VTT contribution to experimental surface-roughness investigations

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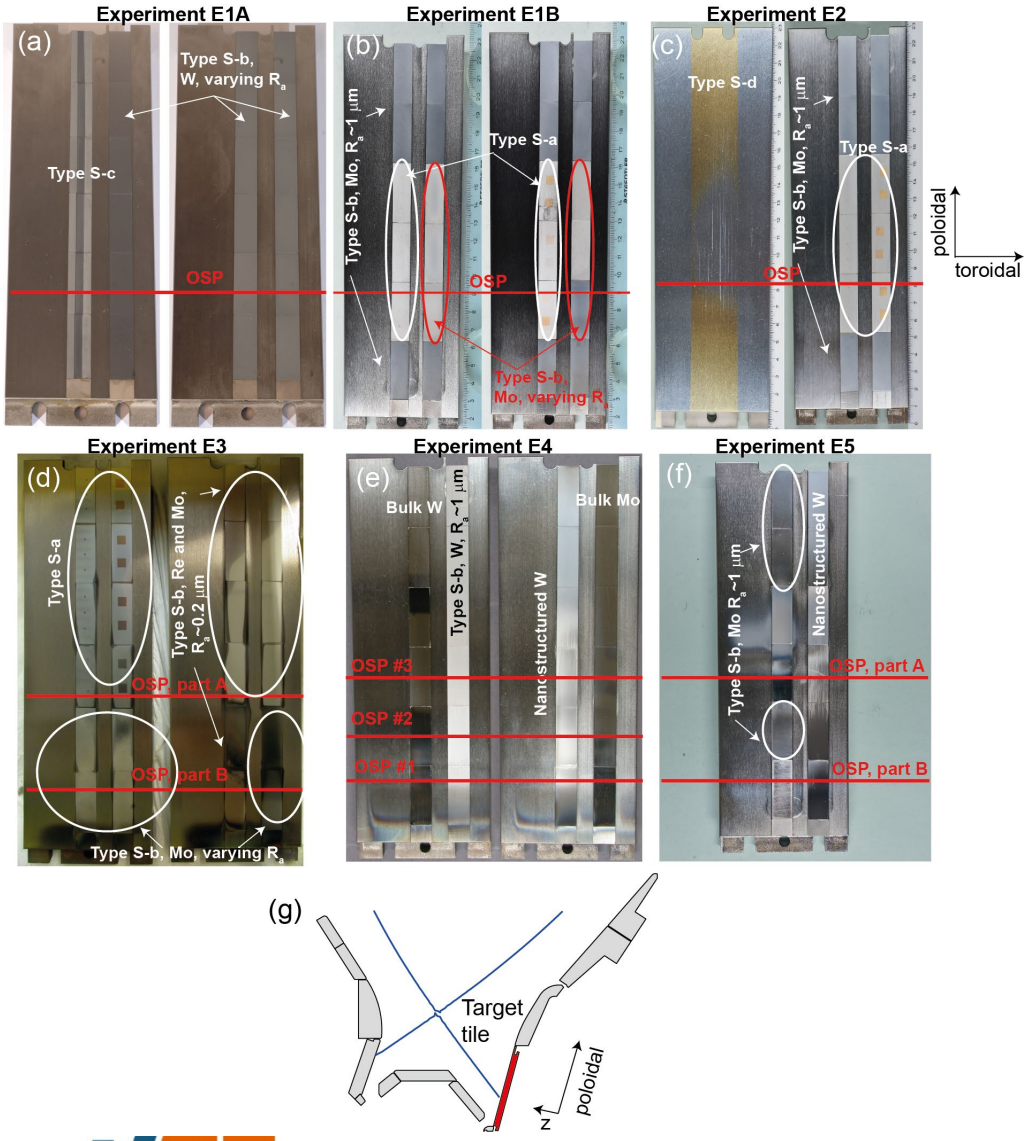
This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Introduction – what has been done, where and why?

