Lithium Surface Coatings Improve Plasma Performance in the National Spherical Torus Experiment

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Coating plasma-facing components with lithium leads to enhanced particle control and improved plasma performance

In the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL) the outer boundary of the plasma approaches an almost spherical shape. Recent research has focused on how coating the plasma-facing surfaces inside NSTX with lithium can inhibit the return of particles which escape from the plasma, thereby providing a way to control the plasma density. A lithium wall coating also has the ability to reduce the influx of unwanted impurities into the plasma from its surroundings, and improves its thermal insulation leading to higher plasma temperatures for the same heating power. Recent NSTX results suggest that a plasma-facing lithium wall could significantly improve future fusion reactor performance.

The NSTX research on lithium-coated plasma-facing components is the latest step in a decade-long, multi-institutional research program aimed at developing lithium as a plasma-facing system that can withstand the intense heat and neutron fluxes expected in a future fusion reactor producing electric power. The results may have eventual application in the ITER device, a large tokamak now being built in France by an international consortium. ITER will produce a burning plasma — one that is predominantly sustained at high temperature by the power of its own fusion reactions.

In the recent NSTX experiments, lithium depositions from just a few milligrams to about 1 gram have been applied between plasma pulses. Among the effects observed in subsequent neutral-beam heated plasmas were decreases in oxygen impurities, plasma density, and increases in electron temperature, ion temperature, and improved energy confinement. These benefits were achieved with the plasma in the high-confinement mode (H-mode) of the tokamak which is the chosen mode of operation for ITER. In addition, there was a reduction in the frequency of the Edge Localized Modes (ELMs), including their complete suppression in some cases. The ELMs are periodic instabilities near the plasma edge which can adversely affect the performance of H-mode plasmas and which, if uncontrolled, could have serious consequences for the lifetime of the plasma facing components in ITER. Figure 1 compares two NSTX plasma pulse traces, with and without lithium coating, of the average plasma density, the total energy stored in the plasma electrons, and a light signal from excited deuterium atoms which indicates the rate of influx of deuterium atoms into the plasma edge. This last signal also indicates the occurrence of the ELM instabilities which appear as sudden upward "spikes" in the light emitted from the plasma edge (Fig.1c). During the period 0.5 – 0.8 s, the ELMs are suppressed in the plasma pulse with lithium, and the plasma electron stored energy rises about 40% above what is achieved in the pulse without the benefit of lithium. NSTX experiments using lithium coatings hold promise for elucidating the underlying physics of ELM instabilities, which could lead to allowing ELM control, and possibly their elimination in future fusion reactors. These results demonstrate the potential of lithium for favorably modifying plasma-surface interactions.

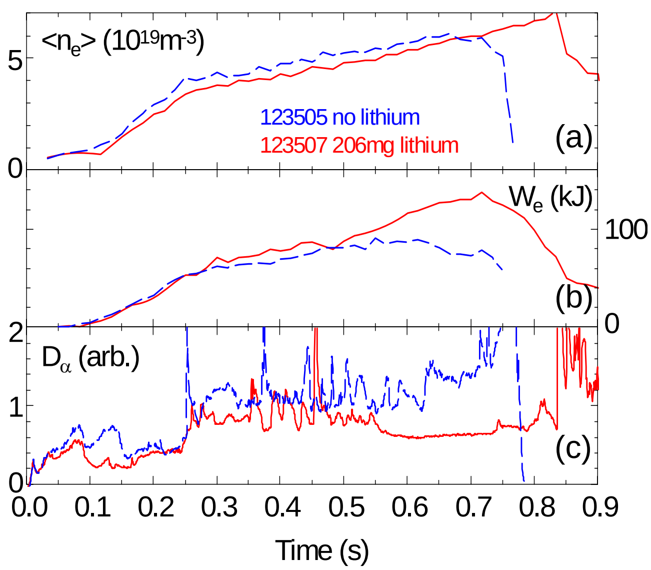

Fig. 1. Time traces from two neighboring NSTX pulses run in the same conditions before (blue) and after (red) the application of 200mg of lithium with the evaporator. The boxes show (a) the volume-average electron density, (b) the total electron stored energy and (c) a signal indicating the brightness of deuterium light from the plasma edge, an indicator of the influx of deuterium from the walls into the plasma and the stability of the edge. Note how lithium (red trace) reduces the deuterium influx, thereby reducing the density and increasing the electron stored energy, and also yields more quiescent edge conditions (fewer ELMS), particularly during the period 0.5 – 0.8 s.

An invited talk [TI2.6] to be presented at the 49th Annual Meeting of the APS Division of Plasma Physics in Orlando, FL will describe the lithium research on the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL).

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