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

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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](http://www.iter.org), left) consists of many tungsten *monoblocks* (on the right).

**Method**

1. **Grain level: neutron damage**
   
   \[
   \frac{dC}{dt} = I_1 \frac{V}{I_2} + V \frac{V}{I_3} - V \frac{V}{I_4} \]

   - **Defect Production**
   - **Evolution**
   - Removal (at sinks)
   - *Scale:* 1-100 μm
   
   Based on Li (2012), Stoller (1990), Yi (2015), Jourdan (2015)

   **Defect Production**
   - **Nucleation**
   - **Removal** (at sinks)

   **Evolution**
   - **Grain size dependence:** The ease with which defects find the grain boundary sink.

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

2. **Polycrystal level: recrystallization**

   **Mean-field model** (Scale 1-100 μm)
   - Microstructure: a set of representative grains.
   - Defect densities \( p, C_p, C_v \)
   - # of represented grains \( N \)

   Each grain interacts with the average microstructure medium.

   - **Nucleation**
   - **Grain growth**

   Grain growth is based on the velocity of the grain boundaries:
   \[ v = \frac{\pi(T) \Delta E_{\text{average/defect density}}}{\text{GB mobility}} \]


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

   **Grain growth** 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.