XP 1540 - Understanding longevity of lithium coatings in NSTX-U

M&P – TSG Review

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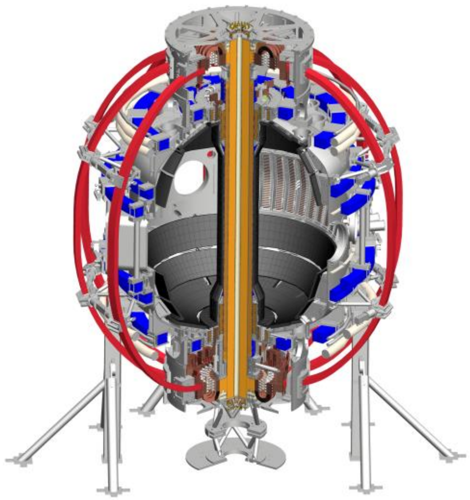
NSTX Upgrade



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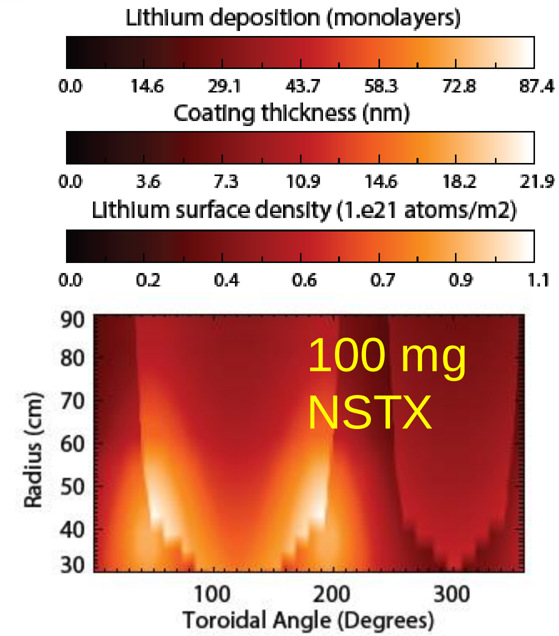
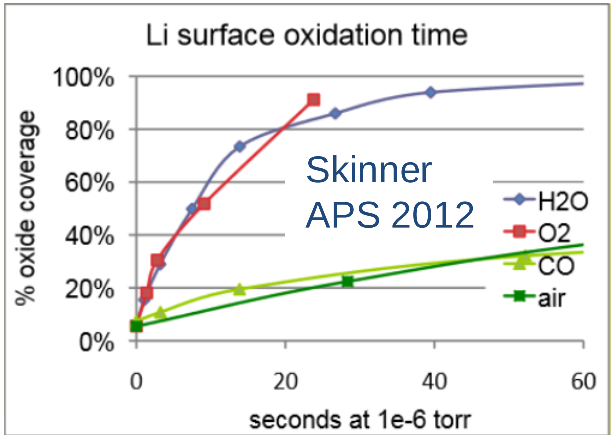
Goal: Understand and characterize lithium coatings longevity, conditioning effectiveness

- NSTX developed empirical recipe for Li conditioning (dose, frequency of pre-discharge evaporation)
  - Effectiveness typically evaluated based on confinement, pedestal changes, ELMs
  - Observed divertor recycling, lithium sputtering evolution inconsistent with gross erosion of pre-applied lithium only
  - Diagnostic capabilities and evaporation history limited conclusions in NSTX
- Goals of this XP are:
  - Understand experimentally-observed lithium coatings lifetime, testing role of different lithium degradation mechanisms
  - Develop a metric for lithium effectiveness based on PMI measurements to correlate with global parameters
  - Complements parallel studies with boronization in XP1505
- Assigned 1day of P-1b priority
- Support Thrust MP-1, MP-2 NSTX-U five year plan
- Cross-cutting with PC-TF
  - "Wall coating optimization for increased particle pumping"

Motivation: What determines lifetime of lithium effects on NTSX/NSTX-U plasmas?

- Different possible mechanisms on experimental timescale:
  - Surface elemental composition (D interaction with Li and not C at strike point):
    - Thickness vs implantation depth (~ 5-10 nm)
    - Thickness vs graphite roughness (~ microns)
    - Areal density vs fluence (gross/net erosion)
    - Intercalation in graphite
  - Surface chemical state (passivation/activation of Li surface):
    - Reaction with background gases (O_2, H_2O, ..)
    - Saturation with deuterium
  - Fraction of first wall with lithium coverage
    - Fraction of PFCs area with lithium thickness above ion implantation depth
    - Progressive coverage of PFCs without direct evaporation





Tools: Enhanced spectroscopic tools + MAPP for most extensive measurements up-to-date

