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Electron dynamics in a HiPIMS Discharge

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High Power Impulse Magnetron Sputtering (HiPIMS) is a sputtering technique capable of depositing thin films with superior density and quality. A magnetron discharge operated with short pulses of extremely high power (kW*cm^{-2}) generates a very high plasma density (>10^{18}m^{-3}) which ionizes the majority of the sputtered particles and makes them susceptible to acceleration by the electric field.The electron dynamics is the crucial piece in the puzzle to understand the whole system dynamics. The electrons are released as secondaries from the cathode, get accelerated in the boundary sheath and enter the ionization zone where they are confined by electric and magnetic fields. In a sequence of successive collisions, they deposit their energy to the other plasma species, particularly to the neutrals (via excitation and ionization) and to the less energetic but much more frequent background electrons (via Coulomb interaction). Both groups of electrons also exhibit complex spatial motion which gives rise to localized plasma structures (called “spokes” or “humps”). Simulation efforts for the electron dynamics with classical approaches like Particle-in-Cell with Monte-Carlo Collisions (PIC/MCC) methods have to deal with much too long computation times, going far beyond acceptable scales. The reason lies in the occurance of densities in the order of 10^{18}m^{-3}. Even higher densities appear in the fusion research. It is thus attractive to employ the strategies of the fusion community which deals with similar problems. Gyrokinetic theory employs the fact that the electron gyration radius r_L is much smaller than the typical system scale L and the mean free path λ, and makes a systematic expansion in the parameter r_L/L. This works investigates the viability of the gyrokinetic approach for HiPIMS by examining the electron motion with help of a 3D single particle simulation. Particular focus is on the interaction of the trapped electrons with the strong field of the cathode sheath and the construction of an effective scattering matrix.This work is supported by the German Research Foundation (DFG) in the frame of the transregional collaborative research centre SFB-TR 87.

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