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FTP/4-2: Integrated Computational study of Material Lifetime in a Fusion Reactor Environment

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The high-energy, high-intensity neutron fluxes produced by the fusion plasma will have a significant life-limiting impact on reactor components in both experimental and commercial fusion devices. Not only do the neutrons bombarding the materials induce atomic displacement cascades, leading to the accumulation of structural defects, but they also initiate nuclear reactions, which cause transmutation of the elemental atoms. Understanding the implications associated with the resulting compositional changes is one of the key outstanding issues related to fusion energy research. Several complimentary computational techniques have been used to investigate the problem. Firstly, neutron-transport simulations, performed on a reference design for the demonstration fusion power plant (DEMO), quantify the variation in neutron irradiation conditions as a function of geometry. The resulting neutron fluxes and spectra are then used as input into inventory calculations, which allow for the compositional changes of a material to be tracked in time. These calculations reveal that the production of helium (He) gas atoms, whose presence in a material is of particular concern because it can accumulate and cause swelling and embrittlement, will vary significantly, even within the same component of a reactor.
Lastly, a density-functional-based model for He-induced grain-boundary embrittlement has been developed to predict the life-limiting consequences associated with relatively low concentrations of He in materials situated at various locations in the DEMO structure. The results suggest that some important fusion materials may be significantly more susceptible to this type of failure than others. This work was funded by the RCUK Energy Programme under grant EP/I501045 and the European Communities under the contract of Association between EURATOM and CCFE. The views and opinions expressed herein do not necessarily reflect those of the European Commission. This work was carried out within the framework of the European Fusion Development Agreement.

Country or International Organization of Primary Author

UK

Author: Mr GILBERT, Mark (UK)

Presenter: Mr GILBERT, Mark (UK)

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