MICROPLASMA DISCHARGE STRIATION IN THE PDP CELL

O.I. Kelnyk, O.V. Samchuk

Taras Shevchenko National University of Kiev, Radio Physics Faculty, Kiev, Ukraine
E-mail: oles@univ.kiev.ua

Striation structures formation was investigated for microplasma discharge inside coplanar dielectric cell via particles in cells (PiC) method. These inhomogeneities appear in the discharge current pulse forefront before the sharp maximum of electron current to coplanar anode. Striation structures are formed as ion bunches and they are related with the disturbance of the potential relief near the address electrode. Formation of these structures corresponds to the increase of electrons' number in the high energy band.
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1. INTRODUCTION

Microdischarges (microplasma discharges) are applied as energy sources for luminescence in the cells of plasma display panels (PDP, [1]). So the energetic efficacy improvement for such a discharges is very important problem for practical application. It is well known that discharges are more energetically efficient for luminescence purpose if the energy distribution function for charged particles becomes non-maxwellian with more particles at higher energies capable for excitation and ionization. One of the ways to obtain such a non-maxwellian distribution is using a plasma with striation structures when the charged particles can be accelerated between plasma spatial structures. Striation of glow-like gas discharge is a well-known experimental fact [2, 3] so this work is devoted to investigation of microdischarge striation for the dielectric PDP cell. Such an investigation might show a possibility of PDPs improvement via the increase of their energetic efficacy.

Phenomenon of striation structure appearance in the microdischarges inside the cell with dielectrically covered electrodes was investigated in [2, 4-6] via computer simulation. These structures usually appear in the anode region and their central maxima move towards the cathode. Striation structures' number and maximal density disturbance depend on gas mixture consistence (neon and xenon mixture is characteristic for most PDPs) and pressure [2,4]. Typical scenery of the striation structures formation usually begins at the first discharge phase when electrons are accumulated on the dielectric surface near anode and positive charge cloud is formed upon that surface. For such a conditions, field in the address electrode direction is shielded and electric field component along that electrode becomes a main factor of electrons' acceleration. This component increases during the striation structures formation. Striation structures are initially formed as small ion spatial distribution disturbances, but later such a disturbances increase and these structures become visible on the potential profile. Authors of [2] noticed that negative charge fluctuation appears near anode and have much less influence in other regions and, consequently, striation formation is strongly depend on this fluctuation.

Main goal of the present work is the investigation of microdischarge striation for the typical PDP dielectric cell in order to find a way to increase its energetic efficacy.

2. SIMULATION PARAMETERS

In this work striation structure investigation was carried out using our original 2D electrostatic code for particle-in-cell (PiC) weakly ionized plasma simulation [7]. Neon (95%) and xenon (5%) gas mixture was considered with 500 Torr total pressure. More than 100 most important elementary processes were taken into account via Monte-Carlo method. Simulations were carried out for coplanar PDP cell (see [1]) with 200 µm height and 700 µm width. Negative driving voltage was applied to one of the coplanar electrodes (coplanar cathode **c1**) at the top of cell, another coplanar electrode (coplanar anode **c2**) was grounded as well as address electrode (**a**) located at the bottom of cell. All electrodes were coated with dielectric sheath. Secondary ion-electron emission from the dielectric walls was taken into account.

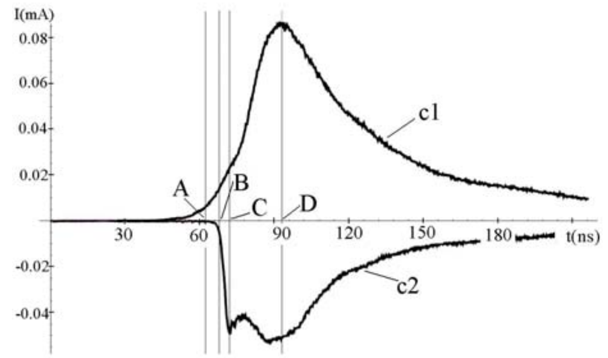

*Fig. 1. Current waveforms on **c1** and **c2** electrodes for the driving voltage 290 V*

