A new full time-dependent collisional-radiative model of helium plasma discharges

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A new spatially averaged time-dependent collisional-radiative model for helium plasmas, coupled to the electron Boltzmann equation (EBE) has been developed. Its main novelties are: 1) Full time dependence for both the multi-species kinetics and the EBE. It is shown that this is necessary to correctly simulate discharges where the parameters vary on nanoseconds-microsecond timescales. 2) All electron processes are accounted for accurately. In particular for the various ionization and recombination processes, free electrons are added or removed at the appropriate energy. 3) The energy dependence of the electron loss by ambipolar diffusion is taken into account approximately. 4) All the processes which are known to be important in helium discharges within the pressure range $1 < p < 760$ Torr and the electron density range $10^9 < n_e < 10^{16} \text{ cm}^{-3}$ are included, and 42 energy levels up to $n = 6$, where $n$ is the main quantum number, are taken into account. Atomic and molecular ions, as well as excimers are also included. 5) The gas temperature is calculated self-consistently. The model is validated through comparisons with known numerical and experimental steady-state results. It is then applied to post-discharge decay cases with very short power decay times and to the nanosecond kinetics of streamer discharges. The time evolution of the population densities and reaction rates are analysed in detail with emphasis on the observed large increase of the metastable state density.