3D SIMULATIONS OF A SINGLE-SUBSTRATE AC-PDP CELL WITH BARRIER RIBS.

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Abstract

Three dimentional, self-consistent simulations of Ne-Xe discharges in a single-substrate plasma display panel (PDP) cell with barrier ribs are presented. We investigate the influence of the address elec- trode and rib spacing on the spreading and confinement of sustain discharges.

Introduction

Numerical simulations of plasma display cells are becoming a common tool in the quest for the best plasma display parameters. In contrast to experiments performed directly on a panel, simulations can give other insights into the operation of the display and the dynamics of many relevant parameters in time and space, e.g., current density, electric field, and densities of all species present in the discharge. It is often more practical to replace certain expensive or difficult experiments with simulations, or at least to demonstrate an experiment's feasibility before investing the time and expense necessary to carry it out. Other times it is more efficient to explore a parameter space with simulations and use experiments only to validate the simulations.

The PDP cell is a very complex object. Its theory is in a rather rudimentary stage [1], explaining a limited number of features and only in one-dimensional or quasi-one-dimensional geometry. One must also make additional assumptions in order to explain the behavior of multi-dimensional systems from a one- dimensional approach. Although, we often succeed, there are many important problems which require quantitative, rather than qualitative descriptions. Further, it is often very difficult, even in the 1D case, to anticipate the behavior of such nonlinear systems or to analyze the applicability/importance of the assumptions of the model without running the complete simulation, and comparing its results with experiment. We believe that in the future 2D [2] and especially 1D simulations will continue to be very important and widely used tools for simulations of PDPs. However, there are some questions that simply cannot be answered using anything less than three-dimensional geometry. For instance, what is the spatial structure of the discharge between barrier ribs, and how does it behave with time? What is the actual appearance of the discharge from the front of the panel? What is the spatial/temporal distribution of the excitations? And how does efficiency depend on the widths of the electrodes and the distances between them, or the distances between substrates and/or the barrier ribs?

These questions cannot be answered from 1D or even 2D simulations. However, 1 and 2D geometry can be used to help find the correct ranges of parameters and problem specifications before running much more time consuming 3D simulations. In this report we demonstrate some of our recent self-consistent 3D simulation results of a single substrate PDP cell of the type developed by Fujitsu and which is currently used in many AC PDP panels. In all of the simulations considered here, a mixture of 93%Ne + 7%Xe was used.

Physical Model

In our model we include direct ionization by electron impact of the background gas atoms and excited atoms, Penning ionization of xenon atoms by excited neon atoms, Penning-like ionization of excited xenon atoms, when they collide with other excited xenon atoms, collisional conversion of atomic ions into molecular ions. and secondary electron emission by ions and excited atoms. We use 0.03 for the effective secondary electron emission coefficient (ESEC) due to the impact of xenon ions or metastables and an E/N dependent expression [3] for neon. We set the ESEC equal to zero at the sidewalls (barrier ribs) of the cell. All the electron driven rates and electron mobility were obtained using our 0D Boltzmann code.

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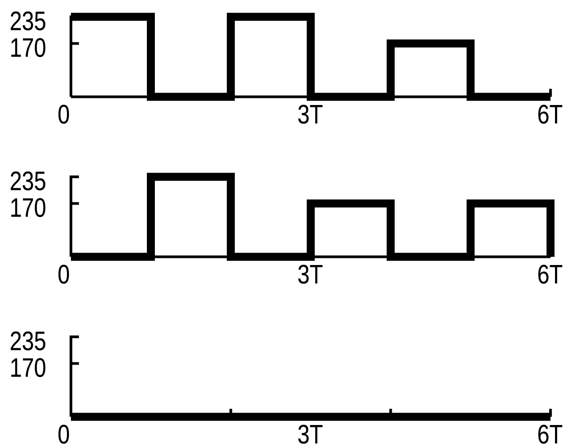

Figure 1. Applied voltage profiles: U_1(top); U_2(middle);U_3(bottom)

Driving Potentials

We fired the discharge by applying a series of 3 high voltage pulses to the sustain electrodes starting with "no charge" conditions. $U_1 = U_{appl}$, $U_2 = 0$, $U_3 = 0$, $t < T$; $U_1 = 0$, $U_2 = U_{appl}$, $U_3 = 0$, $T < t < 2T$; $U_1 = U_{appl}$, $U_2 = 0$, $U_3 = 0$, $2T < t < 3T$. U_{appl} = 235V, T = 5μs. Thereafter, we used 170 Volts for the periodic sustain potentials. The first discharge occurred between the sustained electrode to which we applied the potential Uappl and the address electrode. There was practically no current through the second sustained electrode.

