NSTX

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Comparison of Diverted Plasmas Incident on Liquid Lithium and Lithiated Graphite Surfaces

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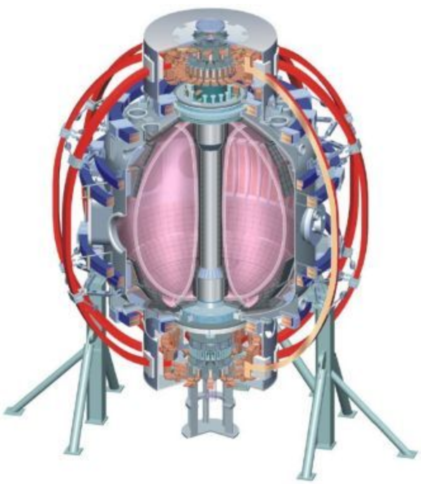

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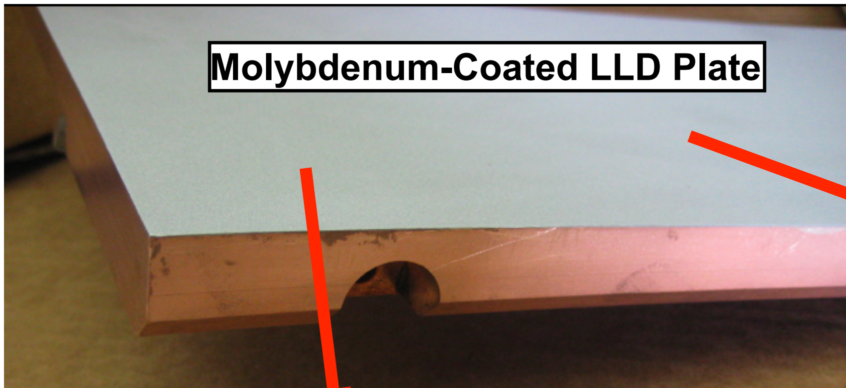
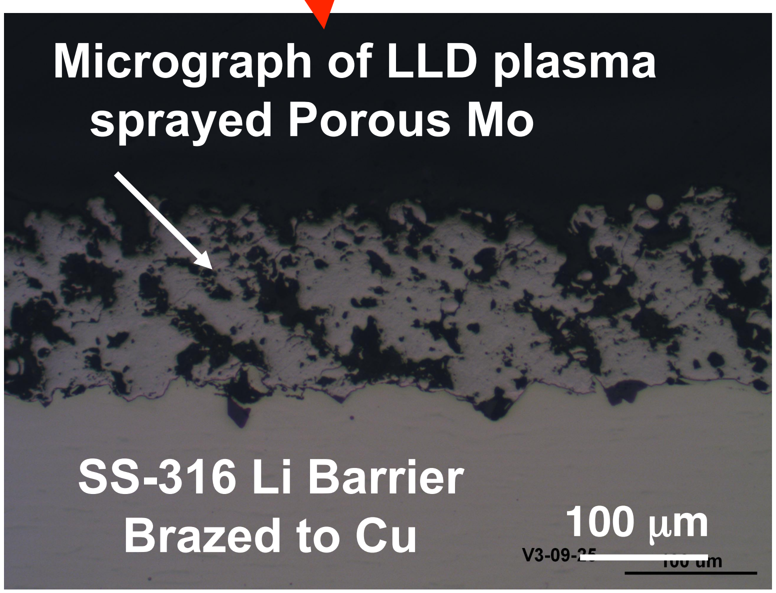
NSTX Plasma Improvements with Solid Lithium Coatings Motivated Experiments with Liquid Lithium Divertor

