Max-Planck-Institut für Plasmaphysik, EURATOM Association

Long-term evolution of tungsten surfaces in ASDEX Upgrade

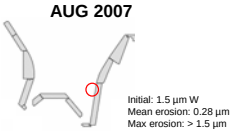
M. Mayer[a], M. Balden[a], E. Fortuna-Zalesna[b], A. Hakola[c], K.J. Kurzydlowski[b], S. Lindig[a], R. Neu[a], M. Pisarek[b], M. Rasinski[a], K. Rozniatowski[b], K. Schmid[a], K. Sugiyama[a], ASDEX Upgrade Team[a]

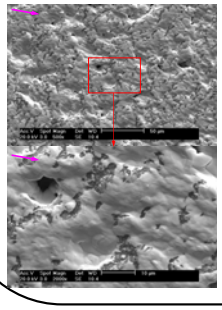
[a] Max-Planck-Institut für Plasmaphysik, EURATOM Association, D-85748 Garching, Germany
[b] Faculty of Materials Science and Technology, Warsaw University of Technology, Association EURATOM-IPPLM, 02-507 Warsaw, Poland
[c] VTT, Association Euratom-Tekes, P.O.B. 1000, 02044 VTT, Finland

1. Introduction

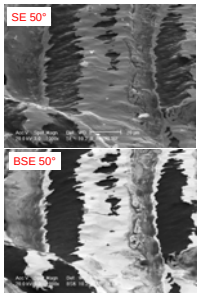
- Inhomogeneous erosion of thin tungsten layers on carbon divertor tiles was observed in AUG and JET, with a much higher erosion (factor 10 and higher) on plasma inclined faces than the mean erosion [1,2].

AUG 2007





JET 2001 - 2004



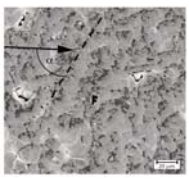
2. Inhomogeneous erosion/redeposition on rough divertor surfaces [3]

Inhomogeneous erosion due to combined effect of magnetic field + electrical sheath potential

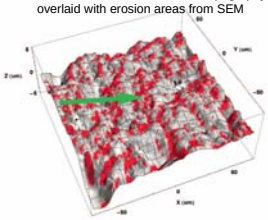
- Real surface topography measured by AFM and used for simulation calculations
- Erosion by D, B, C, O-ions predominantly on leading faces of a rough surface
- Small (or no) erosion in shadowed areas and pores
- Almost homogeneous re-deposition of eroded W on rough surfaces

⇒ **Deposition and re-deposition of tungsten even in global net erosion areas, in shadowed places and pores**

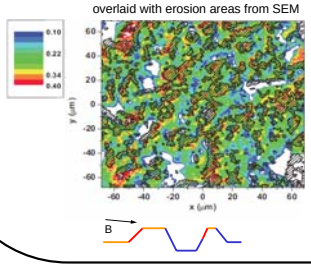
SEM micrograph



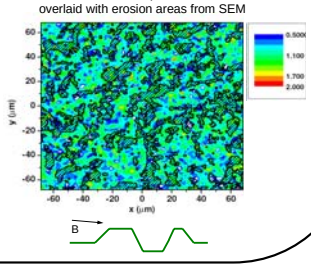
AFM measurement of surface topography, overlaid with erosion areas from SEM



Calculated erosion of W, overlaid with erosion areas from SEM



Calculated re-deposition of W, overlaid with erosion areas from SEM

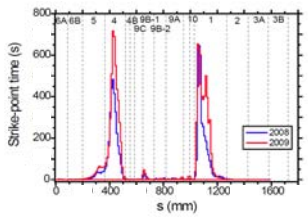


3. Long-term evolution of tungsten surfaces in the ASDEX Upgrade outer divertor

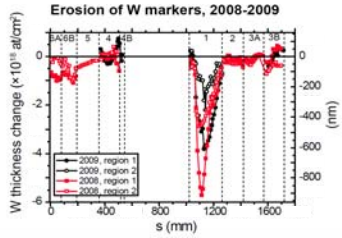
AUG outer divertor strike point area is a global net W erosion area
see A. Hakola et al., poster 16B, this conference

- Outer AUG divertor strike point (Bgr. 1):
  10 µm W layers deposited by CMSII method on fine grain graphite
- Campaign 2009: 5274 seconds plasma in divertor configuration

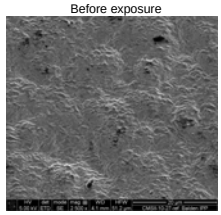
Strike point position, 2008-2009



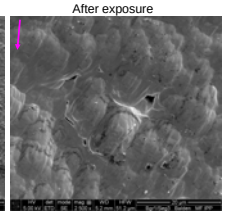
Erosion of W markers, 2008-2009

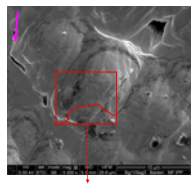


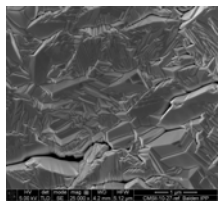
Before exposure

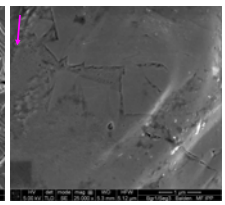


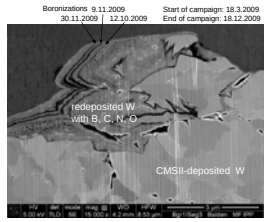
After exposure



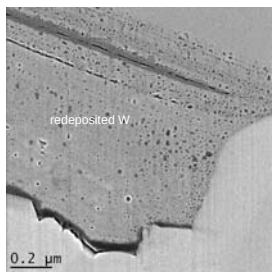




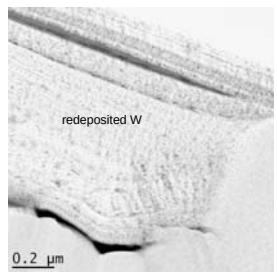


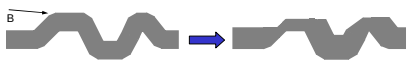


SEM image of FIB lamella



Z-contrast image of FIB lamella





- Smoothing of initially rough surfaces by plasma exposure due to inhomogeneous erosion/deposition of W
  see also E. Fortuna-Zalesna et al., poster 79A, this conference
- Redeposited layers in microscopically shadowed areas consist of inclusions containing many possible mixed phases (for example B_xW_y, W_xC_y, W_xN_y, WO_x) embedded in a W matrix
- Hollow pores in the W matrix exist, but seldom
- Boronizations visible as bands of low-Z material

4. Conclusions

- **Smoothing of initially rough tungsten surfaces due to**
  - Erosion of tungsten dominantly on leading faces of rough surface
  - Re-deposition of eroded tungsten in shadowed areas of rough surface
  - Multi-step process
- **Re-deposited W-layers are co-deposited with B, C, N, O**
  - Inclusions consisting of W mixed with low-Z elements embedded in a W matrix
  - Enhanced storage of N (A. Kallenbach et al., PSI 2010)
- **Long term evolution of surfaces?**
- **Consequences for hydrogen diffusion and inventory?**

References

[1] M. Mayer et al., Phys. Scr. **T138** (2009) 014039
[2] M. Mayer et al., J. Nucl. Mater. **363–365** (2007) 101
[3] K. Schmid et al., Nucl. Fusion **50** (2010) 105004