P-57: Striation Phenomenon of Plasma Display Panel (PDP) Cell and Its Application to Efficiency Improvement

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Abstract

The first observation of striation in plasma display panel (PDP) cell by kinetic and fluid simulations is presented. The striation phenomenon in the kinetic simulation is clearer than that in fluid simulation. The striation is due to the self-consistent interaction of plasma, dielectric wall, and applied voltages. Simulation results indicate that the phenomenon occurs due to the non-uniform accumulation of surface charges on the sustain electrodes, which consequently deform the local potential profile. The surface and space charges locally create multiple-tier potential distribution near anode region that makes plasma bunches. The discharge in this region is governed by ionization process, but the cathode discharge depends on the secondary-electron emission process on the dielectric surface. Based on these discharge characteristics, 80 % efficiency increase of PDP cell is obtained due to triggered striation by the modification of front dielectric material and MgO protective-layer.

1. Introduction

Plasma display panel (PDP) has been one of the most promising candidates for the next generation high-definition display devices. Recently, there have been considerable attempts to widespread PDP technology because of its several advantages over the other display devices. Much work has been in progress to enhance the working efficiency of PDP cell in order to be able to supersede other display devices. However there have been several funda-mental as well as technological issues, which need more careful attention to resolve. These include cost reduction, luminance efficiency improvement, power reduction, driving method, discharge efficiency, and others [1]. We here mainly concentrate upon the discharge efficiency of the PDP cell, and explore the phenomenon of striation. The understanding of this phenomenon can help improving the discharge efficiency. Striation has been reported by several experiments [2-4], but not by simulations [5-9].

As the PDP system is very small, it is difficult to diagnose such a system with the help of experiments. Simulation has been the most plausible tool to investigate various processes in the PDP system. It is possible to obtain various plasma characteristics easily from simulations and investigate the striation phenomenon inside the PDP cell. In this report, we present the first observation and explanation of this phenomenon in PDP cell by kinetic simulation method and its application to the efficiency improvement of PDP cell.

2. Simulation

The discharge evolution and striation phenomenon of PDP cell are presented in Fig. 1. The cell structure is based on coplanar geometry and the size of each component is depicted in the figure. Two sustain electrodes are located in the front panel that are covered by dielectric material and one address electrode is located in the rear panel along the x direction. The gap length between two sustain electrodes is 60 μm and electrode length is 400 μm. The applied voltages are respectively 300, 0, 150V for each left, light sustain electrodes and address electrode. The pressure used in this study is 500 Torr. The neutral gas composition is Ne/Xe (96%/4%). We use OOPIC code [9] as a kinetic simulator.

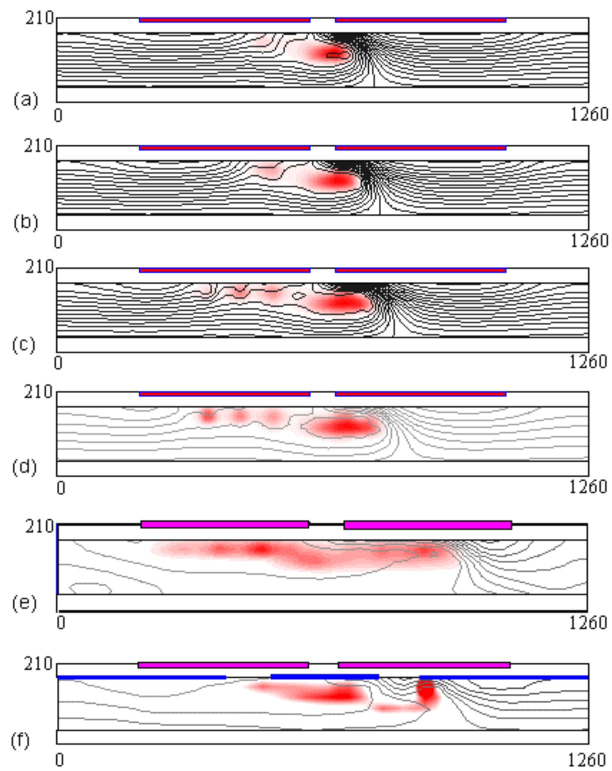

Figure 1. Striation phenomena appearing in the PDP cell by kinetic and fluid simulations

The lines represent equipotential contours and shadings represent density of electrons. The figures are sequentially ordered with time advancement and Figs. 1(c) and 1(d) are results at the same time with different line number and intensity. Figures 1(e) and 1(f) are fluid simulation results. Figure 1(e) shows striation in the fluid simulation with the same condition of Figs. 1(a)-1(d). Triggered striation by modified ITO layer in the fluid simulation is shown in Fig. 1(f). As shown in Figs. 1(d) and 1(e), the striation phenomenon is predominant in the kinetic simulation. The distribution of plasma density bunches occurs along the anode electrode. A wide bunch is located near the inner edge of the anode and extended towards the cathode. The other small bunches are also appeared along the anode

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electrode. The magnitude of density bunches on the anode becomes low from center to the outer edge of the anode, but the sizes of density bunch are nearly the same. The equipotential lines change much on the anode electrode surface with time.

