# New PDP cell designs for high luminous efficiency and radiation transport model in PDP

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## Abstract

*Using two- and three-dimensional fluid simulation codes, we have suggested several new plasma display panel (PDP) cell structures that have high luminous efficiency compared with conventional structure. To improve the luminance and discharge efficiency, we utilize long discharge path, lower electric field region, and reduction of power consumption by adding one auxiliary electrode or reducing the electrode area. Consequently, luminous efficiency increases about 1.8 times. Furthermore for the resonance radiation trapping effect in PDP system, we have described a self-consistent radiation transport model coupled with fluid simulation using modified Holstein's equation.*

## 1. Introduction

Plasma display panels (PDPs) have been the prospective candidate for the next generation large screen high-definition (HD) display [1]. PDPs have more advantages than other displays like CRTs, LCDs, and projection displays in the aspect of screen sizes, thickness, weight, and view angle. However, low luminous efficiency on the order of 1~1.5 lm/W is still one of the most important research issues to be solved in competition with CRTs.

PDPs use the ultra-violet (UV) radiation emitted from plasma discharge and visible light. Therefore, to improve the luminous efficiency, it is necessary to investigate discharge behavior and characteristics in the PDP cell. Numerical simulation is a good way to investigate the plasma discharge phenomena in a PDP cell and to analyze the factors for high luminous efficiency. We have developed and used two- and three-dimensional fluid simulation codes called FL2P and FL3P, respectively [2, 3, 4].

There are three methods to improve the luminance and discharge efficiency. One is the induction of arch-shaped long discharge path between sustain electrodes. Another is the utilization of the low reduced electric field region. The other is the reduction of consumed power in PDP system using small area electrodes. For the improved modeling of UV radiation trapping in PDP system, we have described full radiation transport (RT) using modified Holstein's equation instead of using conventional escape factor method [5]. It is very progressive because it is rare to use full RT in previous other PDP simulation codes.

In this study, we first suggest two PDP cell designs with high luminous efficiency. Full RT modeling in fluid simulation and its results are also discussed.

## 2. Numerical model and Simulation conditions

Our fluid model consists of a set of continuity equation, Poisson's equation, and momentum transfer equation with drift-diffusion approximation [2, 4]. The continuity equation and Poisson's equation are solved by using the alternate direction implicit (ADI) method and the successive over-relaxation (SOR) algorithm, respectively. By employing the semi-implicit method, it is possible to use the large simulation time steps with accuracy [4].

A PDP cell is ignited by voltage difference between scan and address electrodes. After ignition of cell, address electrode is fixed to ground (0V) and square wave pulses with 3μs duration are applied to scan and common electrodes alternately. According to the cell design, driving pulses applied to sustain electrodes can be modified. All of simulation results are obtained during the steady state. In simulation of new PDP cell design, 4% xenon (Xe) and 96% neon (Ne) gases are used with the gas pressure 500Torr. The number of grids for numerical calculation is 63×42 for two-dimensional and 41×18×27 for three-dimensional simulation, respectively.

## 3. Simulation results

### 3.1 PDP designs for high efficiency

Usually, even though long gap distance between two sustain electrodes offers the high discharge efficiency with long discharge path, it also gives the rise in driving voltage [6]. To solve this problem, we suggest one-auxiliary electrode structure.

