Influence of electrical currents driven by thermionic emission on tungsten melt motion

K. Krieger[1], M. Balden[1], R. Dejarnac[2], R. Dux[1], M. Faitsch[1], P. De Marne[1], R.A. Pitts[3], V. Rohde[1], B. Sieglin[1], D. Silvagni[1], P. Tolias[4], ASDEX-Upgrade Team[†], EUROfusion MST1 Team[*]

[1]Max-Planck-Institut für Plasmaphysik, 85748 Garching b. München, Germany
[2]Institute of Plasma Physics AS CR, Za Slovankou 1782/3, 182 00 Praha 8, Czech Republic
[3]ITER Organization, Route de Vinon, CS 90 046, 13067 Saint Paul Lez Durance, France
[4] Fusion Plasma Physics, EES, KTH, SE-10044 Stockholm, Sweden
[†]See the author list of "H. Meyer et al. 2019 Nucl. Fusion ***59*** *112014"*
[*]See the author list of "B. Labit et al. 2019 Nucl. Fusion ***59*** *086020"*

krieger@ipp.mpg.de

Experimental studies of tungsten (W) melt dynamics during repeated ELM transients on both ASDEX Upgrade and JET, together with MEMOS-U melt code analysis, have shown conclusively that melt motion is mainly driven by the Lorentz force due to the magnetic field acting on an electric current passing through the melt layer arising to compensate the thermionic electron emission from the hot plasma-facing surface. On ASDEX Upgrade, these experimental investigations are conducted using dedicated samples installed in special tiles mounted on the divertor manipulator. This allows exposure to specific discharges and rapid retrieval of samples for post-mortem analysis, avoiding further modification due to subsequent plasma operation. Moreover, the probe head instrumentation provides measurement both of the electrical current drawn and the sample surface and rear-side temperatures. In the first of a series of W transient melting experiments [1], these diagnostics were used to quantify the relation between surface temperature and current, providing key input for validation of the thermionic emission and replacement current flow model in MEMOS-U.

To further investigate the contribution of thermionic emission as a driver of melt motion, a new experiment has been performed in which transient melting is compared on two samples of identical geometry (with sharp, protruding edges) and at identical exposure positions, but with one sample electrically floating and the other connected to vessel potential. Thermionic emission cannot drive a current on the floating sample, but will instead modify the local sheath potential at the plasma-facing surface. With the replacement current suppressed, melt motion at the floating sample was expected to be significantly slower than at the grounded sample.

Type I ELMing H-mode plasmas with ELM energy density sufficient to create temperature excursions of several hundred Kelvin at the sample leading edges were used for the exposures. Within a few seconds, the base temperature reached a point at which each subsequent ELM produced transient melting of a few ms time duration. As expected, significant differences were found in the post-exposure morphology of the two samples. Melt motion appears to be weaker at the floating sample surface, supporting the assertion of net replacement current as the main driving mechanism. However, the substantially higher power flux to the floating sample, attributed to an increased local sheath heat transmission factor, complicates the picture, preventing straightforward deductions. Simulations are underway with MEMOS-U to disentangle the two mechanisms. To avoid the effects of different sheath transmission at the floating melt sample, the experiment will be repeated by exposing two grounded leading edge samples made of niobium and iridium, which feature strongly different thermionic emission at almost identical melting temperatures.

[1] K. Krieger et al. 2018 Nucl. Fusion **58** 026024