Numerical modelling of stable glow corona discharges by means of stationary solvers of COMSOL Multiphysics

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The use of stationary solvers for numerical simulations of DC gas discharges carries a number of advantages. This work describes modelling of stable glow corona discharges by means of stationary solvers of COMSOL Multiphysics. As an example, results are shown of calculation of a positive corona in a point-to-plane configuration.

1. Introduction

The physics of glow (stationary) corona discharges has been understood reasonably well and a number of useful theoretical results, including analytical ones, have been obtained under various approximations. It is desirable to have also a fast and robust method of numerical modelling, which could be applied to a wide range of conditions. A standard approach relies on time-dependent solvers; e.g., [1,2]. Advantages offered by stationary solvers in simulations of DC discharges are demonstrated in [3]. In particular, stationary solvers allow computation of discharge modes in the whole range of their existence, thus decoupling physical and numerical stability, and are not subject to the Courant–Friedrichs–Lewy condition and the corresponding limitations on the mesh element size.

2. The approach

As far as COMSOL Multiphysics is concerned, models of DC non-thermal discharges where no insulators are present can be implemented by using the so-called general or coefficient form or by means of using the Transport of diluted species and Electrostatics modules. The only way to accurately implement boundary conditions on the insulator is by means of the Plasma module, which has appropriate internal variables. However, a straightforward application of the Plasma module does not allow working with stationary solvers. The latter can be overcome by building a replica of the Plasma module in the weak form formulation [3]. This approach allows one to introduce also other relevant modifications, in particular, to allow the user to set diffusion coefficients of the ions. However, one loses access to the internal variables of the Plasma module while using this approach.

In this work, the use of stationary solvers with the Plasma module was made possible by, paradoxically, setting equation form as time-dependent and manually controlling which dependent variables are solved for. The above-mentioned modifications were introduced in the Plasma module by editing weak expressions and contributions.

As an example, inception voltages, U_i, and values of the ionization integral, K, computed for the point-to-plane discharge configuration with 1 cm gap [4], are given in Table 1. Also shown are data computed without photoionization, $U_i^{(\gamma)}$ and $K^{(\gamma)}$, and the value of $\ln(1+\gamma^{-1})$.

Table 1: Inception voltages and ionization integral.

γ	U_i (kV)	K	$U_i^{(\gamma)}$ (kV)	$K^{(\gamma)}$	$\ln(1+\gamma^{-1})$
0	12.76	9.58	-	-	-
10^{-4}	12.74	9.54	14.41	12.85	9.23
10^{-3}	12.59	9.25	13.29	10.58	6.91
10^{-2}	11.91	8.01	12.08	8.31	4.62
10^{-1}	10.72	6.03	10.76	6.09	2.40

One can see that $K^{(\gamma)} > \ln(1+\gamma^{-1})$; in other words, the Townsend breakdown condition does not apply. As γ increases, a transition from corona to Townsend discharge occurs as the role of dominating secondary electron production mechanism passes from the secondary electron emission to photoionization.

3. Acknowledgements

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4. References

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