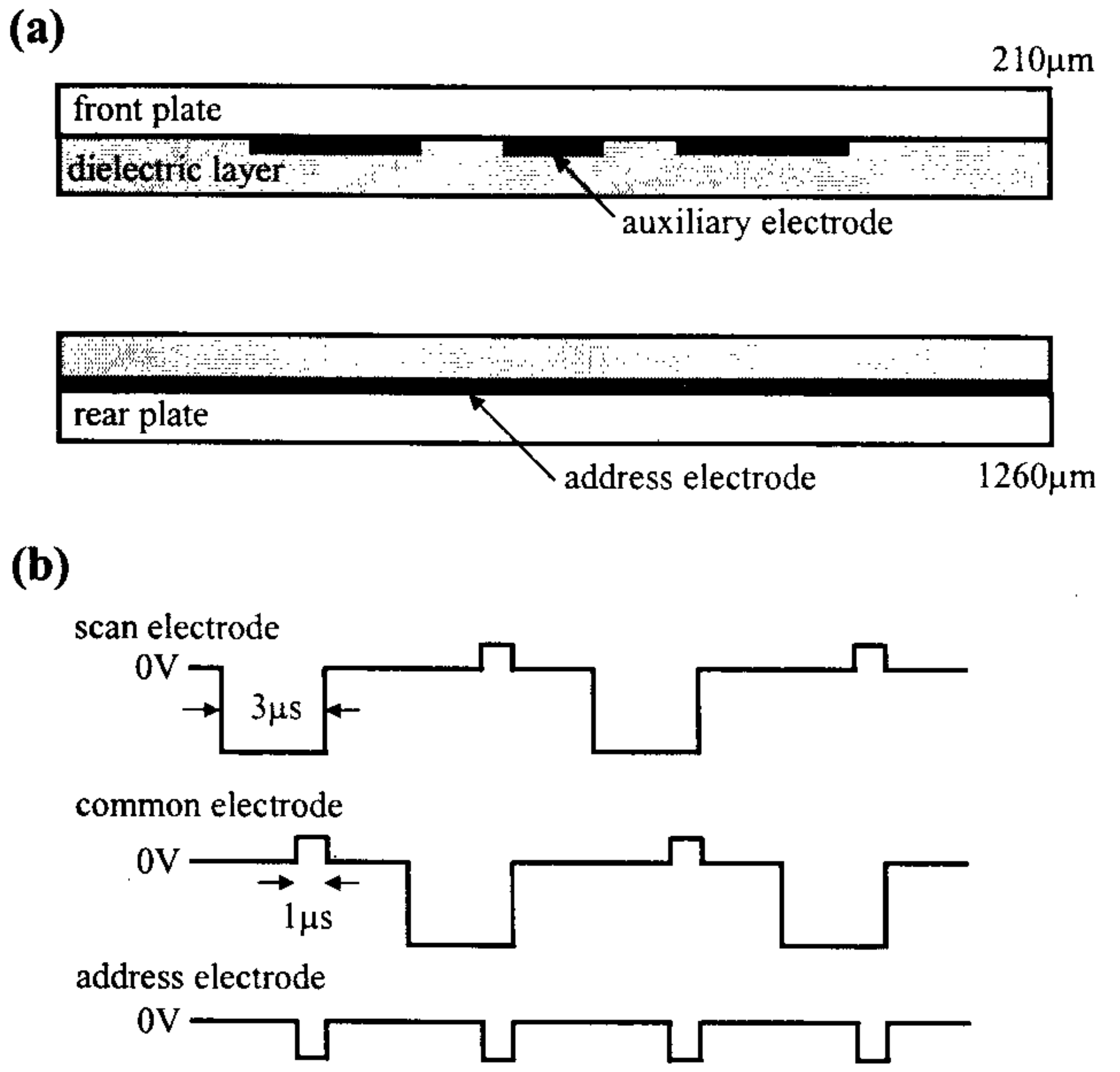


**Fig. 1. (a) Cross-sectional schematics of one-auxiliary electrode model and (b) its driving pulse shape in sustaining period.**

Figures 1(a) and 1(b) show the cross-sectional structure of one-auxiliary electrode model and its specialized driving pulse shape in sustain period, respectively. This model has an auxiliary electrode with small width (100μm) between two sustain electrodes which have wide gap distance about 220~300μm. The roles of this auxiliary electrode are to act like anode at the beginning of discharge and to reduce the firing voltage. Therefore, although the distance between sustain electrodes is long, the distance between anode and cathode is short at the initial time of discharge. To do this, it is necessary to control wall charges on the auxiliary electrode during sustain period using additional pulses on sustain and address electrodes like shown in Fig. 1(b).

