Dynamic retention and erosion/deposition - NSTX measurements with quartz microbalances

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NSTX Results Review

July 26-27th, 2006

PPPL.

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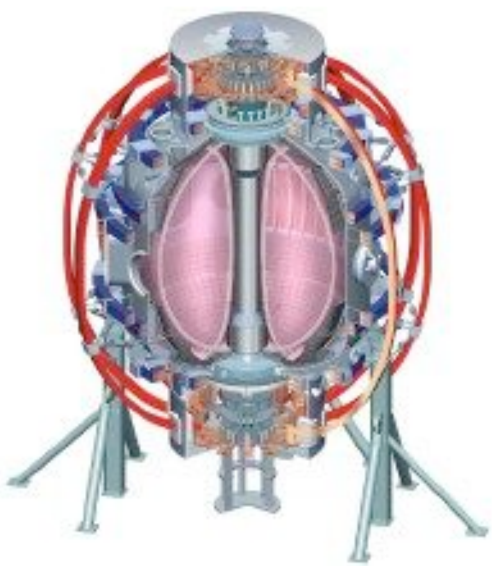

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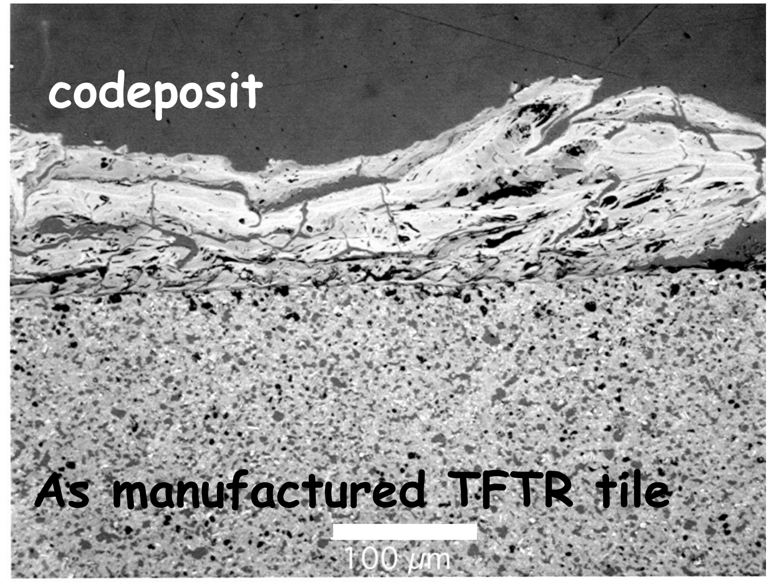
Motivation:

- Erosion / codeposition
  - Changes plasma facing surfaces (and plasma)
  - Leads to long term tritium retention
- Dynamic retention
  - Absorbs input fuel gas
  - Fuels plasma from wall (density control)
  - Short term tritium retention

T retention has high risk, high consequences for ITER

ITPA recognition: Experimental proposal:
"Cross-machine comparisons of pulse-by-pulse deposition.' *DSOL-18* between NSTX and AUG



Conventional Wall Diagnostics:

- Tile / coupon samples
  - Well defined spatial location
  - Time integrated 'archeology'
    - no correlation with plasma events
- Gas balance (fueling & exhaust)
  - Well defined time resolution
  - No spatial information

These typically give widely different values for retention (TFTR a notable exception)

