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Density profile studies of plasmas with Lithium Limiter

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Introduction

During the last campaign of 2005 a liquid Lithium limiter has been faced to FTU plasmas[1]. Lithium has several beneficial effects on the plasma, in particular it reduces oxygen contamination and deuterium recycling, allowing a better control of plasma density. Lithium changes the conditions of appearance and evolution of the MARFE[2] at high density and affects consequently the density profile. The density profiles of this campaign have been studied and systematically compared with similar discharges, in terms of macroscopic parameters, but with different plasma facing materials (Li, B, Mo). Some discharges, with evolving density profiles, allows an analysis of the core transport coefficient using a simple model for particle flux [3]. Density profiles are measured by a two colours scanning interferometer [4,5], having two scanning chords which cover the plasma core (from –8 to 8 cm) and the edge (from 12 cm to 30) with 1 cm of resolution, producing a profile every 64 μs.

The fueling efficiency

The most impressive result after lithization has been the strong modification of the recycling characteristics of the wall related to the strong ability of Lithium in pumping particles, as demonstrated by the large amount of gas required to obtain the pre-programmed density. This fact has allowed to extend the range of operations to the lowest density ever reached on FTU (n_e=1.5x$10^{19}$$m^{-3}$). After lithization no evidence of wall saturation occurs as observed with boronized walls after some pulses at medium-high density [6]. A comparison between lithization, boronization and full metallic walls is evidenced in fig.1 by plotting N_p (the total plasma particle content) as a function of N_g (the total amount of the injected particles) for ohmic plasma discharges at I_P=0.5 MA, B_T=6T. The amount of gas required to obtain similar density conditions is much higher after lithization than in the other two cases, except for fresh and not saturated B film that exibits a behaviour very similar to Li film. In fact, all points with Boron shown in fig 1 with $N_g \geq 5.0$x10^{21} particles are obtained with fresh boronization. This

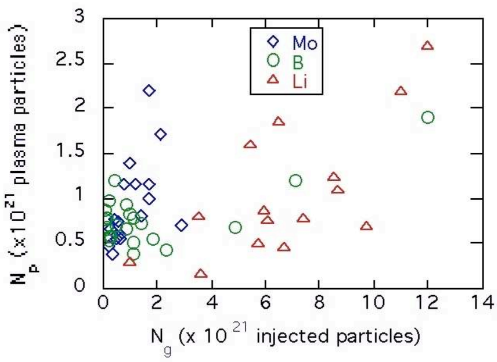

Figure 1. *The total plasma particles N_p versus the total amount of injected particles N_g*

favourable pumping effect for lithium has allowed to extend the density range from $1.5\times10^{19}m^{-3}$ to $2.7\times10^{20}m^{-3}$ on FTU.

Density profile peaking factor

Electron density profiles in FTU are sensitive to many external conditions, as impurity influx, position of the last closed surface and MARFEs that can affect both the particle source and the transport properties. Hence, the comparison of density profile for different wall conditioning is tangled by the variety of plasma phenomena. A selection of discharges with constant density and quiescent edge has been selected with lithizated, boronized and metallic first wall, for the density comparison (here after referred as Li, B and Mo). Unfortunately, similar discharges with metallic wall are only available in a limited range of density, in the set of discharges where the new scanning interferometer is available, as FTU vacuum vessel have been routinely boronized, recently. The peak density is plotted in fig. 2, versus the volume averaged density for all discharges at I_P=0.5 MA, B_T=6T. Different marks are used to distinguish the different type of discharges, in particular, open marks are steady state discharges. At high density, all discharges show an abrupt increase of the H_α emission at the inner side, associated with the presence of a strong MARFE at the plasma edge. As density further increases the MARFE extends annularly up to the plasma center, and oscillations appear on the high-field side chords of the CO2 interferometer (fig 3). These chords, being polluted by the presence of the MARFE, cannot be used for the profile inversion, as the MARFE is poloidally asymmetric. However, channels on the low-field side are not affected by the MARFE and the inversion can be performed using these chords alone. In fig. 3b, the central density is compared with the central density measured by Thomson Scattering, and a good agreement is obtained also during the MARFE, confirming the good quality of the inverted data. The discharges with this oscillation are plotted with full mark (red circles for Li and black squares for B). From fig. 2 we can see that, for low density discharges, profiles

