Towards viable nuclear fusion reactors

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The combined effects of heat and neutrons on the microstructure of tungsten

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

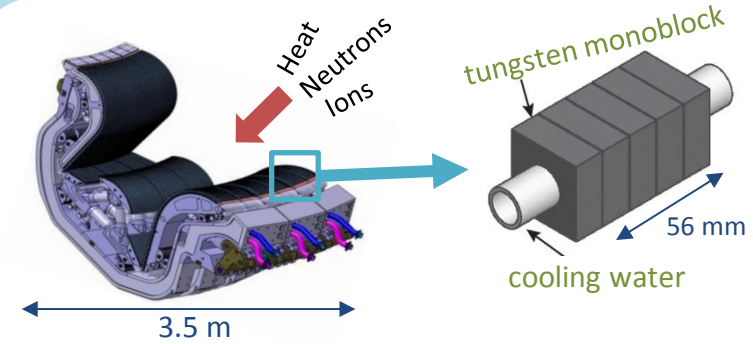


Figure 1: The top of the divertor (www.iter.org, left) consists of many tungsten monoblocks (right).

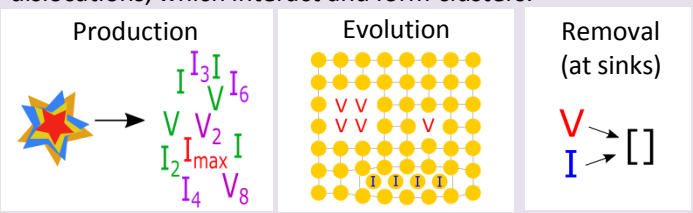
- Help to realize nuclear fusion
- Increase lifetime divertor
- Increase lifetime divertor monoblocks
- Study mechanical evolution of the monoblock under the extreme loads
- Study the microstructural evolution

Research goal

Study the combined effects of **heat** and **neutrons** on the microstructural evolution of tungsten

Method 1 Grain level: neutron damage

Neutrons constantly produce displacement damage, in the form of vacancies (V), self-interstitial atoms (I) and dislocations, which interact and form clusters.

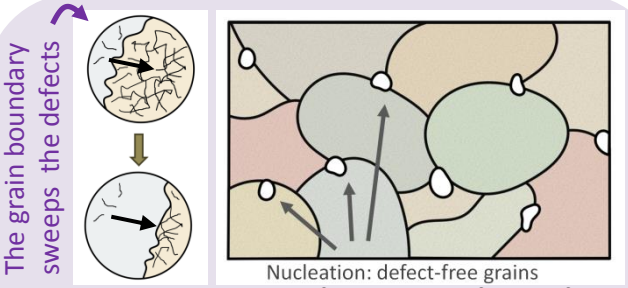


Using **cluster dynamics**, the concentrations as a result of the coupled evolution of the defects is computed.

Scale : Å – μm

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

2 Polycrystal level: damage recovery



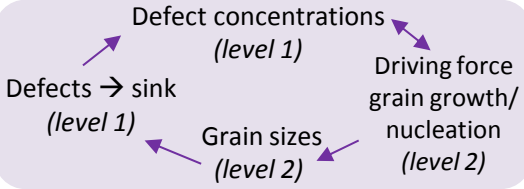
The neutron-induced defects are a form of stored energy in the material. This stored energy forms a driving force for grain growth and recrystallization.

A computationally efficient **mean-field model** is used. This model only requires two properties for the grains: their radius and their defect energy.

Scale : $1 - 100\ \mu m$

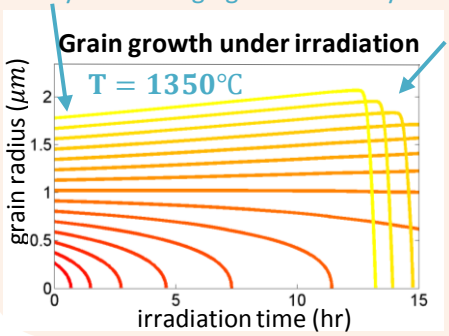
Based on Bernard (2011), Lopez (2015)

Coupling level 1&2



Results

The smallest grains vanish because they have a large grain boundary



The larger grains vanish because a higher defect density has built up in them

Competing mechanisms

- Grain boundary mobility
- Defect production
- Defect recovery
- Probability for formation of a new nucleus

Conclusion

- A multi-physics multi-scale model for the microstructural evolution of tungsten under heat and neutron irradiation was developed.
- The model can be used to make recommendations for extending the lifetime of the divertor by determining the optimal temperature window.