High-heat flux tests of tungsten divertor mock-ups with steady state plasma and e-beam

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Tests of tungsten targets, limiters, and devertor plates in modern tokamaks have shown the significant change in the surface structure under the powerful plasma loads [1]. For the ITER, fusion neutron source FNS and DEMO, full-scale tests of the divertor materials are required. For such purposes, water-cooled mock-ups of the ITER divertor plate are tested with the combination of steady state plasma and e-beam loads: (1) thermocyclic tests with powerful electron beam load of up to 40 MW/m^2 and more in the e-beam facility, water cooling is provided in these tests; and then (2) subsequent testing in the PLM plasma device [2] with steady state plasma loads of 0.5—1 MW/m^2 and more. Such tests are carried out for the first time and simulate the variable load on divertor plates in the ITER during steady state discharges with transient ELM events. Tungsten samples are irradiated with helium plasma in experiments on the PLM plasma device with discharge duration of up to 200 min.
The tests of ITER-grade tungstenVM-P with the combination of steady state plasma and thermocyclic e-beam loads led to erosion, cracking, and nanostructured "fuzz" structure growth on the material surface. Post-mortem scanning electron microscopy and X-ray analysis revealed a stochastic nanostructured surface with dimension of structural elements less than 100 nm. The growth of a nanostructured surface with a "fuzz"-type structure and high porosity is observed. The results of such tests are of interest to estimate the erosion of tungsten in fusion reactors, including ITER, fusion neutron source FNS and DEMO.

[1] V. P. Budaev, Physics of Atomic Nuclei 79 (2016) 1137
[2] V. P. Budaev et al., Journal of Physics: Conference Series 891 (2017) 012304