TMAP-7 SIMULATION OF D_2 THERMAL RELEASE DATA FROM BE CO-DEPOSITED LAYERS

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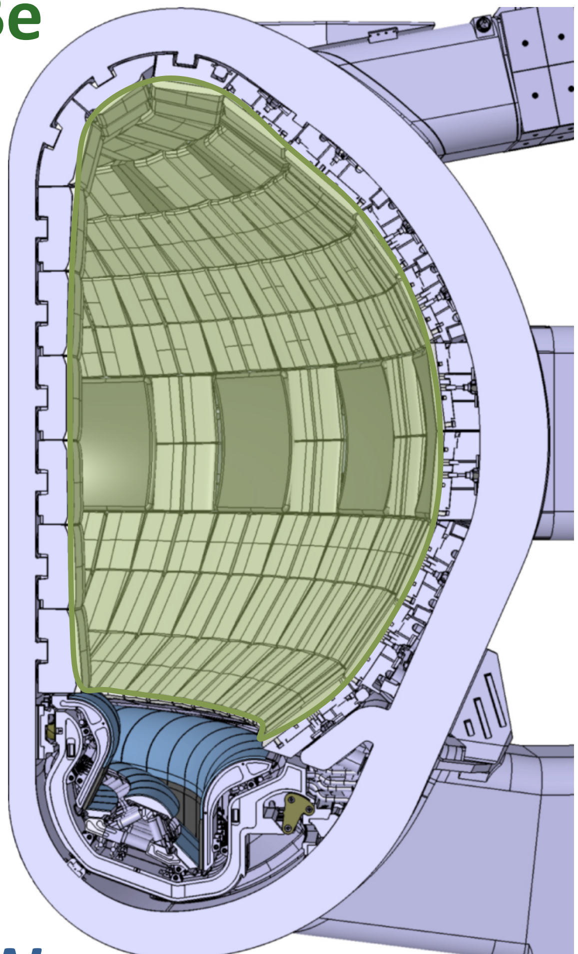
Introduction