- Roughness investigations started in 2014 – several sets of **samples produced and exposed in different plasma environments** during the past 8 years
  - ✓ Laboratory experiments in Ljubljana (JSI)
  - ✓ Experiments in PSI-2 in Jülich (FZJ)
  - ✓ Exposure to tokamak plasmas on AUG (MPG, VTT) → **focus of this talk**
  - ✓ Several other labs included in the post exposure analyses
- **Different sample types** used
  - ✓ Smooth samples of bulk W for reference (MPG)
  - ✓ Milled and sand-blasted graphite substrates (R_a< 10 nm → 5 μm) with W or Mo marker coatings (ENEA, VTT)
  - ✓ Graphite substrates with pre-defined surface morphology (by plasma etching) and equipped with Mo marker coatings (ENEA)
- AUG experiments based on the **usage of the DIM-II divertor manipulator**
  - ✓ Several sample types can be exposed during a single experiment (a handful of plasma discharges) and in different poloidal/toroidal locations at the outer divertor

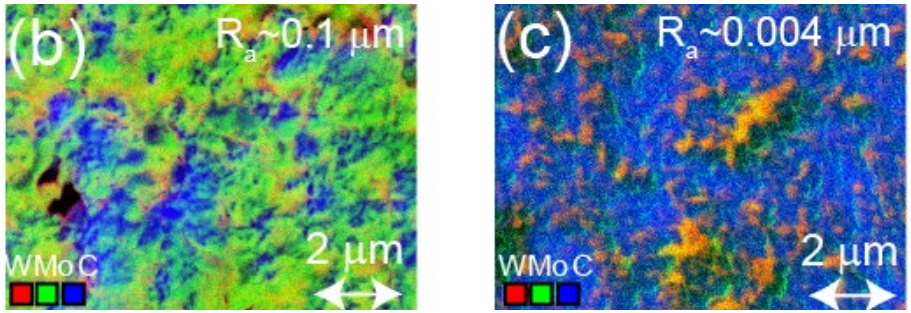
AUG experiments: overview



- A number of experiments performed with a varying selection of samples
- Overview of experiments
  - ✓ **E1A and E1B**: L-mode plasmas with high T_e in D
  - ✓ **E2**: H-mode plasmas in D with large type-I ELMs
  - ✓ **E3**: H-mode plasmas in D with small and frequent ELMs
  - ✓ **E4 and E5**: L- and H-mode plasmas in He
- Most relevant data sets available from
  - ✓ E1A: W coatings with varying surface roughness
  - ✓ E1B and E3: Mo coatings with varying morphology/roughness

