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Progress in Developing ITER and DEMO First Wall Technologies at SWIP

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The ITER enhanced heat flux (EHF) FW panel utilizes a Be/CuCrZr/316L(N) joint structure with hypervapotron (HVT) cooling channel in the CuCrZr heat sink to withstand cyclic surface heat flux up to 4.7 MW/m2. For Chinese CFETR and DEMO, the heat load will be much lower and a simple W/RAFM steel joint with cooling channels in the steel will be used. For all of them, reliable material bonding joint is one of the essential requirements. It is found that the thermal fatigue life of the ITER EHF FW structure could be increased by more than one order if a bottom groove is added to the HVT channel. A hot iso-static pressing (HIP) joining technology has been successfully developed for bonding Be tiles onto the CuCrZr alloy heat sink with a Ti/Cu interlayer. Full-size EHF FW fingers were manufactured with a success rate of ~90%. Analyses show 6 interlayers with Cu-Ti intermetallic phases formed at the interface during the HIP process. Thinning the Cu4Ti layer could lead to a defect-free Be/Cu interface. An ITER EHF FW semi-prototype with 6 Be/CuCrZr/316L(N) fingers was successfully manufactured in 2015. Two finger pairs were subjected to thermal fatigue test at 4.7 MW/m2 for 7500 cycles and 5.9 MW/m2 for 1500 cycles under active water cooling in 2016. The finger pairs remain perfect without any damage. A post-test dimensional examination showed merely 20μm deformation in maximum. The vacuum tightness of their HVT cooling channels were kept as good as before the test. Several manufacture routes are under investigation for W/RAFM steel joints. The key is to use a low activation interlayer to accommodate the thermal stress between them. A defect-free joint was made by brazing at 1270℃ with Fe-Cr-B-Si amorphous filler material and pure V as accommodation layer. The property of the CLF-1 RAFM steel was fully recovered by a PWHT. In developing the fast CVD W coating on CLF-1 steel, a CVD TiN coating was firstly applied on the steel acting as a tritium permeation barrier. Good bonding performance is presented and neither obvious defect nor detachment is found at the working temperature of 550℃. For the HIP joining, a couple of joints have been made by HIP at 740℃ using pure Cr, V and Fe interlayer. Further tests will be done at higher HIP temperature with fast cooling of >20℃/min to enable the recovery of the microstructure and properties of the CLF-1 steel.

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