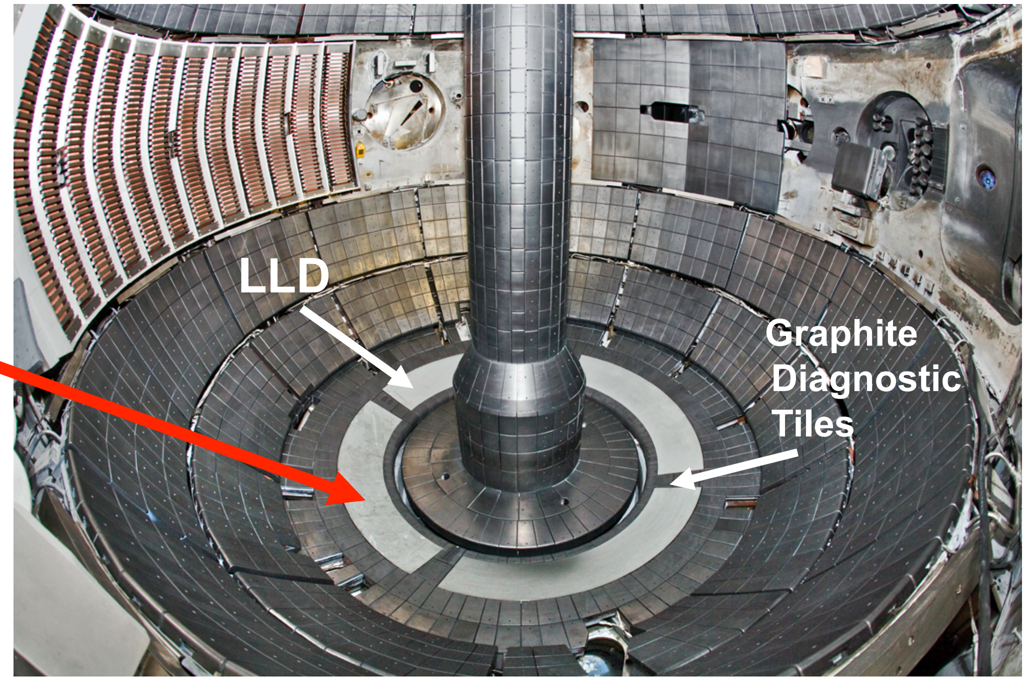
- *Edge recycling is reduced* as plasma D efflux is retained in lithium and lithium compounds
  - **Solid** lithium coatings provide only short-pulse capability
  - **Liquid** lithium has much higher capacity for absorbing D and potential for self healing reactor walls
- NSTX Liquid Lithium Divertor was designed to investigate **static liquid lithium on porous molybdenum substrate**
  - replenished by deposition from evaporators
  - *an approximation to an eventual flowing liquid system*

Liquid Lithium Divertor (LLD) Installed in NSTX with Porous Molybdenum Face to Hold Lithium

0.165 mm Mo plasma sprayed with 45% porosity on a 0.25 mm SS barrier brazed to 22.2 mm Cu.

