Dielectric breakdown model in 3 dimensions

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A large number of physical processes lead to pattern formation, where the resulting structure has non-trivial geometry. An important class of those are the diffusion-controlled growth processes, where the growth of a domain is controlled by a diffusion field. In this miniproject we will consider the dielectric breakdown model (DBM), in which the local advance velocity depends nonlinearly on the gradient of the Laplacian field: $v \sim |\nabla\Phi|^\eta$. Initially developped to simulate dielectric breakdown, such as lightning [1], this model yields intricate fractal patterns.

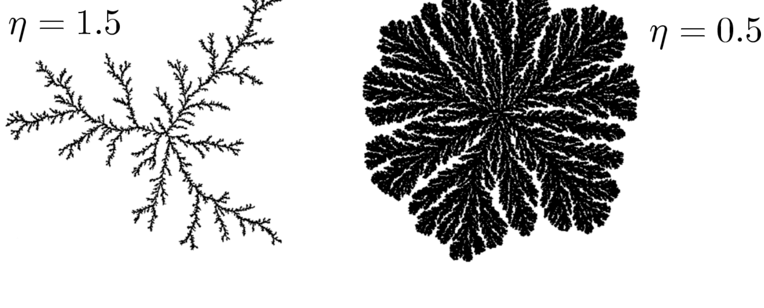
While a straightforward particle based simulation of DBM is computationally very expensive, a recent development [2] employs a technique which enables generating large enough clusters to effectively study asymptotic scaling properties. In this miniproject we will generate and analyse the scaling properties of DBM clusters in 3 spatial dimensions, which has not been feasible with other particle based methods and beyond the applicability of other (conformal mapping based) methods, despite the obvious physical relevance. Questions include how the nonlinearity parameter η influences the fractal dimension and other scaling relations (eg. tip scaling exponent). It has been suggested (but still debated) that in 2 dimensions there is a critical value of η beyond which the growth becomes trivial (one-dimensional). Is this the case in 3D as well?

The work will involve significant amount of programming (a working code for the 2-dimensional case, written in C, will be provided), as well as analysing data.

While this miniproject has the potential for publishable results, at this point it is not expected to directly lead to a PhD project.

[1] L Niemeyer, L Pietronero, H J Wiesmann, Phys. Rev. Lett. **52**, 1033 (1984)

[2] E Somfai, N R Goold, R C Ball, J P DeVita, L M Sander, Phys. Rev. E **70**, 051403 (2004)



Dielectric breakdown model in 2 dimensions for two different values of the nonlinearity parameter η.