Integrated scenario for controlling tritium retention in carbon co-deposits in fusion devices

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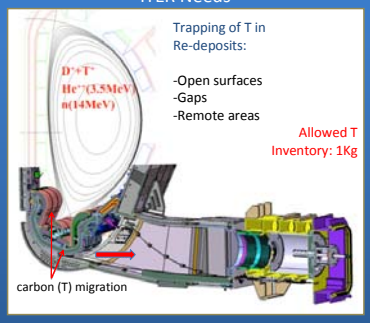
Motivation

- Tritium retention by carbon co-deposits is an important concern in ITER: Only W/Be for active phase proposed
- New techniques are necessary for the removal of these codeposits: Avoid T_2O formation, cleaning of Gaps, material mixing,……
- Recovery form cleaning: Impact of techniques in T processing Plant, wall oxidation, in-vessel components,…
- Gas phase reactions of nitrogen or nitrogen containing species with the C film growth precursor: Formation of non-reactive species that can be pumped away.

ITER Needs



Trapping of T in Re-deposits:

-Open surfaces
-Gaps
-Remote areas

Allowed T Inventory: 1Kg

Recent ERO estimates

A. Kirschner et al./Journal of Nuclear Materials 390–391 (2009) 152–155

Estimated carbon and beryllium deposition and tritium retention rates.

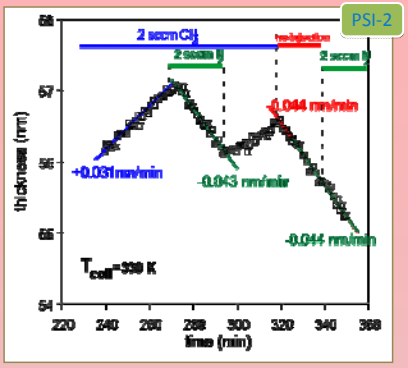
	Carbon layers		Beryllium layers		Σ
	On target (T/C = 0.05)	Remote (T/C = 0.5)	On target (T/Be = 0.05)	Remote (T/Be = 0.05)	
(a) Inner divertor					
HMM	8.0e19 C/s 0.02 mg T/s	4.5e19 C/s 0.1 mg T/s	2.4e22 Be/s 6 mg T/s	5.0e20 Be/s 0.1 mg T/s	6.2 mg T/s
TRIM	2.0e19 C/s 0.005 mg T/s	2.1e19 C/s 0.05 mg T/s	2.45e22 Be/s 6 mg T/s	~0 Be/s ~0 mg T/s	6.1 mg T/s
(b) outer divertor					
HMM	8.7e20 C/s 0.2 mg T/s	3.0e20 C/s 0.8 mg T/s	3.84e21 Be/s 1.0 mg T/s	6.0e19 Be/s 0.02 mg T/s	2 mg T/s
TRIM	7.0e20 C/s 0.2 mg T/s	7.0e20 C/s 1.8 mg T/s	3.84e21 Be/s 1.0 mg T/s	6.0e19 Be/s 0.02 mg T/s	3 mg T/s

T inventory: 200-50 shots

-Scavengers
-GDCleaning
-Thermooxidation

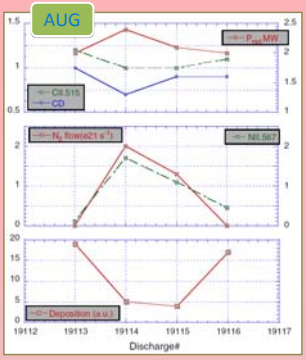
SCAVENGERS (inhibition)

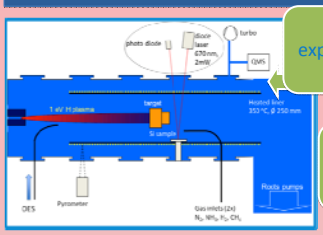
PSI-2



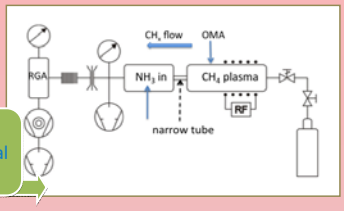
W. Bohmeyer et al J. Nucl.Mater. s2009, 390-391:560

AUG



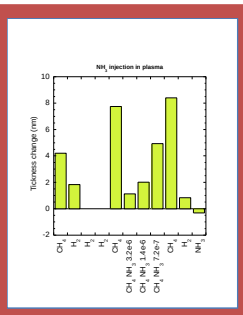


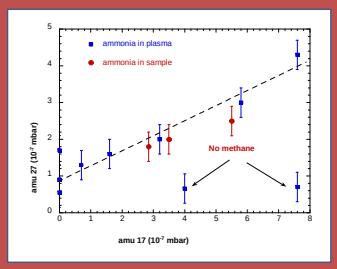
PILOT experimental set-up



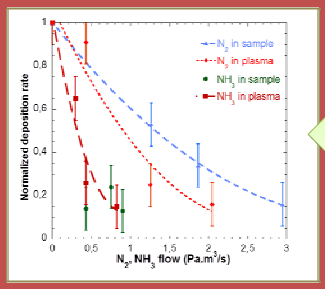
RF experimental set-up

PILOT Results



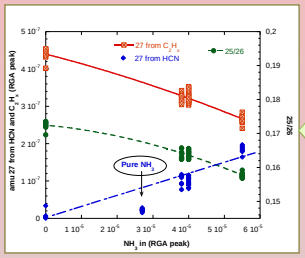


NH3 vs N2



- ✓ Inhibition effect in a set of experiments with different ammonia injections.
- ✓ N_2 → 2-3 higher fluxes for same effect

