Plasma Facing Materials and Components for DEMO

R. Neu[1,2], M. Balden[1], B. Curzadd[1,2], S. Elgeti[1], H. Gietl[1,2], H. Greuner[1], T. Höschen[1], M. Li[1], H. Maier[1], A.v. Müller[1,2], J. Riesch[1], K. Schlüter[1,2], J.H. You[1], J. Coenen[3], C.Garcia-Rosales[4,5], E. Visca[6], ASDEX Upgrade Team[1]
[1]Max-Planck-Institute for Plasma Physics, Garching, Germany
[2]Technical University Munich, Garching, Germany
[3] Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Plasma Physics, Partner of the Trilateral Euregio Cluster (TEC), Jülich Germany
[4]Ceit-IK4 Technology Center, San Sebastian, Spain
[5]Tecnun, University of Navarra, San Sebastian, Spain
[6]Department of Fusion and Technology for Nuclear Safety and Security – ENEA, Italy

Plasma material interaction plays a key role in the realization of a future fusion reactor like DEMO. In the divertor, which will be the area of the highest power loads, up to 20 MW/m² are expected and the fusion neutrons will create up to about 5 dpa/fpy. The performance of the plasma as well as the behavior and the lifetime of plasma-facing components are intimately linked requiring a holistic approach for solving the issues of power and particle exhaust. Currently, tungsten (W) is foreseen as plasma facing material in future fusion reactors, because of its high melting point and thermal conductivity and its low erosion and hydrogen retention. However, W is intrinsically brittle at temperatures below 200-800 °C (strongly depending on machining and processing) and its thermomechanical properties degrade further under plasma and neutron irradiation.

Within the EUROfusion consortium IPP is working on the development of advanced W-based materials and components to mitigate the effect of embrittlement, to enhance the resistance against cracking and oxidation. For the latter, which could lead to an undesirable generation of volatile W oxides during accidental air ingress, W alloyed with Cr and small Y additions were produced by mechanical alloying and hot isostatic pressing. With these allows the oxidation rate at 1000 °C could be reduced by 3 orders of magnitude. Commercially available W heavy alloys with the admixture of a few weight percent Fe and Ni, which might be used in areas where temperatures below 1300 °C are expected, show a strongly increased ductility already at room temperature. Exposed in the divertor of ASDEX Upgrade these alloys are much less prone to cracking than pure W and do not disintegrate even under thermal overload. Tungsten fibres as reinforcement can substantially increase the damage tolerance of W below the ductile to brittle transition temperature (DBTT) and the mechanical tensile strength at high temperature of Cu. Combined in actively cooled components W fibres also reduce the mismatch of thermal expansion between armour (W) and heat sink (Cu). The improved capabilities of such components were successfully demonstrated under cyclic power loads up to 20 MW/m² in IPP's hydrogen beam high heat flux test facility GLADIS. As a further advancement additively manufactured W-Cu components are under development with the aim of minimizing stresses during thermal cycling.