Topic number: 1

The Swarm Analysis of Electron Transport Coefficients Measured in the Mixtures of Tetrafluoroethane ($C_2H_2F_4$) and Argon (Ar)

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Because of its short lifetime in the atmosphere, tetrafluoroethane (or freon R134a) seems to be much more environmentally acceptable than other frequently used coolants (fluorocarbons). For these reasons, plasma etching technology, and other low temperature plasma applications may adopt it as a gas of choice while already it is often applied in nuclear particle detectors. The knowledge of electron transport coefficients such as drift velocities, diffusion coefficients, rate coefficients for individual processes, as well as the detailed set of cross sections, is necessary in order to make accurate plasma models of possible applications.

To the best of our knowledge, there has been only one set of cross sections for electrons in $C_2H_2F_4$ available, and it was mainly based on an extrapolation from those for C_2F_6 [1]. Besides, there were no published transport data except for the recent measurements [2] of drift velocities (W) and effective multiplication coefficients (that is, the difference between ionization and attachment coefficients, $(\alpha-\eta)/N$) in pure $C_2H_2F_4$, over a wide range of reduced electric fields (E/N). Those data were the basis for a preliminary swarm analysis of the existing cross sections [3]. Despite the fact that the derived set of cross sections was consistent with the experimental results for the pure gas, the energy balance was not well established by the experimental data, and it relied on extrapolated inelastic cross sections. Thus this set can only be used for modeling plasmas in mixtures containing small amounts of $C_2H_2F_4$. As the characteristic energy is not available for this gas, and since at these mean energies it is seldom measured experimentally, we have chosen a mixture technique where a small amount of molecular gas controls the mean energy in a mixture of this and some rare gas, e.g. argon. Thus we have used the experimental results for the drift velocities in $C_2H_2F_4$ – Ar mixtures with small abundances of $C_2H_2F_4$, where the momentum balance is controlled by Ar, and the energy balance by the investigated gas to make a further improvement of the cross section set.

The measurements of drift velocities and effective multiplication coefficients were performed by using the pulsed Townsend technique (described in detail in [4]) in the mixtures of five different abundances (from 2 up to 50% $C_2H_2F_4$ in Ar). Briefly, the technique is based on the measurement and analysis of the displacement current produced by the electrons drifting across a parallel plate discharge gap that produces a highly uniform electric field. The initial electrons are released by the incidence of a UV pulse from a Nd-YAG laser (355nm, 5ns FWHM) upon an aluminium cathode. The measurements were carried out at room temperature, and the pressure range was varied between 1 and 600 torr.

The transport coefficients were calculated by using a Monte Carlo (MC) code that we developed and verified against all benchmark tests [5]. The approximate, two term TT results were also obtained and only taken as a guide in the iterative process of adjusting the cross sections. The final adjustments and results were obtained by using the MC code.

The final result of our analysis is the modified set of cross sections shown in Figure 1. Figure 2 shows only one example of how that set reproduce the experimental results in comparison with the previous sets. There is a similar agreement for all other mixtures and transport coefficients. On the basis of this, we can conclude that the present modifications to the original cross section set are justifiable. We have mainly modified the vibrational excitation and dissociation cross sections. While these cross section data fit the experimental transport coefficients, further improvements could be sought when a better knowledge of the energy dependence of the most relevant cross sections becomes available.

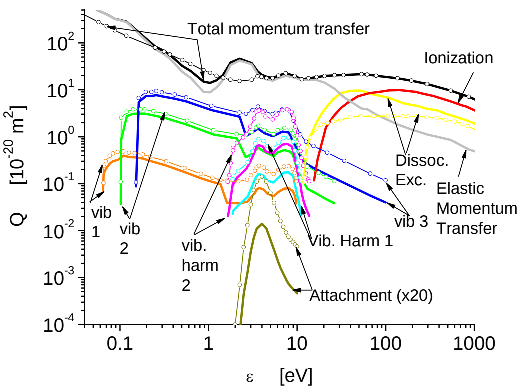

Fig. 1: Presently derived set of cross sections (solid lines) compared to the initial set of Biagi [1] (lines+open symbols).

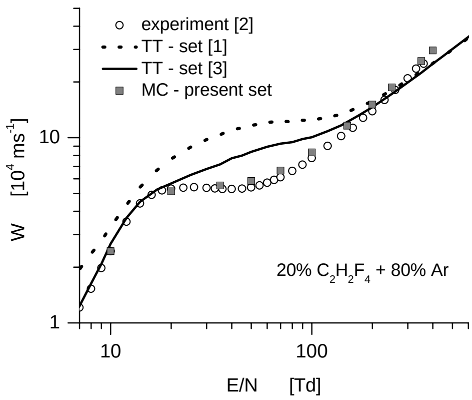

Fig. 2: Comparison of measured drift velocities for electrons in 20% mixture of $C_2H_2F_4$ and Ar with calculated data obtained for three different sets of cross sections.

Reference

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