The Effects of Increasing Lithium Deposition on the Power Exhaust Channel in NSTX

T.K. Gray[1], J.M. Canik[1], A.G. McLean[2], R. Maingi[1], J-W. Ahn[1], M.A. Jaworski[3], R. Kaita[3], T.H. Osborne[4], S.F. Paul[3], F. Scotti[3] and V.A. Soukhanovskii[2] and the NSTX Team

[1]Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA
[2]Lawrence Livermore National Laboratory, Livermore, CA, USA
[3]Princeton Plasma Physics Laboratory, Princeton, NJ 08543 USA
[4]General Atomics, San Diego, CA, USA

Email: tkgray@pppl.gov

Previous measurements on the National Spherical Torus Experiment (NSTX) demonstrated peak, perpendicular heat fluxes, $q_{dep,\ pk} \leq 15$ MW/m^2 with an inter-ELM integral heat flux width[1], $\lambda_{q,\ int} \sim 3$—7 mm during high performance, high power operation (plasma current, $I_p = 1.2$ MA and injected neutral beam power, $P_{NBI} = 6$ MW) when magnetically mapped to the outer midplane. Analysis from multiple tokamaks, including NSTX, indicates that $\lambda_{q,\ int}$ scales approximately as I_p^{-1}[2]. The strong inverse I_p dependence complicates ITER operation since attached divertor plasmas would have $\lambda_{q,\ int} < 5$ mm and deposited heat fluxes greater than 10 MW/m^2, which is above the material limit for tungsten plasma facing component (PFC) divertor operation in ITER.

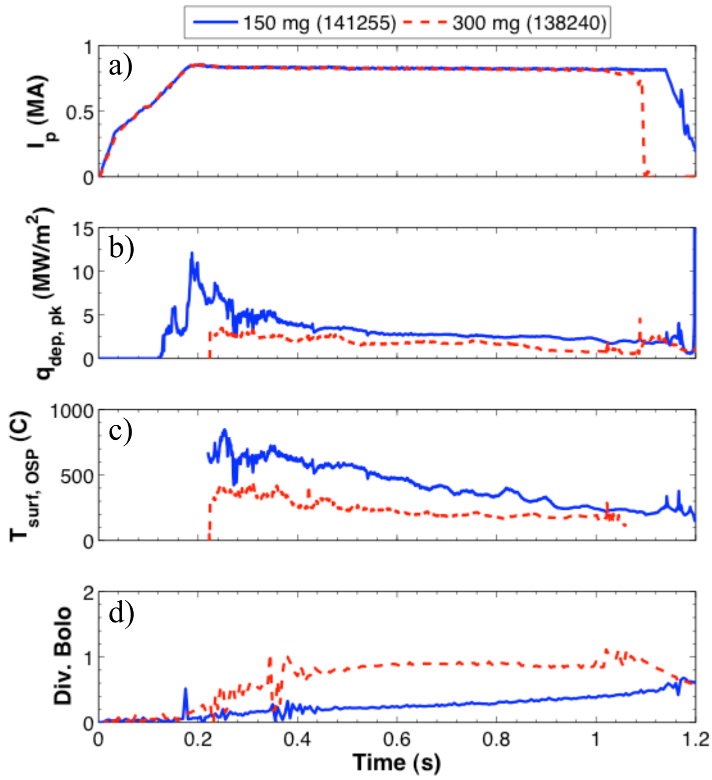

Figure 0: Comparison of 2 similar NSTX discharges ($I_p = 0.8$ MA, $P_{NBI} = 4$ MW, $\delta \sim 0.7$, $f_{exp} \sim 20$) with 150 and 300 mg of pre-discharge lithium evaporation. b) I_p, b) peak divertor heat flux, c) surface temperature at the outer strike point and d) divertor bolometry.

While methods have been developed to mitigate divertor heat flux on NSTX[3,4,5], the application of evaporative lithium coatings onto the lower divertor in NSTX also appears to reduce divertor surface temperature in ELM-free H-mode plasmas when sufficient lithium evaporation is applied. Divertor surface temperature is measured with a unique dual-band IR (DBIR) thermography system to mitigate the effects of changing surface emissivity[6,7]. Figure 1 shows the time history of 2 typical high δ, high flux expansion discharges with $I_p = 0.8$ MA, $P_{NBI} = 4$ MW with 150 and 300 mg of pre-discharge lithium evaporation respectively. Measurements from the DBIR system show reduced divertor surface temperature at the outer strike point for the case with 300 mg of lithium deposition as shown in Fig. 1c. This results in the divertor heat flux being reduced from 5 to 2.5 MW/m^2 s shown in Fig. 1b. In turn, a reduction in divertor power accounting is measured with increased lithium evaporation such that P_{div}^{IR}/P_{loss} ~ 0.3 – 0.5 for discharges with 150 mg of lithium and 0.12 – 0.2 for discharges with 300 mg of lithium. The reduction in divertor power is correlated to an increase in divertor radiation for discharges with 300 mg of lithium evaporation as shown in Fig. 1d.