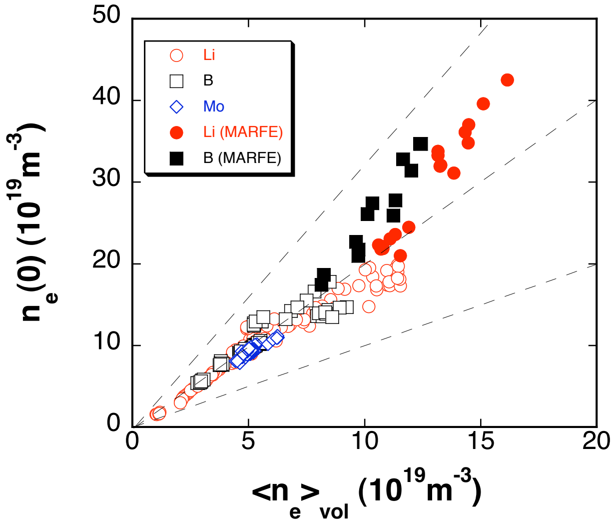

***Figure 2**. Peak density versus volume average density. Black squares for boronized wall, red circles for lithized and blue diamonds for metallic. Full marks are for discharges with MARFE. Straight lines are constant peaking factors 1, 2, and 3.*

are not sensitive to the wall conditioning, this is also confirmed by a direct comparison of the whole profile. The density profile in the set of high density discharges shows a difference in the peaking for discharges with boronized and lithized wall. At fixed volume averaged density the B discharges have a more peaked density respect to the lithized ones. As the MARFE increase and oscillations appear on density, density profiles change drastically. The main increase occurs within a normalize radius of r/a=0.75, while the density decrease slightly between 0.75<r/a<1, as can be seen in fig 4, where density profile at several time (with step of 0.1 s) are plotted. The line density at which the H_α increases is about 7.5×10^{19} m^{-3}, for both B and Li discharges, while the density at which it becomes visible on the interferometer (oscillations), is $1.2\times10^{20}m^{-3}$ per B and $1.5\times10^{20}m^{-3}$ for Li. Another important difference between the B and Li, is observed in the density limit. B discharge reaches a density of $2.1\times10^{20}m^{-3}$ before disrupting for density limit, while the Li discharge reaches a density of about $2.7\times10^{20}m^{-3}$ without disruption, well above the Greenwald limit (for FTU at 0.5 MA is about $1.9\times10^{20}m^{-3}$). The two discharges plotted in fig. 3, are those with highest density. Here the difference of density at which the oscillations appear, and maximum density obtained can be observed. It is worth to note that the appearance of the oscillations in the interferometer is at about half of the density limit value. The profile differences between Li and B discharges at high density, are also evident on the characteristic length of the density profile at half radius and at edge (fig 5). The characteristics length of the Li discharges is above that of the B ones, both at half radius and at edge. Finally, during the MARFE, the edge density remains slightly higher for Li discharges than those with B wall (fig 3b), in contrast with the higher density

