Self-Organization of Microdischarges and Pattern Formation in DBD

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Experimental Setup for Study of Microdicharge Interaction

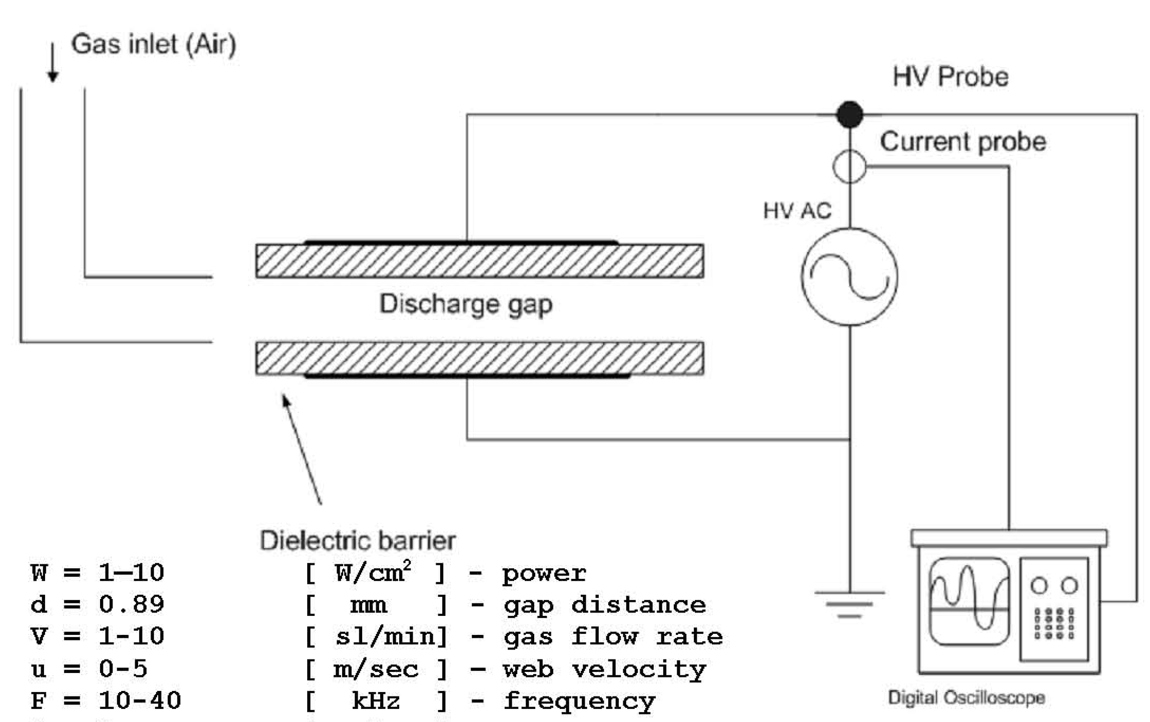
The two-dimensional spatial distribution of microdischarges in atmospheric pressure dielectric-barrier discharges in air was studied.

Experimental images of dielectric-barrier discharges (Lichtenberg figures) were obtained using photostimulable phosphors. The storage phosphor imaging method takes advantage of the linear response of the phosphor for characterization of microdischarge intensity and position.

The microdischarge interaction model in dielectric-barrier discharges is proposed and a Monte-Carlo simulation of microdischarge interactions in the discharge is presented. This interaction is responsible for the formation of microdischarge patterns reminiscent of two-dimensional crystals. Depending on the application, microdischarge patterns may have a significant influence on DBD performance, particularly when spatial uniformity is required.

Comparison of modeled and experimental images indicates interactions and short-range structuring of microdischarge channels.

Self-organization of microdischarges appears to be a strong effect and a dominant feature of the dielectric barrier discharge. The underlying memory and repulsion of microdischarges thus create quasi-Coulomb crystal patterns in DBDs.

