The role of breakdown data in atmospheric studies

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Non-equilibrium low-temperature plasmas are a common phenomenon both on Earth and in space. There are remarkable similarities in many fundamental properties between low-temperature plasmas in various fields, including gas discharges, space science, the near-Earth environment, atmospheric discharges/electricity, and semiconductor physics. An example of this is the creation of different groups of electrons (with varying energies), which is a common occurrence in DC, RF, capacitive, and inductive discharges, as well as space plasma (solar wind) (Kolobov et al. 2020, Kolobov and Godyak 2019). The study of runaway electrons, in particular, can help us understand the initiation of lightning and thunderstorm activity in the troposphere, as well as the formation of electric discharges such as elves, sprites, and jets in the stratosphere and mesosphere. This is especially interesting because runaway electrons tend to occur in front of fast ionization waves, streamers, and leader tips during natural lightning. However, progress in studying and understanding atmospheric discharges on Earth and other planets demands a multidisciplinary approach and collaboration between researchers from different fields.

Studying the breakdown and electrical characteristics of discharges can provide insights into the fundamental properties and processes at play, and help identify new phenomena through experimental observations. By conducting our experimental measurements of breakdown conditions, we are able to gain valuable knowledge of the elementary processes that occur during discharges, including ionization, secondary electron emission, and surface interactions. We will discuss the results of our experimental measurements of breakdown in water vapor and low ODP (Ozone Depletion Potential) and low GWP (Global Warming Potential) gases, specifically 1,1,1,2-tetrafluoroethane (R-134a) and 2,3,3,3-tetrafluoropropene (HFO-1234yf). These measurements yielded breakdown voltages (Paschen curves), critical electrical fields, spatially and spectrally resolved distribution of discharge emission, and effective ionization coefficients. Using the available cross-section data, we analysed the collisional processes in these gasses. Furthermore, obtained effective ionization coefficients (in the region of reduced electric field *E/N* from 680 Td to 6.5 kTd for water vapor, from 2.7 kTd to 6 kTd for R-134a, and from 5 kTd to 23 kTd for HFO-1234yf), as one of the key transport coefficients, can be utilized to normalize existing ionization cross-sections for electron scattering on gases (Petrović et al. 2022, Marić et al. 2014). The implications of these results extend to both atmospheric research and practical applications.

Acknowledgements

This research was supported by the Science Fund of the Republic of Serbia, Grant No. 7749560, project EGWIn. Zoran Lj. Petrović is grateful to the SASA project F155.

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