Be

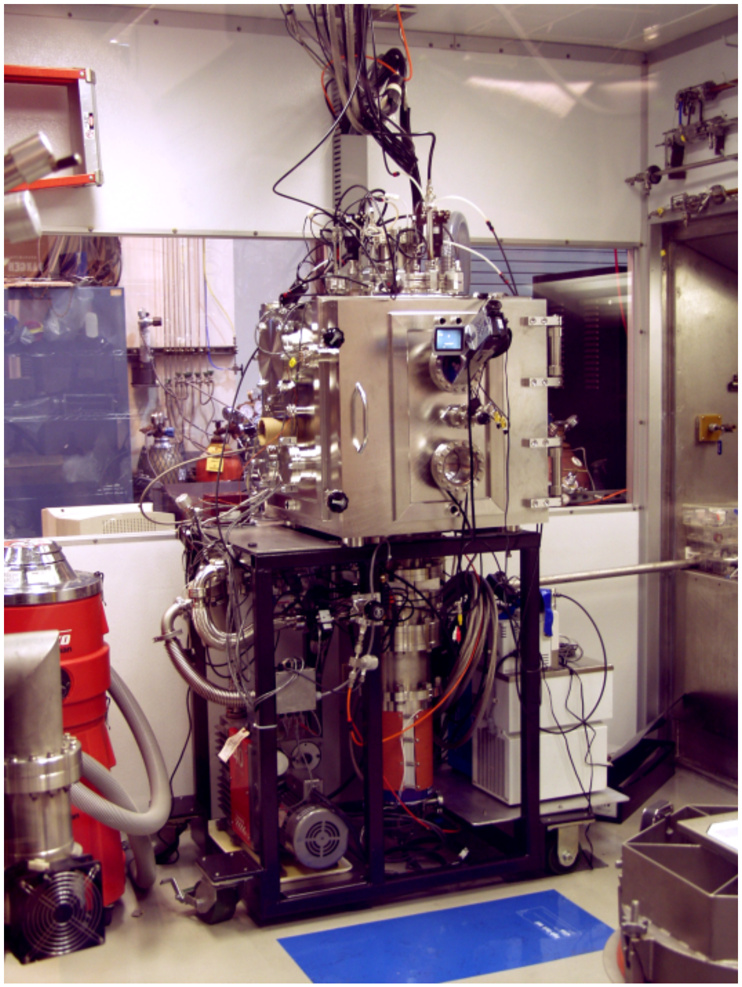


W

- ITER will have 700 sq. m of Be first wall and start-up limiters.
- Nuclear licensing requires low T in vessel inventory, 700 g (mobilizable).
- T accumulation in ITER will be driven by co-deposition.
- PISCES experiments contribute to the understanding of the nature of T inventory buildup & strategies for reduction.
- Inventory control options:
  1) Bulk PFC bake-out, 513 K (main wall), 623 K (divertor). **HOW LONG TO BAKE?**
  2) Transient thermal loads, rapid (< 10 ms) surface heating to high *T* during controlled plasma termination. **HOW MUCH IS RELEASED?**
  3) Remote probes (inefficient, last resort).
  4) Component replacement (when all else fails).

- Efficacy of 1) & 2) examined through experiment and modeling. **REQUIRES IDENTICAL SAMPLES.**

GA magnetron sputter coater produces batches of 'identical' co-deposits



Utilizes 3, 100 W Be sputter guns, operated at 6 mTorr in 80% Ar, 20 % D_2

Be deposition rate 2.5 x10^{15} $cm^{-2}s^{-1}$
Be-D co-deposited layers 1 μm thick

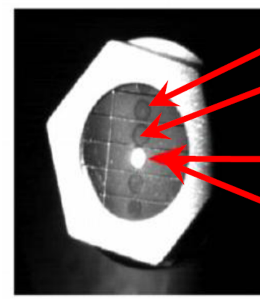
Bake-out Exp.
T_{dep} < 323 K

3 Be sputter guns coat spheres in Be.

Rotating pan.

2 mm dia W spheres.

Transient Exp.
T_{dep} ~ 500 K



Control co-deposit (not flashed)

2.5 mm dia. Be-D codeposits

Laser is aligned to spot.

Fast pyrometer, also aligned to spot, measures surface temperature.

A 50 J, 10 msec YAG laser is used to 'flash' codeposits simulating the radiation pulse during a controlled plasma shutdown in ITER

