NSTX

Supported by U.S. DEPARTMENT OF ENERGY | Office of Science

Deuterium retention in NSTX with lithium conditioning.

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Charles H. Skinner,
W. Blanchard, H.W. Kugel, L. Roquemore, *PPPL,*
J.P. Allain, C.N. Taylor, *Purdue University,*
R. Maingi, *ORNL,*
V. Soukhanovskii, *LLNL.*
and the NSTX Research Team

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
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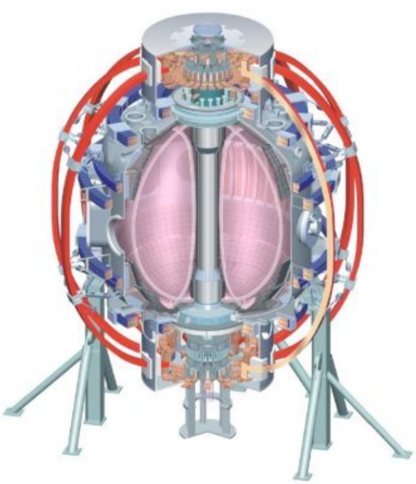
51th APS/DPP meeting, Atlanta, GA,
2-6 November, 2009



Outline:

FY 2009 Joule Milestone

Aims:

1. Measure the effect of lithium on fuel retention in NSTX.
2. Develop understanding of fundamental processes governing fuel retention.

Tools:

1. Gas balance - compare fueling and exhaust.
2. Develop probe to expose and retrieve samples, and study surface chemistry.

NSTX Main Conclusions:

1. Deuterium retention high (~ 90%) at end of discharge, slightly higher with lithium conditioning.
2. Deuterium outgassing reduces retention after a discharge.
3. PMI probe exposed and retrieved samples - analysis shows D atoms weakly bonded in regions near Li atoms bound to O or C.
4. Interesting correlations between gas balance and surface analysis data…

Also: S. L. Allen, Monday CO4.00002:
"Particle Control and Carbon Transport Experiments on DIII-D"

High retention in ohmic discharges

Extensive calibrations preceded experiments.

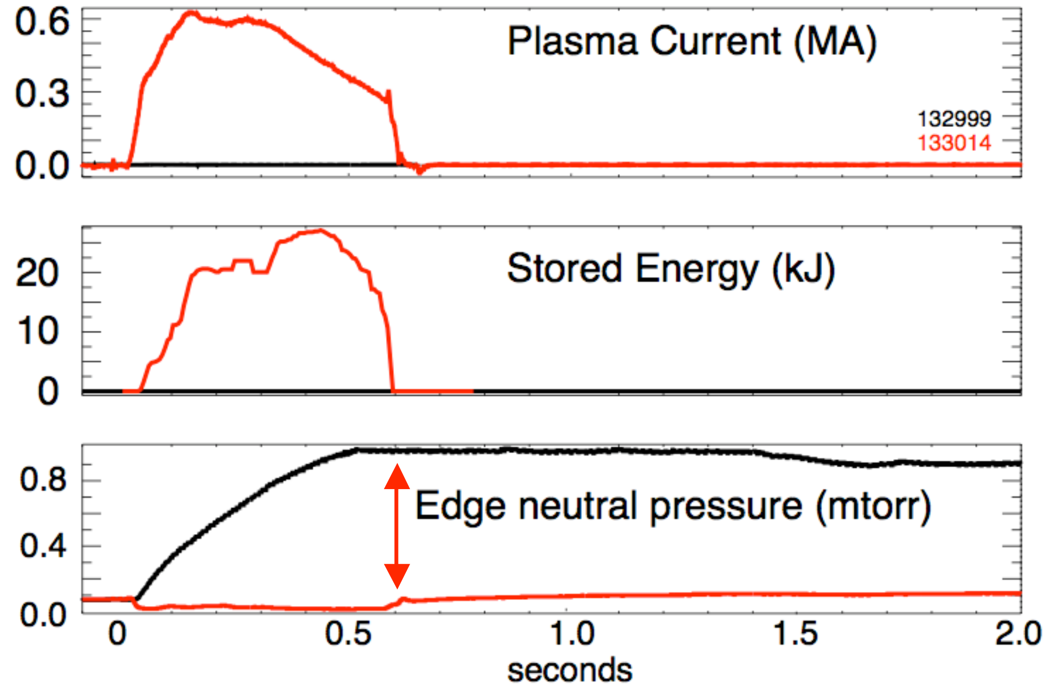
Four gas balance cases:

1. Before-Li ohmic discharges (vessel closed)
2. Before-Li NB heated discharges.
3. With-Li ohmic discharges (vessel closed).
4. With-Li NB heated discharges.

