Positive streamer discharge inception from dielectrics

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We study inception of a positve streamer discharge from dielectrics of various shapes and dielectric permittivities. Due to their polarizability, dielectrics modify the external electric field. Electron attachment and emission on the dielectric surface can also play a role. This all can be important in the context of lightning inception. For our studies, we developed a model based on the fluid description of a streamer discharge. The electric field is calculated by solving the Poisson equation on a domain with a dielectric interface inside.

1. Description of the model

In our simulations, we use the convection-diffusion-reaction model in local field approximation [1]. The ions are assumed immobile on the time scale of interest. The electrons can drift in an external electric field, diffuse, and ionize air due to impact ionization and photoionization. Once an electron reaches a dielectric surface, we assume that it stays there building up a surface charge. The transport equations are coupled to the Poisson equation which is solved on the whole simulation domain, including the dielectric. The Ghost Fluid Method is implemented to discretize the Poisson equation in domains including dielectric or conductive interfaces of arbitrary shape [2]. The discretization matrix is inverted by calling MUMPS [3].

2. Source of electrons for positive streamers

For their propagation, positive streamers, unlike negative streamers, need a source of free electrons ahead of them. In air, the main source of free electrons is photoionization. It is an intrinsically non-local effect continuously providing free electrons ahead of the streamer. The photoionization is implemented according to Zheleznyak's model [4] and approximated by a computationally more efficient model based on solving Helmholtz's equations [5].

However, photoionization does not explain the source of initial electrons, which are necessary for the inception of a streamer. This can be a big issue under certain conditions. For example in thunderclouds, electrons quickly attach to water molecules and no free electrons seem to be available. We study various mechanisms that can potentially provide seed electrons in the vicinity of a dielectric.

3. Results

We demonstrate how a positive streamer discharge can incept from a dielectric in a sub-breakdown electric field.

4. References

[1] U. Ebert, C. Montijn, T.M.P. Briels, W. Hundsdorfer, B. Meulenbroek, A. Rocco, E.M. van Veldhuizen, Plasma Sources Sci. Technol. 15 (2006) S118-S129.

[2] S. Celestin, Z. Bonaventura, B. Zeghondy, A. Bourdon, P. Segur, J. Phys. D: Appl. Phys. 4 (2009) 065203.

[3] http://graal.ens-lyon.fr/MUMPS/

[4] M.B. Zheleznyak, A.Kh. Mnatsakanyan, S.V. Sizyh, High Temp. 20 (1982) 357-362.

[5] A. Luque, U. Ebert, C. Montijn, W. Hundsdorfer,, Appl. Phys. Lett. 90 (2007) 081501.