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Hydrogen Supersaturated Surface Layer via Plasma Exposure with Sub-displacement Damage Ion Energy

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Fuel retention in tungsten (W) as a plasma-facing material, especially of the radioactive hydrogen isotope (HI) tritium, presents severe concerns for operation cost and safety of future fusion devices. In tungsten with very low intrinsic H solubility, HI retention is dominated by trapping at irradiation-induced defects. After deuterium (D) plasma exposure with kinetic ion energies significantly below the thresholds [1] for production of stable Frenkel pairs, a D-supersaturated surface layer (D-SSL) containing ~10 at.% of retained D was observed [2] in W surfaces. As a follow-up work, a physical model for the SSL production by HI plasmas at sub-threshold ion energy based on hydrogen atom-ion synergy effects [3] was recently proposed and experimentally verified via reproduction of an H-SSL on W surfaces. However, the fundamental defect production and in turn SSL formation mechanism at sub-threshold displacement energies remains unresolved.
In the present work, we firstly offer an overview of experimental results on HI-SSL formation with emphasis on the latest transmission electron microscopy (TEM) characterization of defect microstructures in the HSSL fluence series samples. We will then present our understanding from experimental point of view on some of the SSL-involved concepts towards a thorough understanding. The present work is expected to clarify some misunderstanding that already appeared recently in literature and to initiate an in-depth discussion on the underlying mechanism of SSL formation. These will provide us fundamental understanding of hydrogen effects in materials and also HI retention in W materials upon injection of energetic projectiles (ions, charge-exchange neutrals, neutrons) in future fusion devices.
References:
[1] F. Maury et al., Radiation Effects 38, 53-65 (1978).
[2] L. Gao et al., Nucl. Fusion 57 016026 (2017).
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