Three-Dimensional Monte-Carlo/Particle-in-Cell Simulations of the discharge pulse in an AC-PDP cell

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Abstract— **The dynamics of the discharge pulse between coplanar electrodes in an AC-PDP cell is studied by the 3-D Monte-Carlo/PIC simulations. The images obtained from the simulations capture all essential features of the discharge (such as a spatial structure of striations above the anode, and an arch-shaped front of the discharge spreading along the cathode) and show a remarkable resemblance to the experimental data.**

Index Terms— **plasma display panels, PDP, three-dimensional particle-in-cell simulations, Monte-Carlo simulations, striations.**

BARRIER discharges in Plasma Display Panels (PDP) have already been studied numerically in many works. Nevertheless, even the most advanced 3-D hydrodynamic or 2-D kinetic simulations (see e.g. [1]–[3]) could not reproduce spatial structure of anode striations and the ionizing cathode wave observed in experiments [4], [5]. This problem is addressed by our 3-D Monte-Carlo/PIC kinetic simulations described in the present paper.

As one can easily estimate, the number of charged particles transferred during one discharge pulse in a typical PDP cell is of the order of 10^8. On the other hand, the number of macro-particles in typical Monte-Carlo/PIC simulations that can run on a modern PC is about several millions. It means that one positive/negative macro-particle can be taken to correspond to only several tens of real ions/electrons, and therefore, 3-D Monte-Carlo/PIC simulations of a PDP cell are quite realistic.

We consider a standard coplanar PDP cell, filled with neon-xenon (93% - 7%) mixture at a pressure of 500 Torr. The cell length, width, and height are 520μm, 220μm (including barrier ribs), and 160μm (including dielectric layers above sustain and address electrodes), respectively. The distance between sustain electrodes (i.e. between the anode and the cathode) is 120μm and sustain voltage during discharge pulse is 220V.

The main physics of the barrier discharge in a PDP cell very much revolves around the process of the charge deposition on the dielectric surfaces and can be described as follows. At first, the positive charge is accumulated in the gap volume (and the negative charge is deposited on the dielectric surface) right above the inner edge of the anode electrode, see Fig.1 (time moment t_1) and [6]. When the density of the positive charge reaches a certain critical level, ions start to screen the electric field and detain the electrons in the gap volume. As a result, a plasma region forms above the inner edge of the anode and then gradually protrudes toward the cathode (Fig. 1, time moment t_2). There is a substantial positive charge on the tip of this plasma formation (much like the charge on the tip of the conductor placed in an external electric field).

The ongoing deposition of the negative charge on the dielectric surface causes formation of the first striations. When the plasma region approaches the dielectric surface above the cathode (Fig. 1, time moment t_3), the cathode fall (CF) is formed, and the current through the low resistant plasma channel sharply increases. Since the potential drop between the plasma region and the uncharged areas of the dielectric surface is substantially higher than the breakdown voltage, the CF expands along the cathode in a form of the ionizing wave (Fig.1, time moment t_4), and the positive charge is deposited on newer and newer areas of the dielectric surface.

Note that the charging of the anode dielectric surface by the negative charge progresses also in the wave-like manner in which ions created by the ionization processes above the anode play an essential role in delivering electrons to the uncharged areas of the surface.

When the positive charge covers most of the dielectric surface above the cathode, the discharge extinguishes. In the afterglow, the density of plasma gradually decreases through the dissociative recombination of electrons on Xe_2^+ molecules and through the ambipolar diffusion (which pulls the plasma toward all dielectric surfaces).

The images shown below were generated in TIFF format using Wolfram Research Mathematica 5.0.

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REFERENCES

[1] P. J. Drallos, V. N. Khudik, and V. P. Nagorny, “3D simulations of a single-substrate AC-PDP cell with barrier ribs,” in *Proc. SID'98*, Anaheim, CA, 1998, pp. 632 – 635.

[2] Hyun Chul Kim, Sung Soo Yang, and Jae Koo Lee, “Three-dimensional fluid simulation of an AC-PDP cell,” *IEEE Trans. Plasma Sci.,* vol. 30, pp. 188 – 189, Feb. 2002.