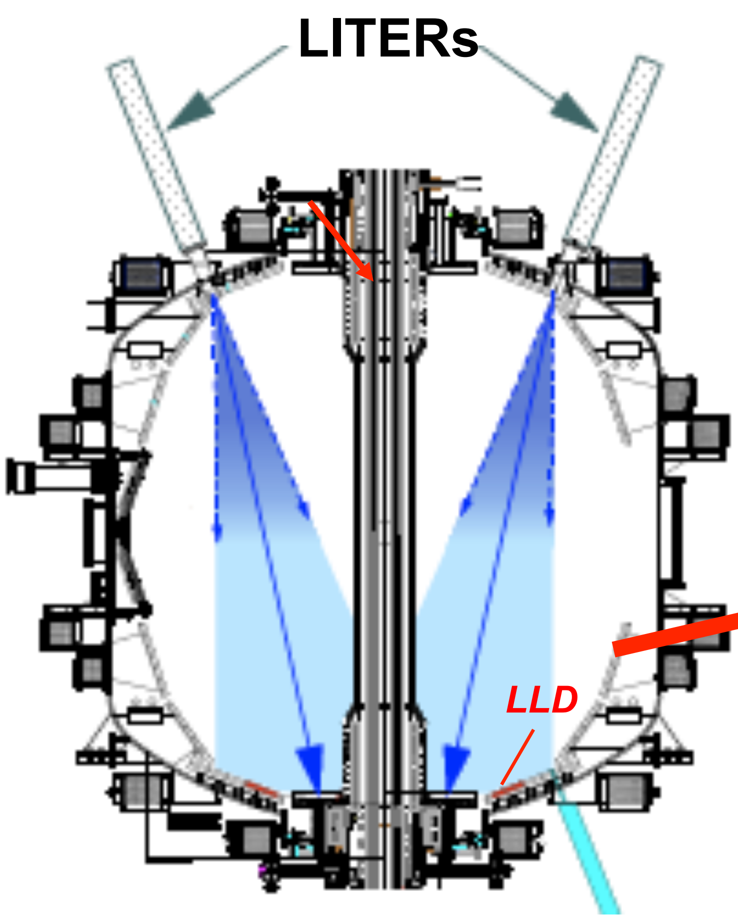






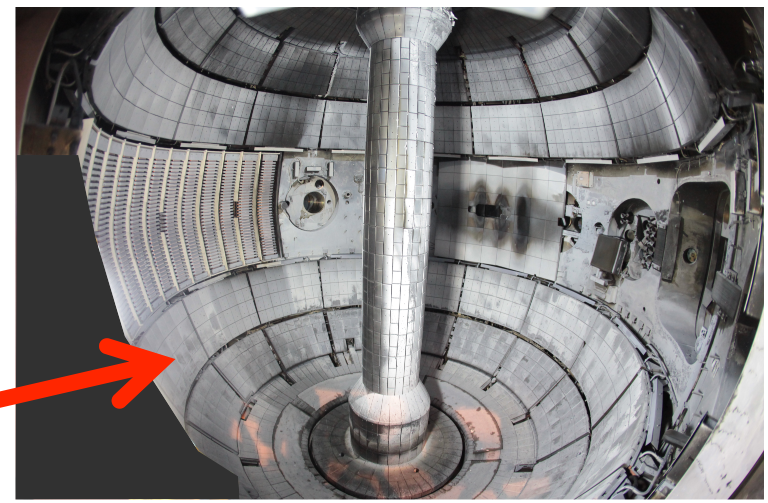
- 4 plates separated toroidally by graphite tiles containing diagnostics
- Loaded by lithium evaporation
  - Porous Mo surface has capacity for 37g Li
  - 2010 experiments with LLD to 100% full

Dual Lithium Evaporators (LITERs) Deposit 100-700mg of Lithium for 10 minutes Between 90% of Discharges



- LITERs aimed toward graphite divertor. Shown are 1/e widths of emitted gaussian-like distribution

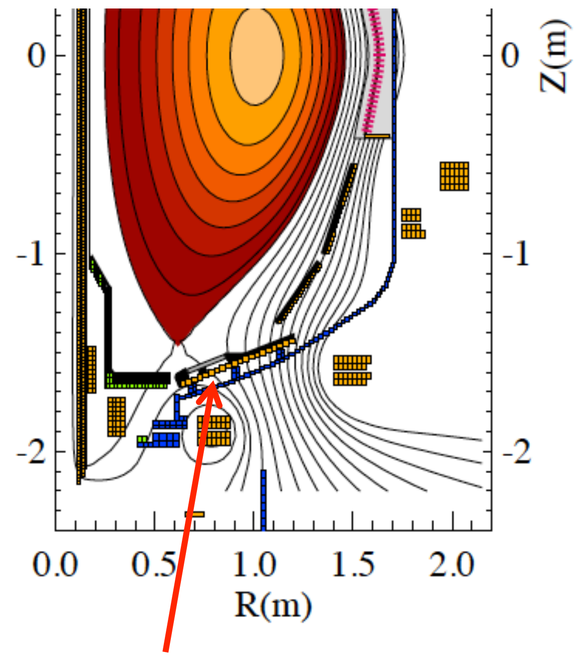
- Lithium transported over broad area by wings of LITER distribution and plasma migration



- After the 2010 air vent, the 1.3kg of lithium deposition converted to white lithium carbonate
  - lithium carbonate removed prior to evacuation with 5% solution of acetic acid to convert lithium carbonate to water soluble lithium acetate

