Topic: EX-D

Achievement of Reduced Recycling and Improved Particle Control from Lithium Coatings Following Wall Conditioning Experiments in NSTX*

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NSTX is confronting particle flux and edge heat management issues through its unique program on lithium coatings and its investigation of liquid lithium as a long-term solution for particle and power handling in ITER and future burning plasma fusion reactors. Motivated by this potential, NSTX has been investigating lithium pellet injection for reduced recycling as part of a phased, three-part approach to lithium PFCs: first lithium pellet injection, then lithium evaporators, and finally a liquid lithium divertor.

As an initial step, lithium pellets have been used recently to create lithium coatings that significantly lowered recycling in neutral beam-heated NSTX plasmas. TFTR obtained reduced recycling and significantly enhanced performance by starting with a limiter thoroughly depleted of hydrogen isotopes and applying two lithium deposition techniques, lithium pellet injection (LPI) and lithium micro-droplet introduction (DOLLOP) directly into low density plasmas. Since TFTR, LPI has also been applied directly into normally fueled, diverted C-MOD, DIII-D and TdeV plasmas. However, without the thorough wall degassing applied in TFTR, it has not yielded similar performance improvement other than a small decrease in impurities. More recently, however, CDX-U succeeded in reducing the global recycling coefficient to less than 50% with a liquid lithium limiter. [1]

In the NSTX experiments, repeated LPI into ohmic helium discharges was used to deposit 30 mg on the Center Stack Limiter (CSL) immediately after pre-conditioning this surface with a series of helium discharges. A following deuterium CSL discharge with neutral beam injection (NBI) with the same gas input, then exhibited a reduction in the volume-average density by a factor of about four compared to a reference shot prior to the Li coating. The density reverted to the pre-LPI level after two further discharges in the same nominal conditions as the lithium was passivated (Fig.1). After another 24 mg of Li was deposited with LPI, almost the identical density behavior was observed in the subsequent CSL NBI reference discharges. These results are similar to the experience with Li deposition in TFTR.

In a subsequent NSTX experiment, diverted, Lower Single Null (LSN), helium discharges were then used to condition the lower divertor target. This was followed by LPI into a sequence of helium discharges which were used to deposit about 25 mg of Li on the lower divertor. As this deposition progressed, the neutral Li line emission from the lower divertor region increased. Finally, a series of three LSN, deuterium plasmas with NBI were applied. In the first of these, the density exhibited a factor of about five reduction from a similar reference discharge at the beginning of the experiment. The reduction in density was less on the second and absent on the third shot, again consistent with exhausting the capacity of the deposited lithium to absorb deuterium.

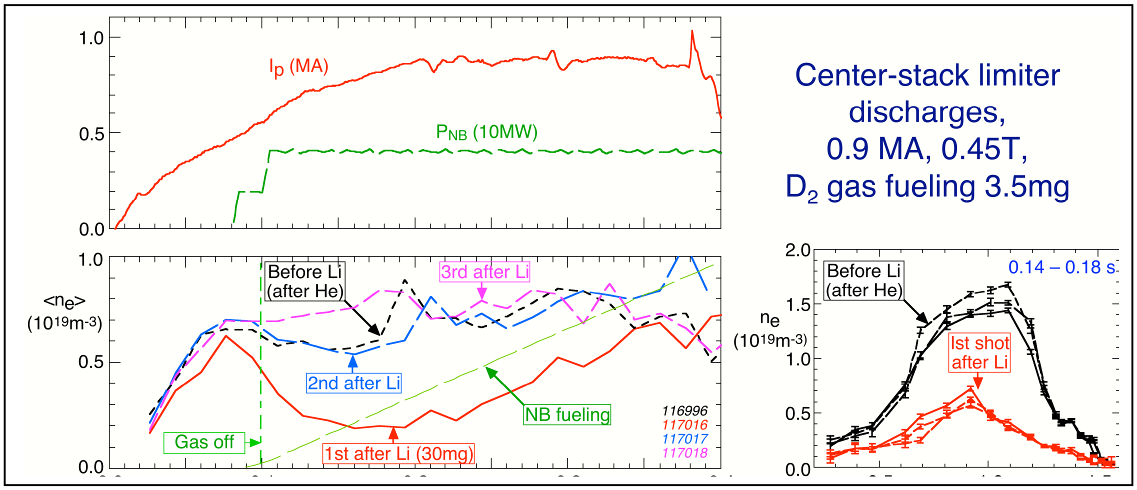

Fig.1. A reduction in the volume-average density by a factor of about four was exhibited by Center Stack Limited deuterium NBI discharges following deposition of 30 mg of lithium using repeated Lithium Pellet Injection (LPI) into ohmic helium discharges.

The use of lithium for particle control in NSTX is the latest in a progression of techniques for controlling impurity influxes and the recycling of deuterium fuel. To date, this has involved a combination of high-temperature bakeout, boronization, and between-discharge helium glow discharge conditioning (HeGDC). In light of NSTX growing needs for density rise and profile control during long-duration H-modes, and in anticipation of similar ITER requirements, we have evaluated variations in the wall temperature during boronization, in the schedule of boronization, and the duration of the effectiveness of hot (250 – 300°C) and cold (20°C) boronization for facilitating access to H-modes. A short boronization, ~15 min, followed by a comparable duration of HeGDC applied in the morning before the start of daily experiments was found to restore and enhance good conditions, as evidenced by impurity levels and ready access to the H-mode. In the past year, we have also evaluated different techniques for helium plasma cleaning to reduce deuterium recycling, e.g. varying the duration of HeGDC between tokamak discharges, using fixed, wall-mounted *vs.* retractable, centrally located anodes for HeGDC, and testing the efficacy of using helium tokamak discharges between deuterium discharges. These comparisons were used to develop procedures for controlling impurities and the density rise during short-duration discharges.[2]

To achieve better density control in long-pulse discharges and more efficient current-drive for non-inductive current sustainment, more effective control of edge recycling is required, and this has motivated the lithium research that is now underway on NTSX. In light of the initial results from thin lithium coatings, a large-capacity lithium evaporator (100mg/sec) is being installed on NSTX for performing routine thick lithium coating over a significant fraction of the plasma facing surfaces in 2006.

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[1] R. Majeski *et al.,* Nucl. Fusion **45** (2005) 519.
[2] H.W. Kugel, J. Nucl. Mater., **337-339** (2005) 495.