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Plasma Wall Interaction Research at IPP for ITER and beyond

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Plasma Wall Interaction plays a key role in the realization of a future fusion reactor. 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 heavily loaded areas of ITER and future fusion reactors, because of its high melting point and thermal conductivity and its low erosion and hydrogen retention [1]. However, the hydrogen retention increases under neutron irradiation and eventually changes due to (seeded) plasma impurities. At IPP numerous laboratory investigations were performed to elucidate the role of traps and their origin (see for example [2,3]) and the influence of trace nitrogen and helium [4,5] for hydrogen retention.

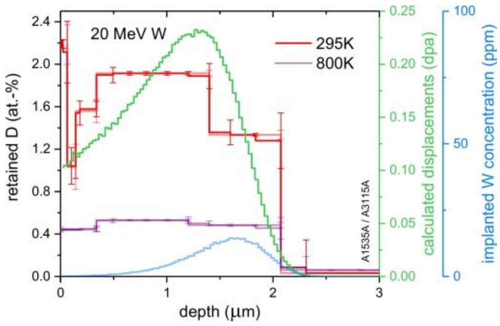

Figure 1: Deuterium depth profile for 20 MeV self-damaged tungsten samples (8×10^{17} W^{6+}/m^2 at 295 K (red) and 800 K (purple)) subsequently exposed to 1.45×10^{25} deuterons/m^2 with <5 eV/D at 295 K. The damage dose (green) and the implanted tungsten concentration (blue) are shown on the right axis [3].

W is intrinsically brittle and its thermomechanical properties can degrade under plasma and neutron irradiation. IPP is working on the development of advanced W-based materials and components to mitigate the effect of embrittlement and to enhance the resistance against cracking. Tungsten fibres as reinforcement can substantially increase the fracture toughness of W and the high temperature strength of Cu. Combined in actively cooled components W fibres also reduce the mismatch of thermal expansion between armour (W) and heat sink (Cu) [6,7].

Figure 2: Cross-section of W_f/W composite after a Charpy impact test: The tungsten fibres show ductile deformation and pull-out leading to increased toughness of the composite [7].

The improved capabilities of such components were successfully demonstrated under cyclic power loads up to 20 MW/m² in IPP's high heat flux facility GLADIS. In ASDEX Upgrade (AUG) which is fully equipped with W plasma-facing components many of the laboratory results were verified under fusion-relevant conditions. Specifically with its sophisticated divertor manipulator complete components can be exposed to high particle and heat loads in a controlled manner. Recently, the effect of repetitive melting of tungsten by power transients originating from edge localized modes has been studied [8]. Encouraged by the results achieved in full-tungsten AUG and in JET with its ITER-like wall [9], investigations were launched at W7-X in order to explore its transition to all-W plasma-facing components.

References

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