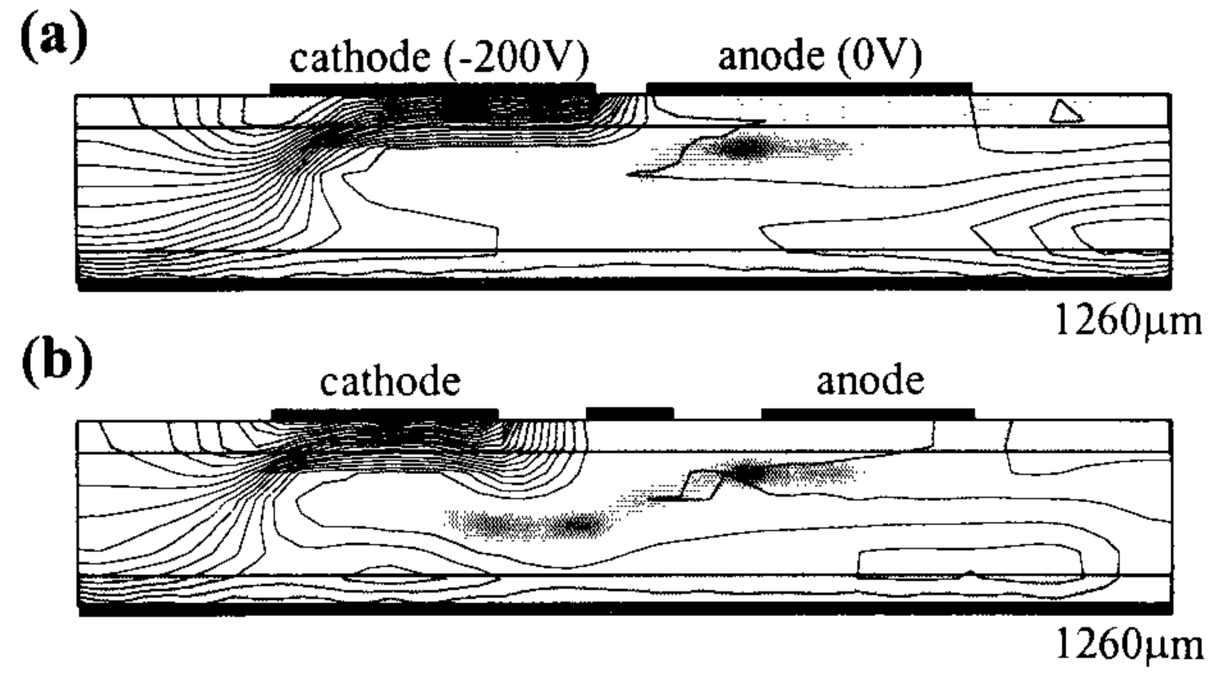


**Fig. 2. Xe*($^3P_1$) density profile and potential contour of (a) conventional model and (b) one auxiliary electrode model.**

Figure 2 shows the Xe*($^3P_1$) density profiles compared with comparison of conventional model and one-auxiliary electrode model at the number peak time. In conventional case, the excitation of Xe atoms occurs along the MgO layer surface horizontally in both anode and cathode side as presented in Fig. 2(a). In one-auxiliary electrode model, on the other hand, we can observe the arch-shaped long discharge path between cathode and auxiliary electrode, in which discharge efficiency is improved and consumed power decreases because long discharge path is related to the wide positive column.

