Influence of thermoelectric effects in near-surface equilibrium non-ideal tungsten plasma on melt rotation during pulse electron beam heating

Popov V.A.[1,@], **Kasatov A.A.**[1] **and Skovorodin D.I.**[1]

[1] Budker Institute of Nuclear Physics of the Siberian Branch of the Russian Academy of Sciences, Lavrentyev Avenue 11, Novosibirsk, 630090, Russia

[@] v.a.popov@inp.nsk.su

One of the main challenges on the path to a commercial fusion reactor is the damage to plasma-facing components under high steady-state and pulsed thermal loads. For tungsten, chosen as the ITER divertor material, melt motion under intense heating can significantly alter the surface geometry, posing a serious issue for areas with strict shape tolerances. Experiments on the BETA facility showed rotation of solidification patterns on tungsten from pulse to pulse. Subsequent theoretical work demonstrated that thermoelectric effects in an ideal tungsten plasma model are significant enough to drive currents through the target exceeding the beam current. This work presents further development of the model by accounting for plasma non-ideality in the form of ion clustering. The coupling coefficients between thermodynamic forces and fluxes are formulated. It is shown that under the assumption of sufficiently strong clustering, the electrical conductivity is higher than for an ideal unclustered plasma, which aligns with experimental observations for tungsten vapor. Assuming strong clustering, the thermoelectric current increases to values sufficient to explain the experimental data. The influence of magnetic fields is also considered, leading to a redistribution of current from the magnetized low-density plasma region into the central dense near-surface plasma. This provides the correct direction of rotation at the melt periphery, where pattern rotation was observed. Thus, a theoretical model is proposed, applicable for heating by particle beams.