QMB offers both space and time information

Model of outgassing of H in traps and solution in carbon

Strong dependence of outgassing rate on H concentration

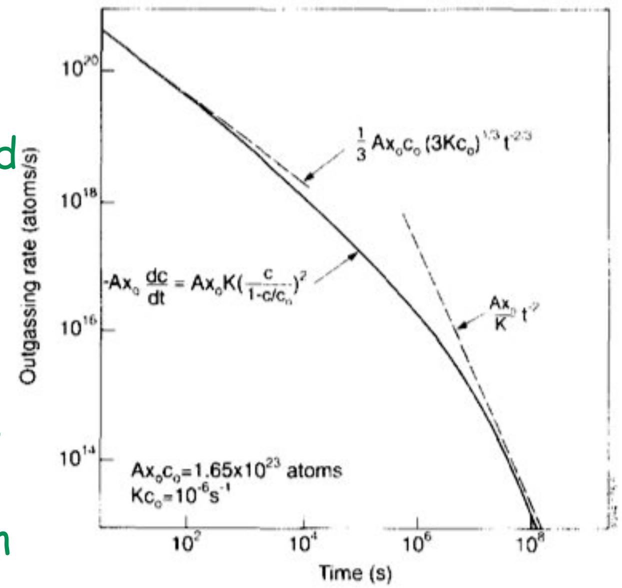
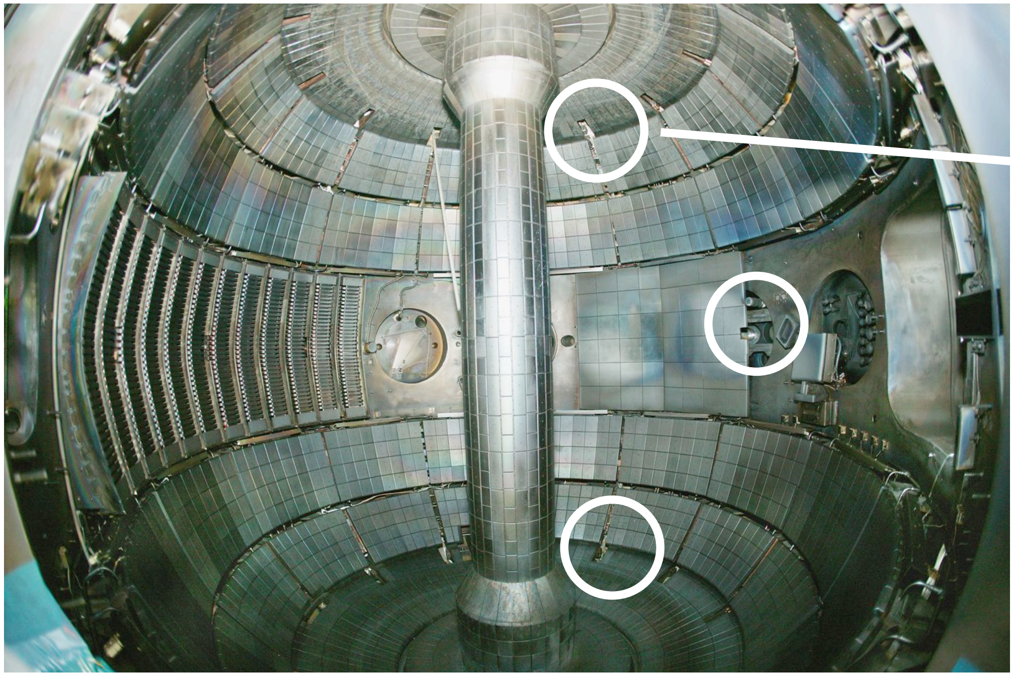


Fig. 1. Outgassing of an initially saturated surface layer as a function of time.

Andrew & Pick JNM 220-222 (1995) 601

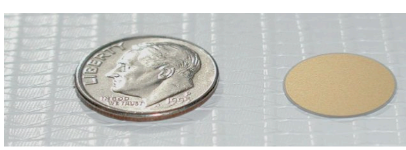
NSTX quartz microbalances:



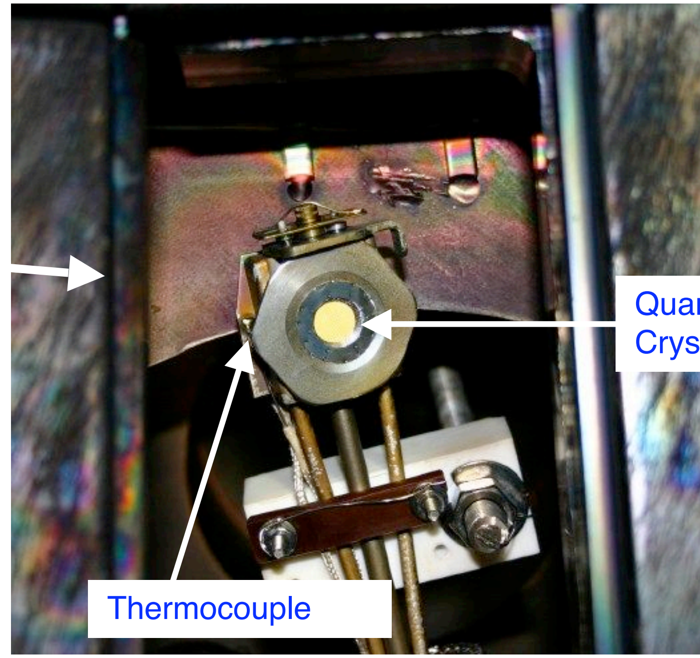
Located at Bay H top & bottom,
7 cm ‘behind’ 7 cm wide gap in tiles

+ Bay I midplane 10 cm ‘behind’ limiter.

