Modeling the Effect of Lithium on SOL Dynamics and the SOL Heat Flux Width Observed in NSTX*

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The pedestal gradient and the scrape-off-layer (SOL) heat flux width are critical quantities for ITER and future tokamaks. It is well known that the pedestal gradient, together with the pedestal width, determines the peak pedestal pressure and hence the overall fusion performance of the machine. The SOL heat flux width, together with the peak power, determine the survivability of the divertor target plates. In this paper, simulations of lithium-induced changes in NSTX suggest that the pedestal gradient and the SOL heat flux width are related by turbulent transport.

The effect of lithium wall coatings on scrape-off-layer (SOL) turbulence is modeled using a new edition of the Lodestar SOLT code that includes finite T_i and ion diamagnetic drift effects.[1] Lithium coatings are expected to reduce recycling and therefore core fueling, providing control over the particle channel independently of the thermal channel. Experimentally, lithium deposition is found to eliminate ELMs on NSTX, improve confinement and modify the pedestal profiles, reducing the density gradient just *inside* the last closed flux surface.[2,3] The goal of our simulation work is to understand the implications of these Li-induced changes for the SOL heat flux width. Corresponding experimental measurements of the SOL heat flux width λ_q , which can be used for validation, show that it is reduced somewhat in Li-coated discharges at low I_p, but the reduction saturates at a minimum $\lambda_q > 0$ for high I_p.[4]

For this work we chose two NSTX experiments previously analyzed for pedestal transport properties,[3] the pre-lithium discharge 129015, and a post-lithium (heavily coated) discharge 129038. The simulations input outer midplane geometry data for R, B_p, B_t, $L_{||}$ (SOL connection length) and are constrained by other available experimental data. One constraint is that the density and temperature profiles in the simulation match the experimental ones inside the last closed surface. Because lithium conditioning modifies these pedestal profiles, reducing the gradients of plasma energy and particle density, it could lead to changes in drift-interchange-driven turbulence, which plays a role in setting SOL heat flux characteristics.

Another constraint is that the total power P_{SOL} flowing out across the last closed flux surface in the simulation matches that in the experimental discharge. Turbulent transport of energy responsible for P_{SOL} in the simulations arises from a competition between free energy sources which drive the modes, the inverse cascade to zonal flows, and dissipative effects which act to absorb energy at high-k. Coefficients for such dissipative effects are not measured directly in the experiment, so we vary dissipation (e.g., diffusion) coefficients to achieve matching of P_{SOL} to the experimental value.

Figure 1 shows plots of (a) P_{SOL}, (b) the SOL heat flux width λ_q for the ion channel and (c) the magnitude of density fluctuations as functions of density diffusion coefficient D_n. Note that P_{SOL} is sensitive to D_n but λ_q is less so: the SOL transport determining λ_q is dominated by mesoscale turbulent fluctuations (blobs and convective cells), not by D_n directly. Each plot compares the result with and without Li. The effect of Li enters the simulation through the profile matching inside the last closed flux surface: Li modifies the experimental density and temperature profiles, and these profiles affect the simulation results in the SOL.

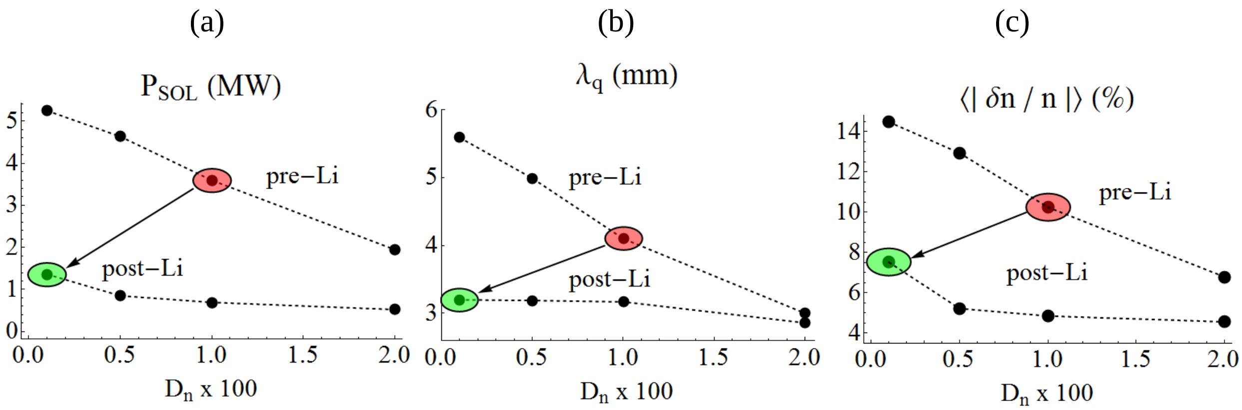

Fig. 1. SOLT simulation results for NSTX discharges with and without lithium coatings vs. density diffusion coefficient D_n showing the variation of power (a), SOL heat flux width for the ion channel, with the electron channel suppressed for clarity (b), and density fluctuation level (c). The large red (green) highlighted points achieve the best power matching with the experiment for the pre-Li (post-Li) discharges.

A number of features of the simulations agree qualitatively with the experiment. In particular, λ_q is somewhat smaller for the case with Li, as observed experimentally, and the density fluctuation amplitude (Fig. 1c.) is smaller for the Li case, in qualitative agreement with experiment: reflectometry measurements showing reduced density fluctuations near the separatrix, post-Li, were reported in Fig. 8 of Ref. 3.

Some issues remain to be resolved. For example, the poloidal flow velocities in the simulations are too high when compared with experimental GPI data.[5] However, the use of flow damping in the simulations improves the comparison; more damping gives larger λ_q and smaller poloidal velocities. The flow damping may be due to neutral friction in the experiment, and this is a direction for future work as it could be related to lithium coatings and neutral recycling. Ongoing work is addressing the turbulent drive, saturation mechanisms, parallel heat flux regime, and the resulting λ_q scaling.

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1 D. A. Russell et al., Bull. Am. Phys. Soc. **57**, 67 (2012), paper BP8-159.
2 R. Maingi, S. M. Kaye, C. H. Skinner, D. P. Boyle et al., Phys. Rev. Lett. **107**, 145004 (2011).
3 J. M. Canik, R. Maingi, S. Kubota, Y. Ren et al., Phys. Plasmas **18**, 056118 (2011).
4 T. K. Gray, J. M. Canik, R. Maingi, A.G. McLean et al., 24th IAEA Fusion Energy Conference, San Diego, USA, October 8 - 13, 2012, paper IAEA-CN-197/EX/P5-27.
5 B. Cao, S. J. Zweben, D. P. Stotler, M. Bell, A. Diallo, S. M. Kaye and B. LeBlanc, Plasma Phys. Control. Fusion **54** , 112001 (2012).