O-18

Response of fibre-reinforced tungsten composites exposed to ELM-like transient events

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Fibre-reinforced tungsten (Wf/W) composites exploit the extrinsic toughening mechanism of drawn fibres embedded in a W matrix. The fibres have superior tensile strength and can deflect cracks formed in the weaker W matrix alongside ductile deformation. Wf/W retains Wf/W ˜95% of the thermal diffusivity of polycrystalline W, similar sputtering resistance, and more favourable mechanical properties [1]. Previous thermal shock studies performance conducted at room temperature indicated similar thresholds to uniform polycrystalline W, in which catastrophic melting occurred when exposed to a single 1.6 GWm-2 transient heat load over 2 ms [2]. This work expands current research by introducing full ELM-like fusion events simulated via. steady-state heating, applied transient heat loading, and dual ion beam irradiations (He+ and D+). Experiments were conducted at the Center for Materials Under eXtreme Environments (CMUXE) using the Ultra-High Flux Irradiation (UHFI-II) vacuum chamber. The UHFI-II is equipped with two broad beam end hall type ion sources which for these studies operated at 100 eV, just below the sputtering threshold for He+ bombardment on W. Steady state heat loading was varied from simulated reactor startup conditions of RT to steady state temperatures of 450 ºC and 850 ºC. Simulated transients were applied to samples using a pulsed millisecond Nd:YAG laser orthogonal to the sample surface. Experiments were performed for one-hour testing with transient heat loadings in the 1-30 Hz frequency range, 0.2-2 ms pulse duration, resulting in a heat flux factors (HFF) ranging 10-50 MJm-2s-1/2 primarily at 850 ºC. Reactor-relevant ion loading (10:90|He+:D+) yielded increased surface bubbles at 450 ºC compared to He only loading which led to enhanced erosion during transient heating studies. Cracking was observed on all Wf/W samples exposed to HFFs greater than 20 MJm-2s-1/2 while analysis of lower HFFs is underway. The W fibres were effective in deflecting cracks, with minor fibre cracking observed at higher HFFs. At HFF greater than 40 MJm-2s-1/2, significant cracking, melting, and recrystallization was observed. Crack depth analysis and testing are underway on W samples fabricated similarly to the Wf/W without fibre integration. This study aims to measure the cracking threshold, effectiveness of fibre addition to crack propagation, and overall effectiveness of Wf/W composites as potential plasma facing materials.

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