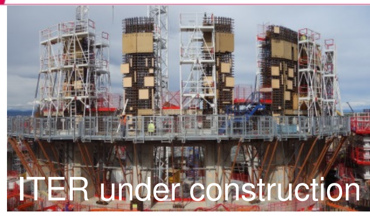
Towards viable nuclear fusion reactors 2

Technische Universiteit Eindhoven University of Technology

Towards viable nuclear fusion reactors

A. Mannheim, J. A. W. van Dommelen, M. G. D. Geers



Research goal: Can the heat extractor (divertor) withstand the extreme loads in a future fusion reactor for a sufficient amount of time?

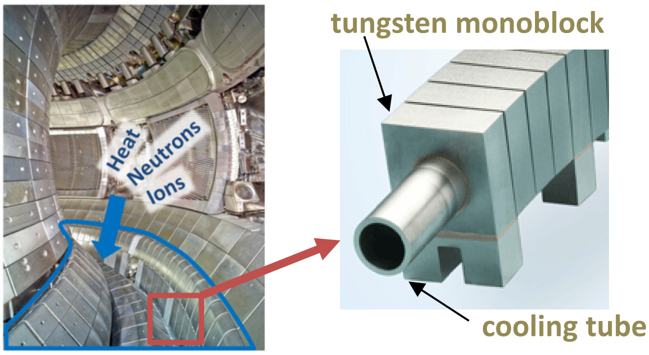
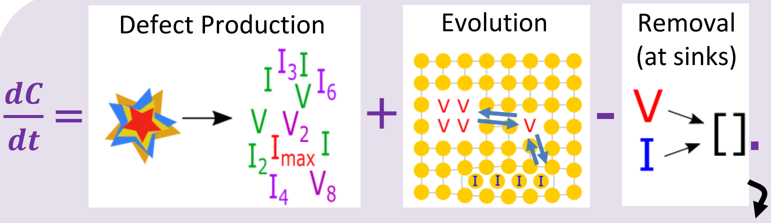


Figure 1: the divertor in the JET reactor (www.iter.org, left) consists of many tungsten monoblocks (on the right).

Help to realize nuclear fusion.
↓
Make the wall of the fusion reactor withstand the extreme loads.
↓
Understand the degradation processes in the divertor monoblocks.
↓
Study the microstructural evolution of tungsten under the combined **heat** and **neutron** loads.

Research goal

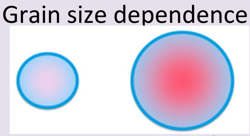
Method 1 Grain level: neutron damage



Method: **Cluster dynamics model** for the concentrations of vacancies (V), self-interstitial atoms (I) and dislocations.

Scale : Å − μm

Grain size dependence:



The ease with which defects find the grain boundary sink.

Based on Li (2012), Stoller (1990), Yi (2015), Jourdan (2015)

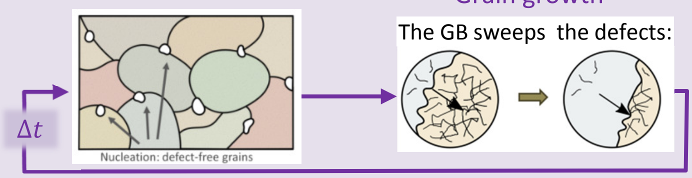
2 Polycrystal level: recrystallization

Mean-field model (Scale 1-100 μm)

Microstructure: a set of representative grains.

- Radius r
- Defect densities ρ, C_I^m, C_V^n
- # of represented grains N

Each grain interacts with the average microstructure medium.



Nucleation depends on:
- GB (grain boundary) mobility
- Defect density: **stored energy**
- GB surface area

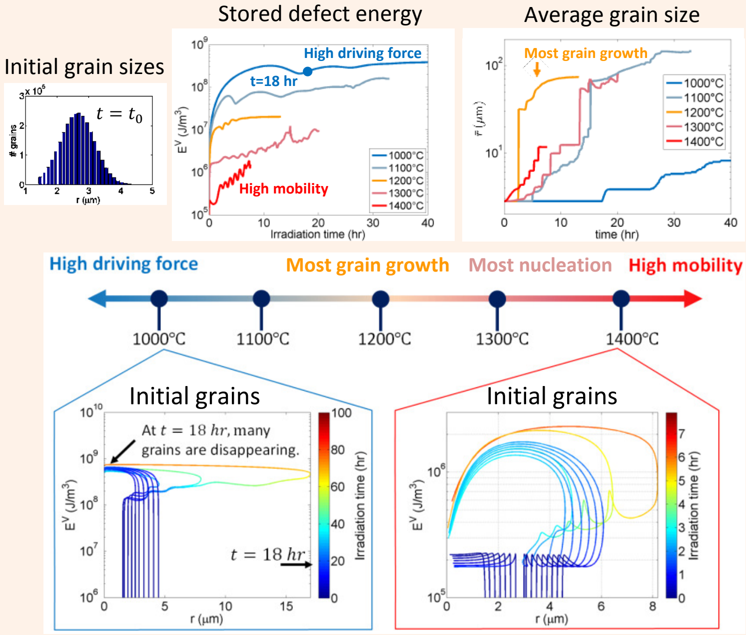
Grain growth is based on the velocity of the grain boundaries:

$$v = m(T)\Delta E_{average/grain}$$

GB mobility ↙ ↖ Defect density

Based on Bernard (2011), Lopez (2015)

Results Microstructural evolution



The largest grains vanish first (most damage accumulation).

The smallest grains vanish first (the GB surface energy dominates).

Damage accumulation vs. recovery

- Defect accumulation / GB mobility / point defect mobility / nucleation rate / individual grain behavior can all be studied with this model.
- Pace of renewal of the microstructure.

Conclusions/Outlook

- The multi-scale model for the microstructural evolution of tungsten under heat and neutrons shows to be a versatile tool to study the temperature dependent stability of the original microstructure and the competition between the various processes for damage and recovery.
- In future, lifetime of the divertor monoblocks will be studied by combining the (stress-dependent) microstructural model with a mechanical FE analysis.