Discharge rampdown controlled to avoid minor disruptions.

1. and 3. are straightforward measurement with all pump valves closed:

Comparison of gas-only and ohmic discharge



$$\text{Retention} = 1 - \frac{\text{pressure after discharge}}{\text{pressure after gas-only shot}} \times \text{ratio of gas input}$$

Before-Li ohmic retention = 92% of D fuelled.

From D-alpha and Langmuir probe data:

$$\frac{\text{D retained}}{\text{D ion fluence to outer divertor}} = 6 - 8\%$$

High retention in neutral beam heated discharges

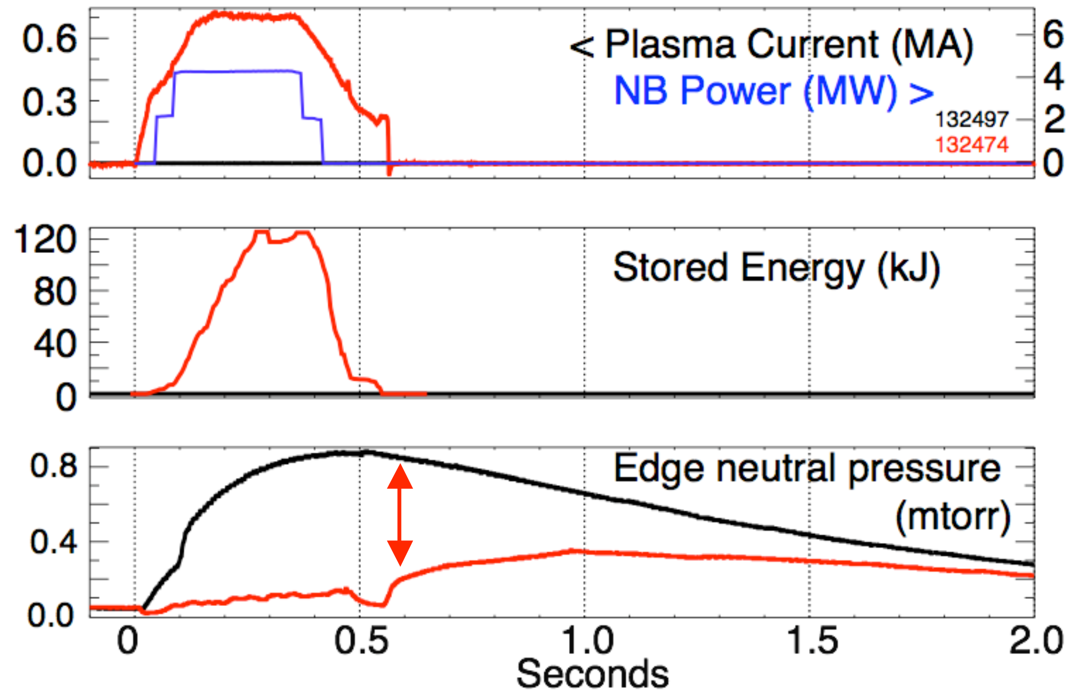
- NB heated discharge.
- Discharge rampdown controlled to avoid minor disruptions.
- Neutral beam valve open, account for
  - gas pumped by cryopanels
  - center stack gas injection
  - cold gas from NB.

$$\text{Retention} = \frac{\text{Gas retained}}{\text{Gas fueled}}$$

$$= \frac{\text{D input during Ip, less D pumped, D in VV}}{\text{D input during Ip}}$$

Retention Summary	Before Li	With Li
Ohmic	92%	94% (48 mg Li)
NB heated	87%	93% (137 mg Li)

Gas-only and neutral beam heated discharge



Before-Li NB heated prompt retention = 87%

Validation of methodology with pumping:
#132493 ohmic retention with pumping = 90%
#132490 ohmic retention valves closed = 92%