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W = 1–10     [ W/cm² ] - power
d = 0.89     [  mm   ] - gap distance
V = 1-10     [ sl/min] - gas flow rate
u = 0-5      [ m/sec ] - web velocity
F = 10-40    [  kHz  ] - frequency
P = 1        [  atm  ] - pressure
T = 300      [   K   ] - temperature
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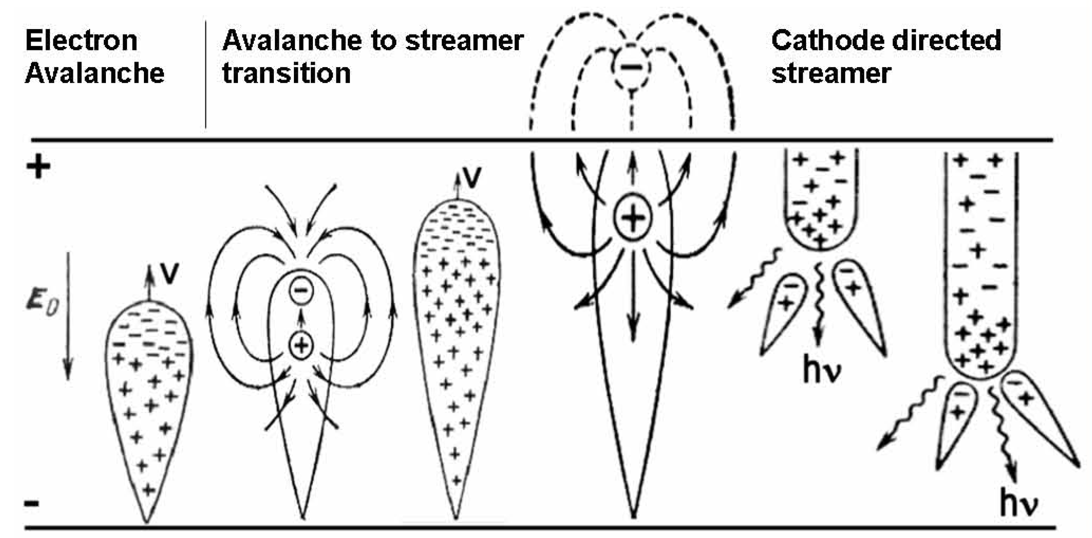
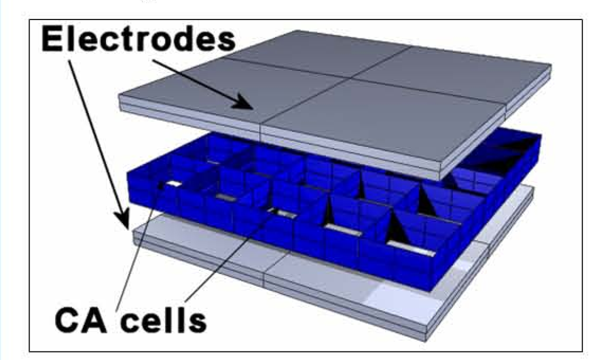


Formation of microdischarges in DBD. Microdischarge is a group of local processes in the discharge gap initiated by avalanche and developed until termination electron current. Typical microdischarge parameters in air 1 atm. presented in table below.

	Duration time	Charge transferred
Microdischarge (0.2 mm radius)	40 ns	10^{-9} C
Electron avalanche	10 ns	10^{-11}C
Cathode directed streamer	1 ns	10^{-10}C
Plasma channel	30 ns	10^{-9}C
Microdischarge remnant	1 ms	$\geq 10^{-9}$C

