Transient-induced tungsten melt motion studies on ASDEX Upgrade

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A series of experiments dedicated to the study of ELM transient-induced melting of tungsten have been performed on ASDEX Upgrade aimed at the provision of high quality data of key quantities for validation of the MEMOS-3D melt motion code, being used as the principal simulation tool for the prediction of melt damage and associated plasma-facing component lifetime on ITER. The experiments complement and extend similar studies on JET. Samples were installed in special tiles mounted on the divertor manipulator, allowing exposure to specific discharges without further modification due to subsequent plasma operation and rapid retrieval of samples for post-mortem analysis. Most critically, the probe head instrumentation provides measurement of current drawn and the opportunity to electrically insulate samples so that the melt motion with and without net current flow can be studied.

In the experiments, two principal sample geometries, a sharp protruding edge and an inclined surface, have been exposed to Type I ELMing H-mode plasmas with ELM energy density comparable to those obtained during the JET melt experiments with identical sample geometries. In conjunction with the MEMOS-3D modelling [E. Thoren, PSI 2018 submitted], net currents drawn by the samples quantitatively validate the picture of strong surface thermionic emission being the main driver for current flow through the samples and the resulting $\boldsymbol{j}\times\boldsymbol{B}$ force on the melt layer. In particular, the considerably lower current density through the molten surface area of the sloped sample in comparison to the leading edge case, and the resulting strongly reduced melt displacement in the poloidal direction are powerful evidence for the assertion that the lower probability for electron escape from the surface is the main driver for the decreased current density. This is an extremely important result supporting the assumptions being made in the melt modelling of shaped ITER divertor monoblocks. The highly complex topology of the final surface melt damage found on the inclined sample is a challenge for the modelling to reproduce and a good indicator of what ITER should expect to see in the case of full surface flash melting.

In new experiments focused on the sloped sample, the current measurements have been complemented by surface temperatures obtained with an IR system directly viewing the exposed sample top surface, providing unique, ELM-resolved observation of melt motion, the poloidal velocity of which can be extracted and is found to be in the range expected for a $\boldsymbol{j}\times\boldsymbol{B}$ driving force at the levels of net current detected during the exposure. The system is prepared and awaiting machine time for exposure of new, electrically floating leading edge samples, in which the flow of replacement current compensating the loss due to thermionic emission will be prevented. The resulting melt patterns are expected to be very different to the electrically connected case and should provide the definitive test of the mechanism driving melt motion.