Spatially dependent kinetics of helium in tungsten under fusion conditions

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1. Introduction

In tokamak based nuclear reactors (ITER, DEMO), the divertor component made out of Tungsten (W) (Figure 1 - left) performs the vital function of extracting heat and helium ash from the burning plasma. Further, predicting the lifetime of the divertor component requires an in-depth understanding of the irradiation damage mechanisms, where the fast neutrons along with high concentration of helium and high temperatures will induce microstructural changes (Figure 1 - right), thereby influencing the material properties. The goal is to predict the long-term behaviour of helium in relation to the irradiation damage and the recrystallisation process in tungsten.

![Figure 1: Schematic of Tokamak inner view (JET) and water cooled tungsten monoblock along with the neutron and helium assisted irradiation damage mechanisms.](image)

2. Methodology: Kinetic rate theory

Evolution and interaction of irradiation induced defects/clusters:

- Coupled set of ODE - PDE: Diffusion - Reaction system.
- One dimensional diffusion of mobile defect/clusters along the monoblock depth.
- Boundary conditions: Desorption and zero flux.

Parameterization:

- Source term: BCA and MD simulations.
- Binding energy between defects: DFT and MD simulations.
- Migration energy of defects: MD simulations.

![Figure 2: Kinetic rate theory master equation: Evolution and interaction of defects under irradiation conditions.](image)

3. Results

a) Influence of He\textsubscript{\text{n}} clusters mobility on defect evolution: t\textsubscript{irradiation} = 10 hrs

- Clustering of helium with vacancies: Nucleation of small bubbles (sub-surface).
- Overall defect evolution: highly sensitive to mobility of clusters.

![Graph showing He\textsubscript{\text{n}} clusters mobility on defect evolution.](image)

b) Influence of defect conc. on lattice stored energy: t\textsubscript{irradiation} = 10 hrs

- Lattice stored energy: Formation energies of defects.
- Influence of He defect mobility.

![Graph showing influence of defect conc. on lattice stored energy.](image)

4. Conclusion and Outlook

- Based on the results for an irradiation time of 10 hours, it is observed that pronounced clustering of helium with vacancies results in the formation of small helium bubbles in the sub-surface region. Additionally, accounting for the mobility of helium based clusters, has a huge influence on the overall defect evolution and the associated lattice energy.
- For future work, larger cluster sizes in the current model will be incorporated by using an appropriate averaging scheme and the influence of helium on the kinetics of recrystallization process will be investigated.

5. References