# PULSE DISCHARGE IN THE DIELECTRIC CELL: SIMULATION VIA PIC METHOD

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2D electrostatic PIC code for simulation of the pulse discharge in the dielectric cell is described. The first simulation results (discharge current temporal dependence, electric potential spatial distribution, electrons' energy distribution) for the discharge in Ne - Xe mixture are presented.

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## 1. INTRODUCTION

Gas discharges in the dielectric cells are common for many laboratory and industrial applications. Many of these applications, especially related to the discharges of microscopic sizes, present difficulties for experimental investigations (see, e.g., [1]). For that case, computer simulation can be very useful for the investigation of the processes in gas discharges. For now, most common approach to the computer simulation of the gas discharges is based on the numerical solution of the kinetic equations for the elementary processes [2-4]. This method is natural for the stationary homogeneous plasma systems, but it does not fit well for the non-stationary gas discharges inside the small dielectric cells. Another methods, such as solving of the hydrodynamic equations (see, e.g. [5]), take into account the plasma inhomogeneities, but do not consider the kinetic effects.

In this work the pulse gas discharge in the dielectric cell is studied via computer simulations using Large Particles in Cells method.

## 2. COMPUTATION ALGORITHM

2D electrostatic PIC model has been applied in the simulation code. That code was developed for the PC platform (MS Windows) with user friendly interface (see Fig.1).

At each simulation step, equations for the electric potential and field were solved on the mesh with variable step using the matrix sweep method. This method is based on the solving of the finite differences' equation set in the shape of matrix three-diagonal equations. The method has a good accuracy for non-uniform spatial meshes so the simulation gives the reasonable results even for large (about $10^6$) amount of time steps. The time performance of matrix sweep method is sufficiently decreased for PIC simulations because main volume of calculations must be performed only once at the first simulation step.

Based on the values of electric field, the new values of the particles' coordinates and velocities are found out from the motion equations.

## 3. PROCESSING OF THE PARTICLES' COLLISIONS

Key part of the simulation code is the processing of the particles' collisions. According to the code purpose, it is devoted to the simulation of weakly ionized plasma that is typical for gas discharge devices like PDP. So all sorts of elementary processes taken into account can be divided

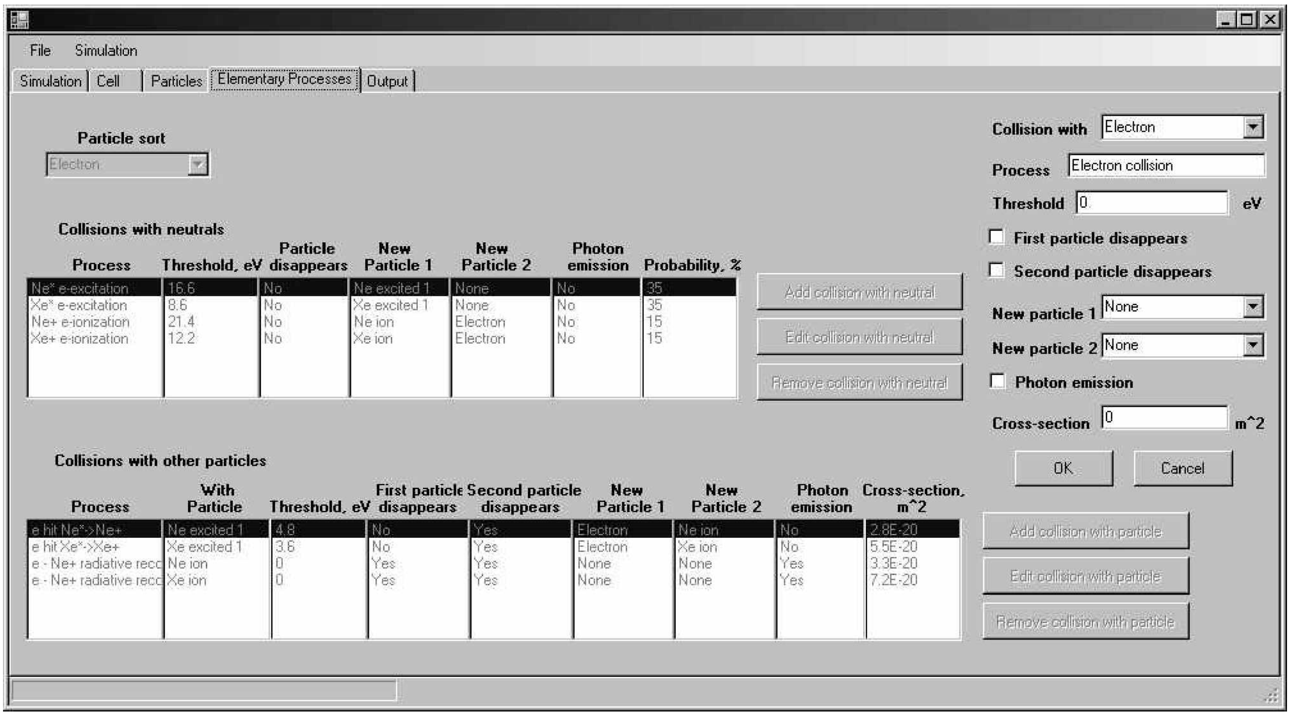



*Fig.1. Program simulator window for the elementary processes taken into account*