Edge pressure and wall inventory changes with Li

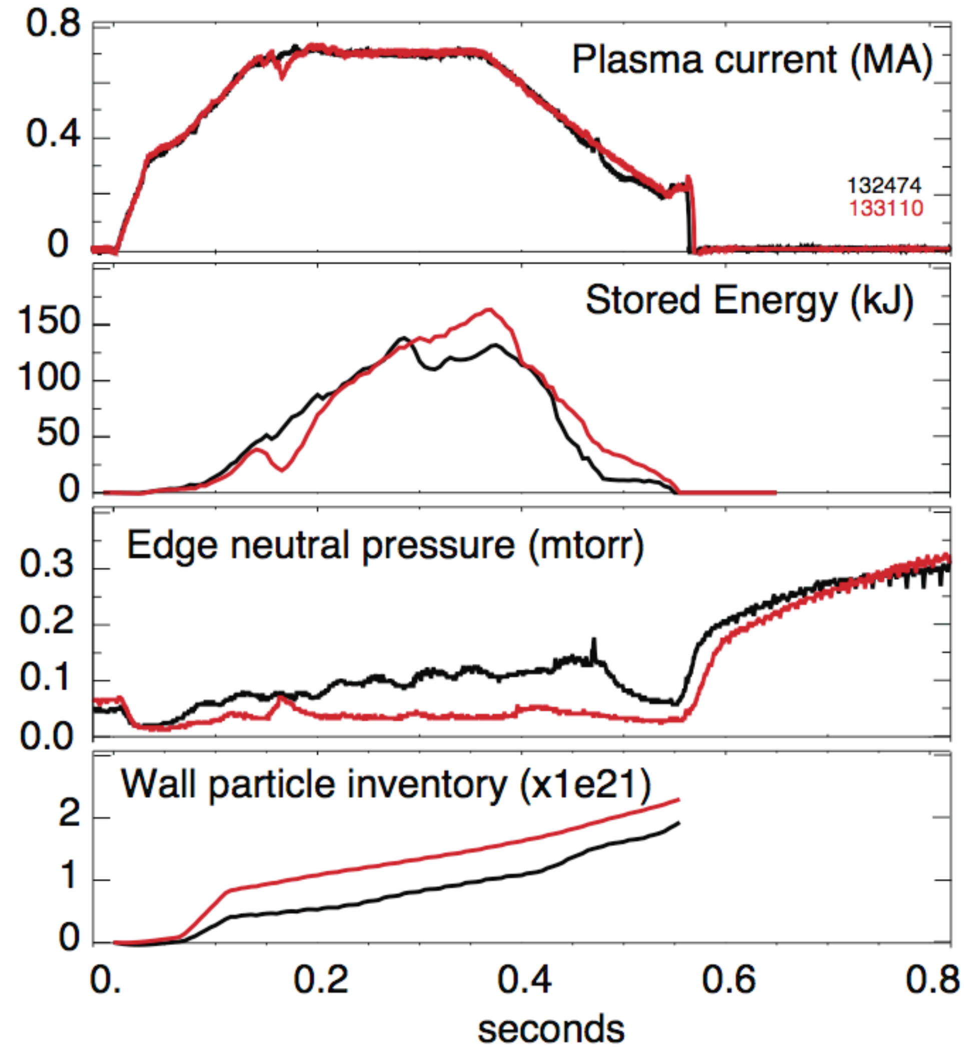
- Li increases stored energy and reduces ELMs.
- With Li:
  - lower edge neutral pressure and
  - higher wall particle inventory.
- Additional D wall inventory is released after discharge.

Wall inventory calculated by dynamic particle balance model.
Vlad Soukhanovskii

$$\frac{dN_i}{dt} = \Gamma_{\text{gas}} + \Gamma_{\text{NBI}} + \Gamma_{\text{NBI-cold}} - \Gamma_{\text{NBI-cryo}} - \Gamma_{\text{wall}} - \frac{dN_n}{dt}.$$

