Analysis and Computation of Electron Transport Coefficients in Cl_2-He Mixtures Using a Two-term Approximation of the Boltzmann Equation for Energy

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Abstract: The accurate electron collision cross sections and electron transport coefficients for the objective gases are indispensable not only for quantitative understanding of plasma phenomena, but also for quantum mechanical calculations. In general, there are three ways for analysing the diffusion and drift of electrons in gases such as the Monte Carlo simulation method, two-term and multi-term approximations of the Boltzmann equation for energy. This work used the two-term approximation of the Boltzmann equation for calculating the electron transport coefficients in binary mixture gases of chlorine (Cl_2) with helium (He). These electron transport coefficients were calculated for the pulsed Townsend, time-of-flight, and steady-state Townsend experiments. In the present study, Cl_2 gas was preferred because of its low global warming potential and high dielectric strength. This gas can avoid the greenhouse problems related to sulfur hexafluoride (SF_6) gas, which has been widely used as an isolated gas in high voltage equipment and is high global warming potential. On the other hand, to the best of our knowledge, neither measurements nor calculations of the electron transport coefficients in Cl_2-He mixtures with the whole Cl_2 concentration range have been performed previously. Based on the accurate electron collision cross section sets for Cl_2 and He molecules, therefore, electron transport coefficients in Cl_2-He mixtures were calculated and analysed by a two-term approximation of the Boltzmann equation in the E/N range (ratio of the electric field E to the neutral number density N) of 10 - 1000 Td (1 Td $= 10^{-17}$ V.cm^2) at 1 Torr and 300 K. The mixture ratios are 0%, 10%, 30%, 50%, 70%, 90%, and 100% Cl_2 gas. These electron transport coefficients are as functions of E/N. Their values, in general, increase progressively to those of pure Cl_2 when the percentage ratio of Cl_2 gas in these binary mixtures increases. These values were also compared respectively with those of the pure SF_6 gas. Because of the accuracy of electron collision cross sections for the present gases and the validity of the Boltzmann equation, the present results are reliable. The negative differential conductivity phenomena in these binary gas mixtures were suggested. The limiting field strength values of E/N, $(E/N)_{lim}$, for Cl_2-He mixtures were also derived and compared with those of the pure SF_6 gas. These binary gas mixtures can be considered as prospective substitutes for the SF_6 gas. The mixture ratio varies depending on the particular application of mixture gas and electrical equipment.

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