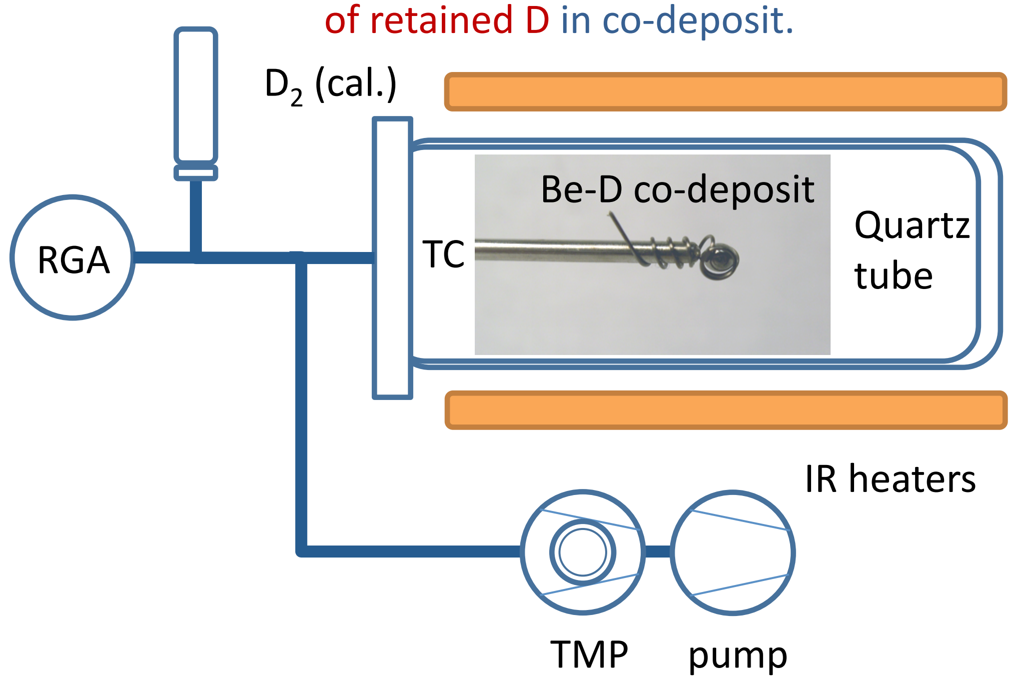
Experiments

Two types of experiment:

1) BAKE OUT -
Identical co-deposited Be–D layers were held at ITER relevant bake temperatures of 513 and 623 K for varied lengths of time up to 25 h.
Remaining D inv. measured.

2) TRANSIENT –
Identical Be–D layers were flash desorbed for 10 ms by focused YAG laser (< 50 J) at 1064 nm.
Remaining D inv. Measured by TDS.

- Special holder designed to give good TC contact to balls
- D inventory is measured using TDS.
- p_{D2} - time profile is calibrated against D_2 leak.
- p_{D2} - time integral a measure of retained D in co-deposit.



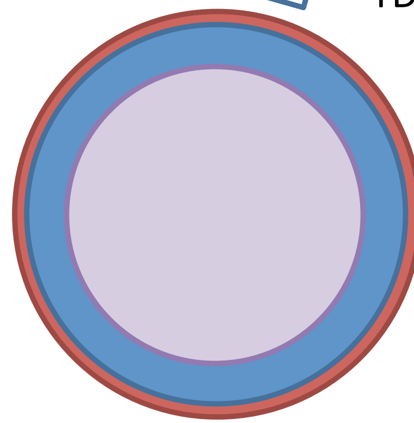
Modeling (TMAP 7)

Enclosure 1 - TDS chamber (300 K)

TMAP Input – (Literature values for Be: *Federici et al., FED 28 (1995))*
for BeO, Be, W:
Longhurst, TMAP7 V&V Manual, INEEL/EXT-04-02352 (2004)

thermal conductivity, heat capacity, D solubility, D diffusivity, D-D_2 recombination, trap conc. & energy

TMAP Output – D_2 surf. Flux (comparable w/ TDS exp. data)



D_2 flow

Ball & flash targets modeled as 1D layers.
3 linked diff. & therm. segments, *T* history
BeO (a few nm), Be (1 μm), W (1 mm).

Enclosure 2 – TMP (300 K)

Be layer thickness & trap concentration input come from experimental measurements.