See also Pigarov Poster NP8.00122 on modeling with WallPSI/WGB code

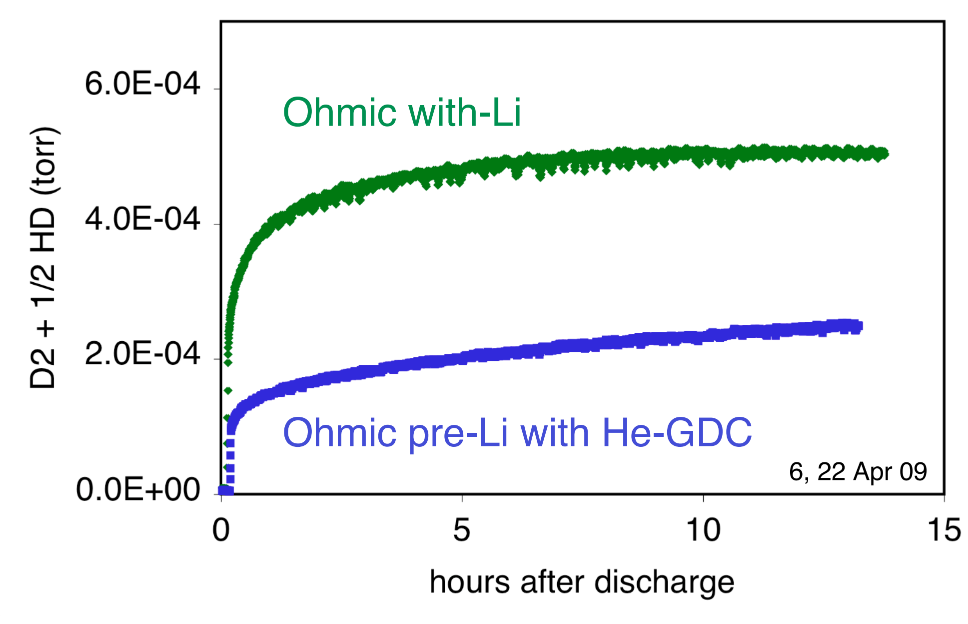
Pre-Li and with Li NB heated discharge

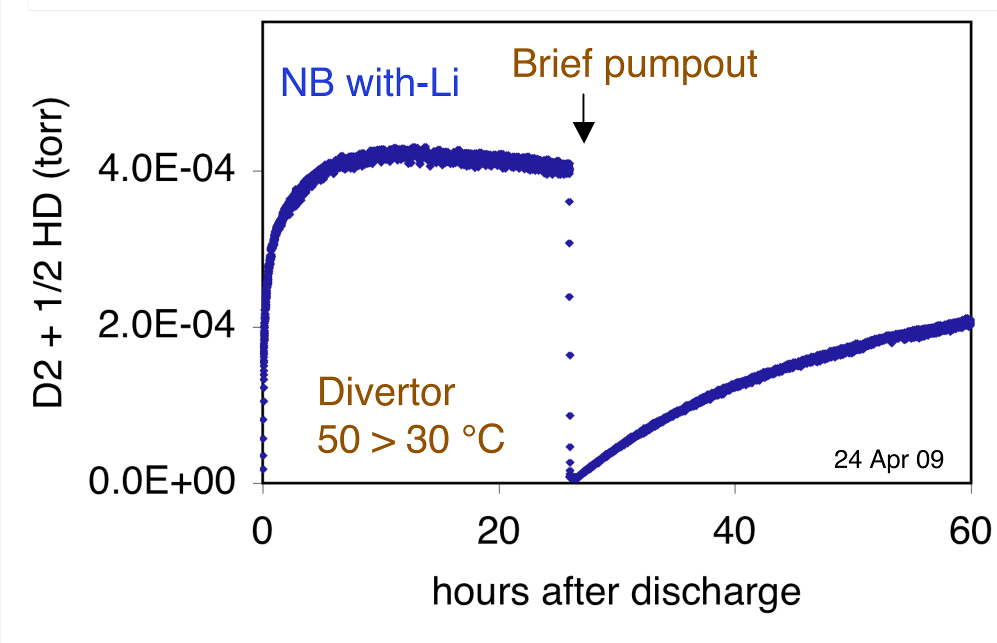


Wall pumping throughout H-mode (unlike C-mod and DIII-D).

Post discharge D outgassing reduces retention

- Pump valves closed for up to 72 h to integrate outgassing.
- Pre-Li case had intershot He-GDC that depleted D from wall.
- D_2 rate of rise is pressure dependent
  - wall pumping of D_2 as divertor cools.
- Long time scale for outgassing (> weeks) makes long-term retention % uncertain.