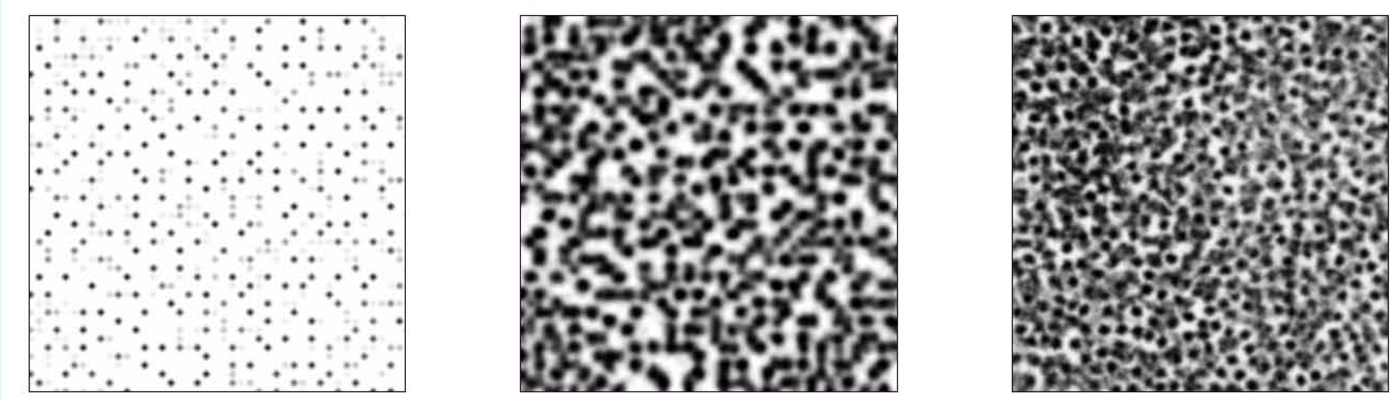
Microdischarge Interaction Model

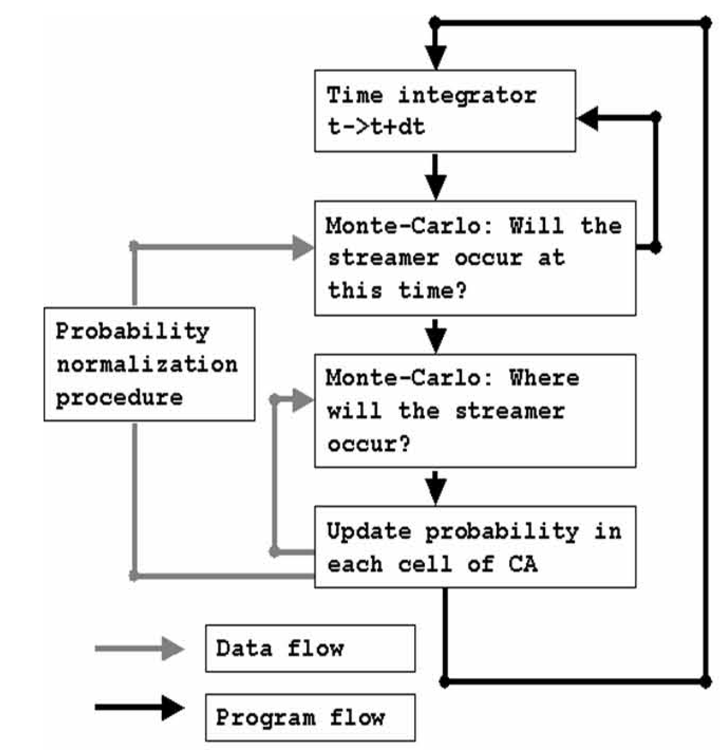
Discharge volume divided into CA cells



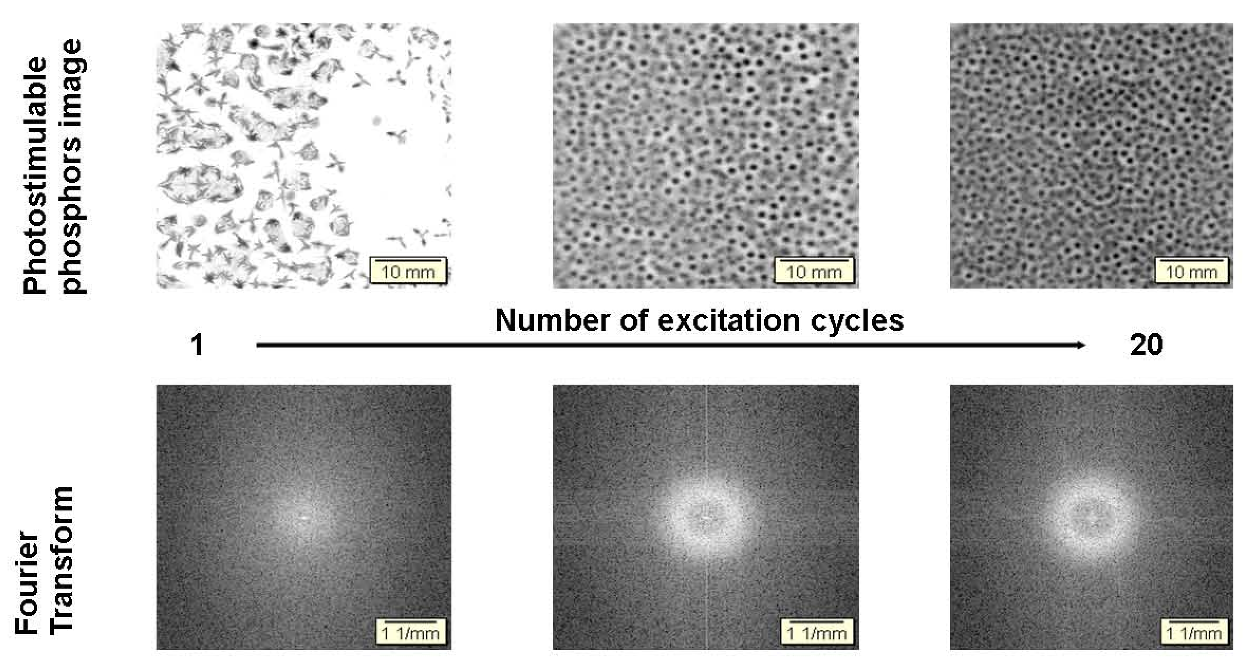
Extended stochastic cellular automata (CA) used for Monte-Carlo simulation of Microdischarge Interaction.

It is assumed that the probability for the occurrence of the streamer depends only on the local value of the electric field. The position of a streamer strike is determined using a Monte-Carlo decision for given probability values in each cell. Once the position of streamer strike is known plasma channel is formed at the same place and total charge transferred by this microdischarge is assigned to the cell to be used later in electric field calculations. An additional Monte Carlo simulation was used to decide whether a streamer will occur or not. If the streamer will not strike plasma channel will not be formed and there will be no microdischarge.