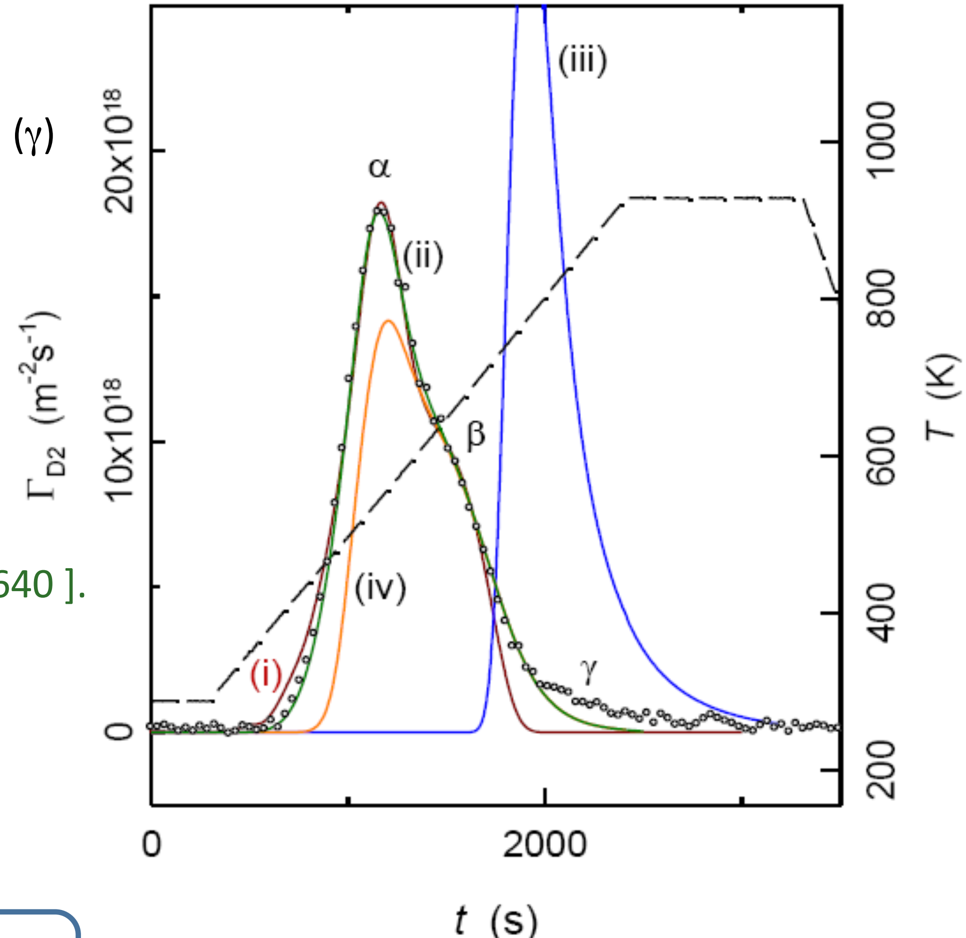
Base modeling co-deposit D_2 release.

- TDS data (symbols) from a Be–D co-deposit sphere. Two trap states (α and β) with a 'tail' (γ) reminiscent of 2nd order release.

- TMAP output (i, ii, iv) - single layer Be(1 μm) model. E_{traps}: 0.80 eV & 0.98 eV.

- (i) Sieverts law release.
- (ii) k_r specified [Federici et al., FED 28 (1995)
- 136 & Longhurst et al. JNM 258–263 (1998) 640].
- (iii) Incl. 10 nm BeO surface layer.
  ~ *Result does not agree with experiment.*
- (iv) simulation (ii), following 10 ms thermal transient to 1123 K.
  ~ *Minimal desorption from low T trap only.*

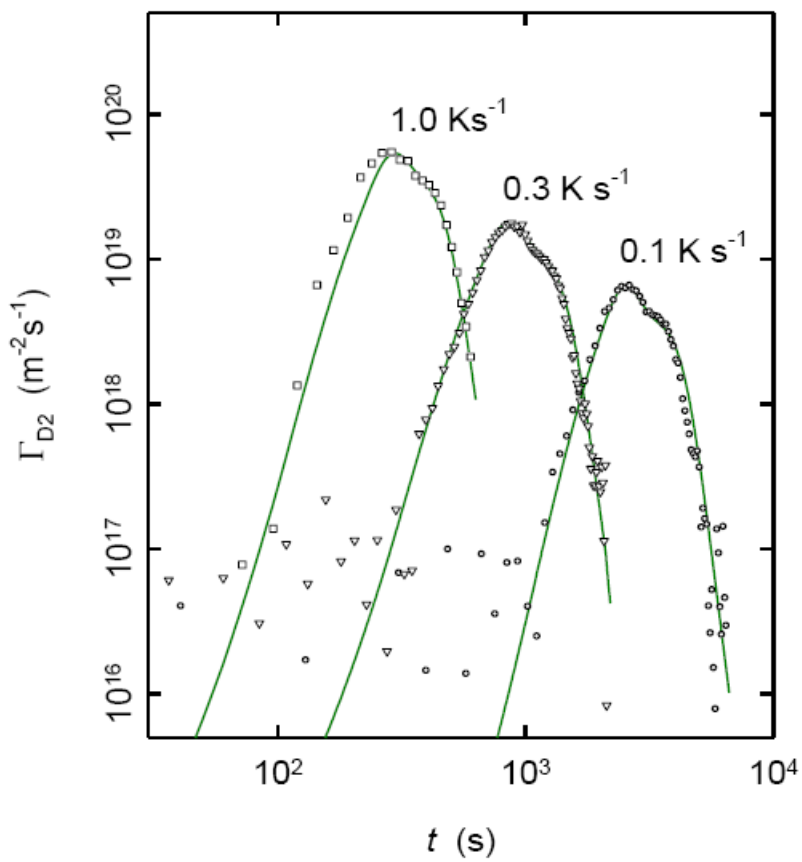
- TMAP single layer model (ii) gives best result.