Exquisitely sensitive to changes of mass smaller than one monolayer



← Quartz Crystal

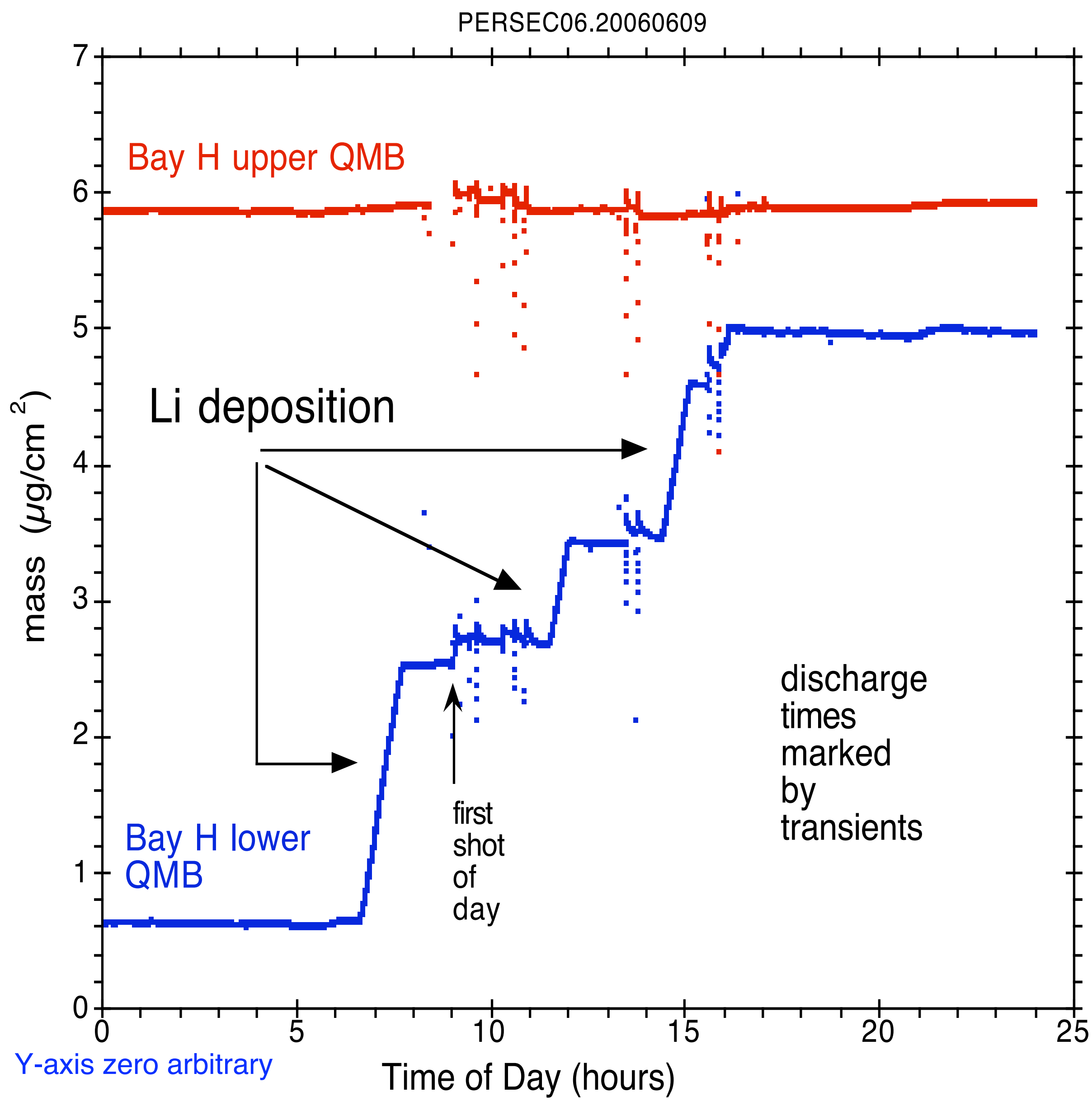


- Quartz crystal oscillates at ~ 5.9 MHz, exact frequency depends on <u>mass</u> and on <u>temperature.</u>
- Temperature effect subtracted using thermocouple data. density 1.6 g/cm^3 assumed.
- Deposition inferred from change in frequency (measured to ~0.1 Å, ~0.1 Hz)
- Data accumulated continuously 24/7.