3. RESULTS AND DISCUSSION

Striation structure formation was investigated for the driven voltage band from 190 to 290 V (discharge formation is most effective for that voltages) with 10 V step. For most voltages those structures initially appear on charge density and potential profiles at first phase of microplasma discharge formation, which corresponds to the forefront of the discharge current pulse on coplanar anode (**c2**) or interval before the first maximum (plateau, growth rate disturbance) on the forefront of current pulse on coplanar cathode (**c1**).

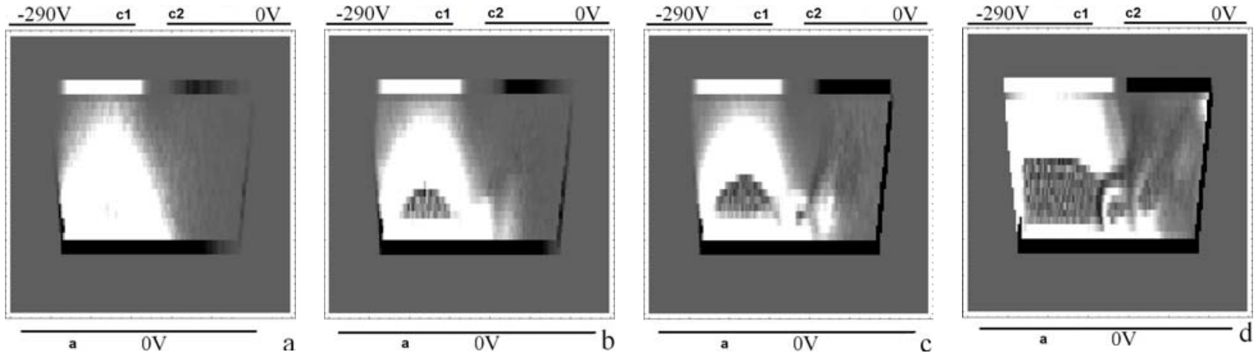

Fig. 2. Electric charge density spatial profile for time points: 62 ns (a), 68 ns (b), 72 ns (c), 93 ns (d)