Measured D/Be agrees with integrated TMAP model release

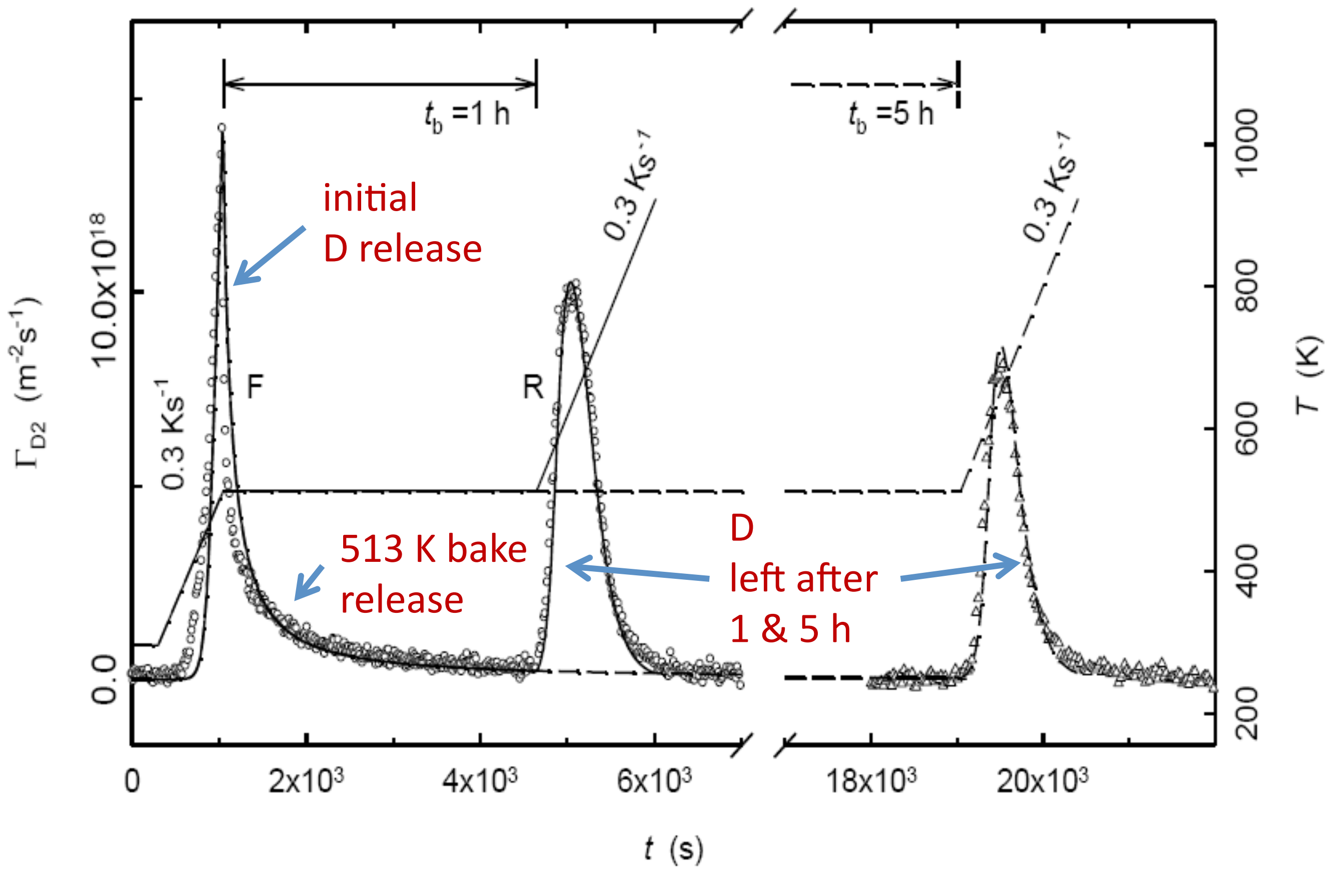
Base modeling co-deposit D_2 release.

