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Material Properties and Their Influence on the Behavior of Tungsten as Plasma Facing Material

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Plasma facing materials (PFMs) for future fusion devices like ITER have to withstand severe environmental conditions such as steady state and transient thermal loads as well as high particle (H, He, n) fluxes. The design and the performance of plasma facing components (PFCs) such as the divertor targets strongly depend on the selection of suitable PFMs, e.g. refractory metals, which meet certain predetermined specifications. For the ITER PFMs material specifications have been set up in the past, which may need further refinement in order to select optimum candidates from a variety of commercially available products. This should help to mitigate material degradation during operation such as macro-crack formation in monoblock type PFCs, i.e. so called self-castellation, which extend from the plasma facing surface down to the W/Cu-interface.

For a possible improvement of the material specification, five different tungsten products manufactured by different companies and by different densification technologies, e.g. forging and rolling, are subject to a detailed microstructural and mechanical materials characterization program. Additional material characterization for two of these tungsten products was performed to investigate the thermo-mechanical performance under intense transient thermal loads, which represent typical ELM or disruption like conditions. The thermal shock tests were performed by electron beam exposure in JUDITH 1 and 2 with different energy densities, base temperatures and pulse numbers in order to determine damage and cracking thresholds.

The obtained mechanical properties in combination with the thermal shock tests show that the thermal shock damage response strongly depends on the microstructure and hence the related mechanical properties of the tungsten product. High mechanical strength leads to less damage formation in terms of crack formation and plastic deformation. In contrast, recrystallized materials, providing the lowest mechanical strength, show severe surface damages such as thermal shock crack networks and surface roughening due to the reduced strength and cohesion between single grains. Accordingly, the materials were, amongst others, identified with respect to their recrystallization resistance and the related feature of a deferred material degradation, e.g. under slow transients up to 20MW/m^2 during normal ITER operation.

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