Direct real time measurements of lithium deposition

3 Li evaporations
XP 601
9 June 2006

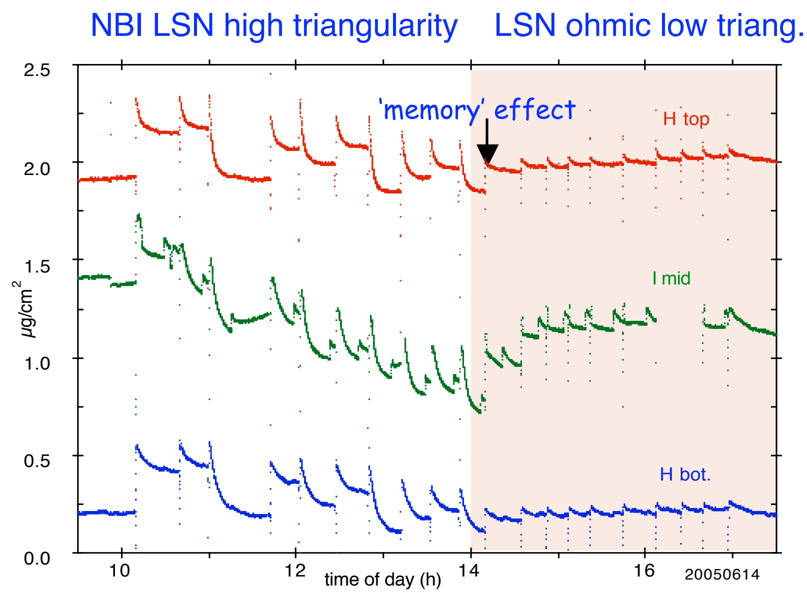
H. Kugel talk.



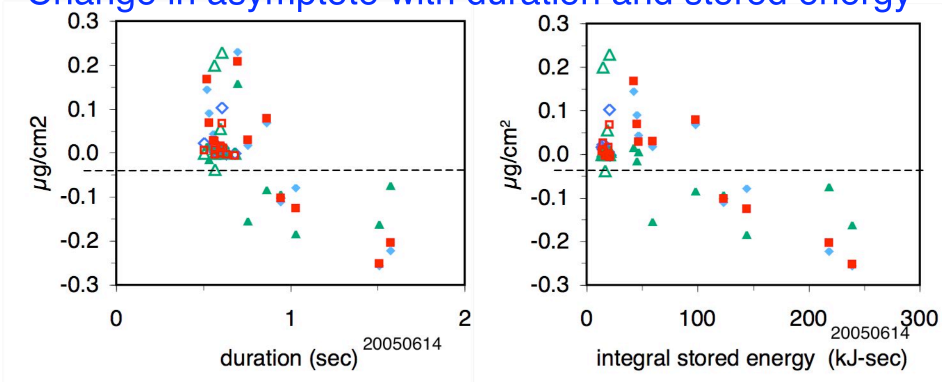
Y-axis zero arbitrary

XP604 results challenged erosion / deposition picture

2005 result:



Change in asymptote with duration and stored energy



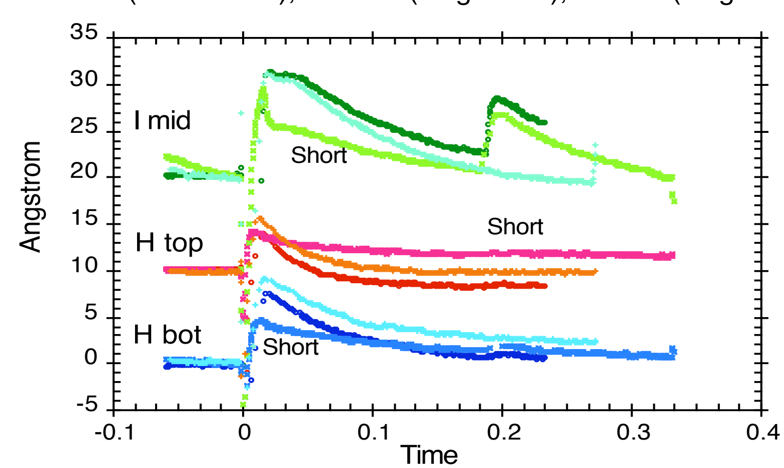
XP604 Aims:

- Does 30 min GDC influence strong 1st shot of day deposition ?
- Does erosion / deposition depend on Ip flattop duration ?