Plasma Performance With LLD Similar To That With Lithiated Graphite

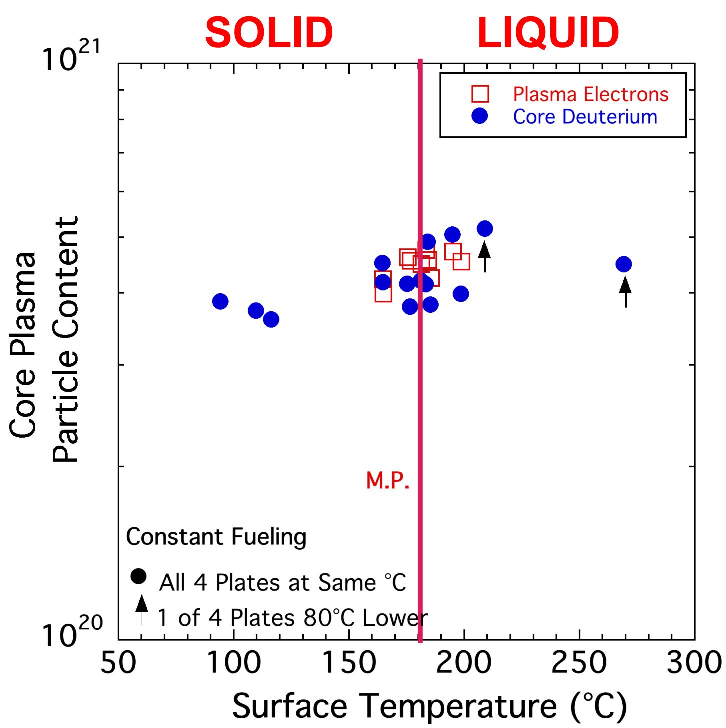
- With outer divertor strike point on lithium-filled LLD surface:
  - Confinement improved over non-lithium cases
  - ELMs suppressed
  - *Volume-average plasma lithium concentrations < 0.1%*
  - Thermal response during discharges determined by substrate (no hotspots observed)
  - No evidence of damage to molybdenum layer or substrate by lithium interactions or heating, *but*
  - There were indications of surface contamination of lithium on LLD surface
  - Surface impurity coatings on LLD and solid Li may have comparable D retention

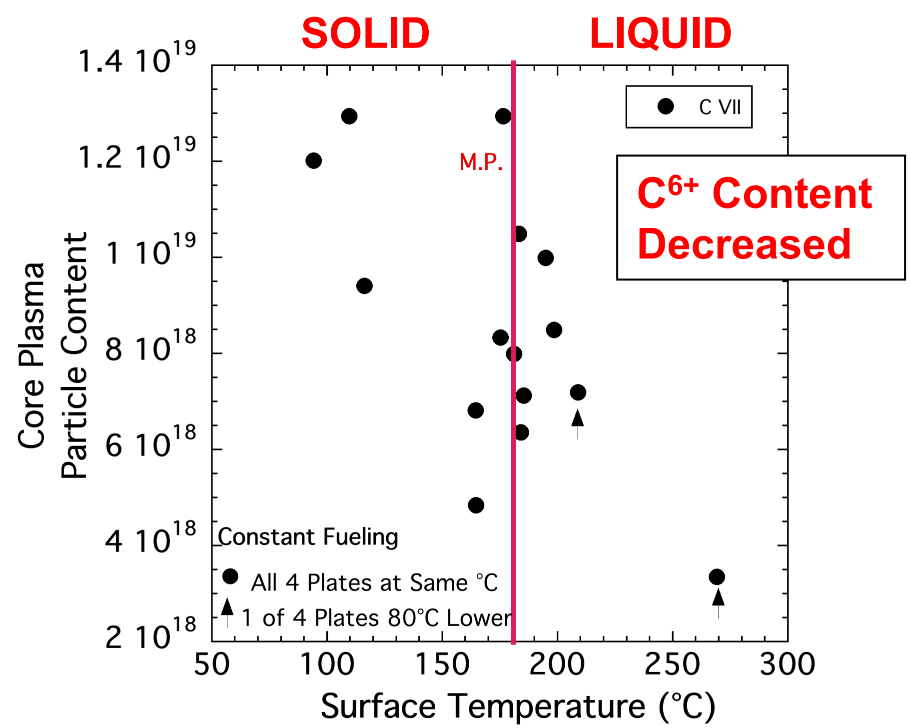


Outer Strike Point on LLD

First Experiment - Heat LLD Through Lithium Melting Temperature: e^- and D Density Remained Relatively Constant, but C^{6+} Decreased

- Same fueling for each discharge
  - -no additional fueling required to maintain density