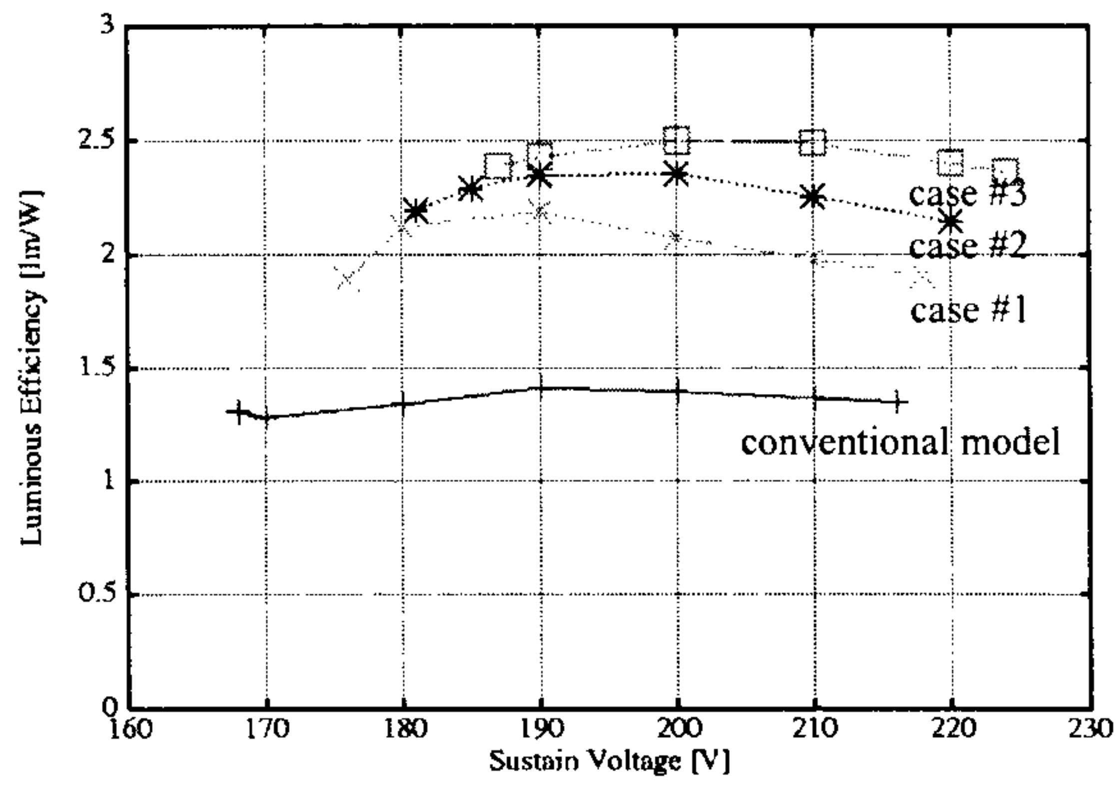


**Fig. 3. Luminous efficiencies of one-auxiliary electrode model and conventional model**

In Fig. 3 we compare the luminous efficiencies of three cases of one-auxiliary electrode model and conventional model. As gap distance between auxiliary electrode and sustain electrodes becomes gradually longer and longer from 60μm (case #1) to 100μm (case #3), luminous efficiency as well as discharge efficiency increases. Due to the long discharge path, the proximity between Xe* density distribution and phosphor layer is increased and the contribution of UV photons emitted from excited Xe atoms can be improved. In case #3 of one-auxiliary electrode model, we have achieved the luminous efficiency improvement about 1.8 times compared with conventional model.

In spite of its fast simulation speed, 2-dimensional fluid simulation has restriction in design of a PDP cell because it cannot consider the 3-dimensional factors, like sustain or address electrode shape, barrier rib, and so on. Recently, to simulate a more realistic PDP cell, we have newly developed a 3-dimensional fluid simulation tool and utilized this code in observing several phenomena in the PDP cell and in optimizing PDP cell for high luminous efficiency [4].

For the comparison with the optimized cells, we first show the simulation results of conventional PDP model. Figure 4(a) shows the top view of the power consumption during one pulse. The excited Xe density and potential contour on the upper dielectric surface are shown in Fig. 4(b) at the number peak and the local discharge efficiency is represented in Fig. 4(c). The local efficiency of anode region is higher than cathode region because most of power is consumed in the cathode region. The conventional geometry does not use the side phosphor effectively because the density peak of the Xe*($^3P_1$), which is optically thick, is far from the phosphor layers on bottom and side barrier ribs.

We have used Π-shaped sustain electrodes as shown in Fig. 5(a) to use side phosphor layer effectively in order to improve luminance efficiency, instead of large area rectangular sustain electrodes like Fig. 4(a). Except electrode shape and length, other geometry factors like gap distance are the same as those of conventional model. In the Π-electrode structure, high plasma density is concentrated near side phosphor as shown in Fig. 5(b). The reduced electrode area not only decreases the power consumption but also divides the discharge into two branches. Each plasma peak density of two branches and driving voltage are similar to those of conventional model. Fig. 5(c) shows the increment of discharge efficiency because the discharge occurs in the center region of anode side where the conductor has been removed. Using this geometry, we have obtained efficiency improvement about 1.8 times.