Result:

- No clear change without GDC
- No clear effect of pulse duration
- No 'staircase' pattern
- 'Memory' effect observed
- Change in paradigm needed !

119278 (short 0.34s), 119277 (long 0.93s), 119274(long 0.9s)



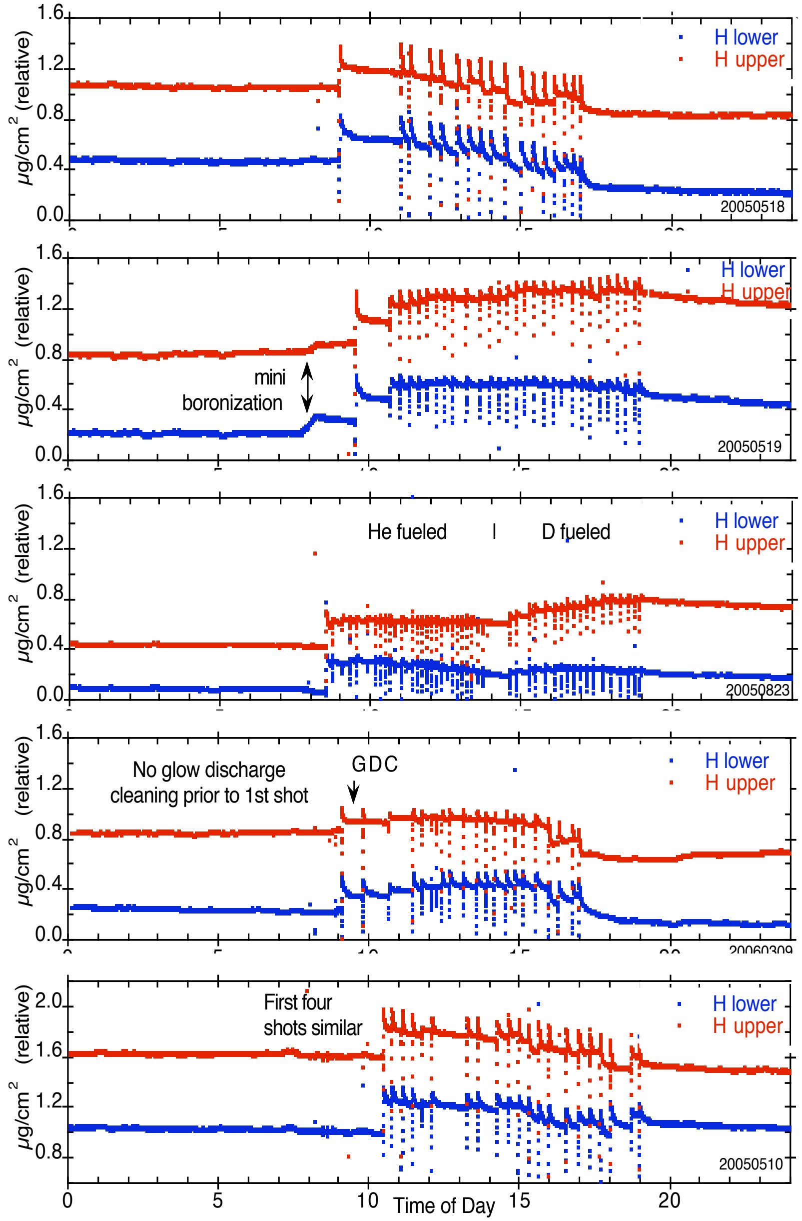
First shot of day effect:

General Features:

- Discharges show transient rise followed by decay.
- Decay time exceeds thermal equilibration time of qmb
- Large stepup in mass on 1st shot of day
  - mass gain exceeds 28 minute boronization

  Effect independent of:
  - prior He glow discharge,
  - discharge type: Ohmic (115476) or NBI, He or D
- Some discharges show longer term step-up or step-down in asymptotic level.
- Slow mass loss at end of day.

