CURRENT WAVEFORMS FOR PULSE MICRODISCHARGE INSIDE DIELECTRIC CELL

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Computer simulation for microplasma discharge inside coplanar dielectric cell was carried out via particles in cells (PiC) method. Discharge current waveforms have a shape of short pulses with length decreasing and maximum earlier appearance for larger voltages applied. Mostly ion current on the negative coplanar electrode has a smooth shape contrary to the mostly electron current on the positive one which has a sharp maximum at the end of electron avalanche. Address electrode current is significantly less than coplanar electrodes currents and has pulsations corresponding to the striation structures appearance.

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1. INTRODUCTION

Microscopic gas discharges are being applied widely in various plasma technological processes as well as in plasma displays (PDP, [1]). One of the most important problems for such discharges' applications is increasing of their energetic efficacy. Optimization of the applied voltage (and, consequently, discharge current) waveform is one of ways to make a microdischarge more energetically efficient.

Among previous works, one can find both computer simulation (see, e.g.[2]) and experimental measurements (e.g.[3]) for the discharge current waveforms inside dielectric cell. Important results already obtained there are the appearance of lag between anode and cathode currents for relatively small voltages (lag vanishes for larger address voltages) and the fact that address electrode current is small in comparison with the current to coplanar electrodes [2]. If additional electrodes are used, gas discharge can proceed in two phases and current temporal dependence has two maximums [3]. But the ion and electron components for discharge currents and features of address electrode current are not yet completely investigated.

2. SIMULATION PARAMETERS

In this work discharge current waveforms are investigated for the case of the gas microdischarge inside the cell with three dielectrically coated electrodes. Computer simulation is carried out via the particles in cells (PiC) method. For such an investigation, original 2D electrostatic PiC code [4] with Monte Carlo collision simulation was applied. About 100 types of elementary processes were taken into account [5]. Dielectric cell dimensions were considered 0.7×0.2 mm (typical PDP cell size). Gas mixture contained 95% neon and 5% xenon with total pressure of 500 Torr. Negative discharge driving voltage was applied to one of two coplanar bus electrodes - coplanar cathode **c1** (based on the front glass plate of cell). Another bus electrode (coplanar anode **c2**) and address electrode **a** (on the cell backplate) were grounded. Driving voltage had a trapezoid shape with 100 ns forefront and 1s total length, and it's magnitude was varied in 190…280 V voltage band (near the optimal discharge ignition conditions).

3. TOTAL DISCHARGE CURRENT AND CURRENTS TO THE COPLANAR ELECTRODES

Waveforms for the total discharge current and the current to coplanar cathode c1 are shown at Fig. 1 for different discharge driving voltages. Total discharge current temporal dependences (Fig. 1, a) have a shape of pulses with relatively short (about 100 ns) length. One can see that for larger discharge voltages total current pulses are shorter and have more smooth shape with earlier maximum appearance. Coplanar cathode current waveforms (Fig. 1, b) have a similar shape but they are smoother than total current pulses. From comparison Fig. 1, a and Fig. 1, b one can see that *c1* electrode current is a main part of the total discharge current. On the other hand, total current waveforms at the initial stage of pulses have several additional peaks relatively to corresponding ones for current to **c1** electrode.