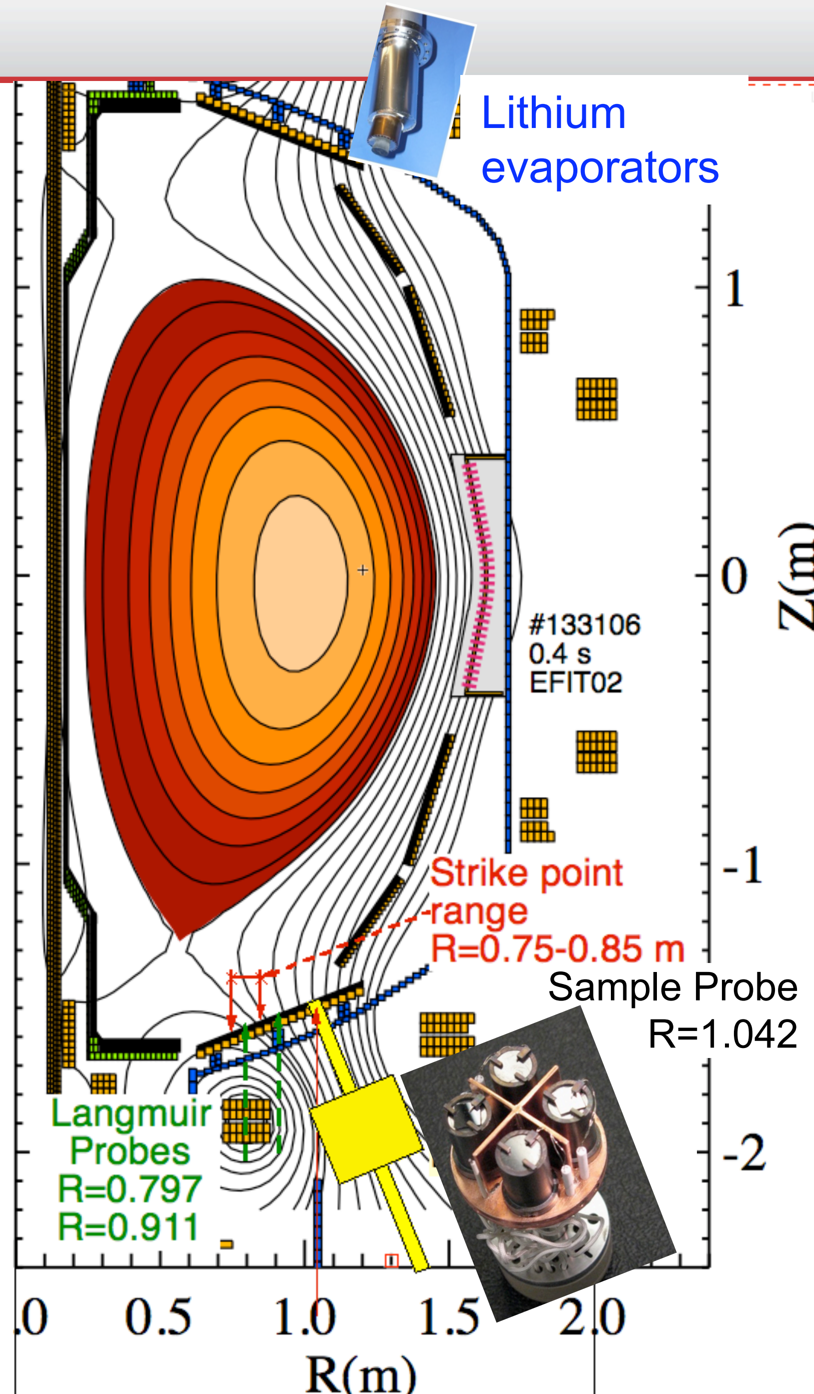
PMI probe elucidates Li chemistry

Specification:
4 samples on a 2" dia. probe
(two ATJ graphite, Si and Si/Pd)

- Secure, disruption- proof mechanical attachment
- Thermal cooling,
- 16 thermocouple wires connections
- 2 Langmuir probes
- Heater connection(s).

Must be installed and removed by one hand reaching through an argon-filled glove bag and through 4" diameter port and without using any tools.

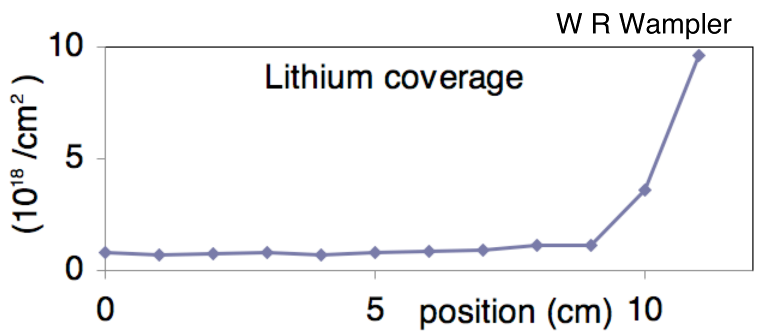
The design met all the specifications and was installed in-time to get before-Li measurements.