Mass change over 24 hours
Plasma discharge times marked by transients

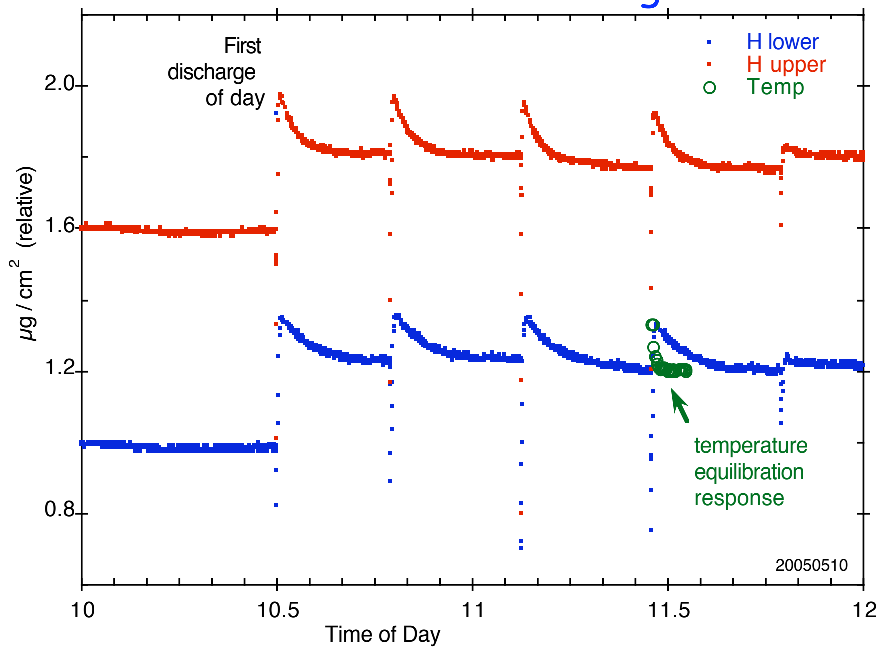


(Y-axis zero point arbitrary)

Behavior explained by dynamic retention of D

Overnight outgassing desaturates wall.
D implanted on 1st shot adds mass.
Outgassing between shots too slow to desaturate wall.

Four similar discharges



Look at numbers:

Compare fueling to deposition:

All four discharges 115467, 48, 49, 50 have:

- 56 torr-l CS mid fueling
- 13 torr-l Bay J lower fueling
- 2e20 D from 4 MW 0.5s NBI

Total fuel = 5e21 D atoms or 0.017g

Interior surface area of NSTX
= 40.66 m^2 = 4e21 $Å^2$

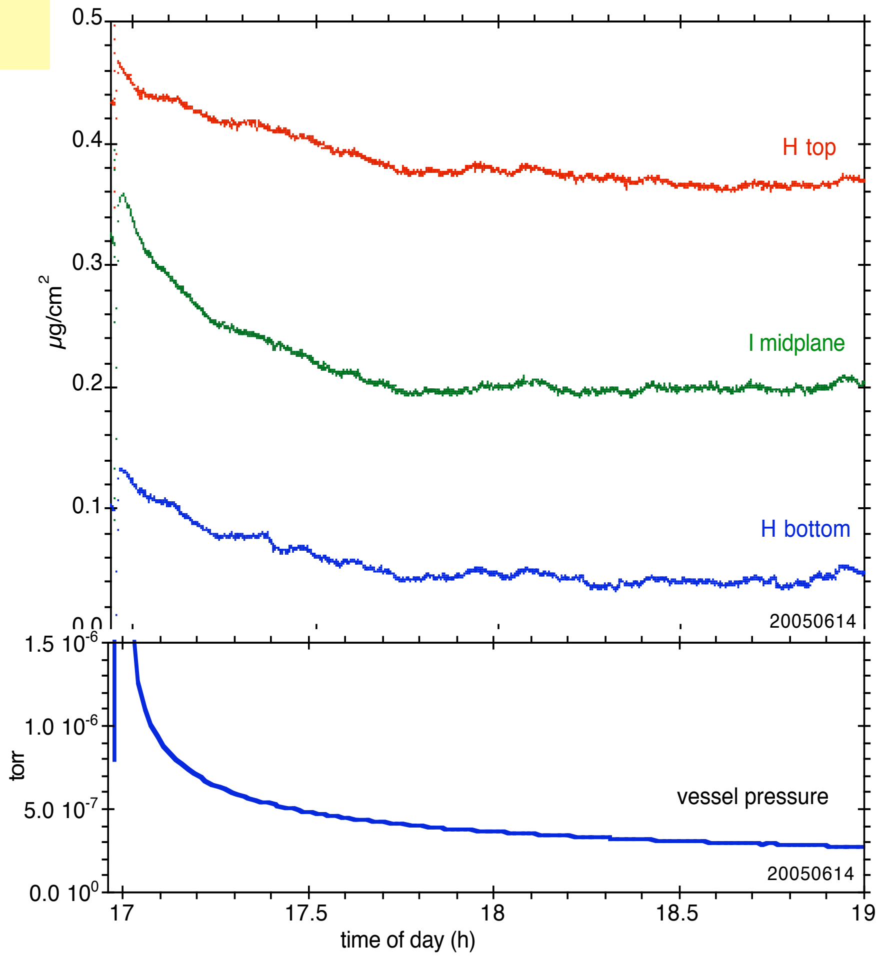
Fueling equivalent to about one D atom per $Å^2$ or 0.04 $\mu g/cm^2$ if smeared over NSTX interior and not pumped.

