First effect of lithization on RFX-mod experiment

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Introduction. In the RFX-mod Reversed Field Pinch (RFP) experiment (R/a=2.0/0.46 m, $I_p \leq 1.9$ MA) first wall is entirely covered by graphite tiles. Graphite as first wall has proven to be a good solution in terms of allowable power load to the wall and impurity control; especially on RFP experiments where the critical role of the conductive shell proximity in the stabilization of magnetic instabilities prevents the use of a divertor. Moreover, on RFPs macroscopic deformations of the plasma often localize plasma wall interactions (PWI) producing a high thermal power deposition that in RFX-mod can locally reach values of the order of tens of MW/m^2. In this framework the high sublimation temperature of graphite and the low Z of carbon help in keeping very low plasma Z_{eff}. On the other hand a graphite first wall prevents hydrogen influx control. In RFX-mod graphite provides a recycling factor usually above one. In a few discharges plasma facing side of tiles becomes completely hydrogen saturated, after that graphite acts as a big hydrogen reserve resulting in a hydrogen influx that depends only on the power wall load. This prevents the operation at a desired density and becomes particularly unfavourable at high plasma current (I_p>1.5 MA) when power load is very high. What is further bad is that the high hydrogen influx from the wall contributes in producing hollow density profiles with high density accumulation at the plasma edge. This seems to affect plasma performance making impossible the attainment of the improved confinement regime associated to the single-helical-axis states (SHAx) [1] at intermediate plasma density ($n/n_G \geq 0.2$).

To overcome the described limitations in the past we have tried to reduce hydrogen influx by different wall conditioning treatments including sessions of He discharges, Glow Discharge Cleanings (GDCs), wall boronization and wall baking, but none of them provided a solution stationary over many discharges. Following the good results obtained on many tokamaks [2-4] and stellarators [5] experiments with a lithium coating limiter, we tested in RFX-mod the same conditioning technique. This is the first time that this technique has been applied to an RFP device. In this paper we describe the optimization of lithization method and its effect on RFX-mod on plasma profiles and performance.

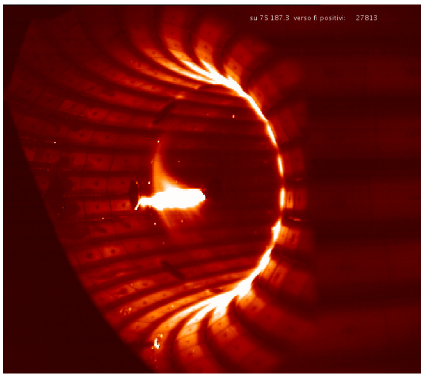

Fig. 1: Image of an injected lithium pellet.

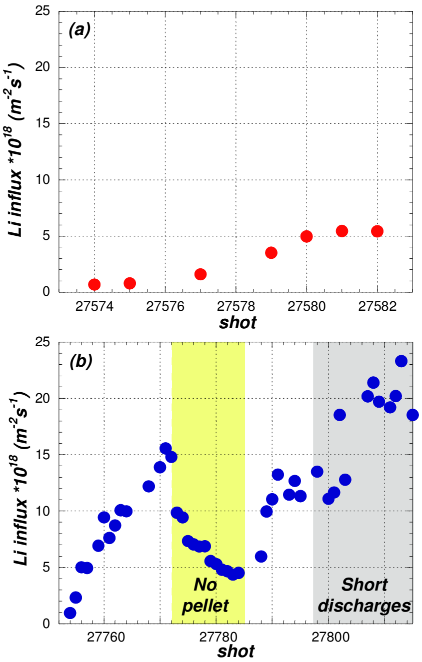

Fig. 2: Lithium influx measured injecting pellet on H dicharges (a), He Discharges (b).