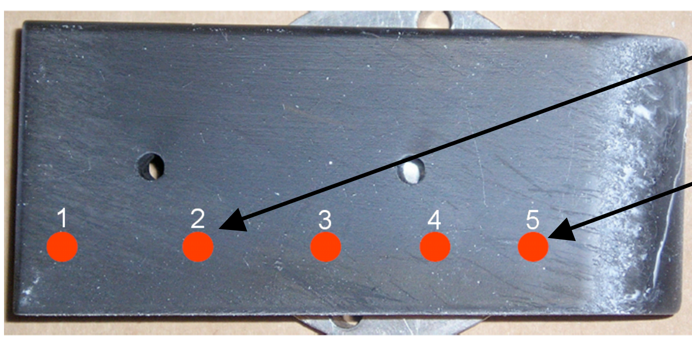


Lane Roquemore

Chemical bonding revealed by X-ray photo-electron spectroscopy

ATJ graphite tile exposed to NSTX



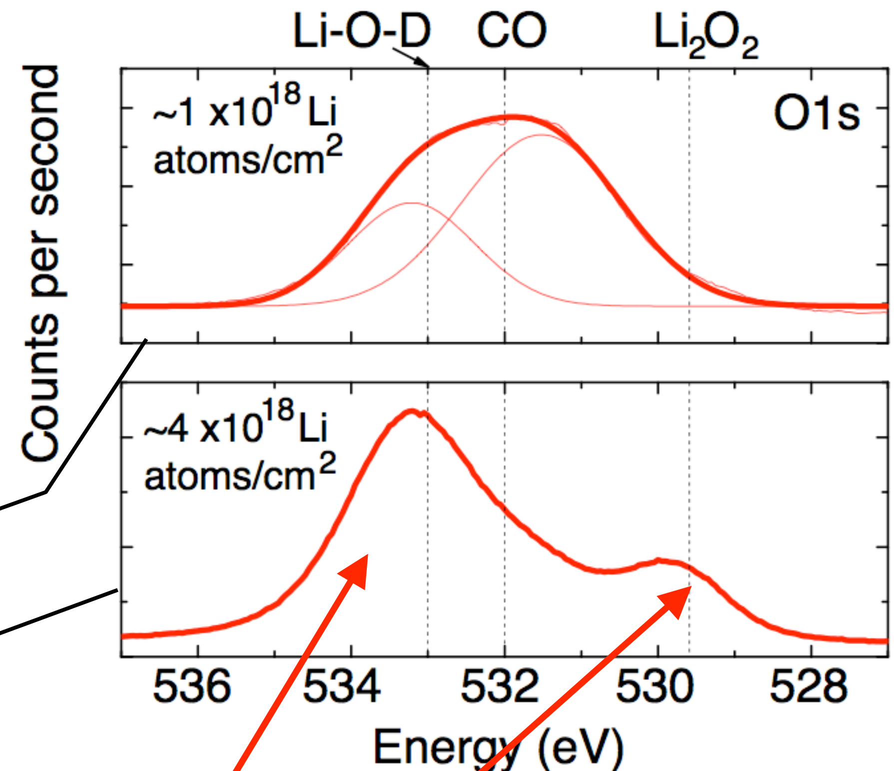


A235-021

See C. N. Taylor et al., Wed 2:00 PM PP8.00040

"Time dependent chemical interactions of Li, D, and O on lithium-coated graphite surfaces."

Molecular state changes with Li concentration.



- Li-O-D and Li-O peaks appear at high Li concentration
- [XPS spectra after 7 h Ar cleaning removed passivated amorphous layer due to O_2 exposure.]

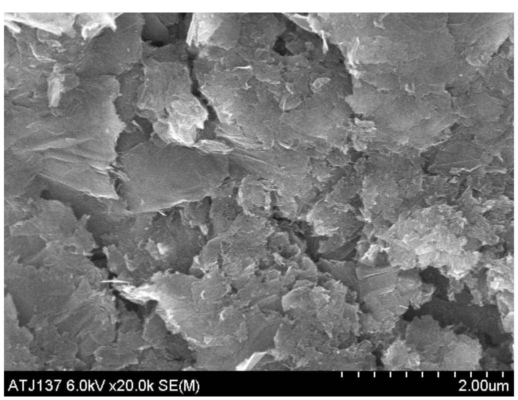
Increased Li changes chemical bonding state

