Additive Manufacturing of Tungsten-Copper Bi-Material Structures for Plasma-Facing Component Applications in Fusion Devices

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ABSTRACT

In future magnetic confinement fusion reactors, so-called plasma-facing components (PFCs) have to sustain high heat flux loadings and intense neutron irradiation reliably. These harsh operating conditions create the need for the development of corresponding advanced materials and component solutions. Tungsten is currently considered the preferred directly plasma-facing material in fusion devices due to its low hydrogen retention as well as its low physical sputtering yield. Apart from that, tungsten-copper (W-Cu) composite materials are currently of interest as advanced high-temperature heat sink materials for highly loaded PFCs. In this context, additive manufacturing (AM) of W can be regarded a potentially useful tool as it provides a way to realise W parts and preforms for composite structure fabrication with a high degree of design freedom. Hence, this approach opens up new possibilities to realise W-Cu composite structures, e.g. with tailored macroscopic thermophysical/-mechanical properties. However, the AM of W is challenging, due to the properties of W which is an intrinsically brittle refractory metal. Against this background, the contribution will summarise topical results regarding the AM of W by means of laser powder bed fusion of metals (PBF-LB/M). This will include results of parametric fabrication studies, including investigations of the structure and resolution limits of the fabrication of delicate lattice-type parts as well as results of melt infiltration tests with Cu as matrix material. Apart from that, results regarding the multi-material AM of W and a copper alloy (CuCr1Zr) will be presented focussing on microstructural analyses. A limit in resolution for the pure W PBF-LB/M process is a BCC lattice with a unit cell size of 0.5 mm. For this cell size closed porosity is created, so the material cannot be completely infiltrated. The multi-material process generates thoroughly interlocked structures with limited cross contamination.

INTRODUCTION

Plasma-facing components (PFCs) in magnetic confinement deuterium-tritium fusion reactors need to sustain high heat fluxes and neutron irradiation [1, 2]. As of yet, the development and qualification of PFC materials which can withstand such conditions is a challenging aspect with regard to the realisation