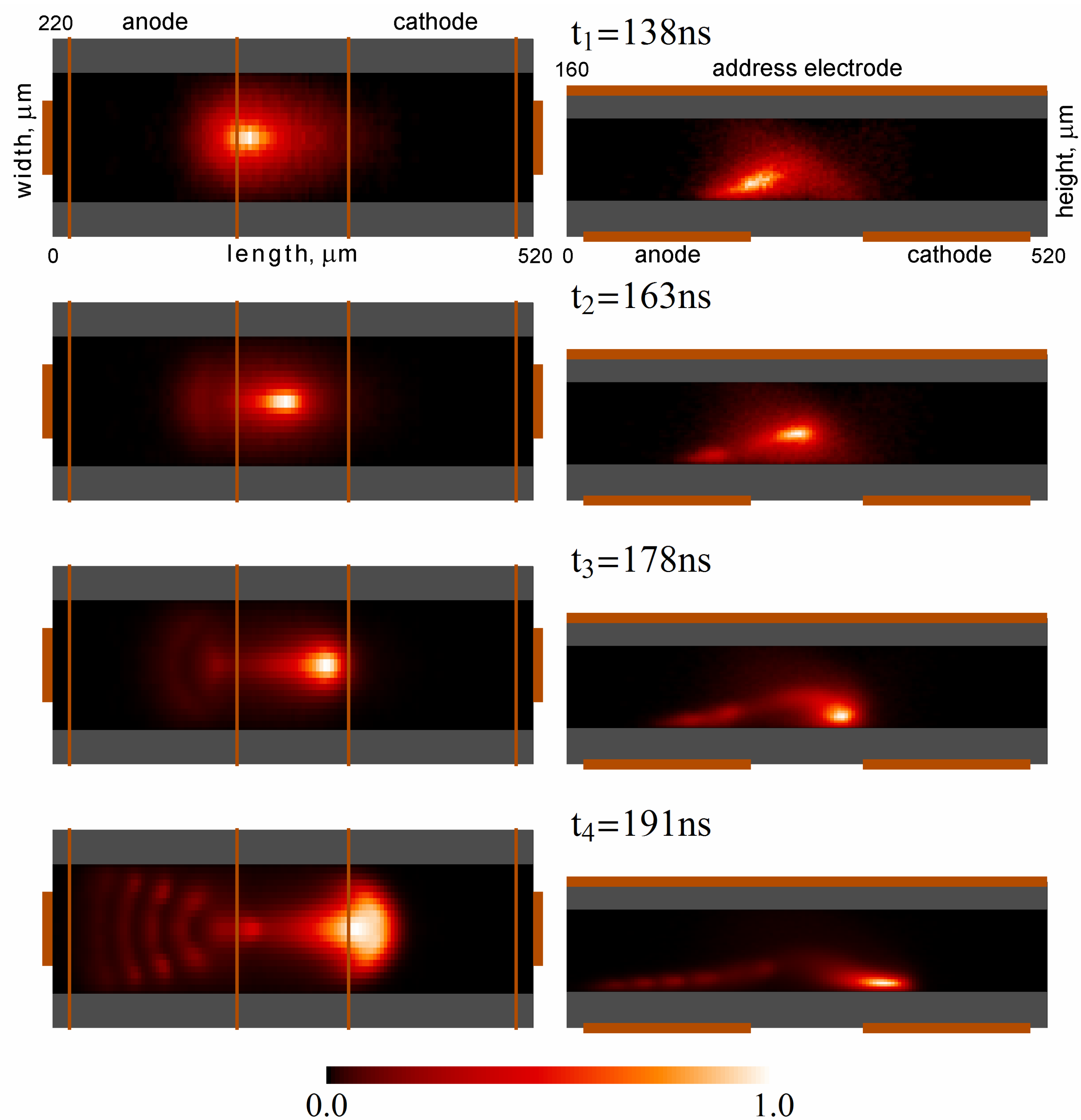

Fig. 1. Distribution of the ion density in the discharge gap at different moments in time (left column – view from the top; right column – view from the side of the PDP cell). Barrier ribs and dielectric layers are shown in gray color, and the electrodes are sketched in brown.

[3] C.H. Shon and J.K. Lee, "Striation phenomenon in the plasma display panel," *Phys. Plasmas,* vol. 8, pp. 1070 – 1080, March 2001.

[4] L.F. Weber, "Status and trends of plasma display device research," unpublished results presented at the International Display Research Conference (EuroDisplay'99), Berlin, Germany, Sept. 1999.

[5] R. Ganter, J. Ouyang, T. Callegari, and J.P. Boeuf, "Physical phenomena in a coplanar macroscopic plasma display cell I. Infrared and visible emission," *J. Appl. Phys.,* vol. 91, no. 3, pp. 992 – 999, Feb. 2002.

[6] A complete movie of the time evolution. [Online]. Available: http://www.plasmadynamics.com.