Initial mass gain of qmbs is ≈ 0.35 $\mu g/cm^2$ i.e. 10 x higher.

CONCLUDE: Dynamic retention concentrated in plasma shadowed regions.

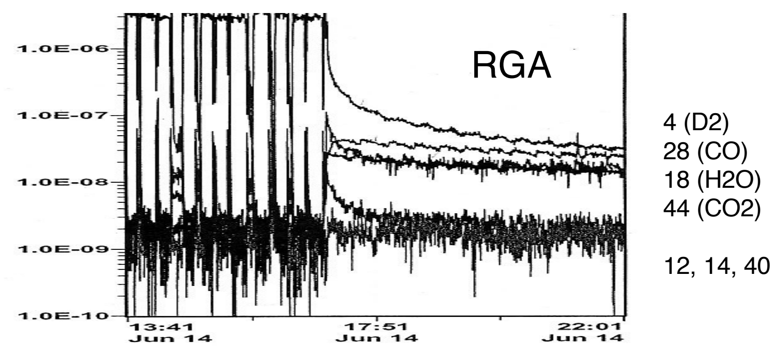
End of day behavior supports dynamic retention:

- Mass loss continues for ~ 1 h after last discharge
- No glow discharge, turbopumps only
- Outgassing of deuterium evident in ion gauge and rga data.



Compare material loss to exhaust pumpout:

- Average mass loss from 17h - 18 h is 0.11 $\mu g/cm^2$
- RGA shows exhaust mostly D (>70%)
- Mass of deuterium pumped by turbopumps from 17h - 18h is ~ 984 μg
- 1 h exhaust is equivalent to mass loss of 0.1 $\mu g/cm^2$ over 1 m^2
  Small area compared to 40 m^2 of vessel interior.
- Suggests dynamic retention occurs over only a small fraction of the NSTX vessel area (consistent with gas uptake on first shot of day)



Erosion / deposition is small compared to dynamic retention (and boronization/lithiumization)

Date	H bottom	H top	
change April 23 - Sept 13 2005	-0.3	2.6	µg/cm2
boronization	4.2	2.1	µg/cm2
plasma only	-4.5	0.5	µg/cm2
average rate	-0.0028	0.0003	µg/cm2/shot
average rate	-0.0051	0.0006	µg/cm2/sec
average rate	-0.32	0.03	Å/s

Conclusions:

- H-sensor being developed to measure H flux to wall (Bastasz).
- QMB's offer time and space resolved data on erosion, deposition and dynamic retention in plasma shadowed regions - unique opportunity to bridge surface analysis and gas balance data and validate models of tritium retention.
- Dynamic retention observed in mass gain after 1st shot-of-day and transient material loss after discharges.
- Step up or step down in asymptotic level observed, depending on plasma shape including shape of prior discharges (memory effect), plasma energy and duration and other parameters.
- Quantative comparison indicates mass gain / loss at measured rate over ~10% of the vessel area can account for D fueled and pumped.
- Long term erosion / deposition small compared to dynamic retention at these locations.

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The authors thank T. Holoman, D. Labrie, P. Roney and the NSTX team for technical assistance and R. Kaita for assistance with the qmb thermal calibration.
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