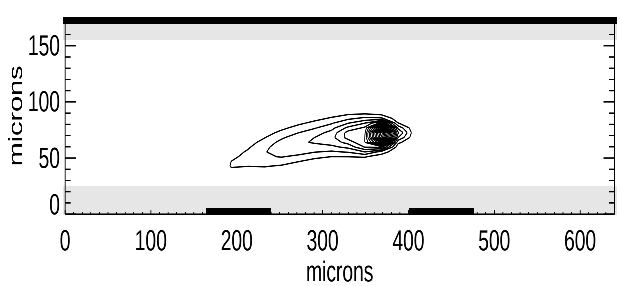

Figure 2. Electron density at t=6.93658E-05 sec

Simulation Results

The electron density during a discharge between the two sustain electrodes is shown in Figure 2. Here, the densities correspond those in a plane cutting along the center-line of the address electrode, and perpindicular to the two sustain electrodes. Although this figure appears typical of data that is obtained from 2-dimensional PDP simulations, there is an important difference. In a 2-D simulation, one could not simulate the discharge between the two sustain electrodes and also include the influence of the barrier ribs and finite width of the address electrode. However, Figure 2 represents a two-dimensional ‘slice’ of data from a three-dimensional, self-consistent simulation in which the barrier ribs and address electrode width are fully accounted for.

Figures 3(a)-(h) illustrate "line-of sight" integrals of the electron densities as viewed from the ’top’ and ’side’ of the discharge during a ‘sustain’ cycle. As noted above, during these sustain discharges, the address electrode does not participate directly in the discharge and the current flows almost entirely between the two sustain electrodes. However, a remnant of the address electrode is clearly seen by the fact that the electron density remains well confined within the region directly below the address electrode instead of spreading out along the sustain electrodes. There are a number of factors which may explain why this is so. For instance, after the initial sustain-address discharge, a localized negative potential is deposited on the sustain electrode immediately below the address electrode. This additional, localized potential causes the following sustain discharge to occur near this region. The resulting discharge remains narrowly confined by its own space-charge fields in a filament along a line joining the nearest point on the opposite sustain electrode to which it deposits charge locally on the second sustain electrode. In this manner, each subsequent sustain discharge deposits charge locally, and directly below the address electrode because the initial discharge took place directly below the address electrode. In addition, the barrier ribs, which run parallel and along either side of the address electrode, also influence the discharge in a manner which serves to further confine the discharge toward the central region and below the address electrode. The thickness of the discharge filament expands and contracts during different phases of the discharge, but seldom extends beyond the width of the address electrode.

In this paper, we will present results of a systematic study of the relative importance of

