First Preliminary Results from the LLD

Lithium Research Topical Science Group Meetings 4/14/10, 4/15/10 and PPPL/Purdue coordination meeting 4/16/10

R Kaita, C Skinner, H Kugel, M, Jaworski

Executive summary:

1. Evidence suggests no significant additional D pumping by LLD so far.
2. Insufficient Li in LLD a potential reason. A 50% LLD Li fill is under consideration.
3. LLD surface contamination levels and effects are unknown.
4. Divertor Imaging spectrometer, Two color IR calibration, air heating of 4th LLD quadrant… should arrive soon.
5. C128 and Purdue experiments planned on porous Mo reflectivity, effective evaporation rate (including porosity and surface impurity effects), surface cleaning, faster Li fueling
6. Plans to benchmark Li evaporation codes against QMB measurements.

Skinner ***Introduction***
(see http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/20100414_LLD_1stResults/)
Reviewed motivation for the LLD as presented to PAC27 with excerpts from 2007 design considerations.

Kugel ***"XP1000 LLD Characterization-Preliminary Results"***
(see http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/20100414_LLD_1stResults/)
Reviewed 1st LLD results, operation to R=0.7m, LLD temp up to 320 °C, beneficial effects but no obvious additional D pumping yet. XP1000 next steps included a 50% LLD fill, round-the-clock heating, during and after the fill, no LLD cooldown prior to XP1000 and liquid Li pumping experiment with LiTER off.

Jaworski ***"Necessary conditions for pumping with liquid lithium"***
Implications for XP1000:
• Deposit more lithium than before
– Remove possibility of early saturation due to thinness
– Reduce impurity to Li ratio, remove possibility of early saturation
– Be prepared to operate at 320C, remove possibility of early saturation due to flux limit and diffusion into bulk as well as impurity sinking
• Run XP immediately following deposition
– Minimize discharges which introduce impurities
– Minimize deuterium loading prior to experiment
– Minimize background gas reactions
• Do everything to actually test pumping by liquid lithium
– As in, not pumping by LLD+Li+C+O+D loading
– Begin replicating the CDX-U test on something more macroscopic than 250nm
Summary:
• Three necessary conditions for pumping described

– Fluence limitation
– Flux limitation
– Impurities (feeding into 1 and 2)
• May not be exhaustive list
– Surface physics between incident plasma and bulk diffusion not considered here
– Something like PMI probe / MAPP or other could help address these issues intershot
• Serious deficiency in literature regarding diffusivity
    – If CDX-U and PISCES are indications, probably not an issue

Paul
Fe lines continue to be most conspicuous on top of heavy impurity "hump" in SPRED spectra

- SPRED shows lines "tantalizingly close" to Mo but actually look like Cl

Mo only seen during RF shots

Stutman
TG spectrometer

- Tangential view across neutral beam
- Two frames per shot

Preliminary data show C and O and possibly N, Cl, and Cu

- Fe and Cl accumulation at end of some shots with high radiative power (consistent with SPRED spectra)
- Generally not much Mo
    - Some evidence of Mo when Soukhanovskii appeared to see Mo in divertor

Kallman ***"LLD lithium inventory and outgassing studies"***
(see http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/20100414_LLD_1stResults/)
Described L245 tests of porous Mo fueling by Li pellets. Expected drop in rga mass 18 due to 2Li + 2H2O > 2LiOH + H2 not seen except when LiTER crosses Li melt temperature. Conversion from rga-torr to real torr revised later. Has summary of NSTX results, lab studies and suggestions.

Skinner ***"Li / D balance"***
(see http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/20100414_LLD_1stResults/)
Overlay of Li evaporation rate and D outgassing rate vs. temperature. Suggests there is not enough Li on LLD so far.