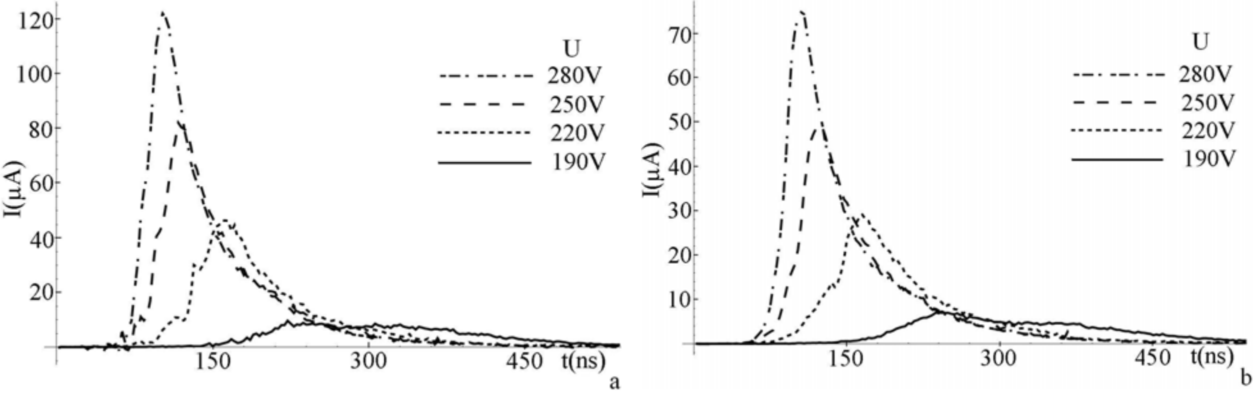

*Fig. 1. Waveforms for total discharge current (a) and current to **c1** electrode (b) at different applied voltages*

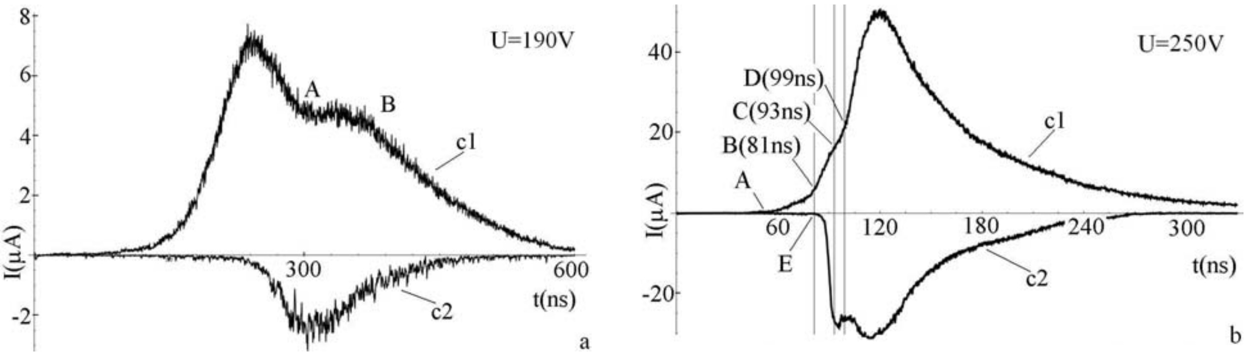

*Fig. 2. Current waveforms on **c1** and **c2** electrodes for driving voltages* 190 V *(a) and 250 V (b)*

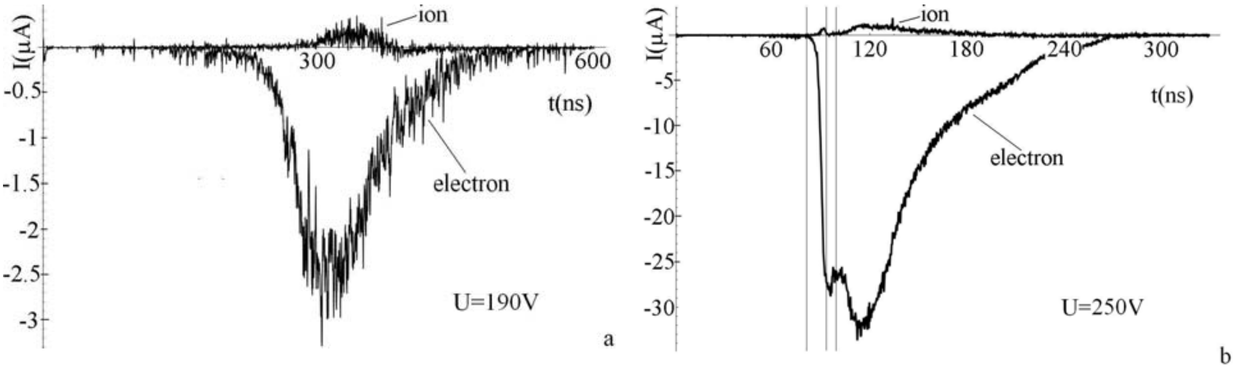

*Fig. 3. Electron and ion current waveforms on **c2** electrode for driving voltages of 190 V (a) and 250 V (b)*