Lithium Injection. Lithium first wall conditioning experiments have been performed by injecting lithium pellets. A room temperature pellet injector (RTPI) launches solid pellets using sabots that are accelerated by a driver gas till they hit a bumper with a central hole. Through the bumper hole the pellets fly to plasma. This set-up allows the RTPI to inject pellets of different sizes and made of any kind of solid material at room temperature. A sabot loader provides a reserve of about 25 pellets allowing a full day operation [6]. For wall conditioning purpose the largest pellets have been used (Ø1.8x5 mm). To get a complete pellet ablation we inject them at a speed of about 100 m/s into discharges with a plasma current over 1 MA. In such a condition, pellets are ablated in about 5 ms and arrive close to the plasma center (fig. 1). The deep pellets penetration provides a uniform toroidal and poloidal Li deposition over the wall. Lithium pellets have been injected both in the case of clean graphite wall and in the case of graphite previously coated by boron. On each conditions a maximum of about 50 pellets were injected for a theoretical Li coating thickness of about 10 nm. Li influx measured during plasma discharges has been used to qualify the pellet effectiveness in conditioning graphite wall. Initially we injected Li pellets on intermediate current H discharges and later on He discharges. The highest Li influxes have been obtained with He discharges, but a further increase was possible by reducing the discharge length (fig. 2).

Li absorbing effect. After Li wall conditioning the wall adsorbs a larger fraction of hydrogen with respect to the standard clean graphite situation. This has been seen in discharges with similar density by comparing the particles retained by the wall before and after Li conditioning. It has been also confirmed by comparing the total number of hydrogen particles absorbed by graphite and lithizated graphite wall between two He glow discharge cleaning operations required to recover the plasma density (fig. 3). Lithium absorbing effect allows a better control of plasma density. On clean graphite at high plasma current, average

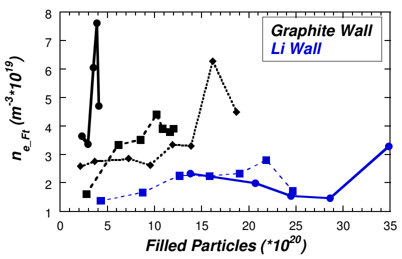

Fig. 3: Total filled/puffed particles between two He GDC.

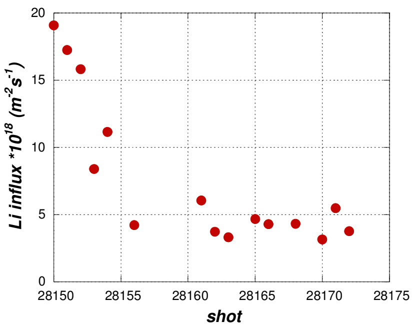

Fig. 4: Time history of Lithium influx on some high plasma current H discharges.

density is due to the hydrogen wall inventory and the power load to the wall. In this situation gas puffing has a little effect on discharges where it is applied, but it strongly affects following ones discharges by causing the saturation of the wall. This is not the case of Li wall conditioning where strong gas puffing that does not saturate the wall, and operation at high densities are possible without losing density control. Lithium absorbing effect disappears after some shots. In principle this could be related to a passivation due to lithium binding with hydrogen, but in RFX-mod the reduced effectiveness of lithium seems mostly related to its disappearing. This last possibility results from the progressive reduction of lithium influx on a shot to shot basis (fig. 4). Samples analysis will investigate if this is related to a lithium removal or a stronger trapping of lithium by graphite.

Li wall conditioning effect on density and temperature. Lithium wall conditioning affects edge density and temperature profiles. Thermal Helium Beam diagnostic measurements performed after lithization show a higher edge temperature and a lower edge density (fig. 5). Temperature increase more than compensates density decrease and provides a higher edge pressure compared to discharges performed with graphite wall. Density profiles measured by a multi-chords interferometer have been compared to see if the observed edge variations correspond to a global modification of density profiles. Since on RFX-mod there is a high variation of density profiles, mostly related to mean density and plasma current, we compared the density peaking factor P_n=n(0)/<n> with its fit (Fit_P_n) calculated on clean graphite discharges as a function of I_p and <n>, see fig. 6. The comparison shows that with lithium the ratio P_n/Fit_P_n is typically higher than one. On the contrary, temperature profiles do not show