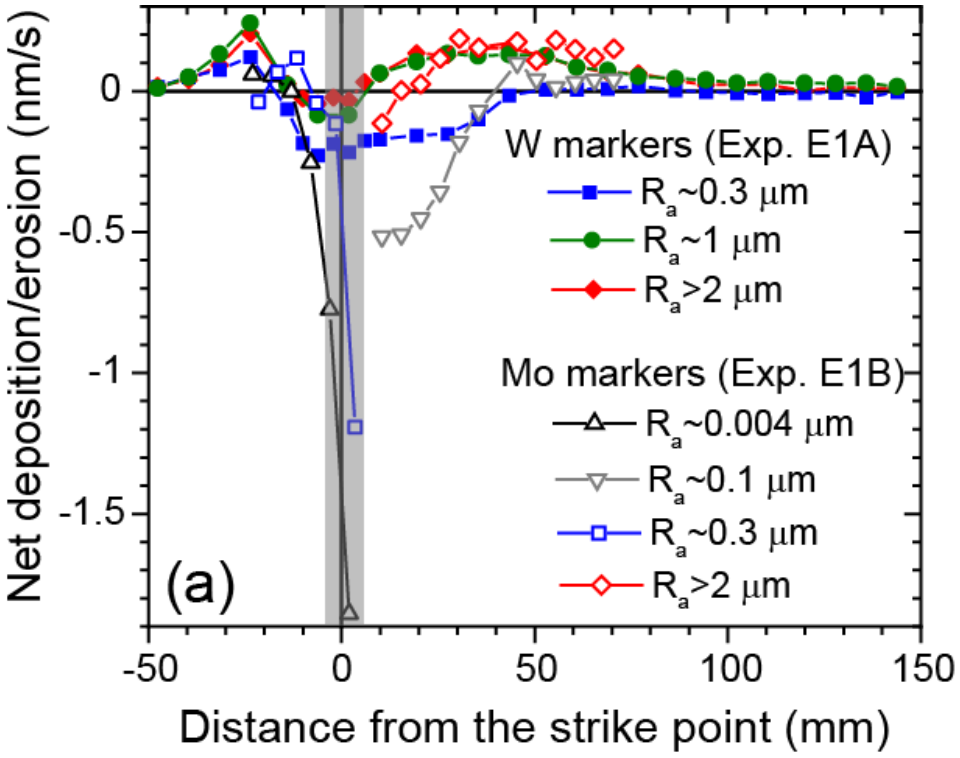
Analysis program

- The **following surface analyses** have been agreed on/completed for the samples
  - ✓ SEM, optical microscopy, and confocal laser-scanning microscopy (MPG)
  - ✓ Broad-beam RBS & NRA (MPG, VTT)
  - ✓ Micro-NRA and PIXE as well as TOF-ERDA (RBI)
  - ✓ NRA and PIXE (JSI)



SEM/EDX data from (left) a medium rough (R_a~0.1 µm) Mo marker and (right) from a smooth sample (R_a~0.004 µm) at the OSP

Net erosion clearly diminishes as surface roughness increases



- Increasing the roughness by a an order of magnitude results in the **reduction of net erosion by a factor of 5-10 in L-mode**
- Strong **net deposition observable** for the roughest samples **next to the OSP** → agrees with ERO simulations with **E×B** drift activated
- On rough surfaces, large amounts of **impurities deposited close to OSP**; on smooth surfaces, only remnants of the original coating left
- However, even with the same value for R_a, erosion/deposition patterns may show large differences → **morphology cannot be described by a single parameter**

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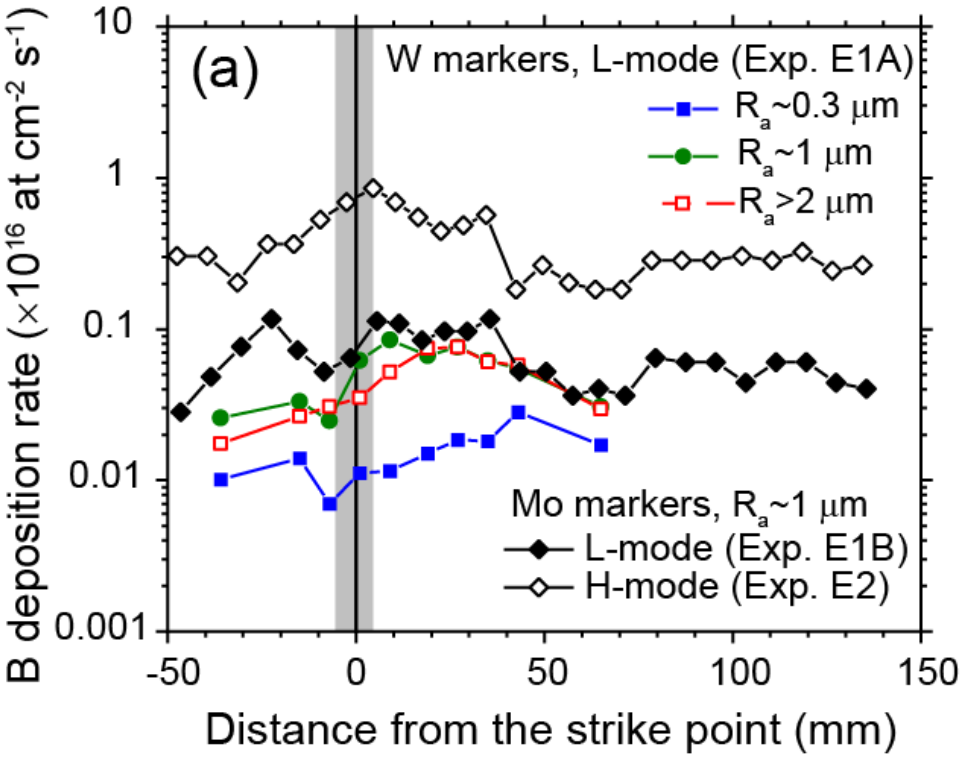

