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The Impact of Nonambipolar Energy Flow on Plasma Facing Materials Erosion and Forecast for ITER.

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In reactor-size fusion devices, such as ITER and DEMO, are expected the critical loads on the divertor plates both during steady state and at transient events (disruption, VDE, ELMs, runway electrons). High heat plasma load leads to enhanced erosion and destruction of material surface accompanied by enhanced absorption of tritium in erosion products.
The paper introduce the experimental dates of nonambipolar plasma flow, due to arcs and sparks, as mechanism of power exhaust, leading to extremely high heat load. The regimes with nonambipolar energy flow on tungsten limiter tiles obtained on the T-10 tokamak for quasistationary stage [1]. In such regimes the interior part of the tungsten limiter is heated up to temperature exceeded 3000 0C and estimated load is more than 50 MW/m2. Sparking, powerful arcing, deep cracks, edge melting and melt motion on ITER-grade tungsten tiles were observed. Also, tiles surfaces were flood by recrystallized tungsten. The edges of the cracks were melted and much arc craters have been located along the cracks.
The nonambipolar mechanism of energy flow on metal surfaces and self-heating, accompanied by sparks and arcs, is discussed to explain enhanced heating of PFM. Additional energy flow from plasma to the metal surface caused by the phenomenon of explosive electron emission (EEE), during the sparks activity [2]. The sparks accompanied by a continuous renewal of microexplosions, which initiated by the plasma and jets of liquid metal from previous microexplosions. Unlike "classical"thermoionic emission, such mechanism can increase electron flux into the plasma over the order of magnitude. It can change the energy and particle balance in the periphery plasma of a fusion reactor and leads to significant heating and melting of divertor plates and, accordingly, to cracking and melt motion. The reason of such sub-μs discharges ignition can be plasma-turbulence-driven fluctuations of particle and energy flux to the plasma-modified surface.
The results of W-tiles erosion by powerful runaway electrons presented, for comparison.
The report analyzes consequences for ITER the EEE appearance on the divertor W surface - the sharpening of SOL power width distribution, parallel to the magnetic field –□q; the melting of the W leading edges of divertor targets and the recrystallization of the W surface as a result of the superheated liquid metal droplets appearance. Melt tungsten can be subject to J × B force. EEE can lead to the erosion enhancement of the divertor plates. Micro-explosions lead to droplets, which, like dust particles, can effectively deliver impurities to the central region of the plasma.
[1] L.N.Khimchenko et al, SOFE-2017, Shanghai, China, report #496.
[2] S.A.Barengolts, G.A.Mesyats, M.M.Tsventoukh 2010 Nucl. Fusion 50, 125004

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