- Deliverables to be compared with global parameters:
  - Local deuterium recycling (OSP, upper div, MAPP)
  - Li, C, O sputtering (OSP, upper div., MAPP)
  - Deuterium pump-out from SGI or LFS gas pulses
    - maintaining high recycling regime, gas amount to be determined in XMP
  - Wall loading rate from deuterium particle balance
  - MAPP elemental composition

- MAPP to complement spectroscopic measurement:
  - Good correlation between spectroscopy and MAPP obtained with boronization in FY16
    - XMP planned for MAPP close-up view on TWICE-I system
  - XPS between shots to provide elemental surface composition
  - Minimal XPS time ~10 minutes (0.1eV/s, 20 eV range, (Li,) C, O) to maintain same history on MAPP and PFCs

- Theory/modeling: UEDGE (+ ERO) to aid in interpretation of surface composition from spectroscopic results

Experimental plan: test effect of erosion, intercalation, reaction with background gases

- Established highly shaped ELM-free Li-conditioned H-mode from XP1529
- 1) Test effect of thickness-areal density/fluence (~1 day):
  - Scan ~32x in areal density/incident ion fluence and 16x in thickness
  - 50mg (~10nm~D^+ range) to 800mg (~160nm)→0.5-8e21 at./m^2
  - For every lithium dose, scan integrated incident ion fluence:
    - Repeat shots with 4-6 MW NBI until performance degradation (2-4 per condition)
    - Further enhance particle flux via div. gas puff, SGI?
- 2) Test effect of reaction with background gases
  - Constant dose but different rate, scan time before the next shot
- 3) Test effect of intercalation (timescale tested separately via MAPP):
  - Constant Li dose at different rates ending right before next shot (5, 10, 20 mg/min)
- 4) Evap. coatings vs. plasma deposition, real-time Li to refresh coatings?
  - Add LGI sub-ELM threshold (300 μm) to shots that show passivation

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Discharge considerations

- LSN ELM-free H-mode or with infrequent ELMs, ~1s flat top
  - Use reference discharge from Li introduction XP (XP1529)
  - Should run right after XP1529 to minimize lithium amount in vessel
  - Frequent ELMs at low lithium amounts would complicate measurements
  - Is degradation decision point based on ELM-reappearance enough?
- Ideally high δ. Low δ with OSP as far out as Row 2 also OK
  - Need to minimize outer strike point drift over time
- High power L-mode (e.g., 204202) also possibly OK
  - Would decouple PMI changes from pedestal changes but complicates deconditioning decision point (need something like O II/D-γ with TMB)
- How to include MAPP? Every MAPP scan is ~ a lost shot
  - One right after evaporation and one at the end of series for two doses?

Shot plan: Option 1

- Scan lithium deposition (8x): e.g., 50-100-200-400 mg
  - XP1529 will inform on minimum useful lithium dose
- Repeat discharges at max available NBI power to increase fluence on PFCs until degradation of performance observed
- 14 shots, 800 mg condition (+4 shots) only if time allows

Example of areal density/fluence scan assuming 1s, 1.e23 ion/m^2/s @ OSP

Li evaporation (mg)	50	100	200	400	800	
Areal density (at./m^2)	5E+20	1E+21	2E+21	4E+21	8.00E+21	
Thickness (nm)	10	20	40	80	160	Estimated fluence (ions/m^2)
	5.00E-03	1.00E-02	2.00E-02	4.00E-02	8.00E-02	1.00E+23
	2.50E-03	5.00E-03	1.00E-02	2.00E-02	4.00E-02	2.00E+23
		3.33E-03	6.67E-03	1.33E-02	2.67E-02	3.00E+23
		2.50E-03	5.00E-03	1.00E-02	2.00E-02	4.00E+23

Shot plan: Option 2

- Based on the assumption that we can do 2s H-modes with Li
- Repeat discharges to increase fluence on PFCs until degradation of performance observed
- 15 shots, 800 mg condition (+5 shots) only if time allows

Example of areal density/fluence scan assuming 1&2s, 1.e23 ion/m^2/s @ OSP

Li evaporation (mg)	50	100	200	400	800	
Areal density (at./m^2)	5E+20	1E+21	2E+21	4E+21	8.00E+21	
Thickness (nm)	10	20	40	80	160	Estimated fluence (ions/m^2)
	5.00E-03	1.00E-02	2.00E-02	4.00E-02	8.00E-02	1.00E+23
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		2.50E-03	5.00E-03	1.00E-02	2.00E-02	4.00E+23
			3.33E-03	6.67E-03	1.33E-02	6.00E+23
			2.50E-03	5.00E-03	1.00E-02	8.00E+23