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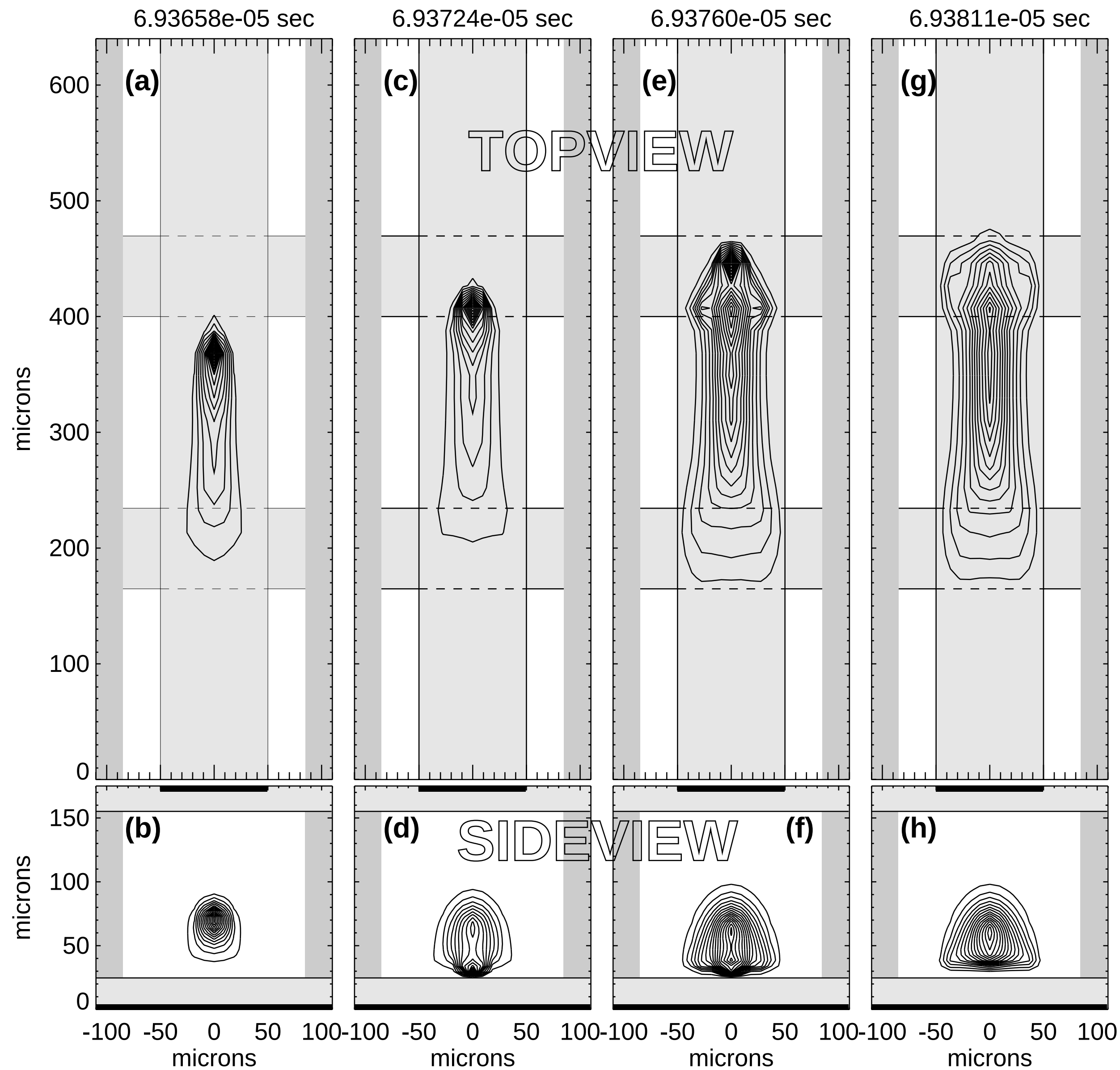

Figure 3(a-h) Line-of-sight electron densities for top and side view at various moments during discharge.

various factors which contribute to the confinement or spreading of the discharge. For instance, by varying the barrier rib spacing and the width of the address electrode. Since the spreading or confinement of the discharge directly affects the effective capacitance of the cell which, in turn, directly affects the dynamics and timing of the discharge, it may be very important to quantify and understand these three-dimensional effects. We also re-emphasize the fact that such investigations are not possible from simulations having anything less than three dimensions.

Conclusions

As far as we know, this work represents the first self-consistent three dimensional simulations of AC-PDPs. As a tool, such simulations offer a means for investigating influences on the discharge by geometrical factors which cannot be addressed from one or two-dimensional analyses.

At the time of this writing, the present work is at a stage where the fundamental testing of the code has been completed and systematic investigations are just begining to get underway. Where

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appropriate, we find our initial results to be qualitatively consistent with the results of 2D simulations. However, there are many features of the 3D representation which have no analog to its one and two dimensional counterparts. For instance, our preliminary data show that the position and width of the address electrode plays a significant role on the geometry and dynamics of a discharge occuring between two sustain electrodes, even though the current to the address electrode is insignificantly small. The subject of our present systematic study is to further quantify this relationship and that of the barrier ribs to the shape and confinement of the sustaining discharges.

References

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