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THERMALISATION TIME OF ELECTRON SWARMS IN NOBLE GASES FOR UNIFORM ELECTRIC FIELDS

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The time taken for an electron swarm to reach its equilibrium with an instantaneously applied electric field (E/N) is typically less than 10^{-9} s for most medium and high-pressure plasmas (p=0.01-5bar). Thus, a steady-state Boltzmann code is usually sufficient to deduce the electron energy distribution function (EEDF) and the requisite electron swarm parameters as a function of E/N for plasmas driven by relatively slow time-varying voltage waveforms ($\tau >> 10^{-9}$ s). In the last few years, however, plasmas driven by fast transient voltage pulses (e.g. risetimes >100V.ns^{-1}, 1-10ns duration) are being rapidly developed, as reviewed in the Special issue on Fast Pulse Discharges 2017. It is not yet clear whether the EEDFs in these fast transient plasmas deviate significantly from “thermalised”. To investigate this issue, we have calculated the time taken for electrons to become thermalised for a given E/N, over a range of fields applicable to most medium-high pressure plasma discharges (Boyle et al. 2019). We have numerically solved the multi-term, spatially-homogenous Boltzmann equation (BE), subject to a constant electric field, to follow the EEDF as it evolves from an initial room-temperature Maxwellian distribution toward the steady-state. Transport quantities such as the mean energy ε, the drift velocity W, and the ionisation coefficient α_i, were calculated as a function of time. The time taken for the slowest swarm parameter (α_i) to converge to an acceptable level (e.g. to within 90% of its steady-state value) has been used universally as the benchmark for evaluating the thermalisation time. In this work, we report results for thermalisation times in noble gases from helium to xenon, and discuss the presence of short-lived (transient) discrepancies that occur in the EEDF from low-term BE calculations.

References

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