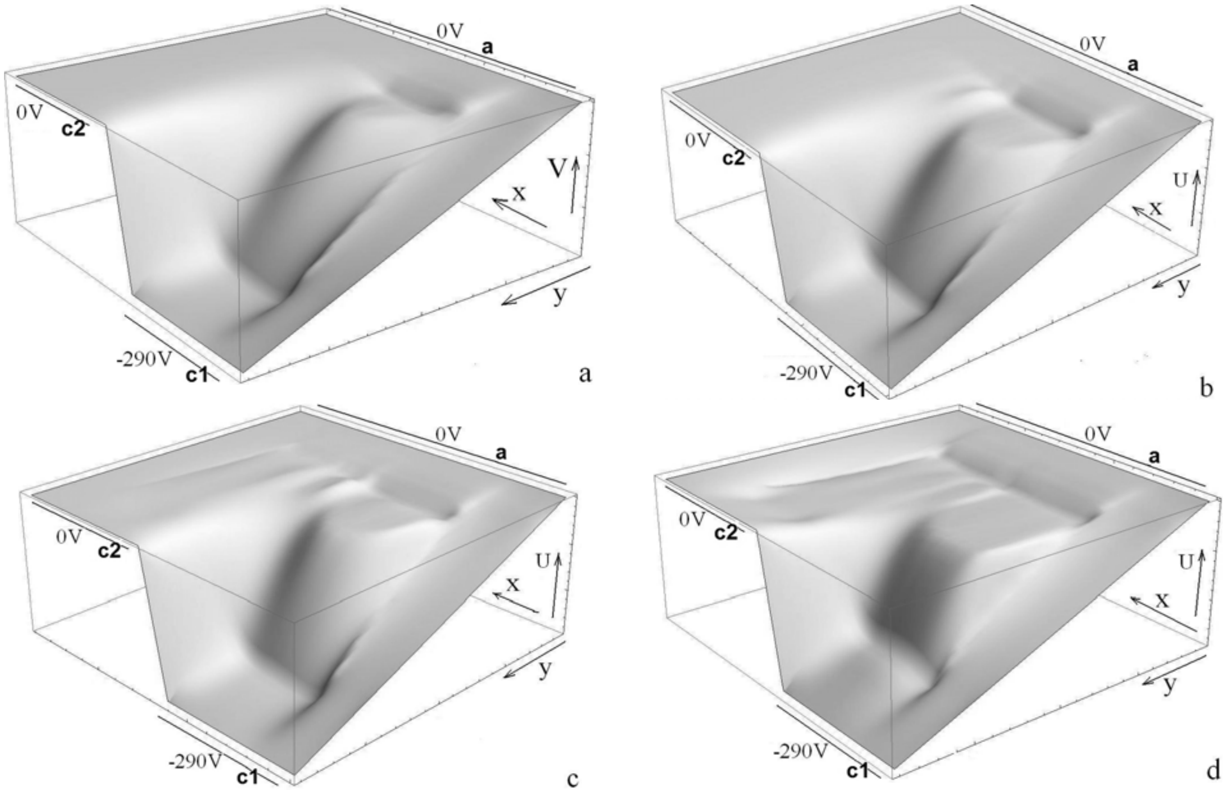

Fig. 3. Electric potential spatial profile for time points: 62 ns (a), 68 ns (b), 72 ns (c), 93 ns (d)

All inhomogeneities in the striation structure was formed sequentially one after another. The first (main) ion bunch corresponds to the discharge main column and is formed between **c1** and **a** electrodes. Real striation begins from the second ion bunch that appears near **a** electrode in the direction of **c2** electrode. All additional ion bunches appear in that direction. In the simulation, for discharge driving voltage of 190 V striation structures did not appear. For 200 V first additional ion bunch becomes visible (more expressed for the 210 V). For the voltages from 220 to 290 V two additional bunches were formed as well as corresponding maxima at the potential profile.

Note that in our simulation we considered that discharge anode and cathode are not located in one plane (potential configuration was defined by the real PDP cell described above), contrary to [2, 4-6]. Practically, electrodes were located one opposite to another as in the matrix cell geometry so the discharge ignition and striation structures' formation proceed in the corresponding way. Initial and secondary electrons moving from coplanar cathode **c1** to complex anode (that consists of coplanar anode **c2** and address electrode **a**) over the main discharge region, ionizing neutrals and finally being accumulated on dielectric walls and shielding applied voltage.

On Fig. 1 one can see **c1** and **c2** current waveforms for 290 V discharge driving voltage. Time points A(62ns), B(68ns), C(72ns), and D(93ns) correspond to different stages of striation structure formation. Fig. 2 shows the charge density spatial distribution at those moments and Fig. 3 shows the corresponding electric potential profiles. Time point A lies in the interval where **c1** current begins to increase significantly while the **c2** current is yet negligible. One can see that charge density profile contains only main discharge column (see Fig. 2, a). Lots of positively charged ions remain in the cell volume but significant amount of negative charges are stored on the dielectric wall near **a** electrode. Potential profile also has not any striation structures (see Fig. 3, a).

At the next stage, electrons' numbers in the discharge volume is increased, due to the growth of positive charges amount inside the main column. At the time point B, one can see the dark spot in the centre of the main positive column at the charge density spatial profile (see Fig. 2, b).