Diagnostics

- Need:
  - Upper and lower divertor fast cameras (E-top, J-top, J-mid, H-bot)
  - TWICE-I, TWICE-II
  - Core profile diagnostics: MPTS, CHERS
  - Operational diagnostics: (magnetics, EIES, plasma TV, neutrons)
  - Langmuir probes
  - IR camera (fast)
- Want:
  - QMB
  - DTI, GPI, ENDD
  - EUV spectrometers
  - IR Camera (slow)
  - LADA
  - VIPS2, DIMS, UTK spectrometers
  - 1D-CCD cameras
  - Core + divertor bolometry

Already operational in FY16
Not yet operational in FY16

Strategy: Simultaneous monitoring of different lines for divertor impurity influxes

- **Simultaneous** measurement of multiple lines of same charge state (carbon and lithium) to avoid uncertainty in plasma parameters (T_e, n_e) in lower divertor
  - C II lines with different dependencies on plasma parameters
    $\rightarrow$ C^{1+} influx determination (514, 723 nm)
  - Li I lines with different dependencies on plasma parameters
    $\rightarrow$ Li^{0+} influx determination (460, 610, 670 nm)
  - Gerö band (CD) + C II line
    $\rightarrow$ chemical vs physical contribution
  - 909 nm region
    $\rightarrow$ C^{0+} influx, evaluation of f_{chem}/f_{phys}
- Upper divertor views to inform on evolution of upper PFCs

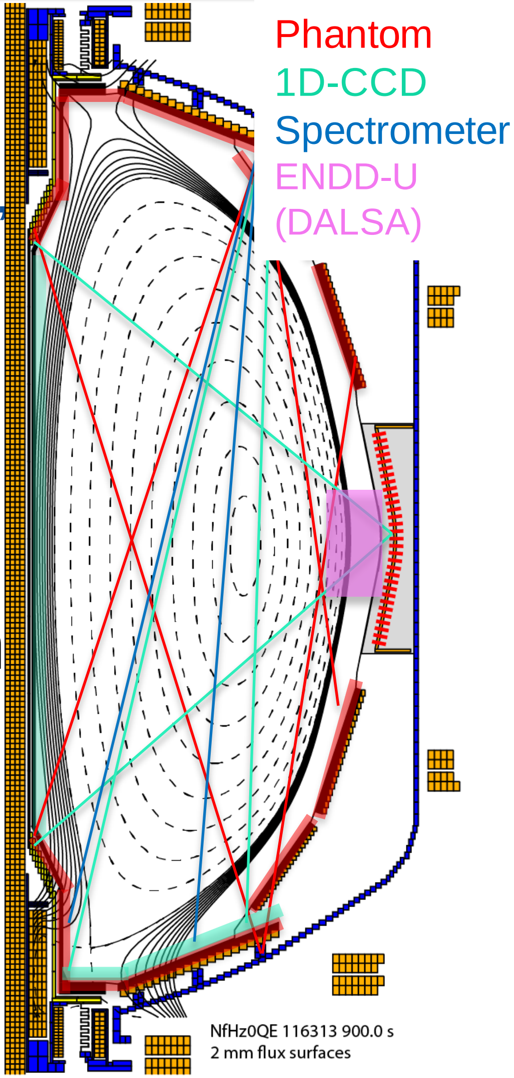
Backup

Strategy: Simultaneous monitoring of different lines for divertor impurity influxes

- **Simultaneous** measurement of multiple lines of same charge state (carbon and lithium) to avoid uncertainty in plasma parameters (T_e, n_e) in lower divertor
  - TWICE-I: Li I (460 nm) + Li I (610 nm)
  - TWICE-II: O II (441 nm) + D-γ
  - Phantom E-top: C I (909 nm)
  - Phantom J top: C II (723 nm)
  - Phantom J mid: C III (465 nm)
  - DIMS: Gerö band region
  - VIPS2: C I (909 nm) region
  - H bottom: Li I (670 nm)
  - ENDD: D-α
  - 1D-CCD (LD, UD, CS): C II (514 nm)
  - 1D-CCD (LD, UD, CS): Li I (670 nm)
  - 1D CCD (LD, UD, CS): D-α

Tools: Upgraded diagnostics for full poloidal, toroidal coverage of impurity emission

- Full poloidal coverage of impurity emission + full toroidal divertor coverage
  - Phantom (4), CIDTEC (2 two-color), DALSA (1), 1D-CCD (9) cameras, 3 spectrometers
- High resolution views for MAPP and inboard divertor
- View of the NBI armor tiles (ENDD)
- Views centered at probes toroidal location
- Availability/reliability of probes limited extrapolation of influxes
  - Redundant wavelength approach implemented for FY2015



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