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Additive manufacturing of tungsten by means of laser powder bed fusion for plasma-facing component applications

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Tungsten (W) is currently considered the preferred plasma-facing material (PFM) for future magnetic confinement thermonuclear fusion reactors. This is mainly due to the fact that W exhibits a high threshold energy for sputtering by hydrogen isotopes as well as a low retention of tritium within the material. From an engineering point of view, however, W is a difficult metal to work with, as it is intrinsically hard and brittle which makes the processing and machining of W laborious and expensive. This is also the reason why rather simple geometries, for example flat tiles or monoblocks, are typically used for W armour parts in plasma-facing components (PFCs).

Against these limitations, additive manufacturing (AM) technologies could represent a versatile and up-to-date approach for the realisation of W parts for PFC applications. The characteristic feature of AM processes is that three-dimensional objects are created by sequential layerwise deposition of material under computer control which means that such a technology is well-suited for producing objects with complex geometry.

In this context, the present contribution will summarise results of research work conducted by the authors during recent years regarding AM of pure W by means of laser powder bed fusion (LPBF). In more detail, results will be presented regarding parametric material manufacturing investigations. These investigations include parameter variations regarding laser exposure and substrate preheating temperature as well as experiments performed on different LPBF facilities and with differing raw powder materials.

In general, the investigations showed that bulk pure W can be consolidated directly by means of LPBF with a comparably high relative mass density of approximately 98%. However, it was also found during these investigations that W consolidated by means of LPBF can exhibit defects that are frequently encountered with respect to LPBF processing, such as porosity or crack formation due to the fact that LPBF processes typically induce high thermal gradients during material consolidation. The suppression of such defects is still considered a challenging issue with regard to LPBF of high melting point refractory metals like W.

Furthermore, the contribution will present the latest results regarding AM of more complex and thin-walled W structures. In this context, two possible PFC applications will be discussed. On the one hand, the fabrication of tailored preforms for the manufacturing of tungsten-copper (W-Cu) composite material structures will be described. If such structures with optimised W-Cu material distribution are applied at the heat sink level of PFCs they can enhance the performance and integrity of such components notably. On the other hand, the fabrication of tailored anisotropic W lattice structures will be discussed. Such structures are currently of interest regarding DEMO first wall high-heat-flux limiter PFCs.

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