GROSS AND NET EROSION BALANCE OF PLASMA-FACING MATERIALS IN FULL-W TOKAMAKS

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INTRODUCTION

Successful operation of future fusion reactors requires detailed understanding of the balance between gross and net erosion of plasma-facing components (PFCs), predominantly that of tungsten (W).

How has this been addressed?
- Marker samples exposed to series of plasma discharges on ASDEX Upgrade (AUG), marker tiles during entire campaigns on WEST
- Varied parameters: (i) plasma type (L- and H-mode) and gas (D and He), (ii) marker material (W vs. Au or Mo vs. Re), (iii) surface roughness
- Spectroscopic data extracted during plasma operations combined with the results of post-exposure analyses of the marker samples

Main goals of the present work:
- Elucidate how gross and net erosion depend on local plasma conditions and PFC material properties in D and He at the divertor
- Compare the results obtained from two full-W devices with each other

OVERVIEW OF THE EXPERIMENTS

AUG
- Exposure of marker samples in the low-field side (outer) strike point (OSP) region – erosion determined from changes in the thickness of the marker layers
  a) Mo-coated (~300 nm) graphite samples with small Au marker spots (~30 nm)
  b) Different spot sizes: 1×1 mm2 (gross erosion) and 5×5 mm2 (net erosion)
  c) Graphite samples with W and Mo (~30 nm) markers and uncoated trench (~0.2 mm)
  d) Bulk W tile (~0.2-0.3 μm) with Mo coating and broad (~30 nm) Au markers

WEST
- Marker samples exposed to C3 (in D) and C4 (in D and He) campaigns
  a) Part of the tiles removed after C3
  b) Properties of the marker tiles
    - Mo and W layers → full-W components
    - Actual markers (Mo and W) on top

OVERVIEW OF RECENT AUG RESULTS
- General observations in D, see [1-3] and Fig. 2
  - Erosion peak around OSP, Au and Mo eroded at higher rates (factor of 3-15) than W (Fig. 2a)
  - W shows deposition peaks on both sides of the OSP due to local re-deposition and ExB drift
  - Strongest impact on net erosion comes from the shape of the Tc profile
  - Gross erosion can also be determined by post exposure analyses → sub-mm samples needed

OVERVIEW OF RECENT WEST RESULTS
- Spectroscopically determined divertor gross erosion in line with AUG data, see [8]
  - Impurities (O, C for WEST) have a strong role in determining the erosion patterns
  - Campaign-averaged net erosion/deposition picture similar to AUG results, see [9]: erosion
  - Effect of surface roughness, see [4]
    - Increasing roughness reduces net erosion (Fig. 3a), strongest samples over the deposition/erosion peak
    - Erosion also depends on the type and structure of the coating (comparison Mo markers: Fig. 2c and 3a)
  - Erosion in D and He, see [5-7]
    - Strong erosion sources in He but also stronger flow of material into divertor → net deposition if impurities predominantly present (Exp 1)
    - Minimizing the presence of impurities (Exp 2) leads to the occurrence of net erosion → but less in D?

CONCLUSIONS

1. Small enough marker samples can be used for determining gross and net erosion
2. In H-mode, gross erosion >10-100 but net erosion x2-4 higher than in L-mode
3. Rougher surfaces → suppressed net erosion and enhanced formation of co-deposits
4. In He plasmas, erosion amplified by higher mass/charge of plasma particles but impurities can overcompensate this → apparent net deposition