Li induced changes in D-C and D-O functionality seen in both samples and tiles

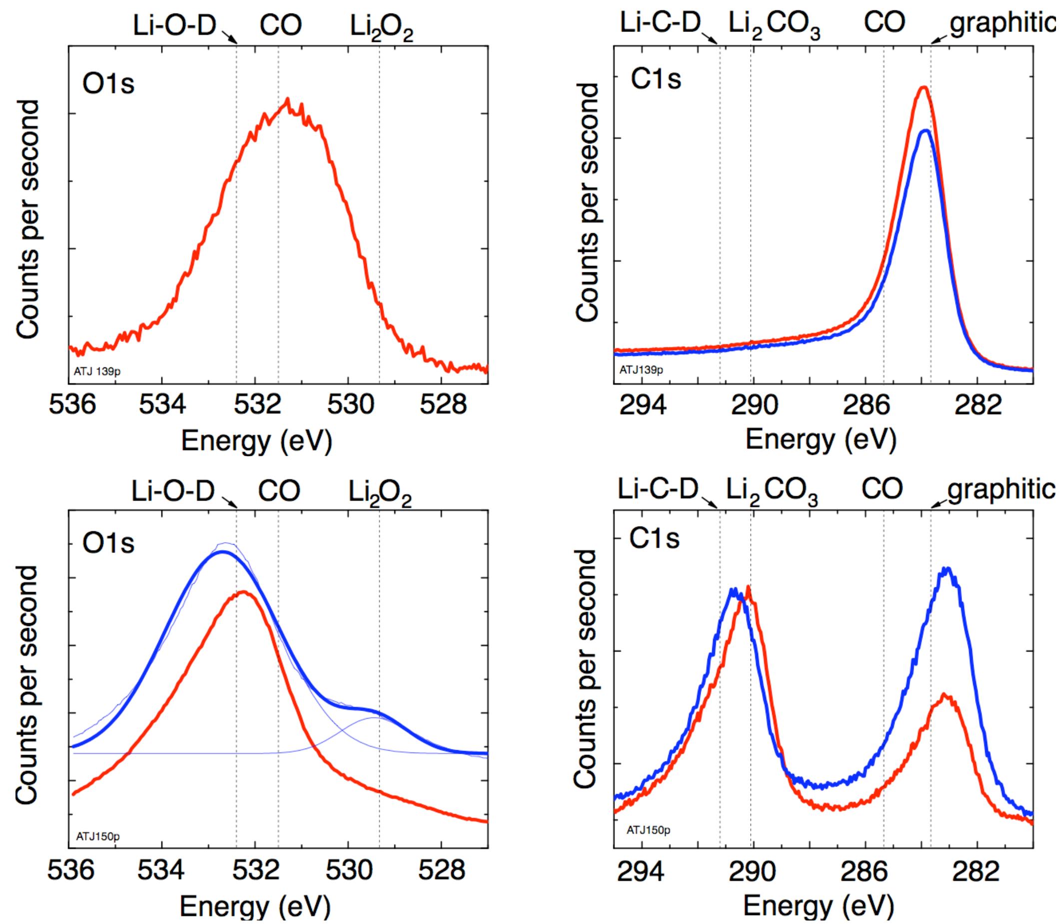
After 0.56 g Li evaporation
~ 63 nm nominal Li 'thickness'
ATJ graphite exposed to 6 NB heated discharges

After 7.3 g Li evaporation
~ 817 nm nominal Li 'thickness'
ATJ graphite exposed to 40 NB heated discharges

Polished graphite surface as modified by NSTX plasma.



XPS analysis of exposed samples shows molecular state changes with Li concentration.



After 15m (red curve) or 45m or 1h (blue curve) Ar cleaning removed passivated layer due to trace O_2. Consistent with increased Li effect on retention with higher Li evaporation.

