R. Bartiromo, G. Mazzitelli and D.H. McNeill, Proc. 14th Int. Conf. on Plasma Physics, Innsbruk,1992

[2] M.L. Apicella, G. Apruzzese, G. Bracco, et.al., Nucl. Fusion, **37**, No.3 (1997)

[3] N.R. Badnell, et al., J. Phys. B **29**, 3683 (1996)

[4] V. Pericoli et al., "Current Drive experiments at high density in the FTU tokamak", this conference