Zakharov
Li deposition Code modified to indicate predicted Li deposition on LLD and measurements expected with quartz deposition monitor. Output can be displayed in NSTX Control Room. Josh has requested to include Li evaporation from LLD. Presentation from Leonid's laptop – no slides in DragNDrop

4/15/10 – Lithium Research Topical Science Group Notes (continued)

McLean ***"Status of IR measurements of LLD surface temperature"***

Temperature < 400 °C on LLD is indicated and significant heating of leading edge on gap bullnose tile. Needs further "offline" calibration work to get "two-color" temperature distributions

Scotti "***Preliminary results from LLD fast cameras diagnostic: reflectivity, D-alpha and Li II emission profiles***"
Surface albedo decreases 250 – 300 °C No significant difference in LiII and D-alpha emission from "cold" and "heated" LLD segments, Higher D-alpha emission on OSP from warm LLD.
No "shiny" surface as seen in "offline" lithium loading experiments on porous Mo surfaces

Soukhanovskii: *bullets on Mo, D-alpha (recycling) and change in Ne (given by Skinner* end of Skinner slides*)*
1) No steady-state molybdenum influx observed from LLD, except in several shots where singular transient events interacted with lower divertor and Mo I lines were clearly seen (from VIPS 2 spectra, Bay C location)
2) In general, D-alpha intensity was always higher on LLD than on bullnose carbon tile (from 1D CCD, Bay D location). Will use Langmuir probe ion flux to calculate recycling coefficients.
3) D-alpha on LLD typically increased with the 220-250-320 C temperature trend (from 1D CCD, Bay D location)
4) Li II emission was increasing with the 220-250-320 C temperature trend (from 1D CCD, Bay D location)
5) In hotter LLD divertor (320 C vs 220 C), it appears that 1) much reduced oxygen flux was observed 2) much higher LiD molecular flux was observed (VIPS 2 spectra, Bay C location)
6) No clear trend was seen in core deuteron inventories and deuteron densities (from CHERS analysis) with LLD cold, warm, hot trend and strike point trend
7) Propose to run XP 1001 ASAP to document LLD regime through an accurate particle balance accounting and tau-p-star measurements.

Stutman: First data from Transmission Grating Spectrometer shows emission from C, O, N?, Cl?, Cu? With Fe, Cl accumulation at end of some shots. Mo 75Å band may be observed in divertor 137488.

Paul: SPRED spectrum 137619 shows Cl, Fe, but no Mo.

Allain ***"Surface chemistry analysis of hot lithium coatings on porous Mo substrates"***
(see http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/20100414_LLD_1stResults/)
Movies show Li melting on porous Mo surface, and no mirror coating at 509 C!. Li deposition / D irradiation / heating of porous Mo samples. / XPS peaks of O1s, C1s, Li 1s shift when Li melts.. Surface is 72-82% Li, next element 7-22% O. Decrease in mass18 and increase in mass2 seen when Li melts. Surface chemistry results show typical lithium hydroxide formation for solid Li deposited films and more "metallic" chemical state of Li for melted Li coatings. Melted surfaces show diffusion and

percolation of liquid lithium through the porous Mo microstructure observed by the existence of Mo 3p XPS peaks and their absence for solid lithium coatings for depositions of 2-5 micron equivalent thickness. TDS (thermal desorption spectroscopy) conducted *during and post* deuterium irradiation at the in-situ facilities at Purdue. Results identify a weakly-bonded implanted deuterium state with formation temperatures ranging from 250-400 C. During D irradiation emission of D2O and HDO into the gas phase is observed while maintaining the temperature between 250-270 C. Post-irradiation TDS shows peak D2 and HD emissions at about 400 C. This data remains preliminary and further investigation is still necessary.

Discussion

LLD Surface Cleaning
Strike point – carbon co-deposition is liability

LLD Surface Diagnostics
D-alpha, Lyman-alpha, and LLD Langmuir probes – need modeling to link to LLD to surface conditions

LLD Pumping Diagnostics
Should consider appropriate "metrics" – are effects due to lowering Z-effective (on loop voltage, for example) as opposed to actual pumping

LLD Pumping Sequence
Li thicknesses on PFC coatings in general may far exceed prior levels and overwhelm any incremental effect from LLD – Allain reports that going from 10 to 40 microns should not make much difference on carbon

C128 Experiments (M. Jaworski)
(see http://nstx.pppl.gov/DragNDrop/Topical_Science_Groups/Meetings/lithium_research/20100414_LLD_1stResults/)