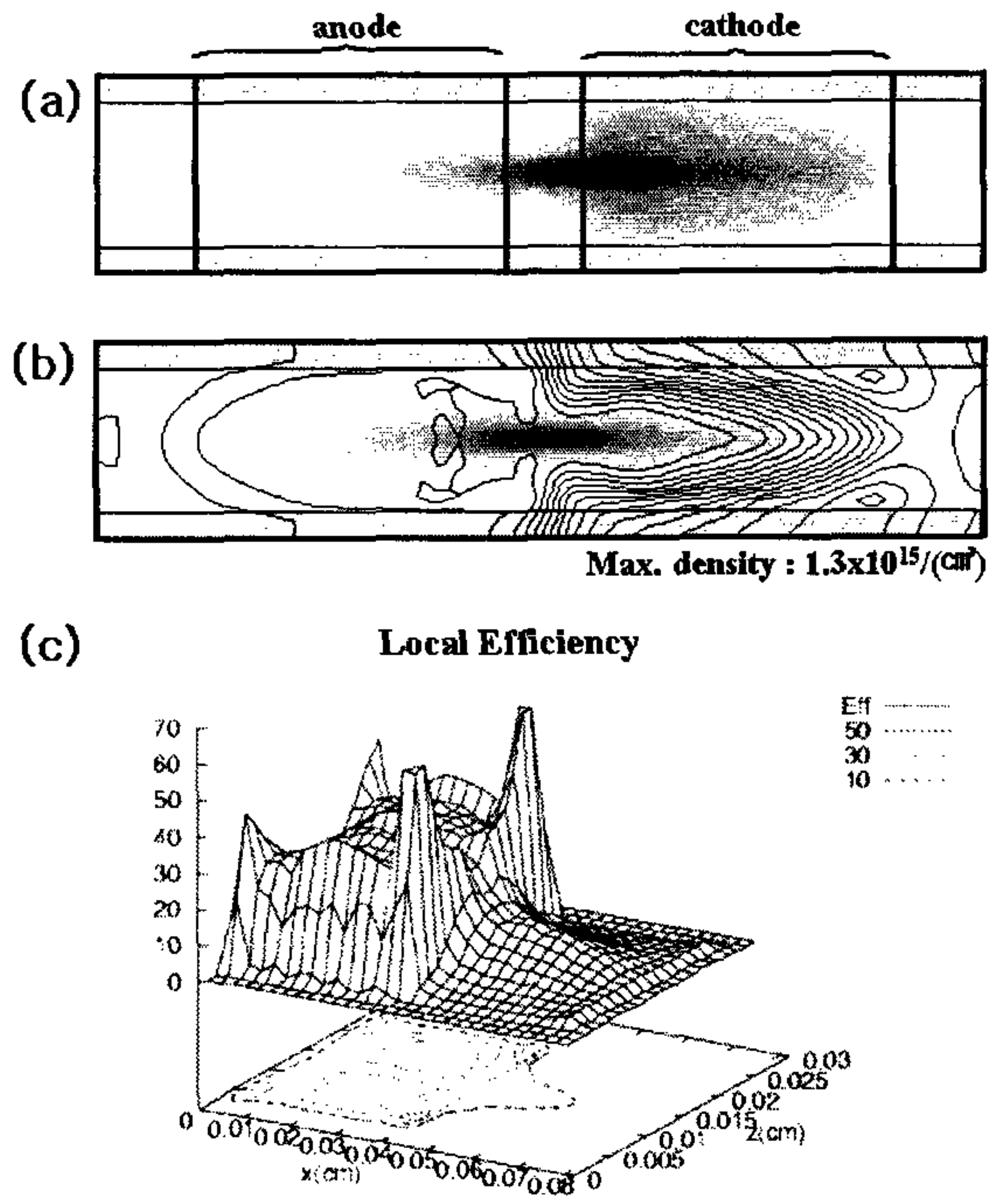


**Fig. 4. In the conventional PDP cell, (a) top view of local power consumption, (b) Xe*($^3P_1$) density profile and potential contour on the upper dielectric surface, and (c) local efficiency.**

