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Spark formation as a moving boundary process

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The growth process of spark channels recently becomes accessible through complementary methods. First, I will review experiments with nanosecond photographic resolution and with fast and well defined power supplies that appropriately resolve the dynamics of electric breakdown [1]. Second, I will discuss the elementary physical processes as well as present computations of spark growth and branching with adaptive grid refinement [2]. These computations resolve three well separated scales of the process that emerge dynamically. Third, this scale separation motivates a hierarchy of models on different length scales. In particular, I will discuss a moving boundary approximation for the ionization fronts that generate the conducting channel. The resulting moving boundary problem shows strong similarities with classical viscous fingering. For viscous fingering, it is known that the simplest model forms unphysical cusps within finite time that are suppressed by a regularizing condition on the moving boundary. For ionization fronts, we derive a new condition on the moving boundary of mixed Dirichlet-Neumann type ($\phi = \epsilon\partial_n\phi$) that indeed regularizes all structures investigated so far. In particular, we present compact analytical solutions with regularization, both for uniformly translating shapes and for their linear perturbations [3]. These solutions are so simple that they may acquire a paradigmatic role in the future. Within linear perturbation theory, they explicitly show the convective stabilization of a curved front while planar fronts are linearly unstable against perturbations of arbitrary wave length.

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[3] B. Meulenbroek, U. Ebert, L. Schäfer, Phys. Rev. Lett. **95**, 195004 (2005).