Active control over carbon deposition by gas feeding for protection of diagnostic mirrors in ITER

P90B

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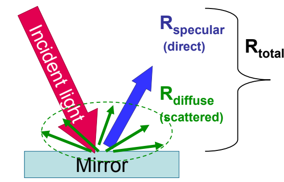
Motivation

- Metallic mirrors – first plasma-viewing elements for optical diagnostics
- Optical and polarization characteristics of mirrors in ITER will
  - influence the entire performance of the respective diagnostic system
  - have to be preserved over the entire period of experimental campaign
  - suffer from erosion, deposition, particle implantation [1]
  - represent a critical aspect for ITER operation

✓ Deposition mitigation techniques should be developed and implemented
✓ Dedicated experiments are required
✓ Gas feeding is a promising technique

Reflectivity: $R_{tot} = R_{diff} + R_{spec}$



Experiment in TEXTOR

Exposure of Periscope system – a prototype of diagnostic duct [2,3]

Aim: Development of a deposition mitigation technique for diagnostic mirrors' protection

Means: Shift net-deposition to net-erosion

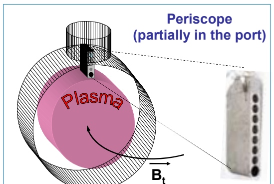
↓ Increasing surface erosion
✓ Physical sputtering
✓ Chemical erosion

↓ Balancing incoming plasma flux

↓ Gas feeding

D_2 feeding
- dissociation (4.56 eV)
- ionization (D/D_2: 13.6/15.2 eV)
- physical sputtering
- chemical erosion (carbon)

He feeding
- non-reactive gas
- ionization (24.6 eV)
- physical sputtering



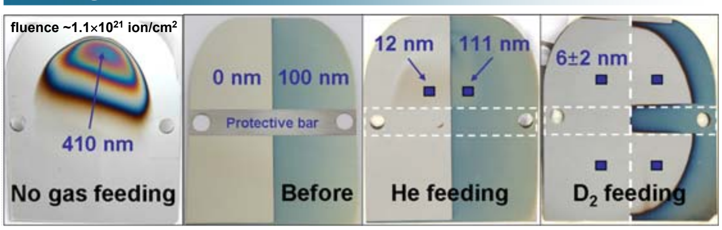
Exposure:

Periscope in SOL plasma of TEXTOR under deposition-dominated conditions

Plasma parameters:

$T_e \approx 25$ eV, $n_e \approx 1.5\times10^{12}$ cm^{-3},
T_{mirror}: ~ 460 °C,
Total fluence:
~ 8.3×10^{20} ion/cm^2

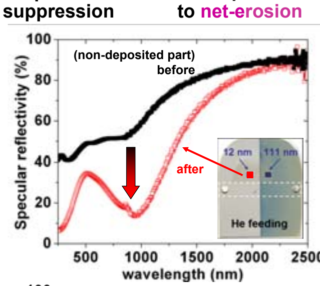
Investigations of the 1st mirror:



Strong deposition	Before exposure: Half of mirror pre-deposited with a-C:D layer	Slight deposition on the surface: Deposition suppression	Dynamic change from net-deposition to net-erosion

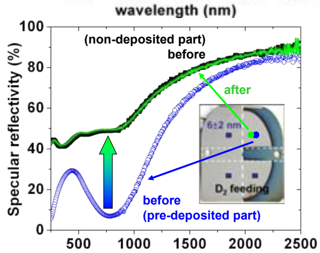
Results: He feeding

- Significantly reduced deposition
- Still strong decrease of the reflectivity
- Periodic cleaning is necessary for removal of deposited layers



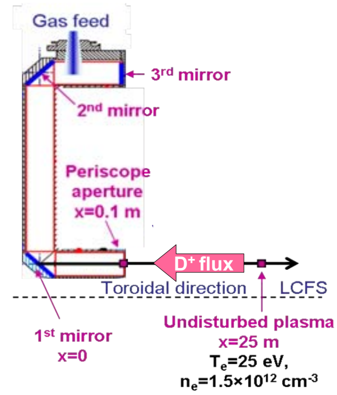
Results: D_2 feeding

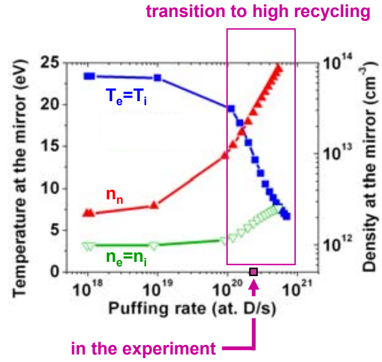
- Deposit removal; R_{spec} restored
- Similar optical characteristics and layer thicknesses for both halves of the mirror
- Surface carbidization on the entire area: implantation from background plasma



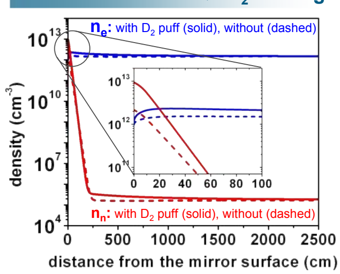
Modeling

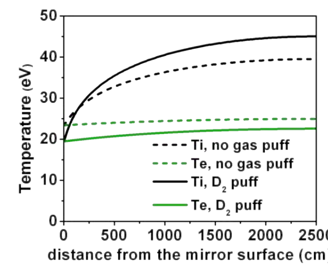
- Stationary one-dimensional model for the SOL plasma [4]
- Solving system of coupled equations for conservation of plasma particles incl. recycling particles, momentum and heat transfer along the field lines
- $T_i \neq T_e$ (low collisionality [5])
- Injection of D_2 gas: source function $S(x) = \frac{1}{\sqrt{2\pi\Delta}} \exp\left(-\frac{x^2}{\Delta^2}\right)$





Results:
- No gas feeding: sheath limited regime
- D_2 feeding: weak detachment, recycling regime





Conclusions

- He feeding: strong mitigation of deposition
- D_2 feeding: deposit removal under deposition-dominated conditions, restoration of reflectivity
- Carbide formation on both preliminary pre-deposited and non-deposited parts of the mirror
  - → May lead to carbon diffusion deeper into the bulk
  - → May provide difficulties in cleaning
- Second and third mirrors: intact
- Modeling: gas feeding leads to transition from sheath-limited to high recycling regime

Outlook

- Further modeling of local plasma conditions inside the duct with He puff
- Experiments with Langmuir probe measurements near the first mirror
- Investigation of the effectiveness of the technique on mixed layers

[1] A. Litnovsky et al, *J. Nucl. Mater.* 363–365 (2007) 1395–1402
[2] P. Wiehnold et. al., *J. Nucl. Mater.* 337–339 (2005) 1116
[3] A. Litnovsky et al, J. Nucl. Mater. (2010), doi:10.1016/j.jnucmat.2010.12.146
[4] O. Marchuk, M. Z. Tokar, *J. Comp. Phys.* 227 (2007) 1597-1607
[5] A. Huber et al., *Plasma Phys. Control. Fusion* 42 (2000) 569-578

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