in two different classes – collisions with neutrals and collisions with other particles. Neutrals in ground (non-excited) state are not treated as sorts of large particles but form a background. Based on the free path of the particles and probabilities of all possible elementary processes with ground state neutrals, these processes are simulating using the Monte Carlo method. The elementary processes taken into account are non-elastic collisions, excitations on different levels, ionization, recombination, photon emission and absorption (the radiation transport is also considered). The collisions between the particles and cell walls are also considered as well as the secondary emission from these walls.

## 4. SIMULATION PARAMETERS

Simulation was carried out for the cell of plasma display panel. Simulation parameters are given below. Discharge cell with dielectric walls has dimensions 500×200 μm, partial pressures of neutral gases are 450 Torr for neon and 50 Torr for xenon. Direct driven voltage of 200 V is applied upon 200 μm cell side and is turned on at t=0. The initial portion of large particles' contains 50 electrons, 25 ions $Ne^+$ and 25 ions $Xe^+$. Simulation time step was $10^{-12}$ s. Large particle sorts taken into account included electrons, Ne and Xe ions and Ne and Xe excited particles with excitation energy enough to excite the phosphor – simulation was carried out for the cell of plasma display panel. We made 1 million steps of simulation (that correspond to real driven voltage pulse length) and controlled the amount of radiated photons.

## 5. SIMULATION RESULTS

Using the code mentioned above, computer simulation of the pulse discharge in the dielectric cell was carried out. The results for the plasma density and electric field spatial distribution and for the electron energy distribution are in good accord with the respective experimental results.

Current temporal dependency on Fig.2 corresponds to the known facts about the gas discharge in the dielectric cell. Such a discharge is initiated by the electron avalanche that appears in the electric field of driven voltage (front of the current pulse on Fig.2). Moving in this field, charged particles can reach the isolated electrodes and adsorb on the dielectric surfaces, so those planes are charging and counter voltage is appearing. When that voltage compensates the driven voltage, the discharge initiating field disappears and discharge starts to extinguish (current pulse back front). The duration of discharge current pulse is determined by the time of the charging of cell electric capacitance (about $2{\cdot}10^{-13}$ F for that case) by this current. Maximum charge for the 200 V voltage must be about $4{\cdot}10^{-11}$ Cl. So the duration of almost triangular current pulse with 300 μA magnitude must be about 250 ns that corresponds to duration of the pulse presented on Fig.2. The shape of the discharge pulse is also in good accordance with the experimental dependence [1].

Evolution of the electric potential spatial distribution during the duration of discharge current pulse is shown on Fig.3. One can see that discharge positive column appears near the positive electrode at the beginning of this pulse (Fig.3a).

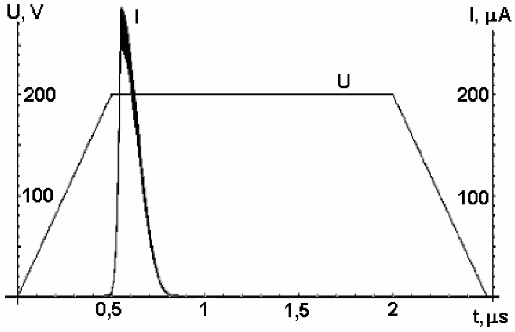
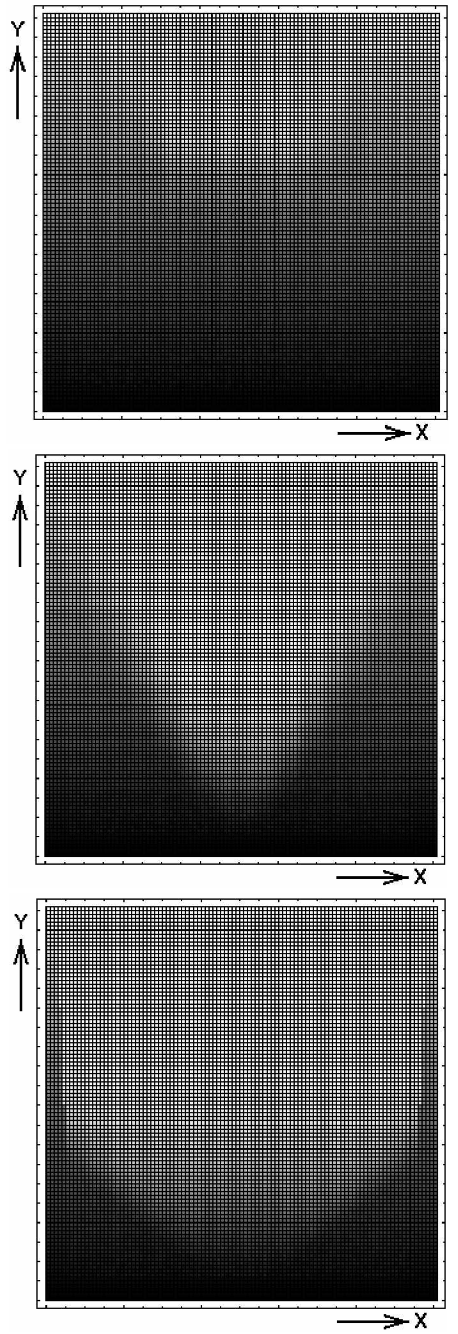



