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Overview of plasma surface interactions in tungsten with helium plasma exposure

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The performance of plasma facing components (PFC) is one of the main issues facing ITER and future magnetic fusion reactors. Tungsten will be used in ITER as the PFC material and is considered to be one of the primary candidates for future reactors. However, recent experiments that exposed tungsten to He plasma exposure or He ion irradiation with ion energy less than about 100 eV (well below the threshold energy for physical sputtering or Frenkel pair production in tungsten) reveal significant surface modification, including the growth of nanometer-sized “fuzz”, and formation of a layer of nano-bubbles in the near-surface region [1,2]. It is widely accepted that He atoms in tungsten, like in other metals, are insoluble and tend to form small clusters, which serve as the nucleating event for the formation of larger gas bubbles. It is also clear from atomistic simulations [3,4] that the processes of trap mutation produce W interstitial atoms that lead to surface morphology modification as the interstitials diffuse to and annihilate at the surface, in addition to plastic flow and dislocation loop punching processes driven by high compressive stresses caused by over-pressurized clusters, or nanometer-sized bubbles, and these processes can alter both the tungsten surface morphology and the He clustering dynamics.

One of the challenges with describing these effects for the large-extrapolations in performance required for the PFCs in next-step devices beyond ITER is the large span of spatial and temporal scales of the governing phenomena and, therefore, the theoretical and computational tools that can be used. Fortunately, recent innovations in computational modeling techniques, increasingly powerful high performance and massively parallel computing platforms, and improved analytical experimental characterization tools provide the means to develop self-consistent, experimentally validated models of plasma materials interactions that govern the performance and degradation of the divertor and PFCs in the fusion energy environment. This presentation will describe the challenges associated with modeling the performance of divertor PFCs in a next-step fusion materials environment, the opportunities to utilize high performance computing and present examples of recent progress to investigate the dramatic surface evolution of tungsten exposed to low-energy He and H plasmas, as well as the coupled He-defect evolutions in bulk structural materials exposed to high-energy He and neutron irradiation before laying out a vision for developing a computational materials modeling framework for fusion materials behavior.

- [1] S. Takamura, et al., Plasma Fusion Res. 051 (2006) 1
- [2] M. J. Baldwin and R. P. Doerner, Nucl. Fusion 035001 (2008) 48
- [3] F. Sefta, et al., Nucl. Fusion 073015 (2013) 53
- [4] A. Lasa, et al., NIMB 156-161 (2013) 303

Eligible for student paper award?

No

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