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Tungsten and copper (alloy) based divertor target plasma-facing components –state-of-the-art and developments towards the application of tungsten-copper composites

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A substantial challenge regarding the realisation of magnetic confinement fusion (MCF) reactors is the reliable exhaust of power and particles. In this regard, plasma-facing components (PFCs) in the divertor region have to withstand high particle and heat flux loadings in combination with sustained fusion neutron irradiation. The latter inevitably leads to the deterioration of desired properties of PFC materials, like conductivity or toughness. Divertor target PFC designs have been devised for next generation MCF devices, especially ITER and DEMO-like devices. These solutions are based on joining a monolithic tungsten (W) armour to a high-conductivity heat sink based on copper (Cu) alloy, which ensures an acceptably high heat removal capability of the PFC. However, the use of monolithic W and Cu represents a technological challenge, in particular in terms of the thermal expansion mismatch that can lead to high thermomechanical stresses, which are a persistent driving force towards the failure of a PFC under cyclic high heat flux (HHF) loading. In this context, the demanding boundary conditions for next generation and reactor-scale devices outlined above ask for the development of advanced material and design solutions for divertor PFCs with improved performance and durability. One promising route regarding this further development is the use of composites, aiming at sophisticated combinations of W and Cu products that mitigate known design concerns through targeted PFC material reinforcement and macroscopic property tailoring. Against this background, the contribution will summarise the current state-of-the-art regarding solid W and Cu (alloy) based divertor target PFC designs, as adopted for ITER and foreseen to be used in DEMO-like devices. Further, advanced design options based on W-Cu composites will be discussed, especially including concepts based on the reinforcement of PFC materials with high-strength W fibres, as well as the use of tailored composite structures realised through additive manufacturing (AM). These approaches have undergone several years of development and have been evaluated by means of HHF testing on PFC mock-ups. In addition, related activities regarding the industrial upscaling of composites fabrication will be discussed.
Keywords: plasma-facing component, tungsten, copper alloy, composite, fibre-reinforcement, additive manufacturing

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