Figure 2a shows the peak parallel heat flux as a function of I_p for 150 and 300 mg of lithium constrained to early times in the I_p flat-top of the discharge when density is lower such that $n_e/n_G \leq 0.6$. A reduction in the heat flux is shown when 300 mg of lithium is used. $q_{||,\ pk}$ is consistently reduced over a scan of I_p from 0.8 – 1.2 MA when 300mg of lithium is used compared to 150 mg with an average reduction in $q_{||,\ pk}$ of between 30 – 50%. While the measured divertor heat flux is reduced with heavy lithium evaporation, $\lambda_{q||,int}^{mid}$ is measured to contract from 11 to 6 mm at I_p = 0.8 MA for 150 and 300 mg of lithium respectively as shown in Fig. 2b. When I_p is increased to 1.2 MA both the 150 and 300 mg data contract with $I_p^{-\alpha}$ as previously observed for boronized discharges[2, 3] resulting in $\lambda_{q||,\ int}$ ~ 7 mm and 3 mm for 150 and 300 mg of lithium respectively. Modeling of these discharges will be performed with SOLPS[8] to quantify the divertor radiation profile constrained against experimentally measured divertor D_α, Li II, C II and heat flux profiles as well as midplane n_e, T_e and T_i measurements. Implications for NSTX-U operation with heavy lithium coatings in the divertor will also be explored.

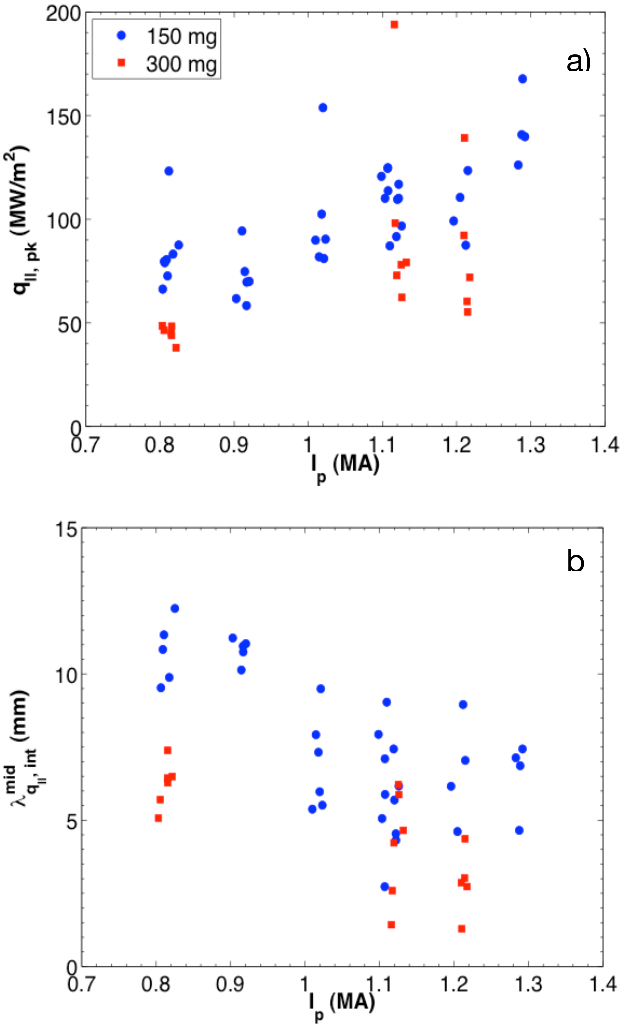

Figure 2: a) Peak parallel heat flux as measured with the DBIR system and b) $\lambda_{q||,\ int}^{mid}$ as a function on I_p for 150 and 300 mg of pre-discharge lithium evaporation with P_{NBI} = 4 MW, δ ~ 0.7, f_{exp} ~ 20 and $n_e/n_G \leq 0.6$.

This work was supported by U.S. Department of Energy contracts: DE-AC05-00OR22725, DE-AC52-07NA27344 and DE-AC02-09CH11466

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