EU Development of High Heat Flux Components

J. Linke[1], P. Lorenzetto[2], P. Majerus[1], M. Merola[2], D. Pitzer[1], M. Rödig[1]

[1]*Forschungszentrum Jülich GmbH, EURATOM Association, D-52425 Jülich, Germany, j.linke@fz-juelich.de*
[2]*EFDA Close Support Unit Garching, Germany*

The development of plasma facing components for next step fusion devices in Europe is strongly focused to ITER. From a heat flux point of view, the divertor represents the most critical plasma facing component which has to withstand 3000 cycles at a power density level up to about 3 MWm^{-2} for the upper part of the vertical target which will be manufactured from flat W-tiles or W-monoblocks attached to a CuCrZr-heat sink. The lower straight part of the divertor will be subjected to even higher thermal loads (up to 20 MWm^{-2} for about 10% of plasma discharges during the so-called 'slow transients'). The reference design for this component is based on the monoblock principle with 3-directional CFC tiles attached to a straight coolant tube made from a precipitation hardened copper alloy with twisted tape inserts.

For the primary first wall panels of the shielding blanket modules, the EU has developed a design based on a key system mechanically attached to the front of the shield. Here the plasma facing panels consist of beryllium tiles which are joined by brazing or by Hot Isostatic Pressing to a water cooled bi-metallic structure made from a CuCrZr or CuAl25 alloy heat sink layer and a 316L(N) stainless steel back plate. These components shall be designed for a peak heat flux of 0.5 MWm^{-2} for up to 30,000 cycles.

Electron beam simulation experiments have been used to investigate the performance of high heat flux components under ITER specific thermal loads. These tests have been performed on a wide spectrum of different design options, including the above mentioned reference solutions for ITER with tungsten, CFC, and beryllium armor. Beside thermal fatigue tests which are primarily focused to the integrity of the joint between the plasma facing armor and the heat sink, also transient events which occur during off-normal plasma operation with deposited energy densities up to several tens MJm^{-2} have been investigated experimentally. These events are expected to occur on a time scale of a few milliseconds (plasma disruptions) or several hundred milliseconds (vertical displacement events) and have been identified as a major source for the production of neutron activated metallic or tritium enriched carbon dust which are of serious importance from a safety point of view.

The irradiation induced material degradation is another critical concern for future D-T-burning fusion devices. In ITER the integrated neutron fluence to the first wall and the divertor will remain in the order of 1 dpa and 0.2 dpa, respectively. This value is low compared to future commercial fusion reactors; nevertheless, a non-negligible degradation of the materials has been detected, both for mechanical and thermal properties, in particular for the thermal conductivity of carbon based materials. Beside the degradation of individual material properties, the high heat flux performance of actively cooled plasma facing components has been investigated under ITER specific thermal and neutron loads.