Micro-structuring of tungsten surface for mitigation of ELM induced thermal fatigue


Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich, Germany

a.terra@fz-juelich.de

The micro-structured tungsten is a new concept trying to address one of the main issues of tungsten as high heat flux (HHF) plasma facing material (PFM), which is its brittleness and its propensity to crack formation under pulsed, ELM like, heat loads [1, 2]. With power densities between 100 MW/m² and 1 GW/m², cumulative thermal fatigue adds up for each pulse and show damage like roughening, subsequent cracking and even melting may occur, all influenced by the base temperature. This represents a serious issue for the use of tungsten as HHF-PFM, as in future tokamaks, such as ITER, about 10⁸ ELMs are expected to occur during the operation lifetime. This is a clear limitation to exploitation and brings concerns in term of maintenance and costs.

In the past, several approaches have tried to overcome this brittleness issue, e.g. alloying tungsten with others elements [3] or introducing pseudo-ductility by the additions of fibers thus creating composites [4], or even by specific grain size and shape. However all these approaches show concerns in term of durability because they may lose their effectiveness with time, neutron irradiation or high temperature (recrystallization), a concern that does not apply to micro-structure tungsten.

The current investigation of both, reference and micro-structured tungsten, was performed in the PSI-2 facility [5] with a combined steady state deuterium plasma (5.1×10²⁵ D+ m⁻², 51 eV, 180°C, 150 min) loading with sequential laser pulses (up to 7.10⁴ pulses of 0.68 GW/m², 3 mm spot diameter, 23 J, 1 ms pulse duration, up to 25 Hz pulse frequency). Recrystallized fibers were used for micro-structured tungsten sample, in order to isolate the intrinsic material properties contribution to the performance already demonstrated. Contrary to the reference tungsten sample, the micro-structured sample, despite recrystallized material, did not reveal any damage.

To confirm these results, micro-structured and reference tungsten samples have been loaded with up to 10⁶ pulses of 0.55 GW/m² and 0.5 ms pulse length in the high power electron beam facility JUDITH 2 and characterized by metallographic means. The results of both experiments will be discussed and compared.