# Propagation of Cathode-Directed Streamer Discharges in Air

Y. Serdyuk[1]

[1]Chalmers University of Technology, Gothenburg, Sweden

## Abstract

Introduction
Cathode-directed (also called positive) streamer electrical discharges are considered as a main cause of a complete electrical breakdown in air at atmospheric pressure and intermediate (below ~10 cm) distances between energized electrodes. Streamers are usually formed in a region with a strong electric field which may exist, e.g., at a surface of an electrode with high curvature (needle, wire, etc.). Being formed, a positive streamer is able to propagate for long distances even in space where the electric field is relatively weak (~4-5 kV/cm). Development of such a discharge is supported by a strong field at its front which is generated by produced space charges and, therefore, a streamer can be considered as a self-sustained ionization wave propagating in neutral gas which is converted into low-temperature plasma behind the wave front. Typically, the radius of streamer plasma channel is of order of hundreds of micrometers and propagation velocity is in the range 10e5-10e7 cm/s.

Numerical simulations of positive streamers in air have attracted significant attention during last two decades due to practical needs, e.g. ongoing development of new insulation technologies for voltage levels up to 800 kV dc and 1 MV ac, and also because of experimental difficulties accounted in investigations of streamer discharges where required high space and time resolutions are of primary concern. The most simple and popular formulation of a streamer propagation model in air is based on so-called drift-diffusion approach within which evolution of densities of three generic types of charge carriers (electrons, positive and negative ions) in space and time is considered, see e.g. [1].

Such formulation results in three convection-diffusion PDEs which account also for rates of physical processes leading to generation and loses of charged species, e.g. due to collisional ionization by electrons, recombination, electron attachment, photo-ionization, etc. These equations are coupled with Poisson's equation needed for obtaining distribution of the electric field affected by the produced space charge. In order to implement photo-ionization of the gas (which is the key process supporting positive streamer propagation) into the model in an efficient way, at least two Helmholtz equations are required [2]. In essence, the six PDEs with proper boundary and initial conditions as well as kinetic and rate coefficients form a self-consistent model which needs to be solved numerically due to its strongly non-linear nature.

Use of COMSOL Multiphysics®

In the present paper, an implementation of the model above in COMSOL Multiphysics® is presented focusing on numerical challenges appearing, in particular, when solving convection-diffusion equations for charge carriers' transport, in meshing procedure, etc. Two study cases are presented demonstrating propagation of a "short" (5 mm) and "long" (30 mm) streamers in air under normal conditions in a needle-plane electrode system. The characteristics of the discharges obtained from the simulations match well experimental results. Improvements needed to be introduced in the numerical model are discussed.

## Reference

1. R. Morrow, J. J. Lowke, Streamer propagation in air, J. Phys. D: Appl. Phys., Vol. 30, pp 614-627 (1997)
2. A. Bourdon et al, Efficient models for photoionization produced by non-thermal gas discharges in air based on radiative transfer and the Helmholtz equations, Plasma Sources Sci. Technol., Vol.16, pp 656-678 (2007)