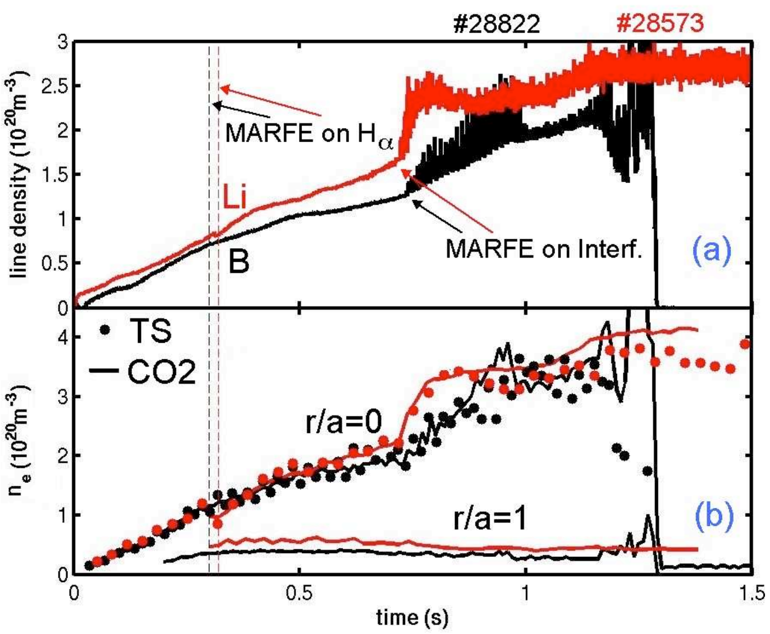

Figure 3*. a) Central chord of line integrated density Boronized and Lithized discharges. Oscillations at 0.7 s are due to an extended MARFE present at the edge. Vertical lines mark the time when MARFE appears on H_α. b) central and peripheral density for the same discharges. TS central density is also reported for comparison (full circles).*

limit reached with the Li wall. However, the errors on the inverted edge density do not allow to draw a decisive conclusion, even though this difference is not observed by Langmuir probes[1]. This point has not been well understood and need further investigations.

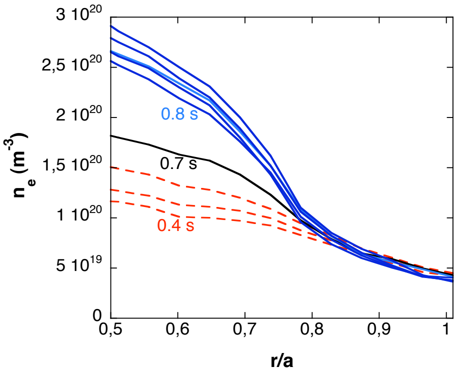

Figure 4*. Density profile evolution in a discharge with marfe. Marfe apprear at 0.7 s.*

Core transport at low density

In discharges where the density profile is changing a local analysis of the particle transport can be performed, at least in the core where the neutral source is negligible. Equalizing the variation of the density within a certain volume V to the particle flux ($\Gamma = -Un_e + D\partial n_e/\partial r$) through the volume surface [3], the diffusion coefficient (D) and the inward pinch (U) can be obtained separately. Considering the large error in this calculation and that this technique can be applied only in few discharges, (all without MARFE), no differences have been observed between Li and B discharges up to r/a = 0.5. The average diffusion coefficient D = 0.1 m^2/s and U=-0.5 m/s at r/a=0.3. These data are in agreement with the results obtained in ref [3].

Conclusion

Wall lithization produces a strong modification of the recycling characteristics of the wall related to the strong capability of Lithium in pumping particles. The comparison of density profiles with different wall conditions does not show any meaningful differences at low density. At high density the presence of a Lithium layer on the wall changes the evolution of the MARFE and, as a consequence, the peaking of the density profile. Density profiles of boronized discharges are more peaked at fixed volume averaged density, but lithized discharges reach higher density limit.

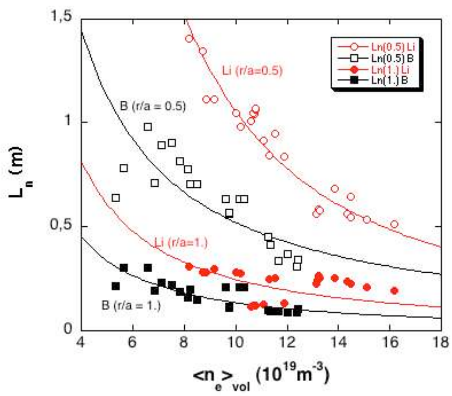

Figure 5*. density profile characteristic length for discharges with marfe, at half radius(open marks) and edge (full marks).*

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