*Fig.2. Temporal dependencies of driven voltage and discharge current during the simulation*




*a*

*b*

*c*

*Fig.3. Electric potential spatial distribution during the simulation: a) t=0.51ns, b) t=0.52ns, c) t=0.54ns*

Then positive column expands quickly (Fig. 3b), so the duration of the current pulse front is rather small – about 10 times smaller then the entire pulse duration. At the moment directly after the discharge current reaches its maximum value (Fig. 3c), one can see that positive column is quite close to the negative electrode, so the dielectric surface of electrodes' isolation is charged quickly, that tends to discharge extinguishing.

Fig.4. shows the evolution of the electron energy distribution during the discharge current pulse duration. The small initial portion (about 100 large particles) assigns at the beginning of simulation (t = 0) with random velocities distributed uniformly. As more of new particles appear inside the cell due to the elementary processes, such as ionization and excitation, electron energy distribution tends to be closer to Maxwellian shape.

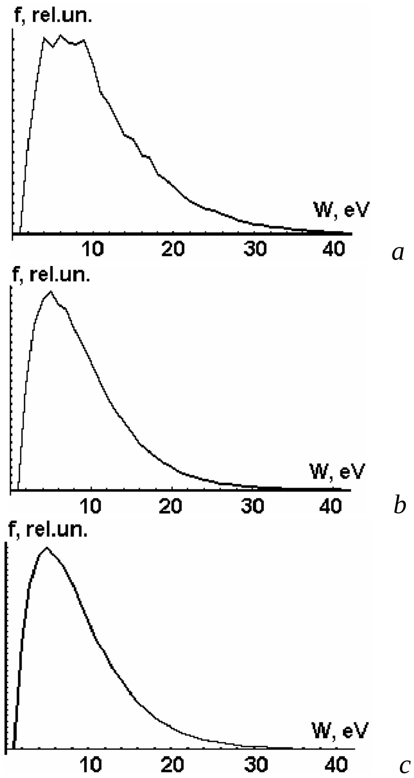



*Fig.4. Electron energy distribution during the simulation: a) t=0.51 ns, b) t=0.52 ns, c) t=0.54 ns*

On Fig.4 one can see the electron energy distributions for the same moments as the potential dependencies on Fig.3. At the beginning of current pulse (Fig. 4a), about 58000 electron large particles are distributed in a Maxwellian-like shape, but with diffused maximum. At the middle of pulse front (Fig. 4b – about 190000 electron large particles) and, especially, for the moment near the discharge current maximum (Fig. 4c – about 280000 electron large particles) the electron energy distribution practically corresponds to Maxwellian law.

## 6. CONCLUSIONS

1. Two-dimensional code for simulation of weakly ionized plasma systems (such as discharge devices, plasma display panels etc.) is developed and tested for the case of pulse discharge in dielectric cell.

2. Spatial distribution of the potential inside dielectric cell during the discharge current pulse has a positive column region that is quickly expanding and, finally, fills almost the entire cell. Then the discharge extinguishes.

3. Electron energy distribution during the current pulse changes towards the Maxwellian shape.

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## ИМПУЛЬСНЫЙ РАЗРЯД В ДИЭЛЕКТРИЧЕСКОЙ ЯЧЕЙКЕ: МОДЕЛИРОВАНИЕ МЕТОДОМ ЧАСТИЦ

***А.И. Кельник, О.В. Самчук, И.А. Анисимов***

Описывается двумерный код для электростатического моделирования импульсного разряда методом частиц в ячейках. Приводятся первые результаты моделирования разряда в смеси неона и ксенона (временная зависимость разрядного тока, пространственное распределение потенциала, распределение электронов по энергиям).

## ІМПУЛЬСНИЙ РОЗРЯД У ДІЕЛЕКТРИЧНІЙ КОМІРЦІ: МОДЕЛЮВАННЯ ЗА МЕТОДОМ ЧАСТИНОК

***О.І. Кельник, О.В. Самчук, І.О. Анісімов***

Описано двовимірний код для електростатичного моделювання імпульсного розряду методом частинок у комірках. Наводяться перші результати моделювання розряду у суміші неону та ксенону (часова залежність розрядного струму, просторовий розподіл потенціалу, розподіл електронів по енергіях).