Topic: EX-D

Comparison of helium glow and lithium evaporation wall conditioning techniques in achieving high performance H-mode discharges in NSTX

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Good discharge reproducibility and H-mode performance was realized in the National Spherical Torus Experiment (NSTX) with an extensive wall conditioning program. The graphite plasma-facing components were baked for several weeks to 350 ºC at the beginning of a campaign, with extensive deuterium and helium glow discharge cleaning (HeGDC). Periodic boronization was used, and enabled reliable H-mode access. Daily run preparation included 15-30 minutes of pre-run HeGDC, followed by inter-discharge HeGDC of 9-14 minutes, depending on the target discharges, with a resulting inter-discharge time of 15-20 minutes[1]. With the development of inter-discharge lithium evaporation[2], however, the necessity of both inter-discharge HeGDC and lithium evaporation became questionable.

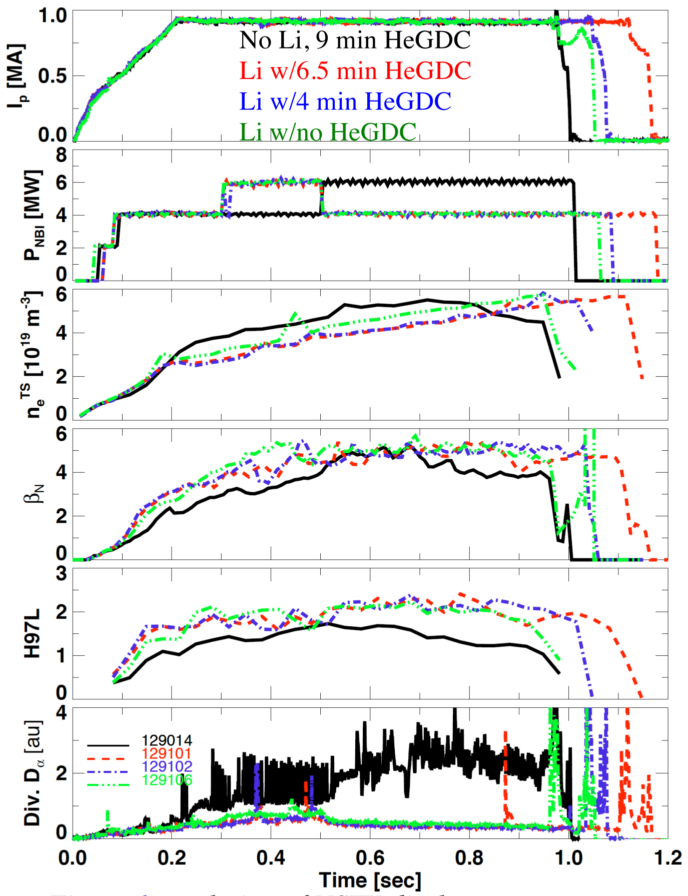

Figure 1: evolution of NSTX discharge parameters with variable HeGDC time preceding Li evaporaton. A reference ELMy discharge without lithium and with standard HeGDC is also shown.

To assess the viability of operation without HeGDC and directly compare with inter-discharge lithium evaporation, experiments were conducted in which lithium evaporation was used while systematically reducing the inter-discharge HeGDC from the standard 9 minutes to zero. Good discharge reproducibility without HeGDC was achieved with lithium evaporation doses of 100 mg or higher; evaporations of 200-300 mg typically resulted in very low ELM frequency or ELM-free operation, reduced recycling, and improved energy confinement, e.g. as shown in Figure 1.

The inverse experiment, i.e. when lithium evaporation was terminated, and inter-discharge HeGDC was re-initiated, with a systematic increase in HeGDC duration and decrease in external fueling, was also conducted; similar results were obtained to those described above. In addition, an experiment in which a large lithium dose (~25g, ~100 times the typical inter-discharge evaporation) prior to operations was conducted. In this case, about 100 plasma discharges over three run days were conducted with neither inter-discharge Li evaporation nor HeGDC. Nearly all of these achieved H-mode, but the pulse lengths and performance were irreproducible. At the end of the sequence, recycling started to slowly increase, external fueling was decreased, and inter-discharge HeGDC was resumed.