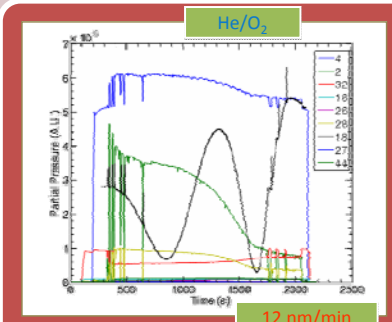
Results RF plasma



- ✓ NH_3 and CH_4 injected simultaneously for HCN production (mass 27)
- ✓ $NH_3+CH_3 \rightarrow HCN+2H_2+H$
- ✓ $NH_2+CH_4 \rightarrow HCN+2H_2+H$

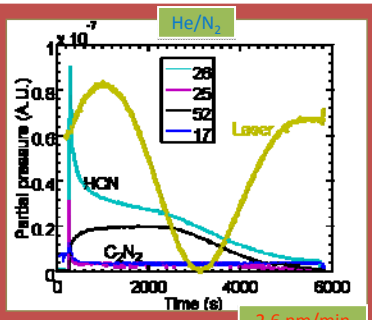
Plasma Cleaning of C:H films: O_2,N_2,NH_3 and NO_2

He/O_2



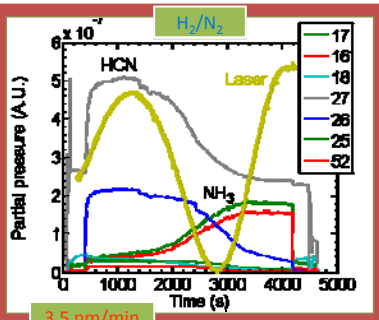
12 nm/min

He/N_2



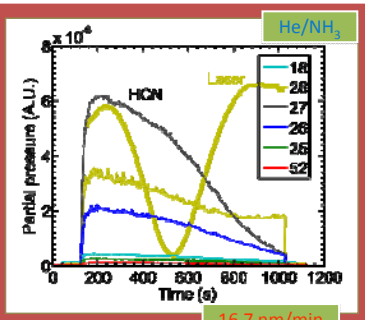
2,6 nm/min

H_2/N_2



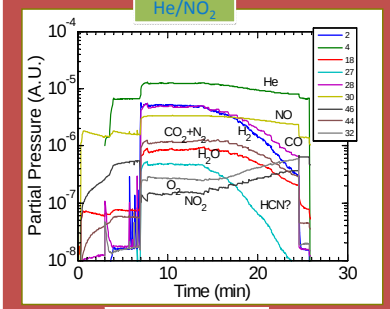
3,5 nm/min

He/NH_3



16,7 nm/min

He/NO_2

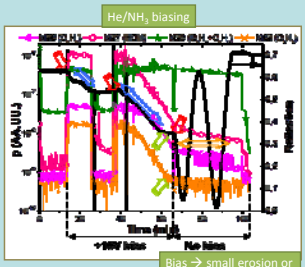


49,5 nm/min

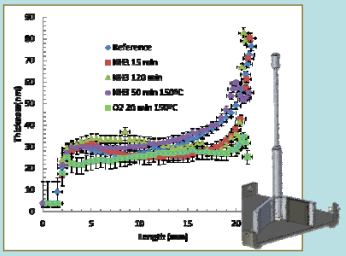
Plasmas in Gaps:

- ✓Same setup as in I. Tanarro, J. Ferreira, V. Herrero, F. Tabarés, C. Gómez-Aleixandre, J. Nucl. Mater. 390-391 (2009) 696-700.
- ✓Thickness measured by laser interferometry. He/NH_3 plasmas for cleaning
- ✓No dependence of the NH_3 erosion with time → Observed erosion due to changes in optical properties?
- ✓No erosion observed at 150ºC (NH_3) nor room temperature with NO_2
- ✓Erosion successfully measured for He/O_2 cleaning
- ✓High erosion rates in open surfaces in NH_3 and NO_2. No erosion in surface at floating potential → *Mechanism involving ions!! (RF plasmas can do it better???)*

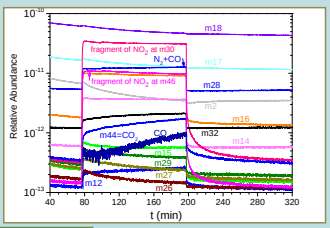
He/NH_3 biasing



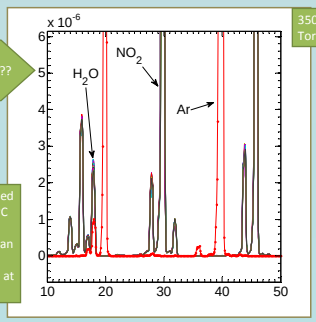
Bias → small erosion or change in optical properties



Thermo-oxidation: O2 vs NO2



H2O production???



350ºC NO_2 0,5 Torr

As deposited (~120nm)

- After 4h exposed to NO_2 at 250ºC
- At 300ºC completely clean after only 1h
- O_2 <100 nm/h at 400ºC

Conclusions

✓Nitrogen Chemistry highly suited for carbon deposition control in ITER with CFC targets. Integrated scenario to control T inventory. Scavenger during operation, plasma cleaning for open surfaces (independent of temperature) and thermooxidation to clean gaps in tiles.

✓NH_3 injection demonstrated in PILOT-PSI

✓NO_2 cleaning plasmas best results in open surfaces

✓NO_2 Thermooxidation: Better than O_2 at T_w~300ºC

✓ But: Water production using NO_2. NH_3 and NO_2 DC plasmas don't clean in gaps