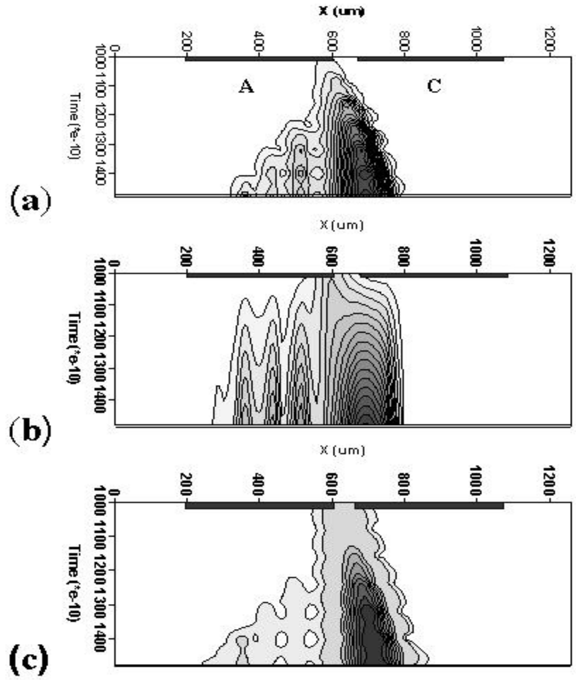

Figure 2. The discharge propagation of (a) electron (b) Xe^+ and (c) Ne^+.

As a quantitative comparison with experimental results of VUV emission spectrum, the time developments of plasma density-contours at 500 Torr are shown in Fig. 2. Figures 2(a)-2(c) are electron, Xe^+, and Ne^+ density-contour propagation with time. We observe that the peaks develop from the anode inner edge to outer edges of electrodes with time. The speed of propagation to the anode side is faster than that of near the cathode side. The propagation speeds of local peaks along anode electrode and that of first peak towards the cathode are compared with experiment [4]. The propagation speeds of peaks and first peak are about 7.80 km/s, 1.35 km/s from the simulation and 7.50 km/s, 2.0 km/s from the experiment. Though the conditions of the system are different, the orders of magnitude show an excellent agreement between simulation and experiment.

The evolution of particle numbers and three-dimensional potential profiles with time are shown in Fig. 3. Figure 3(a) shows the number of plasma particles in the PDP cell with time. The discharge reaches the peak plasma density and starts to decrease. The potential profiles are obtained at the times indicated by arrows in Fig. 3(a). Figures 3(b)-3(d) show potential distributions before number peak. The potential changes considerably near the anode surface. After the number peak [Figs. 3(e) and 3(f)], the potential on the anode dielectric surface is reduced much compared with the applied one at the anode and becomes flat. This indicates that the surface charges on the anode (mainly due to electrons) electrode have a crucial effect in influencing the local potential profile.

The striation mechanism can be explained self-consistently as follows. To begin with, there exists a large electric field between the

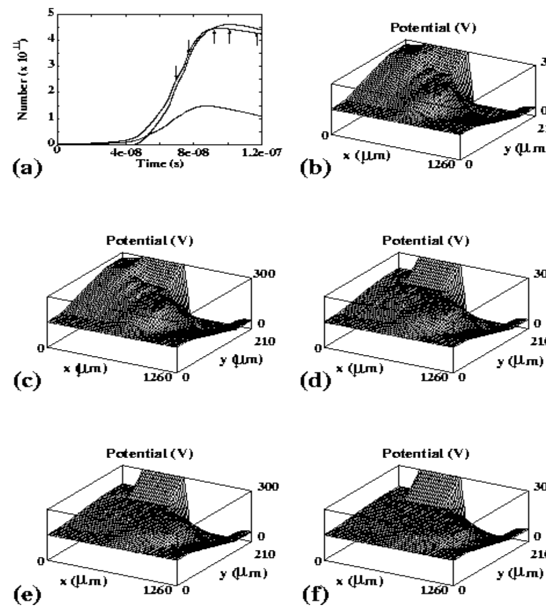

Figure 3. (a) The number trace and (b)-(f) potential changes in the PDP cell with time (the arrows indicate the time of (b) – (f)).

two electrodes, which ignites the nearby discharge by creating electron-ion plasma. The discharge then moves towards the cathode side by the secondary electron emission (SEE) due to ions [Fig. 1(a)]. It persists there for a sufficiently long time as the most dominant bunch of the striation and propagates towards the cathode edge mainly due to the γ–process (SEE) [Fig.3].

