Measurements of core lithium concentration in diverted H-mode plasmas of NSTX

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Lithium has been proposed as a candidate plasma-facing material to handle the large power flux to the wall of fusion devices [1]. To investigate the possible dilution of the core plasma caused by lithium influx from the plasma periphery, measurements of core lithium concentration, $n_{Li}(R)$, have been performed in diverted H-mode plasmas of the National Spherical Torus Experiment (NSTX [2]). Experimental scenarios representative of the NSTX operating space are explored from the 2010 NSTX experimental campaign, during which a total of ~1.3 kg of lithium was evaporated into the vessel [3]. These results will be used for projections of n_{Li} behavior in the upgraded device NSTX-U. Lithium can be introduced in the NSTX vessel from two *lithium evaporators* (LITERs [4]) and from a *lithium dropper* (Li-Dropper [5]). The latter releases small lithium granules from the top of the machine either before or during the discharge. Lithium density is measured through charge-exchange recombination spectroscopy of Li III emission at 516.7 nm. The major source of uncertainty is a C VI line located at the same wavelength as the Li III line. Because the relative Li III and C VI emissions are difficult to separate, the inferred n_{Li} actually represents an upper limit [3].

The temporal evolution of $n_{Li}(R)$ for a representative NSTX discharge using LITER is shown in Fig. 1. Note that ELMs are not destabilized, as inferred from the smooth Dα trace, which leads to accumulation of carbon in the core (Fig. 1c). The lithium profile starts to build up after the transition to H-mode at ~0.15 s (Fig. 1d), but $n_{Li}(R)$ remains <2% of the carbon density (Fig. 1e) and <0.1% of the electron density. The corresponding plasma dilution caused by lithium is negligible, with $\Delta Z_{eff} \leq 0.01$. Similar values are found for discharges with varying toroidal field (3.5-5.5 kG) and plasma current (0.65-1.1 MA). A modest increase is observed as current and field are increased, probably because of a general improvement of confinement. No systematic trend in the lithium accumulation is observed when the aspect ratio, hence the gap between plasma and center column, is increased up to the values expected for NSTX-U.

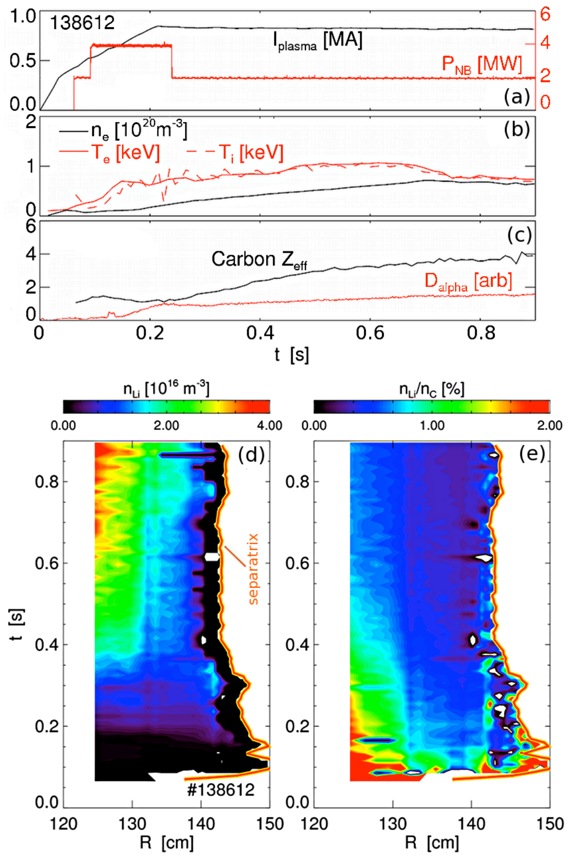
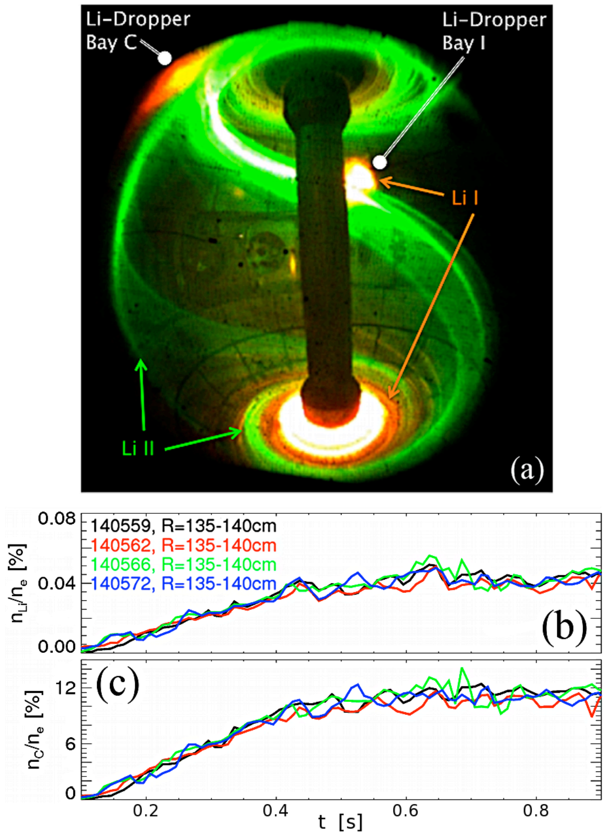


