Swarm parameters in Cl_2/rare gas mixtures

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We present calculations, using a Boltzmann equation solver, of electron transport and rate coefficients (swarm parameters) in rare gases mixtures containing Cl_2 as a function of E/N. We use a recent update [1] of Cl_2 cross sections for electron scattering from ground state neutral chlorine molecules in the energy range from 0.01 to 100 eV.

Gas mixtures containing molecular chlorine (Cl_2) are widely used as plasma processing gases for etching of semiconductor, and Cl_2 is also an important component of gas mixtures used for rare-gas-halide lasers [2]. Models of these and other discharges in Cl_2-containing mixtures require a set of electron-Cl_2 scattering cross sections consisting of the momentum transfer cross section for elastic scattering, total (angle integrated) cross sections for the individual inelastic, ionization, and attachment collisions. A minimum criterion for validity of a cross section set is consistency between calculated and measured swarm parameters as functions of E/N, the ratio of the electric field strength to the neutral gas number density. The calculated values are obtained by suitably averaging over the electron energy distribution function (eedf), which is itself obtained by using the cross sections as input to a Boltzmann solver [3].

When comparing to rare gases and other processing gases (O_2, N_2, …), experimental swarm data in Cl_2-containing mixtures are limited. This and the fact that swarm data can be useful to characterise Cl_2-containing discharges led us to present in this communication calculations for electron drift velocity v_{dr}, characteristic energy D_T/μ (where D_T is the transverse electron diffusion coefficient and μ is electron mobility), density-reduced ionization α/N, attachment η/N, and net ionization coefficients λ/N as a function of E/N (1-1000 Td) for discharges in Cl_2/He, Cl_2/Ar and Cl_2/Kr, for the following Cl_2 percentages in the mixture: 100%, 50%, 25% and 10%. For the Cl_2 electron scattering cross sections we use a recent update set [1], and, for comparison, also the widely used set suggested by Rogoff *et al* [4].

For the working conditions we can say that for a given reduced field, α/N increases with the rare gas percentage and with the rare gas ionization potential. The electron energy distribution function of the mixture with the rare gas with higher ionization potential will be more populated at higher electron energies. Consequently the always more important Cl_2 ionization contribution to the total α/N will increase with the rare gas ionization potential, conversely, as expected, the rare gas contribution to α/N decreases.

Fig. 1 presents calculated λ/N vs E/N for several Cl_2/rare gases mixtures. For λ/N it is not possible to state a general comment as for α/N, however we can say that the field to which occurs zero net ionization decreases when increasing the rare gas percentage and the rare gas ionization potential.

Fig. 2 presents calculated v_{dr} vs E/N for several Cl_2/rare gases mixtures. The drift velocity obtained using Rogoff *et al* [4] cross sections set is always higher (therefore the plasma is less resistive) than when using [1], specially at low E/N. This is mainly caused by the significant difference in the cross sections for elastic momentum transfer and vibrational excitation. We also obtain that with [1] more energy goes into vibrational excitation. In particular from 20 to 300 Td vibrational excitation is the principal mechanism for energy losses (being substituted by ionization for higher E/N), while when using [4], between 20-600 Td, the energy losses are mainly do to dissociative excitation.

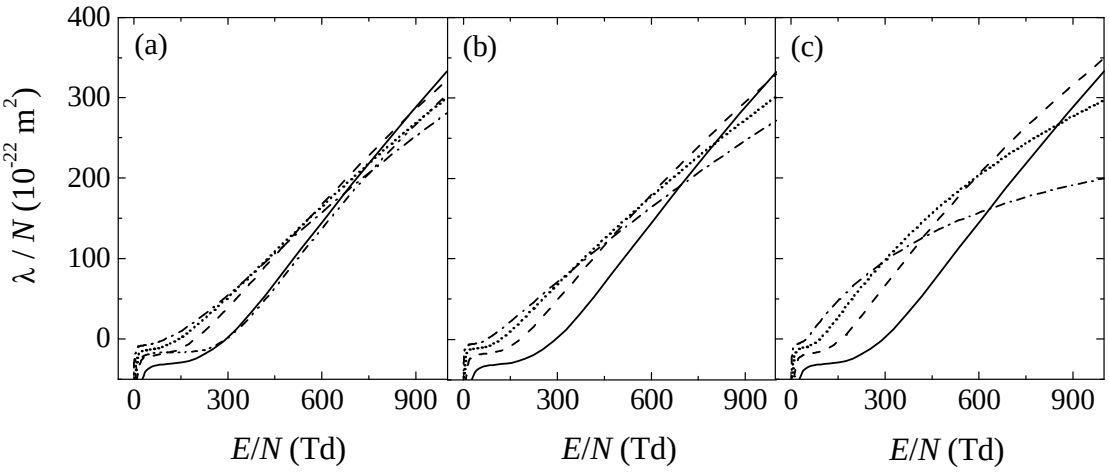

Fig. 1: Calculated λ/N as a function of *E*/*N* for mixtures of Cl_2 with Kr (a), Ar (b) and He (c) for the following Cl_2 percentages: 100% (solid line), 50% (dashed), 25% (dotted) and 10% (dashed-dotted). In (a) are presented calculations using [4] for pure Cl_2 (dashed-dotted-dotted line).

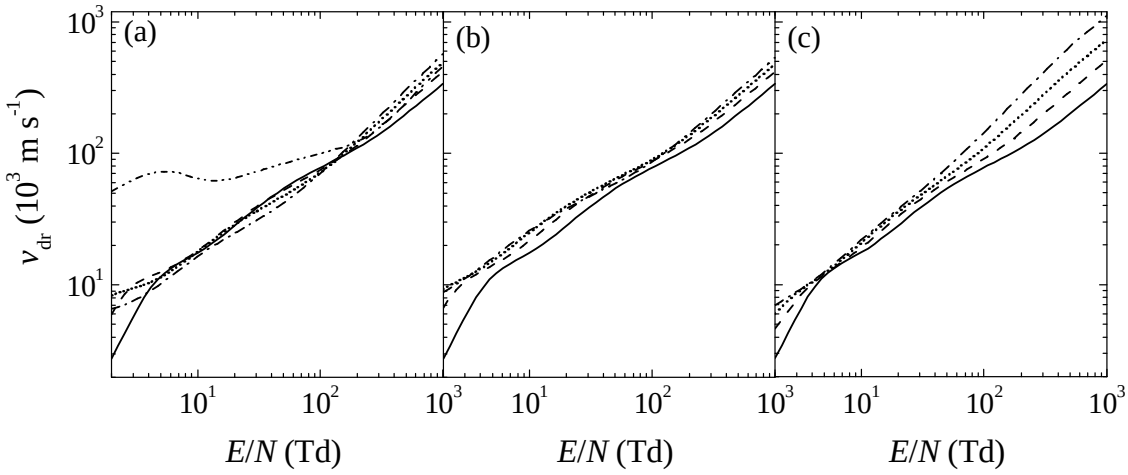

Fig. 2: Calculated v_{dr} as a function of *E*/*N* for the same conditions of Fig. 1.

Calculations of swarm parameters in other gas mixtures can be easily performed on-line on the LXCat website (www.lxcat.laplace.univ-tlse.fr) or by using the full, download version of BOLSIG+ [3] and the cross sections available on the SIGLO database website.

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References

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