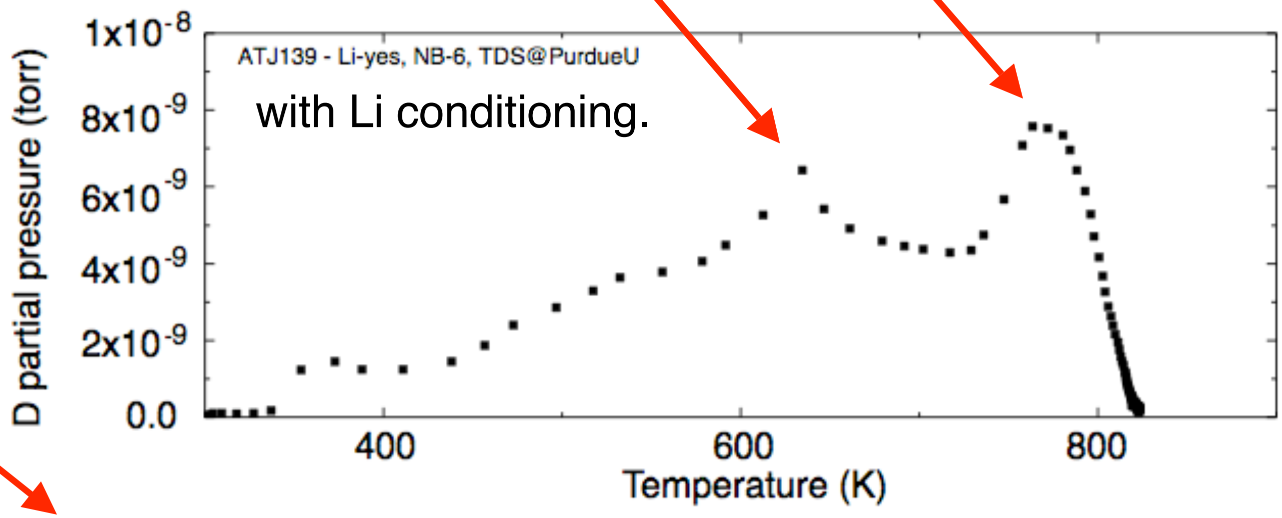
Weak D bonding with Li found

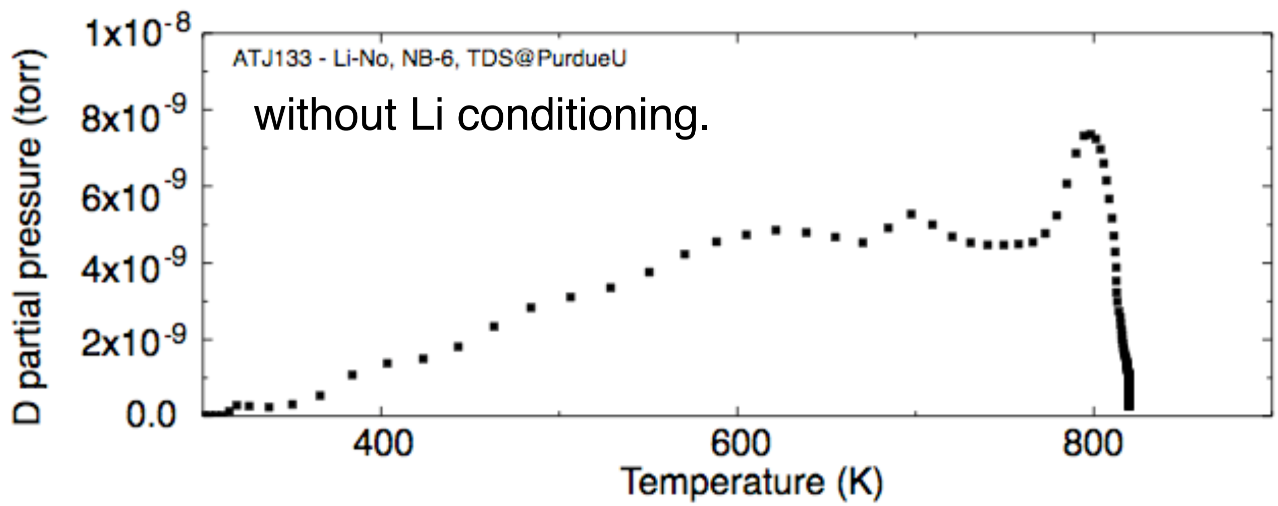
600 K peak with Li has weaker bonding of D 'in solution'.

800 K peak indicates covalent bonding of D to Li, O and/or C.

Thermal desorption spectra (TDS) of ATJ graphite samples exposed to neutral beam heated discharges
- with Li conditioning

and
- without Li conditioning.





- Two TDS peaks correspond to effective release of D.
- Consistent with prompt release of additional D after NSTX discharge in previous slide.
- Investigation of D hybrid-ization with Raman spectroscopy planned (Purdue U.)

Conclusions:

GAS BALANCE:	SURFACE ANALYSIS
Retention at end of discharge ~ 90%.	PMI probe commissioned - permits on-vessel surface analysis.
Retention higher with Li, difference increases with Li concentration.	XPS shows D atoms are weakly bound in regions near lithium atoms bound to either oxygen or the carbon matrix. Chemical bonding changes with Li concentration.
Additional D retained with Li is released promptly after discharge	Weak D bonding with Li conditioning observed in TDS.
Outgassing reduces retention over next minutes - weeks.	Upgrade to PMI (MAPP) probe with on-vessel XPS, DRS planned for 2011.

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