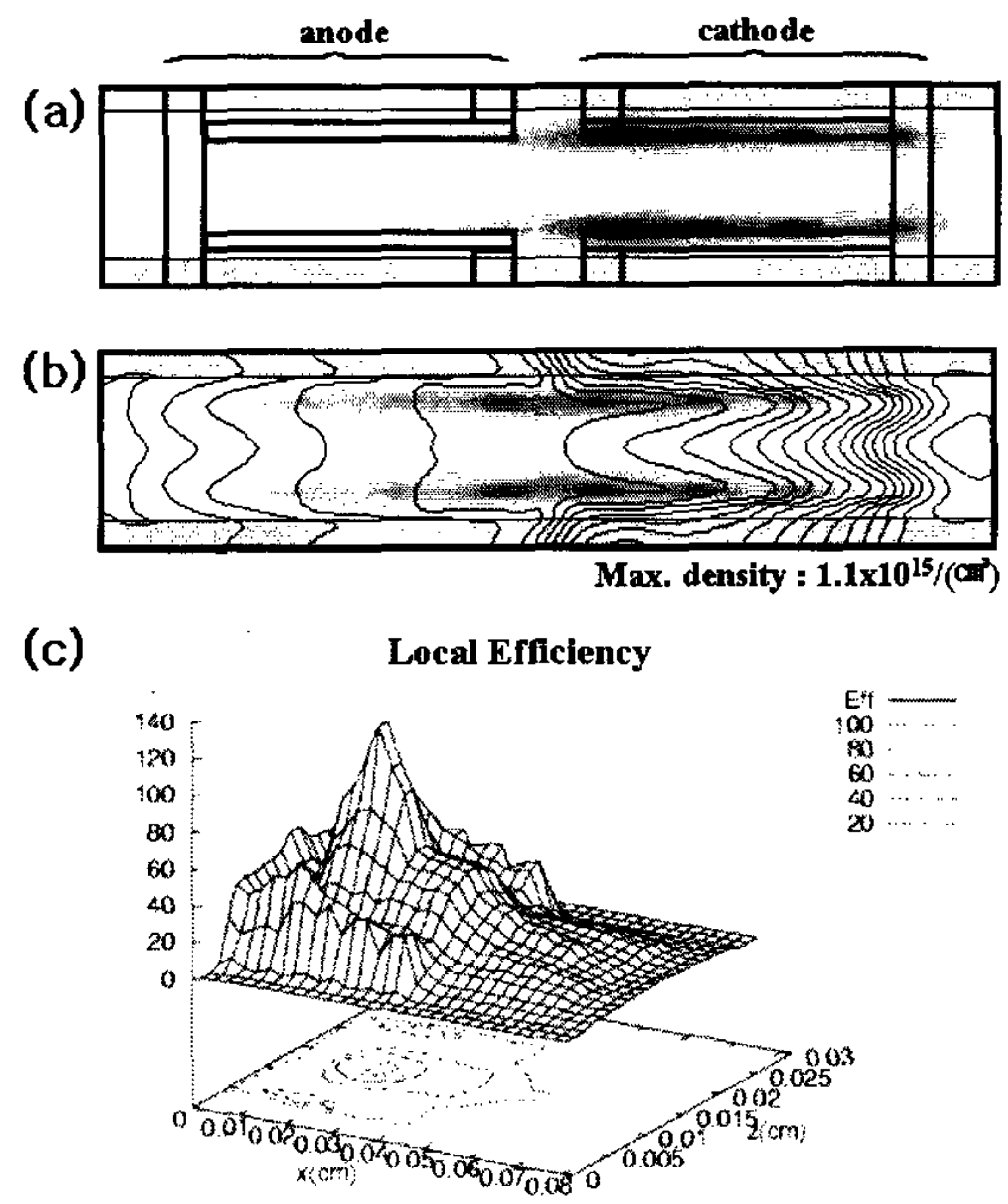


**Fig. 5. In the Π-electrode model, (a) top view of local power consumption, (b) Xe*($^3P_1$) density profile and potential contour on the upper dielectric surface, and (c) local efficiency.**

### 3.2 Radiation transport model

To describe the resonance radiation transport of UV emitted from excited Xe atoms, effective trapping factor method has been used widely because of its simple and quick calculation. However this method cannot treat the redistribution of excited Xe species density and the radiation decay time exactly. In PDP system, especially, 147nm UV emitted from $Xe^*(^3P_1)$ is one of the most dominant UV lines and optically thick. Therefore $Xe^*(^3P_1)$ species undergoes radiation trapping by absorptions and reemissions of resonant UV photons and the redistribution of it is important in PDP system. For the calculation of UV radiation transport in 2D and 3D fluid PDP simulation, we use the modified Holstein's equation

$$\frac{\partial}{\partial t} n^*(\mathbf{r},t) + \nabla \cdot \mathbf{\Gamma}(\mathbf{r},t) = S(\mathbf{r},t) - \frac{1}{\tau_v} n^*(\mathbf{r},t) + \frac{1}{\tau_v} \int n^*(\mathbf{r}',t) G(\mathbf{r},\mathbf{r}') d\mathbf{r}',$$

where $n^*(\mathbf{r}, t)$, $\Gamma(\mathbf{r}, t)$, and $S(\mathbf{r}, t)$ are the resonant state density, particle flux, and the production rate, respectively. $\tau_v$ is the vacuum radiation decay time and $G(\mathbf{r}, \mathbf{r}')$ is the kernel function [5].