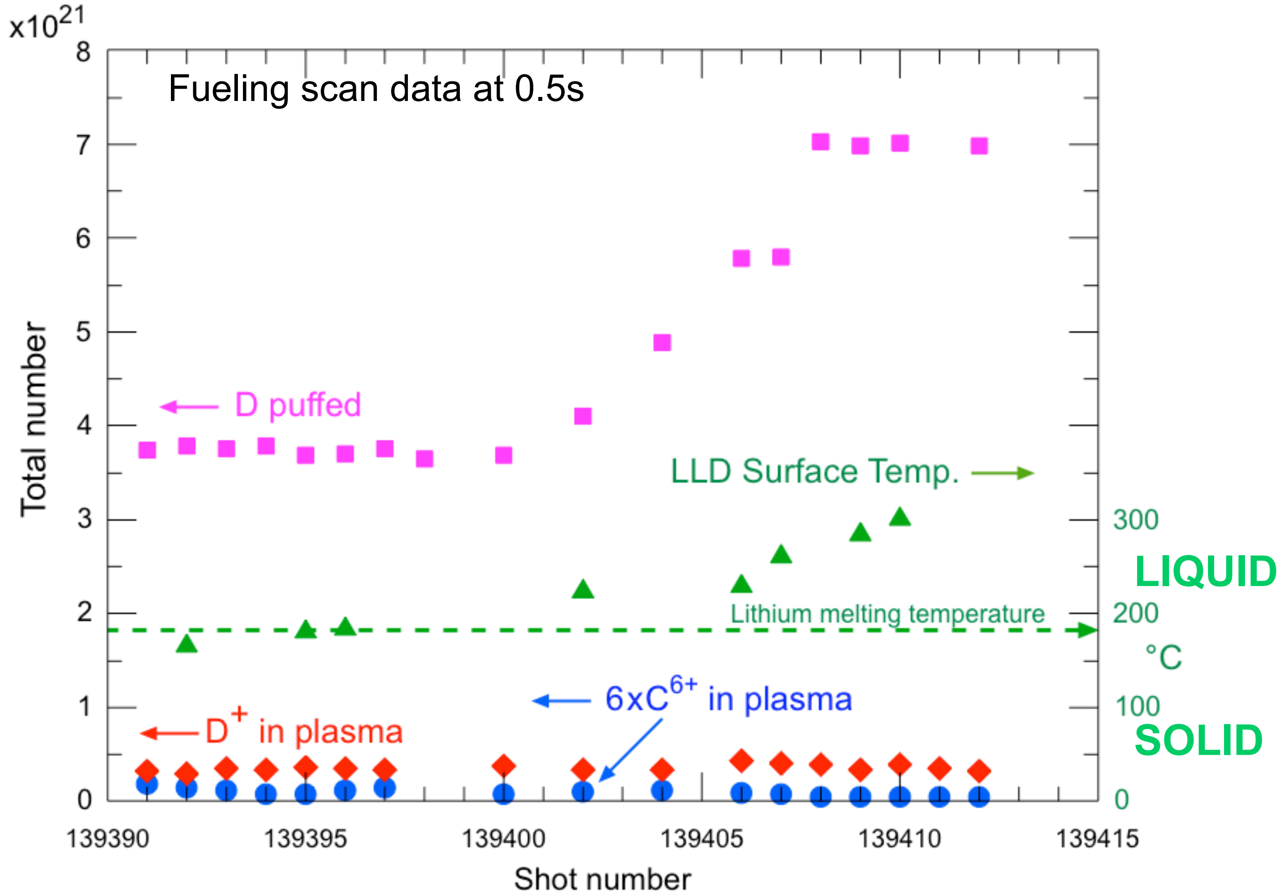


- Indicates that D absorption at solid and liquid lithium temperatures was same
- The decrease in carbon content as LLD temperature increased was coincident with increasing ELMs (need to do reverse experiment, i.e., from liquid to solid)

Second Experiment - Use Plasma Heating to Liquefy Lithium: Saw Change in Apparent Efficiency of Fueling by D Puffing

- As LLD was *heated by plasma heat flux* over series of shots, it became necessary to increase D puffing significantly to maintain plasma density and stability

Total number of D particles puffed (gas fueling), and resultant D and C^{6+} plasma content and LLD surface temperature during plasma