- Good agreement between TMAP single Be layer model (ii) and TDS data acquired with different heating rates in the range 0.1 – 1.0 K.



Using TMAP to model Bake-Out Exp.

TMAP models bake-out, but k_r *must be adjusted as in* Longhurst *et al*. JNM 258–263 (1998) 640, *by the factor, [1+exp(c_D/A)], where c_D is the D conc. in the near surface, and A is a constant. Sharp fall (F) and rise (R) are better modeled as a result.*



- TDS data (symbols) for 1 & 5 h fixed temp bake at 513 K.
- Lines – TMAP
- t_b varied up to 25 h
- Data collected for 513 K and 623 K bakes.

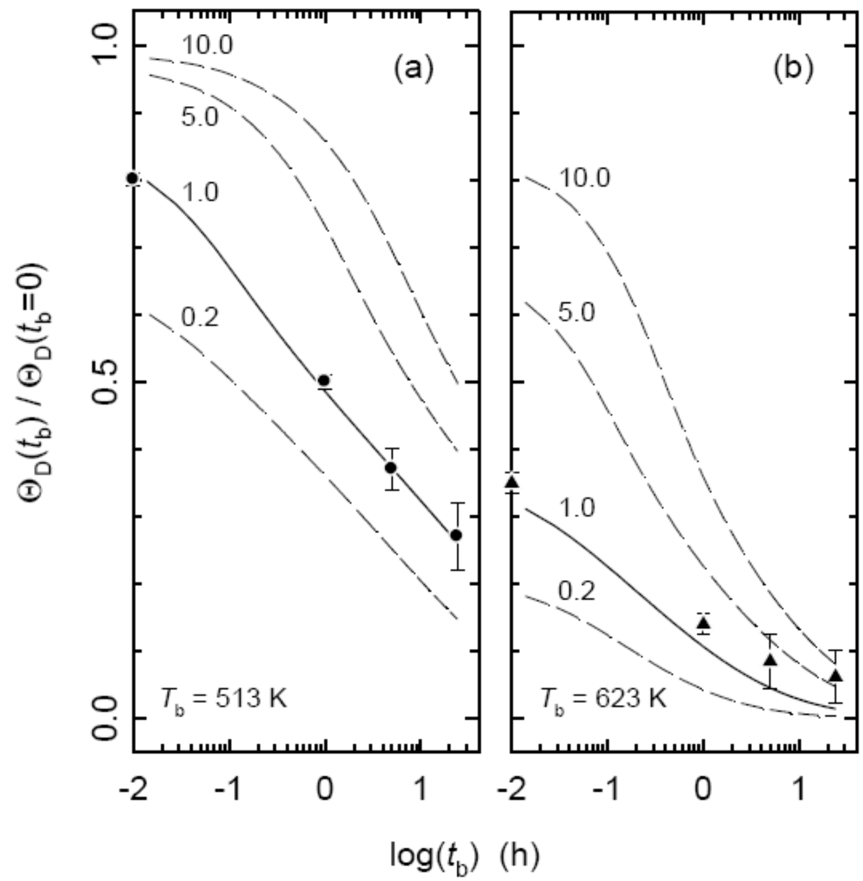
D Inv. left after bake: Exp & TMAP.

