ALTERNATIVE ELECTRO-CHEMICALLY BASED PROCESSING ROUTES FOR JOINING OF PLASMA FACING COMPONENTS

W. Krauss, J. Lorenz, N. Holstein, J. Konys

Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen, Germany

Corresponding author: wolfgang.krauss@kit.edu

Tungsten is considered in fusion technology as functional and structural material for future application in DEMO. In contrast to the actual blanket – where tungsten is foreseen as functional FW coating – the design of a He-cooled divertor applies tungsten or tungsten-based alloys as both functional and structural material. Two essential types of joining are necessary in the field of He-cooled divertor development. The first one has to connect tungsten to the steel under structural aspects and to withstand internal He gas pressure loading of 80 MPa at about 600°C operational temperature. The main challenges are the large expansion mismatch besides metallurgical, mechanical and radiation correlated issues. In the application of high temperature brazing of W to W-alloys, excellent surface wetting, crack stopping ability and minimal risk of intermetallic brittle alloy formation are standing in the foreground.
The application of simple Cu casting for fitting together W and steel components as well as brazing of W to W-alloys by Ni-Co-Si based amorphous metals showed during high heat flux testing the limits of such not adapted joining methods. The failure scenarios were gas leakage by missing W-Cu metallurgical reaction or improper crack stopping by embrittlement of filler metals at high temperature in the field of W-W alloy joining due to formation of brittle intermetallic compounds.
The joining needs and the observed failure scenarios initiated the development of improved joining technologies inclusively the development of functional scales based on electro-chemical processing routes. The electro-chemical processing was analyzed as ideal tool due to the high flexibility in application as method for deposition of materials on complex shaped components and its easily accessible parameters guaranteeing reproducibility and controllable scale thickness. In the first development phase, which had also to provide the technology in handling Eurofer steel and tungsten in combination with electrolytes, the focus was directed on metals which can be processed from aqueous systems. Thus electro-chemical joining activity was started by deposition of Ni as functional scale on W to reach a metallurgical bonding with the subsequently deposited filler metal Cu for joining W to Eurofer in bare and Ni activated surface conditions. In the paper the pre-activation for W-alloys for Ni coating will be discussed depending on the applied shaping method (e.g. spark erosion EDM, turning) inclusively the reaction under annealing up to 1100°C. Micro structural analyses and diffusion profiles of W-Eurofer joints will be presented for joining temperature of 1100°C. Under this aqueous deposition activity also W-W joints were successfully fabricated by application of subsequently deposited Ni and Cu scales.
First basic investigations (voltammetric scanning analyses) for refractory metal deposition from organic salt systems (also known as ionic liquids) will be presented and discussed in view of advantages to design high temperature joints based on these elements which can not be handled in aqueous systems. The successfully performed deposition of tungsten, in dependence of IL to salt mixture ratio and the major deposition parameters, will be presented. This positively implemented development line opens the path towards Ni free W-steel joints and application of electro-chemically deposited scales for high temperature W-W joining.