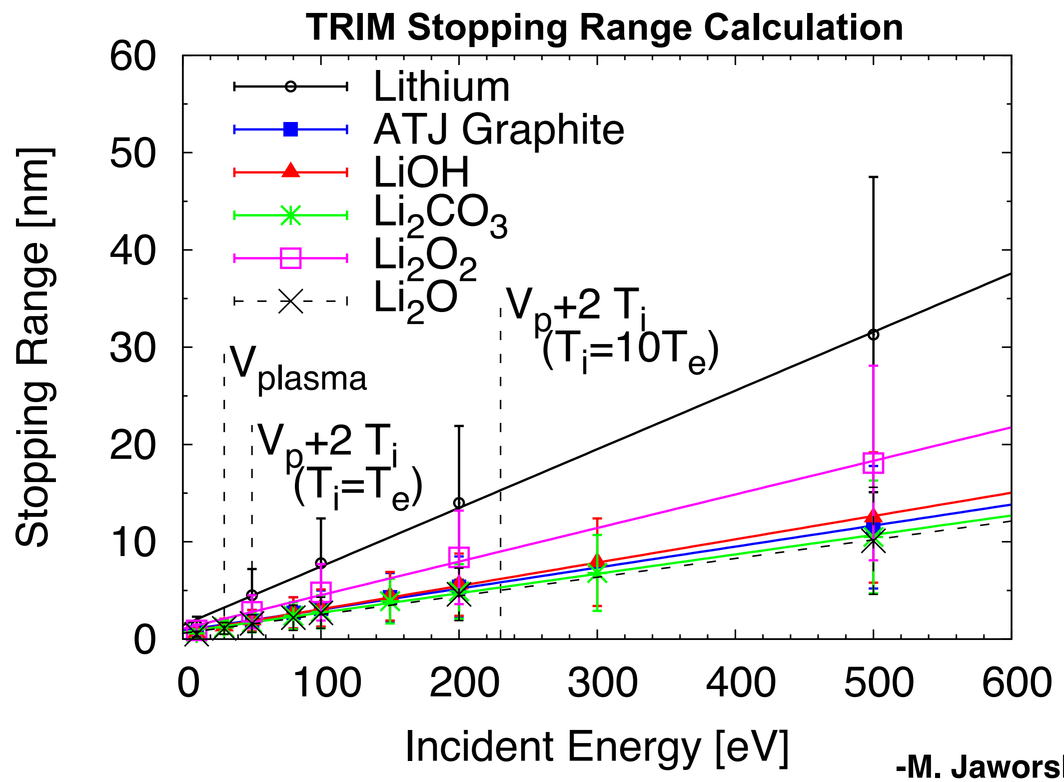


- Hypothesize that added D ionized in SOL, flowed on open field-lines to LLD and was absorbed by the liquefied (and possibly re-activated/cleaned) Li

Decreased Range of D^+ in Li Compounds on LLD May Explain Similarity With Solid Li Coatings on Graphite

- Static liquid lithium on LLD, *getters* the vacuum residual gases (H_2O, CO, CO_2)

- H_2O at 1×10^{-6} Torr could saturate 20 monolayers of Li (5nm) in 20s
  - Skinner, PP9.00025
- Oxygen codeposited on liquid Li segregates to surface
  - Bastaz & Whaley FED 72 (2004) 111



-M. Jaworski

- Incident D^+ energies ~50eV on LLD surface (divertor LPs, midplane CHERS)
- Estimated stopping range of ~3nm in typical Li impurities
- Investigating retention of D in D-Li-O-C complexes on lithiated graphite (J.P. Allain, P12.00006) and liquid lithium

Successfully Operated NSTX LLD

- Operated with outer strike point on lithium-filled surface
- LLD in its effect on plasma performance did not clearly differ from graphite PFCs with evaporated lithium coatings
  - Deuterium absorption capacity of lithium in LLD may have been affected by formation of impurity compounds on surface
- Plasma heating was used to raise LLD surface above lithium melting temperature
- Assessing possibility of continuing LLD experiments in NSTX-Upgrade
- Issues of lithium vacuum chemistry are being investigated in the laboratory
  - for understanding LLD results,
  - to aid in design of flowing liquid lithium system for NSTX-U