Contribution ID: **48** Type: **contributed**

On the damage threshold in an interstitial hydrogen-occupied tungsten lattice

Wednesday, 17 July 2024 11:25 (20 minutes)

Hydrogen isotope (HI) retention in plasma-facing materials, especially of the radioactive tritium, presents severe concerns for the operation cost and safety of future fusion devices. For tungsten (W) with intrinsically low HI solubility, HI retention is dominated by trapping at irradiation-induced defects. To create irradiation defects (i.e., stable Frenkel pairs) in W, a minimum energy transfer of ˜40 eV from the incident particle to the lattice atom is required; equivalent to incident HI ion energies of ˜1840 eV for hydrogen (H), ˜920 eV for deuterium (D) or ˜600eV for tritium (T) [1, 2]. However, low-energy HI (415/215 eV for H/D) plasma exposure of W surfaces resulted in the formation of a few nm thin HI-supersaturated surface layer (HI-SSL), which retained an unusually large amount (˜10 at.%) of HI [3-5], attributed to trapping at lattice damage during plasma exposure. Although a complete understanding of the sub-displacement-threshold defect production and the resulting SSL formation are still missing, the experimental observations posed an important question to the fusion community, namely: is it meaningful to extrapolate the displacement threshold determined via electron beam damaging [1] to the irradiation conditions in fusion reactors?
In the present work, we revisit the fundamental displacement process and focus on the threshold energy to produce lattice defects in W upon low-energy HI plasma exposure. When interstitial HI and defect sinks co-exist near the primary ion-W collision site, the threshold for lattice damage creation was demonstrated to be even lower than the theoretical formation energy of self-interstitial atoms (SIAs) in W (9.6 eV [2]). HI atom-ion synergy in the presence of a nearby defect sink is proposed to account for the lattice damage observed at the extremely low HI ion energy with respect to the conventionally considered values measured with MeV electron beam [1, 2]. Such a concerted defect production process under HI plasma exposure is expected to occur in PFMs of future fusion devices: under high-energy neutron irradiation, interstitial H/He atoms via diffusion- or transmutation-induced gas production will be present in the PFM lattice nearby defect sinks such as cracks, interfaces, GBs and phase boundaries. Under such conditions, the resulting saturation level of fuel retention may be enhanced significantly, and therefore, should be monitored carefully. Some possible solutions to suppress the described synergistic defect production in future fusion applications.

[1] F. Maury *et al.*, *Radiation Effects* **38**, 53-65 (1978).
[2] K. Nordlund *et al.*, *J Nucl Mater* **512** 450-479 (2018).
[3] L. Gao *et al.*, *Nucl. Fusion* **57** 016026 (2017).
[4] L. Gao *et al.*, *Acta Mater.* **201** 55 (2020).
[5] L. Gao *et al.*, *Acta Mater.* **256** 119137 (2023)

Primary author: GAO, Liang

Co-authors: UNTERBERG, Bernhard (FZJ, Germany); Prof. LINSMEIER, Christian (FZJ, Germany); COENEN, Jan Willem (FZJ, Germany); Prof. WILDE, Markus (IIS, Tokyo Uni., Japan); Dr KEMBLETON, Richard (Gauss Fusion GmbH); Prof. BREZINSEK, Sebastijan (FZJ, Germany); Dr SCHWARZ-SELINGER, Thomas (IPP Garching, Germany); YI, Xiaoou (USTB, China)

Presenter: GAO, Liang

Session Classification: PSI and PMI experiments