Streamer propagation as a pattern formation problem

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Negative impact ionization streamers propagating into a non-ionized medium have been modelled by simple fluid models. A careful investigation of the numerical solutions of such models can be found in [1]. These simulations have inspired the theoretical concept that streamers can be understood as an interfacial pattern formation problem [2]. Streamers then fall into the class of Laplacian growth problems, just like viscous fingering in two fluid flow or the growth of solidification dendrites into undercooled melts. Like in the latter cases, quantitative analytic predictions require a detailed understanding of the propagation of the front between ionized and non-ionized area. We explain the general line of research, and present results on planar fronts and their transversal (in)stability modes as an ingredient to the analysis of the fully developed curved fronts [3, 4, 5].

In parallel, we also develop new numerical tools for efficient numerical solution of streamer problems. Here negative streamers of the type of [1] give a new challenge to numerical mathematics, since the "pulled" nature of the front makes advanced numerical techniques like local grid refinement inefficient, and new numerical approaches have to be developed. Essentially, the strong point of numerical adaptive grid codes is that a fine grid is chosen only in the area of sharp gradients. In negative streamers, however, also other areas require a good numerical approximation.

The model used in [1-4] is a pure fluid model. A completely different model emerges from Raether's concept that streamers propagate by rare avalanches initiated from random places by photoionization. This concept is recalled in many text books on gas discharges like [6]. Such a concept could be approximated by models of the dielectric breakdown type [7]. We compare these different models corresponding to different physical mechanisms of streamer propagation.

References

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