While the discharges with longer inter-discharge HeGDC times performed modestly better than those with shorter or no HeGDC durations, the discharge performance improved substantially in NSTX with increasing lithium dose, in both moderately shaped[3, 4] and strongly shaped[5] plasmas. To quantify this effect, a sequence of H-mode discharges with increasing levels of pre-discharge lithium evaporation ('dose') with high triangularity and elongation boundary shape, and without inter-discharge HeGDC conditioning, was analyzed with the SOLPS edge transport code. Globally, energy confinement increased, and recycling decreased with increasing lithium dose, similar to a previous lithium dose scan in medium triangularity and elongation plasmas. Data-constrained interpretive modeling with SOLPS quantified the edge transport change: the electron particle diffusivity decreased by 10-30x (Figure 2). The electron thermal diffusivity decreased by 4x just inside the top of the pedestal, but increased by up to 5x very near the separatrix. These results provide a baseline expectation for lithium benefits in NSTX-U, which is optimized for a boundary shape similar to the one used in this experiment. New results from upcoming wall conditioning experiments in NSTX-U will also be presented, when available.

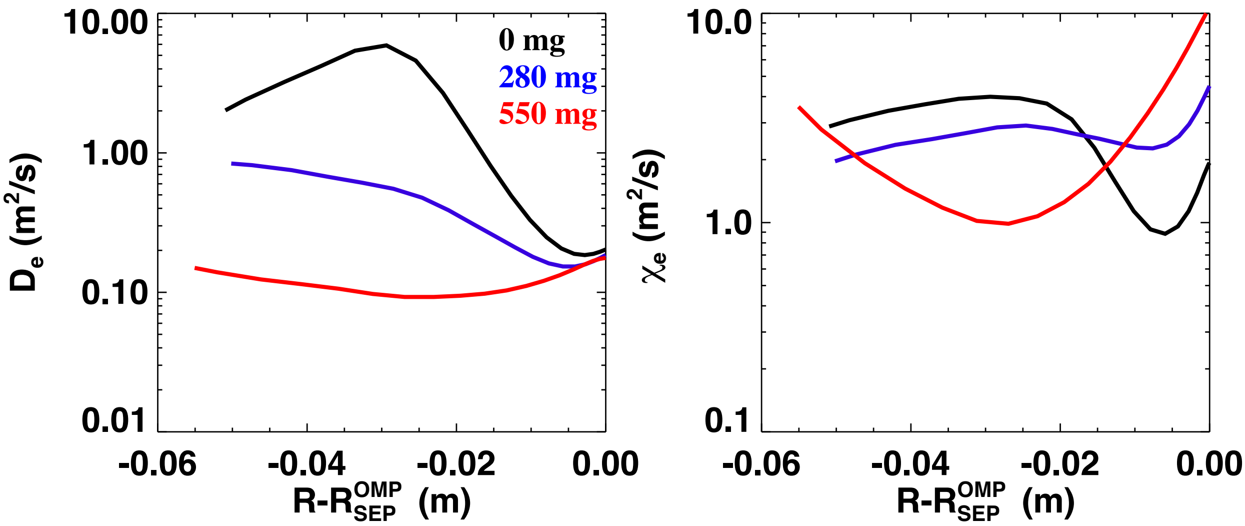

Figure 2: (a) effective electron particle diffusivity D_e and (b) electron thermal conductivity χ_e vs. distance from the separatrix at the outer midplane. The lithium evaporation dose is indicated.

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References:

1. Kugel HW, *et al.*, *J Nucl Mater* **313** (2003) 187.
2. Kugel HW, *et al.*, *Phys Plasmas* **15** (2008) 056118.
3. Maingi R, *et al.*, *Nucl Fusion* **52** (2012) 083001.
4. Canik JM, *et al.*, *Phys Plasmas* **18** (2011) 056118.
5. Maingi R, *et al.*, *J Nucl Mater* **463** (2015) 1134.