So the general shape of waveforms for total discharge current is defined mostly by **c1** current with the exception of additional sharp peaks at initial discharge pulse stage. Current to the coplanar cathode **c1** forms the main smooth part of the total current. Such smoothness of **c1** current results from its almost completely ion consistence due to the negative potential on that electrode. Additional sharp peaks in the total current waveforms are deposited by the mostly electron current on the coplanar anode **c2**. Fig. 2 shows **c1** and **c2** currents for driving voltages 190 V (a) and 250 V (b). For relatively small applied voltage of 190 V, **c1** ion current waveform has two maxima and the first maximum is larger than the second one. For larger driving voltages such as 200…220 V, the second maximum substantially increases and oversize the first maximum. For even larger voltages, the first maximum transforms into plateau and, for voltages of about 250 V it almost disappears (Fig. 2, b) acting only as current growth rate variation. From Fig. 2, one can see that the first maximum of **c1** current corresponds to the quick increase of **c2** current, but the second **c1** current maximum appears when **c2** current is already decreasing.

For small driving voltage such as 190 V, the external electric field is quickly shielded by charged particles formed during gas discharge initial phase so the resulting voltage isn't capable for support of the next phase of discharge evolution. Consequently the plateau is formed instead of the second current maximum (Fig. 2, a, interval AB). Then the discharge quickly decays and inhomogeneities (like striation structures) are not formed.

Contrary, for the larger voltages like 250 V, such a structures are effectively formed and the second phase of discharge evolution takes place. On Fig. 2, b, interval AB corresponds to the electron avalanche between **c1** and **a** electrodes. Electrons appeared during that interval contribute to the formation of striation structure in discharge (interval BC). The first maximum (plateau, growth rate variation) on **c1** current waveform temporal dependence, which is depicted by interval CD, corresponds to the burning gas discharge in striation structure when the ion **c1** current growth rate becomes smaller.

From comparison Fig. 1, a and Fig. 2 one can see that additional sharp maximum of the total discharge current correspond to sharp peak of **c2** current (see Fig. 2, b). This peak appears with some delay after the first maximum of **c1** current. This effect corresponds to the result obtained in [2]. Practically, **c2** current begins to increase later than **c1** current (respectively points E and A on Fig. 2, b) but increases much faster. For smaller voltages delay is significant and **c2** current maximum appears between first and second maxima of **c1** current (Fig. 2, a). For larger voltages (250 V) **c2** current grows very fast and its peak practically coincides with the first maximum of **c1** current (Fig. 2, b, point C). Later phases of discharge main maximum and decay for **c1** and **c2** currents for that voltage are almost synchronous.

4. ELECTRON AND ION CURRENTS' COMPONENTS

Waveforms for electron and ion components of **c2** electrode current (for **c1** electrode current electron component is negligible) are shown on Fig. 3. One can see that electron component forms most of that current but ion component is also noticeable. Fast growth of **c2** current corresponds to its mostly electron consistence. Small ion component of **c2** current have its maximum with some delay relatively to the electron component.

Waveforms for ion and electron components of current on the address electrode **a** are shown on Fig. 4.

