Moment models based on a Hilbert expansion for the kinetic equation of electrons in a weakly-ionized plasma

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We investigate the kinetic equation of electrons in a weakly-ionized plasma. We consider conditions that are characteristic of industrial atomic plasmas, such as those used for material processing for nanoelectronics (both for deposition and etching thin films) or electric propulsion. The starting point is the generalized Boltzmann equation, including the electrostatic force, electron-electron, electron-ion, and electron-gas elastic collisions, electron-gas inelastic collisions, and electron-gas reactive collisions. We perform a dimensional analysis of this equation and analyse the order of magnitude of the resulting non-dimensional numbers under the considered conditions. We propose a perturbative solution of the kinetic equation, based on a Hilbert expansion, where we exploite the mass disparity of the electrons and the heavy-species (ions and atoms) to simplify the collision operators, as previously proposed by Graille et al. [1]. We analyse the resulting integro-differential equations at successive orders of approximation. We propose a moment model where the macroscopic variables are the scalar even velocity moments whereas the vectorial odd moments are computed as transport fluxes. Different moment moment closures will be studied, including regularized-Grad's models, quadrature moment models and entropy based closures. More information can be found in Ref. [2].

Références

[1] Graille, B., Magin, T. E., & Massot, M. Kinetic theory of plasmas : Translational energy, *Mathematical Models and Methods in Applied Sciences*, 2009, 19(4), 527–599.

[2] Alvarez Laguna, A.& Pichard, T. Kinetic theory and moment models of electrons in a reactive weakly-ionized non-equilibrium plasma *Kinetic and Related Models*, 2025, 18(6) : 824-871.

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