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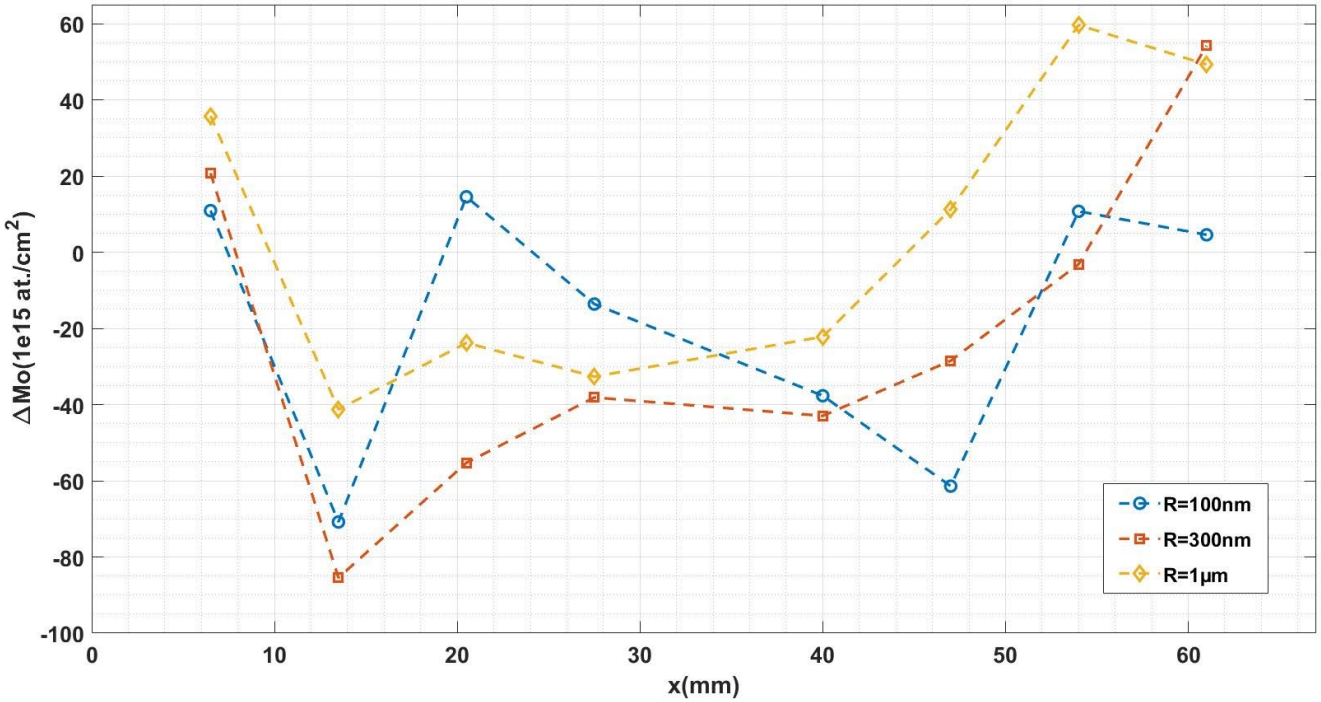
H-mode brings in large alterations in the erosion profiles



- In H-mode, the conclusions are still the same but the **erosion peaks are typically broader (in poloidal direction) than in L-mode**
- For some sample types **local alterations from net erosion to net deposition** can be observed
- Also observed for standard sample types, indicating strong damage to the marker coatings, even complete removal, in specific locations