However, the discharge on the anode side is governed by the ionization process (α-process) by electrons that response to the potential changes faster than ions. The corresponding time advancement of electron density, surface charge, and potential profiles are shown in Fig. 4. Electrons in the first main bunch are pulled apart towards the anode side under the influence of high

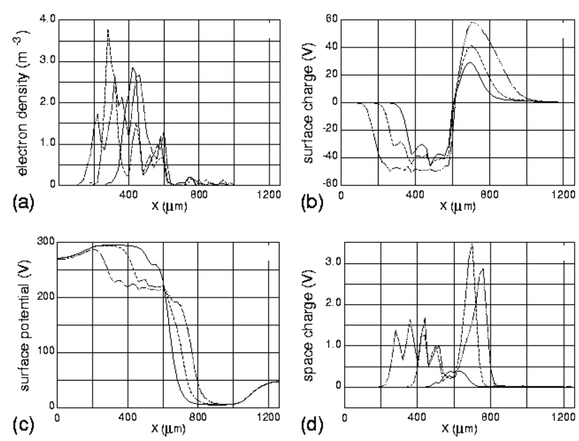

Figure 4. (a) Electrons on the dielectric surface, (b) total surface charge on the front dielectric material. (c) potential on the dielectric surface, and (d) space charge below 20μm from the dielectric surface.

electric field between the anode and the cathode. These electrons then accumulate near the anode (behaving as surface charges), thereby reduce the applied voltage (flattening the potential). Nevertheless, the potential difference between the flattened and applied potential is still higher than the ionization energy of the neutral gas [Fig. 4(c)]. In this high electric field region, electrons gain sufficient energy to ionize the neutral gas and make another bunch. Then the second bunch makes another flat potential region. This process continues in a similar manner till the combination of applied and surface potential becomes low and flat at the local region. The spatial distribution of potential acquires a well-like shape and is sufficient to confine and produce electron species in the space. The surface charge density profile, consisting of several peaks, is shown in Fig. 4(b). As time advances, the surface charge structures follow the plasma density fluctuation in space. This means that the plasma particles respond self-consistently to the combined electric field of applied and surface charge potentials. As surface charge profile changes with time, the space charge potential also follows [Fig. 4(d)].

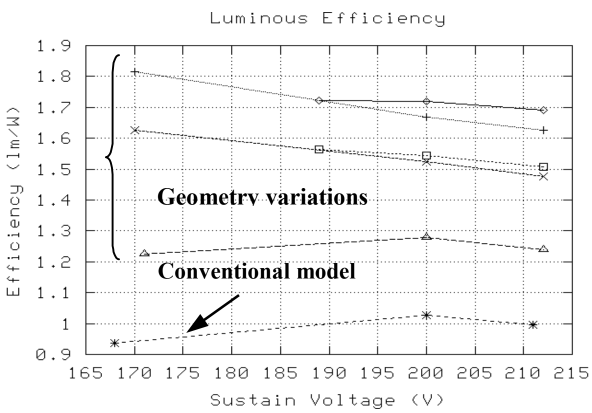

Figure 5. Efficiency for geometry variations

As shown in Fig. 4, the potential-drop moves to the outer side and the difference becomes smaller. Therefore the plasma in the outer side of the cell is dominated by lower electric field, which has higher discharge efficiency. The concept of geometry variation for higher efficiency is to increase the outer electric field by tapering of dielectric constant or dielectric shape. In this kind of variations, plasma is pulled towards the outer side of the cell, where the electric field is still low compared with the center. Because discharge is dominated by lower electric field, the improvement of efficiency is expected. Figure 5 is the efficiency comparisons when the geometry variations is combined with the increase of gap size between the sustain electrodes. The results are obtained by fluid simulations. The combined effect gives more than 80 % increment of efficiency (gap size effect is about 40 % and geometry effect is 40 %). As the E-field in the outer sides of electrodes becomes higher by the dielectric shaping, applied voltages need not be changed with the increase of gap distance.

3. Conclusions

We observed striations in the PDP cell by kinetic simulation. Two different discharge processes occurred in the PDP cell. The propagation speed of these processes was compared well with the experiment. The striation was caused by the self-consistent interactions of plasma, wall, and applied potential as explained by the simulation results. We described the effects of several geometry variations of PDP by fluid simulation. The efficiency of PDP cell was improved by the modifications of dielectric layer and MgO protective layer. The striation become clearer by the dielectric modification and triggered striation occurred by MgO modification. When the increase of electrode-gap and the dielectric variations were combined, more than 80% of efficiency improvement was obtained.

4. References

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