Fig. 1: (a-c) Plasma current, injected NB power, central densities and temperatures, divertor Dα and central carbon Z_{eff} for NSTX discharge no. 138612. Note the absence of ELMs, as deduced from the smooth Dα trace. (d) Measured evolution of the lithium density profile. (e) Ratio of lithium to carbon concentration. The magnetic axis is at R~105 cm. The radius of the separatrix is indicated by a red line.

In addition to LITER, other lithium-conditioning techniques may impact the core lithium accumulation via different impurity source terms. Four discharges with similar amounts of lithium inserted from either LITER or Li-Dropper before and during the discharge are compared. Visible camera images during Li-Dropper injection (Fig. 2a) show that lithium granules do interact strongly with the scrape-off-layer plasma and at the plasma edge. In spite of this, similar values of n_{Li} are measured for discharges with lithium evaporation from LITER prior to the shot, with lithium from the Li-Dropper or with both together (Fig. 2b-c).

The effect of the divertor conditions on n_{Li} is also explored. The LLD plate temperature is varied from ≈100 °C (solid lithium) up to ≈300 °C (liquid lithium) by positioning the lower strike point on the LLD plates. The lithium-to-carbon ratio remains roughly constant for different plate temperatures. Along with the observations of a similar response to different lithium conditioning techniques, these results indicate that lithium in the core plasma of NSTX is rather insensitive to the specific characteristics of the plasma facing components (solid or liquid) and to the details of the plasma-wall interactions in the divertor region.

It is worth noting that, among all the scenarios investigated on NSTX, the only case for which a clear increase of $n_{Li}(R)$ is observed is during anomalous events. For instance, a transient increase of n_{Li} is measured when the plasma interacts with a macroscopic, localized accumulation of lithium located in the lower divertor region. In this case, the lithium concentration reaches values of ~0.2% of the electron density. Although n_{Li} is larger than in typical NSTX plasmas, it should be emphasized that its contribution to plasma dilution remains nevertheless very modest, resulting in an increase in Z_{eff} of only $\Delta Z_{eff} \approx 0.012$.



shot no.	*LITER*	*Li-Dropper*
140559	240 mg	—
140562	240 mg	240 mg + 240 mg/s × 1.2 s
140566	240 mg	0 mg + 100 mg/s × 1.1 s
140572	120 mg	240 mg + 120 mg/s × 1.2 s

Fig. 2: (a) Visible light image of lithium interacting with the edge plasma during Li-Dropper operations for discharge no. 140572. (b-c) Lithium and carbon concentrations, normalized to the electron density. The Table reports the amount of lithium introduced in the vessel via LITER and Li-Dropper for each shot. For the Li-Dropper, the first (second) value corresponds to the amount introduced before (during) the pulse.

In summary, $n_{Li}(R)$ remains insignificant in NSTX plasmas, typically <<0.1% of the electron density in spite of the large amount of lithium (hundreds of milligrams) introduced in the vessel either before or during a discharge. Measured values of n_{Li} are rather insensitive to variations of plasma current, toroidal field, divertor conditions and of the specific technique utilized for lithium conditioning of the vessel wall [3]. These results enable projections to the higher field and current and longer pulse length of the NSTX Upgrade (NSTX-U), suggesting that lithium contamination will remain negligible compared to other impurities such as carbon.

Work supported by U.S. DOE Contract DE-AC02-09CH11466.

References:
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