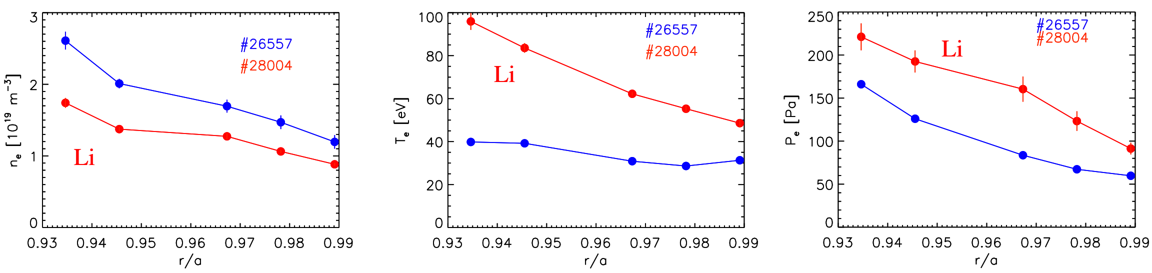

Fig. 5: Edge density, temperature and pressure measured on similar discharges before #26557 and after lithization #28004.

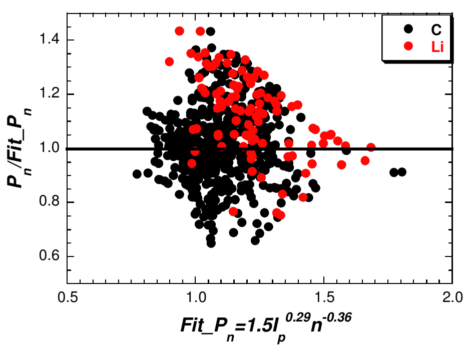

Fig. 6: Electron density profile peaking factor comparison between discharges whit and without Lithium conditioning.

any clear modification related to the lithium conditioning.

Particle and energy confinement time. The pumping effect of lithium coating provides a small increase of particle confinement time as it can be seen by comparing discharges performed on similar density range as function of plasma current (fig. 7). The same figure shows also that only by the lithium coating it was possible to obtain discharges with current over 1.6 MA. Up to now particle confinement time increase does not correspond to an improvement of the energy confinement time (fig. 8).

Conclusions. Wall conditioning by means of lithium proved to be an effective tool in controlling wall recycling. The technique is particularly effective in increasing hydrogen wall absorbing capacity, opening the possibility to externally control electron density during discharges. Lithium wall conditioning seems also very effective in modifying edge plasma parameters like density and temperature. Up to now is not clear if this is a direct effect of the different influx from the wall or if it is due to a lower Z_{eff} at the edge. The beneficial effect of wall conditioning does not seem to extend to the plasma core; it is not clear whether this is effectively due to the wall conditioning or to a lack of discharge optimization in presence of Lithium conditioning.

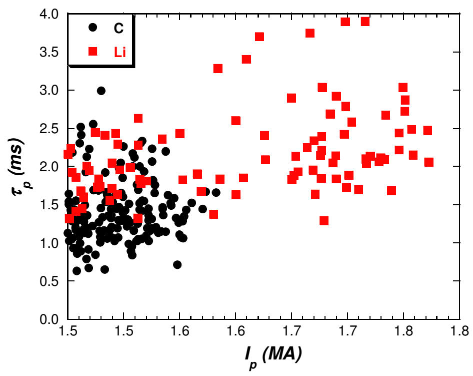

Fig. 7: Particle confinement time versus plasma current of discharges with an average density of about $3 \cdot 10^{19}$ m^{-3} with and without Lithium conditioning.

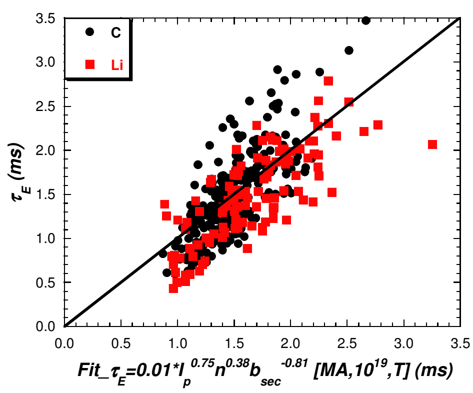

Fig. 8: Energy confinement time of discharges with and without Lithium conditioning.

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