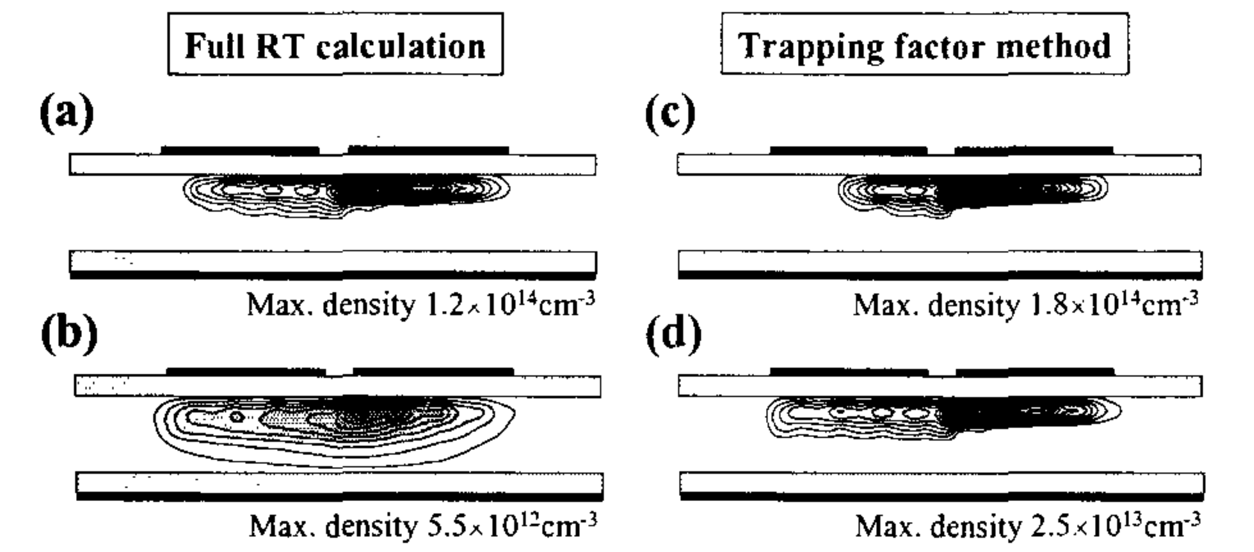


**Fig. 6 Xe*(3P1) density profiles obtained from full RT calculation [(a) and (b)] and trapping factor method [(c) and (d)] at 400ns[(a) and (c)] and 1μs[(b) and (d)].**

Figure 6 is the simulation results that show the difference between full RT calculation using modified Holstein's equation and trapping factor method. Before peak number (Figs. 6(a) and 6(c)), the excitation of Xe by electron impact is dominant. However, after peak number, the decay rate by radiation transport is more significant and $Xe^*(^3P_1)$ density is redistributed as shown in Figs. 6(b). The amount of generation rate of 147nm UV is also increased by full RT calculation.

## 4. Summary

To propose the new PDP structures with high luminous efficiency, we have used 2D and 3D fluid simulation codes. In one-auxiliary electrode model, we have obtained the maximum 80% improvement of luminous efficiency due to the arch-shaped long discharge path using the auxiliary electrode and long gap distance between two sustain electrodes. Also we have achieved 1.8 times efficiency improvement in Π-electrode structure using the phosphor on side barrier ribs effectively. The full radiation transport model was coupled with 2-D and 3-D fluid simulation to incorporate the resonance radiation trapping effect in a PDP cell. The time evolution of the spatial profile of the resonant excited state and the amount of UV generation show the differences between full RT model using Holstein's equation and simple escape factor model.


## 5. Acknowledgements

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## 6. References


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