Tungsten migration in the Alcator C-Mod Divertor

G.M. Wright, H.S. Barnard, B. Lipschultz, D.G. Whyte

Plasma Science & Fusion Center, MIT, Cambridge USA
Different tungsten (W) erosion scenarios lead to different W sources for plasma impurities

Sputtering Scenario:
- For two campaigns (2007-2008), W erosion is due to physical erosion (via plasma impurities) of W tiles at outer strike point.
- Small, toroidally-symmetric W source
  - Small amounts of W in the core
  - Tile measurements: “acceptable” net W sputtering rate of ~0.05 nm/s = 1.5 mm/year

Melting Scenario:
- Failed W tile leading to significant W melting in 2009-2010 Campaign
- Strong, local W source
  - Significant W detected in core.
  - Operation with OSP on W row impossible due to excessive W core contamination
Tiles are removed from C-Mod to measure campaign-averaged W deposition

- 1-3 MeV protons give probing depths of up to 10 μm
- Characteristic W x-ray peaks are identified.
- Results are quantified by comparison to thick target yields
Sputtering scenario: Net deposition in the lower part of the outer divertor indicates prompt W ionization & re-deposition.

- Prompt re-deposition can also mean potential self-sputtering.
Sputtering scenario: Deposition pattern across the dome indicates W transport through private flux region

- Divertor dome shows neutral transport and ion transport through the private flux region.
- Ion transport towards inner divertor is in agreement with ExB drift
Sputtering scenario: Deposition on inner divertor indicates W transport through SOL and/or core

- W migration to inner divertor is a combination of ion transport through the PF region and ion transport through the SOL and/or core.
Sputtering scenario: Poloidal W inventory in the divertor yields an approximate net erosion rate

- A net effective thickness $4 \times 10^{21}$ W atoms/m² (~60 nm) has been removed from W tile
  - ~0.05 nm/s
  - ~1.5 mm/exposure-year
Significant W melting led to high W core contamination during operation.

- Strike-point could not be operated on the W row after the melting event due to W in the core and disruptions.
Melting scenario: W deposition in the outer divertor is non-uniform toroidally and highest far from melted tile

• Much higher deposition than in sputtering scenario.
• Orders of magnitude difference in W deposition on neighboring tiles.
Melting scenario: W deposition in inner divertor shows very little contribution from melted tile

- Deposition is not in excess of sputtering scenario
  - NO line of sight deposition from melting event
- Deposition shifted higher on inner divertor likely due to higher position of ISP to avoid running outer strike point on melted W tile
What have we learned?

Sputtering Scenario:
- Poloidal inventory indicates very low W sputtering rate (~1.5 mm/exposure•year) in typical plasma operations.
- W transport through the divertor is qualitatively consistent with picture of ionization, redeposition and ExB transport.

Melting Scenario:
- Local regions of very high W concentration and high core W contamination indicates erosion due to local melting orders of magnitude dominant over sputtering.
- Non-uniform toroidal distribution of W in melting scenario indicates transport is much less clear.
  - Largest deposits were in regions distant and out of line of sight of the melt event location.