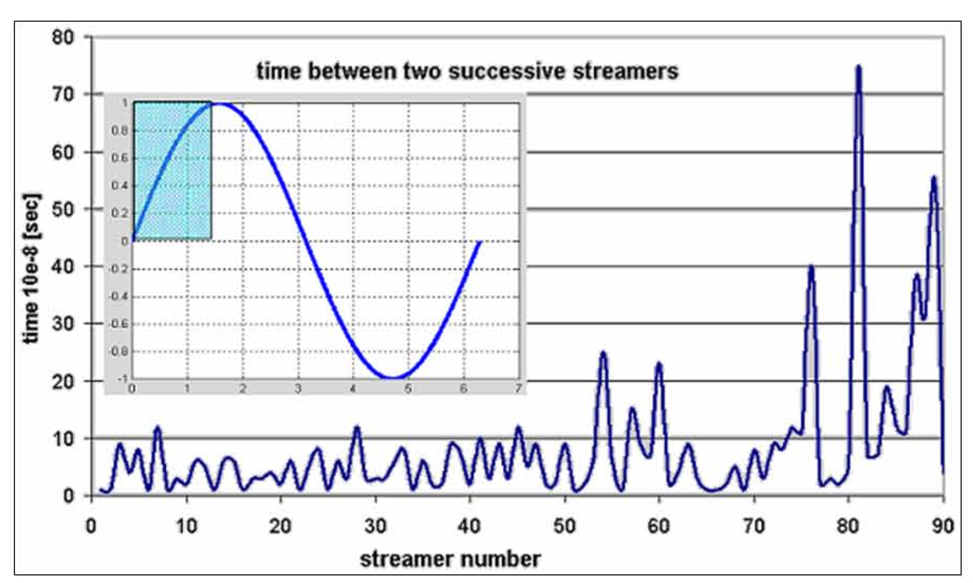


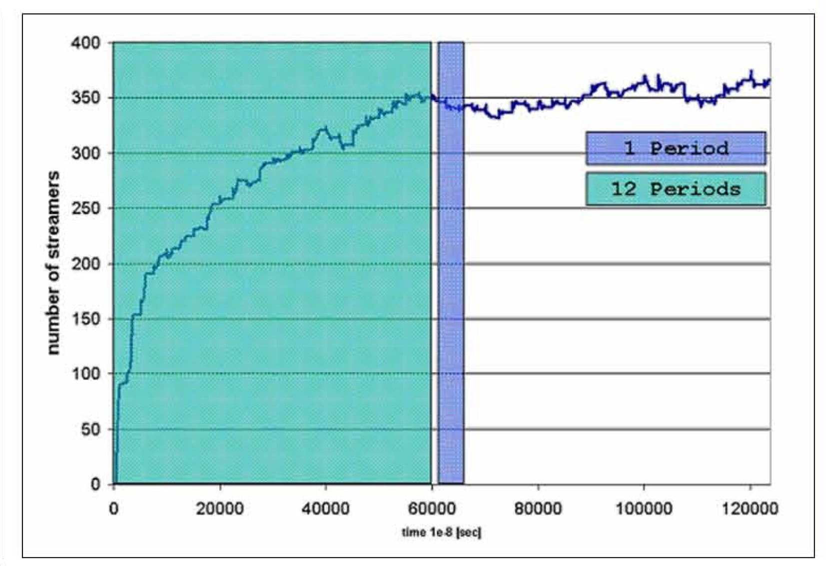


Self-Organization of Microdischarges

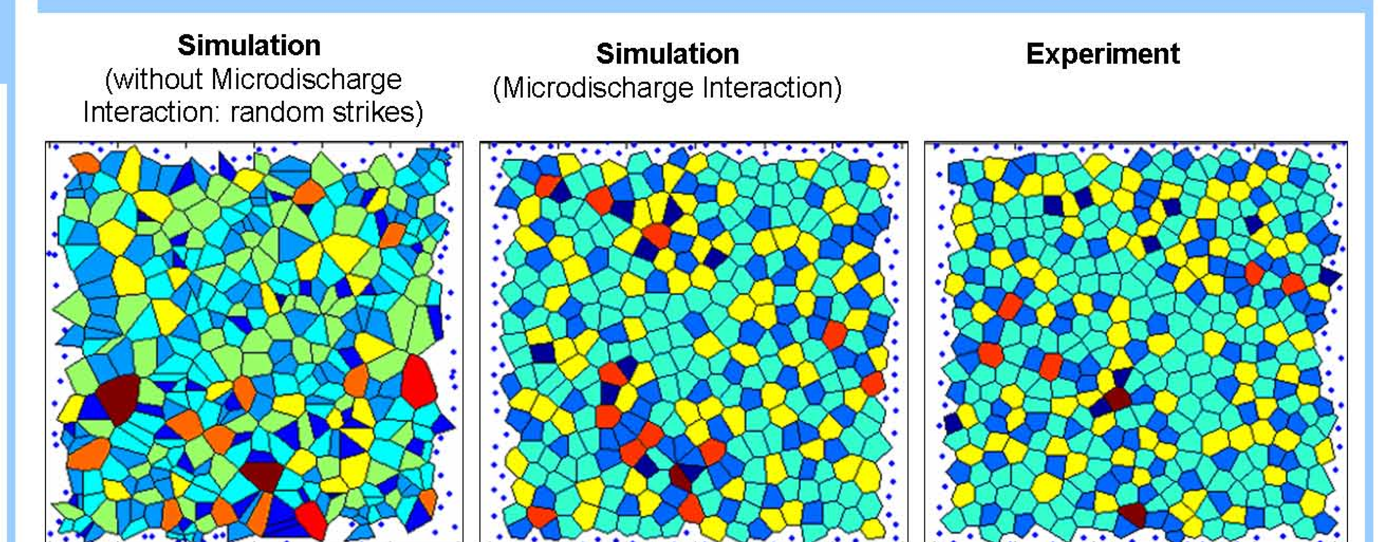


Simulation of DBD warming-up period





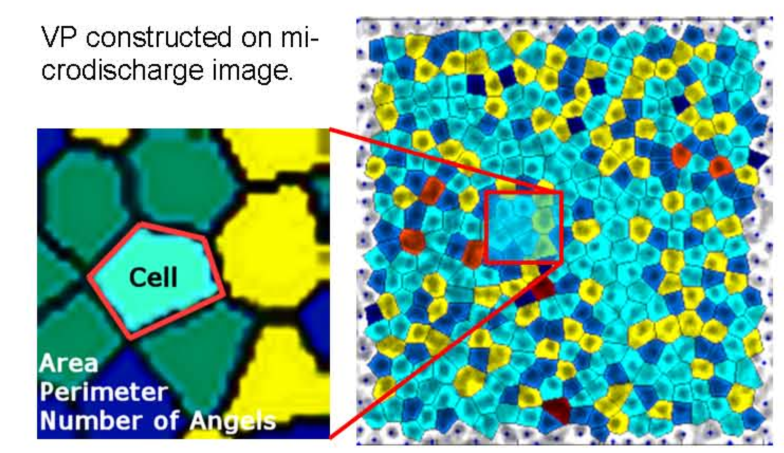
Microdischarge Patterns Comparison



A new method for analysis of microdischarge patterns is presented based on Voronoi polyhedra, which is invariant to the position of particular microdischarges, arbitrary stretching and rotation of the pattern. Using this method results of simulation were compared with experimental results yielding convincing evidence of microdischarge interaction in DBD, and demonstration the validity of the model.

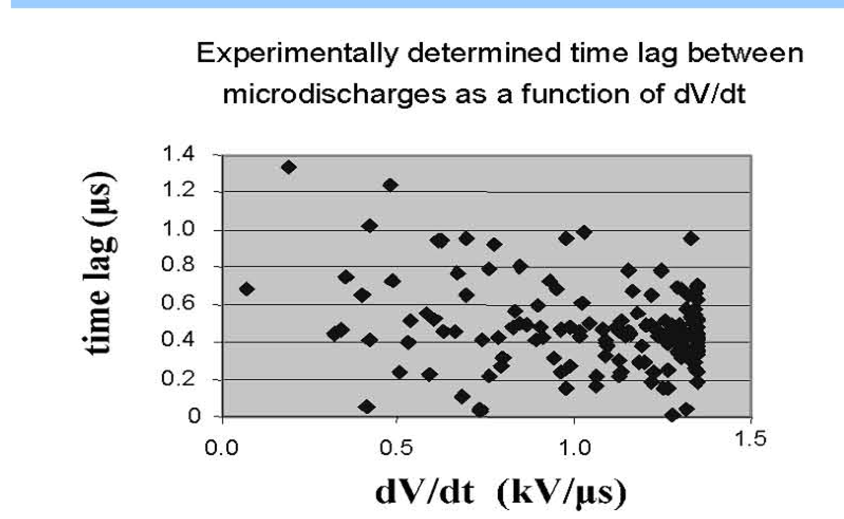
Voronoi Polyhedra

VP constructed on microdischarge image.



Voronoi polyhedra (Dirichlet tessellation): The partitioning of a plane with *n* points into *n* convex polygons such that each polygon contains exactly one point and every point in a given polygon is closer to its central point than to any other.

Time Lag between streamers



Discharge area from which light was collected: 1.98 × 1.98 cm

Total discharge area: 5 × 5 cm

The data were accumulated over 6 half cycles and show that the average time interval between optical pulses is between 0.4 and 0.5 μs. Thus time lag for total discharge area is about 70 ns.

Phosphor imaging plates offers some advantage over photographic film for imaging microdischarges in barrier discharges.

In contrast to the nonlinear sensitometric response of photographic emulsions, storage phosphor plates show a wide-range linear response with respect to impinging energy. This means that the signal intensity at any particular pixel is directly proportional to the amount of energy deposited.

We have verified in our equipment that the signal intensity in the images is linearly proportional to the dissipated energy in the barrier discharge cell.

Formation of photostimulable centers as a result of UV excitation comprises about 10% of the total signal intensity in the image. Electron bombardment of the phosphor from the microdischarge is the main excitation responsible for the formation of photostimulable centers on the imaging plate.

Comparison of Simulation with Experiment