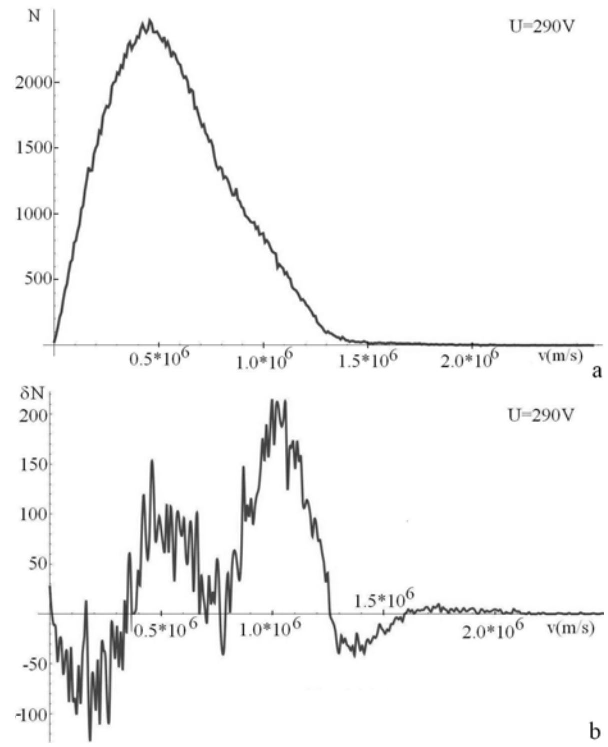

Fig. 4. Electrons' velocity distribution function (a) and its difference from nearest maxwellian function (b) for the time point 68 ns

As a result, electron current on the second coplanar electrode increases quickly. Also, the first additional striation bunch is formed (positive spot to the right from the main column at Fig. 2, b, local potential maximum on Fig. 3, b). One can see the formation of another ion bunch on Fig. 2, c and Fig. 3, c (point C on current waveform on Fig. 1). For this striation structure formation time is about 10 ns. At the moment D, inhomogeneity magnitude in the striation structure strongly decreases (see Fig. 2, d; Fig. 3, d) and this structure practically disappears at the time about 110 ns.

Striation structures are formed much faster when the driving voltage increases. For 290 V, one bunch can be formed during 10 ns. For smaller voltages, this time increases: e.g. 90 ns for 270 V and 150 ns for 230 V.

Fig. 4 shows the electrons' velocity distribution function and its difference from the nearest maxwellian function at the moment of maximal striation inhomogeneity. One can see that this distribution is significantly non-maxwellian for the high energy band where electrons are capable for effective ionization and excitation. So the striation structures' formation can increase the energetic efficacy of the microplasma discharge.

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ОБРАЗОВАНИЕ НЕОДНОРОДНОСТЕЙ МИКРОПЛАЗМЕННОГО РАЗРЯДА В ЯЧЕЙКЕ ПЛАЗМЕННОГО ДИСПЛЕЯ

О.И. Кельник, О.В. Самчук

Исследовалось образование неоднородностей для микроплазменного разряда в копланарной диэлектрической ячейке путем моделирования методом крупных частиц (PiC). Такие неоднородности возникают на переднем фронте импульса разрядного тока перед резким максимумом электронного тока на копланарном аноде. Неоднородности формируются как ионные сгустки и связаны с возмущением профиля потенциала вблизи адресного электрода. Формирование таких структур связано с возрастанием количества электронов в высокоэнергетической части распределения по скоростям.

УТВОРЕННЯ НЕОДНОРІДНОСТЕЙ МІКРОПЛАЗМОВОГО РОЗРЯДУ В КОМІРЦІ ПЛАЗМОВОГО ДИСПЛЕЮ

О.І. Кельник, О.В. Самчук

Досліджувалося утворення неоднорідностей для мікроплазмового розряду в копланарній діелектричній комірці шляхом моделювання методом великих частинок (PiC). Такі неоднорідності виникають на передньому фронті імпульсу розрядного струму перед різким максимумом електронного струму на копланарному аноді. Неоднорідності формуються як іонні згустки і пов'язані зі збуренням профілю потенціалу поблизу адресного електроду. Формування таких структур пов'язане із збільшенням кількості електронів у високоенергетичній частині розподілу за швидкостями.