- Experiment (symbols) & TMAP (solid line) shows remaining D in 1 μm thick co-deposit falling significantly in ~1 day at ITER bake-out temperatures of 513 K & 623 K.

- TMAP output (dashed lines) are other layer thicknesses, 0.2, 5 and 10 μm.

- Thick layers require longer bake-out in TMAP simulations as a consequence of high trap concentration (analogous to reduction in diffusivity).

- Bakes longer than ~1 day are increasingly ineffective.



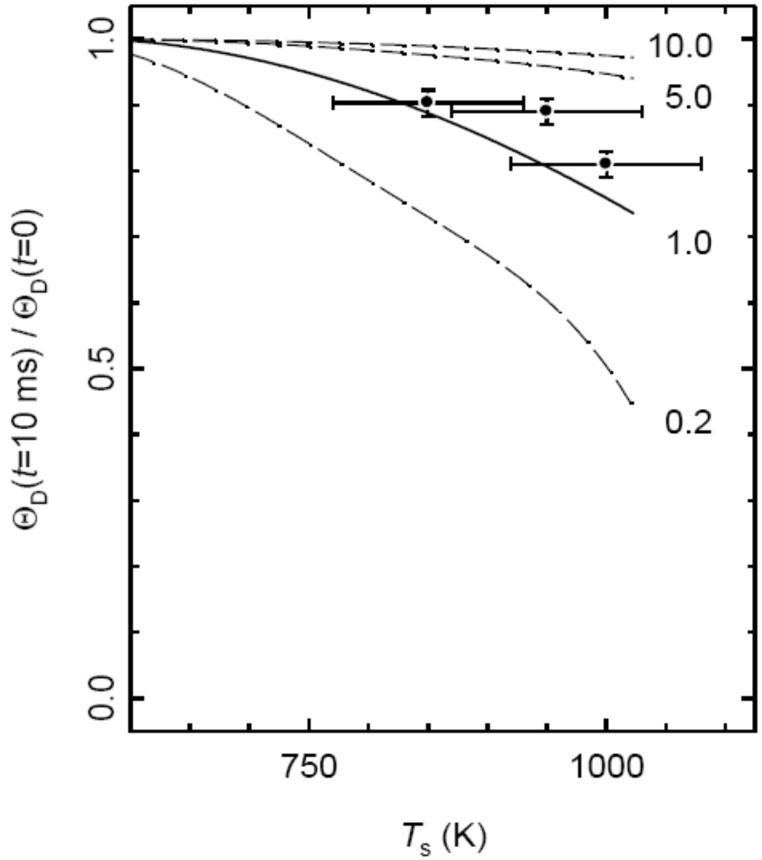
D Inv. left after thermal transient to 1000 K for 10 ms: Exp & TMAP.

- Remaining D inventory in co-deposits (normalized) remains high following a 10 ms laser pulse for layer temperature up to 1000 K.

- TMAP simulation agrees reasonably well with (full line) experiment.

- Dashed lines show TMAP output for other co-deposit thicknesses of 0.2, 5 and 10 μm.

- Again, thicker co-deposits desorb less



Summary

- The efficacy of 1) bake-out at 513 & 623 K, and 2) thermal transient (10 ms) loading to up to 1000 K, is explored for reducing D inventory in 1 μm thick Be–D codeposited layers.
- A single layer TMAP model utilizing traps with activation energies, 0.80 & 0.98 eV yields good agreement with measured codeposit release behavior.
- TMAP modeling results agree well with release behavior over a span of eight orders of magnitude in heating rate, providing some confidence in the ability to extrapolate the modeling to other codeposit thicknesses.
- TMAP modeling suggests that thick built-up co-deposits will hinder ITER inventory control, and that bakes are more effective in reducing inventory than higher temperature transient thermal loads.
- Thickness prediction will be confirmed by additional experiments.