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Progress regarding tungsten-copper metal matrix composites based on additive manufacturing for plasma-facing components

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The divertor, being the most heavily loaded component of a magnetic confinement fusion device, must withstand high heat flux (HHF) loads and intense neutron irradiation during fusion operation. Established designs for plasma-facing components (PFCs) in the divertor region comprise a combination of monolithic tungsten (W) armor blocks and a copper (Cu) alloy heat sink. One established design is the so-called monoblock design, which uses W armor blocks joined to a Cu alloy heat sink pipe. This design has demonstrated good damage resilience, but is not readily scalable because of the high number of individual W monoblocks needed for a reactor-scale divertor PFC. Another known approach is the so-called flat-tile design, which comprises flat W armor tiles bonded to a bulk Cu alloy heat sink. While the flat-tile design exhibits a higher heat removal capability and follows a more straightforward manufacturing route than the monoblock design, the thermal expansion mismatch between monolithic W and Cu causes high thermomechanical stresses that can lead to delamination of armor tiles from the heat sink. Against this background, the contribution presents an advanced concept for PFCs, utilizing additive manufacturing (AM) processes to create W-Cu metal matrix composites (W_{AM}-Cu MMCs). Exploiting the design freedom of AM, W_{AM}-Cu MMCs can be tailored to minimize thermally induced stresses in a PFC under HHF loading. Results regarding the fabrication and HHF testing of small-scale PFC mock-ups based on such an approach will be presented. The investigated mock-ups are based on AM W preforms that were built by means of a powder-bed fusion process and subsequently infiltrated with Cu utilizing a vacuum-assisted melt infiltration process. These mock-ups were then tested in the GLADIS HHF test facility at the Max Planck Institute for Plasma Physics (IPP) in Garching. The contribution presents results of HHF tests on four different W_{AM}-Cu MMC mock-up specimens including accompanying FEM simulations and post-exposure metallographic investigations.

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