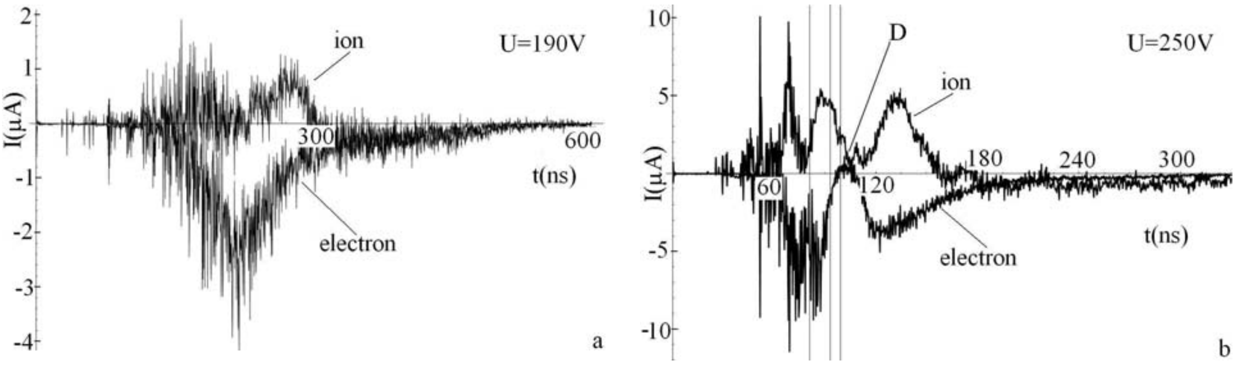

Fig. 4. Electron and ion current waveforms on address electrode for driving voltages of 190 V(a) and 250 V(b)

Such a current is much less than c1 and c2 currents so the discharge burns mainly between coplanar electrodes. One can see the oscillations with varying period for both electron and ion current components. These oscillations are related with the oscillations of electric potential near address electrode and, for the larger driving voltages like 250V, correspond to the striation structures' formation. Decrease of that current at the late discharge phase corresponds to the potential profile smoothing due to the discharge decay.

5. CONCLUSIONS

For the most effective voltage band, total current of microplasma discharge mostly consists of currents to **c1** and **c2** coplanar electrodes. Current to **c1** electrode practically has only the ion component, **c2** current is formed mostly by electrons with the small ion component. General waveform of the total current is determined by **c1** current while **c2** current adds a sharp peak before the main maximum of discharge current pulse. Small current to the address electrode have a pulsations corresponding to the oscillations of electric potential in this region.

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ФОРМА ИМПУЛЬСОВ ТОКА ДЛЯ МИКРОРАЗРЯДА В ДИЭЛЕКТРИЧЕСКОЙ ЯЧЕЙКЕ

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Проведено компьютерное моделирование микроплазменного разряда в диэлектрической ячейке методом крупных частиц (PiC). Временные зависимости для разрядных токов имеют вид коротких импульсов, для которых при увеличении приложенного напряжения длительность уменьшается, а максимум появляется раньше. В основном, ионный ток на копланарный катод имеет сглаженную форму в отличие от тока на копланарный анод (в основном, электронного), который имеет резкий максимум в конце электронной лавины. Ток на адресном электроде имеет гораздо меньшую величину, чем ток на копланарных электродах, и содержит пульсации, связанные с формированием неоднородных структур.

ФОРМА ІМПУЛЬСІВ СТРУМУ ДЛЯ МІКРОРОЗРЯДУ В ДІЕЛЕКТРИЧНІЙ КОМІРЦІ

О.І. Кельник, О.В. Самчук

Проведено комп'ютерне моделювання мікроплазмового розряду в діелектричній комірці методом великих частинок (PiC). Часові залежності для розрядних струмів мають вигляд коротких імпульсів, для яких при збільшенні прикладеної напруги тривалість зменшується, а максимум з'являється раніше. В основному, іонний струм на копланарний катод має згладжену форму на відміну від струму на копланарний анод (в основному, електронного), який має різкий максимум наприкінці електронної лавини. Струм на адресному електроді істотно менший за струм на копланарних електродах і містить пульсації, пов'язані із формуванням неоднорідних структур.