Investigation of discharge characteristic of Shadow Mask PDP

Yan Tu, Baoping Wang, Xiong Zhang, Lanlan Yang, Jian Zhang, Wei Cui
Dept. of Electronic Engineering, Southeast University, Nanjing 210018, P.R.China

Abstract

The discharge characteristic of a novel AC PDP with Shadow mask (SM-PDP) has been studied with 2-D and 3-D simulations. Compared with the conventional coplanar PDP, the SM-PDP has lower ignition voltage, higher response frequency and higher brightness. It's easy to realize a high definition display while keeping a good performance with the SM-PDP. The discharge process as measured with a fast Intensified CCD (ICCD) compares favorably with the simulation results.

1. Introduction

Plasma display panels (PDPs) are a promising technology for large area flat panel display. Although PDP technology has many advantages, such as high brightness, high contrast, wide viewing angle and rather long lifetime, properties such as cost, power consumption and luminous efficacy need to be improved. Today most manufacturers adopt the surface discharge AC Coplanar PDP structure (ACC PDP). A dielectric material is used as a barrier rib between the cells. However, it is difficult to make thin ribs with dielectric materials having equal height and width in large area in ACC PDP. This may cause low yield in manufacturing and, hence, it increases cost. It is also difficult to make fine pixels in the vertical direction for improving the definition due to the limitation of the width of scan electrodes and common electrodes. As the addressing discharge spaces are formed by subdividing the substrate with the barrier ribs, the limited uniformity of the height of the dielectric barrier ribs for the whole panel makes the cost and power dissipation of the drive circuits high. These problems can be improved or solved by using the novel SM-PDP invented by Southeast University [1]. The biggest difference between the SM-PDP and a conventional ACC PDP is that a shadow mask is used for the barrier ribs instead of a dielectric material. This brings many benefits, such as lower firing voltage, high response frequency, good uniformity, lower cost and longer lifetime. Furthermore, high resolution can be realized easily with the SM-PDP architecture.

Since the SM-PDP is a new structure, a detailed investigation is necessary and important. It is difficult and expensive to do experimental research because the discharging cell is very small and the discharge process is very fast. Numerical simulation has some advantages in this case, since the effect of various parameters can be studied systematically. Many numerical simulation models of PDP discharge have been developed over the last few years and have been of help to guide the optimization of PDPs [2, 3, 4]. A detailed simulation study on the discharge characteristics of the SM-PDP will be presented in this paper.

2. Calculation model

2.1 Description of the structure of the SM-PDP

Figure 1 shows the panel structure of the SM-PDP. The front and rear plates are almost identical with that of a normal ACC PDP. Parallel scan electrodes, composed of transparent electrodes and narrow metallic bus electrodes are applied to the front glass substrate. The address electrodes, which are orthogonal to the scan electrodes, are applied to the rear glass substrate. A dielectric layer is formed on these electrodes and an MgO protecting layer is evaporated on the dielectric layer. Tri-primary color phosphors (Red, Green and Blue) are printed on the inner surfaces of the shadow mask.

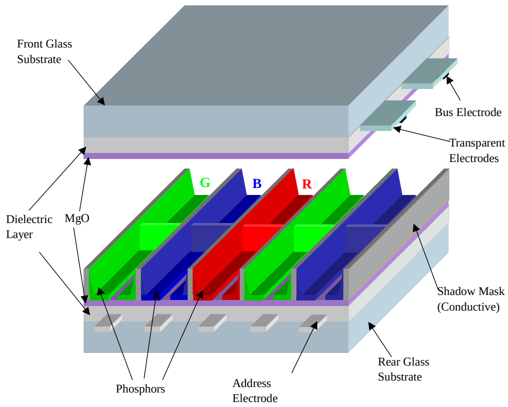


Figure 1 Panel Structure of SM-PDP

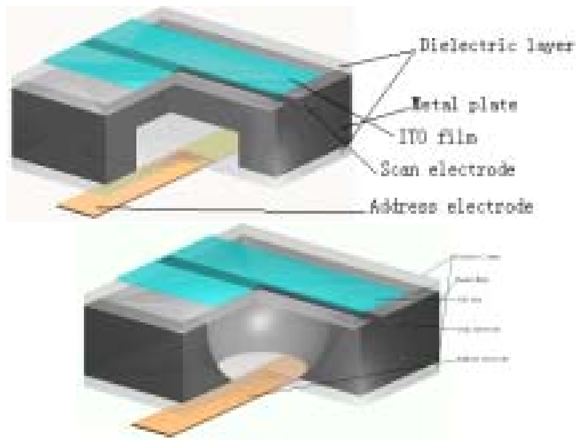


Figure 2 Cell structure of SM-PDP

Fig.2 shows the structure of one discharge cell of the SM-PDP. Because of the presence of the metal shadow mask, the field strength near the corners increases and the discharge becomes easier than that in the conventional coplanar PDP. Different discharge performance can be obtained with a different structure of the discharge cell. The symmetry properties of the cell are used in the simulation model in order to save computational efforts. For example, cylinder coordinates are used for a rotational symmetric structure. This makes the calculation much easier [5].

2.2 Physical model

We have used a fluid model for the plasma in our study. The calculation model consists of the three moment equations for the transport of electrons, positive ions and neutral particles. Furthermore, we use Poisson's equation for the electric field with appropriate boundary conditions. The local electric field approximation model (LFA) is adopted. It has been found that this approximation is sufficient to describe the discharge process in a PDP-cell [3]. The continuity equations and the momentum transfer equations in the drift-diffusion approximation for electrons, positive ions and neutral particles are written as follows

$$\frac{\partial n_p}{\partial t} + \nabla \cdot (n_p \vec{v}_p) = S_p \qquad (1),$$

$$n_p \vec{v}_p = \pm n_p |\mu_p| \nabla V - D_p \nabla n_p$$

where n_p is the density of particle p, $\mathbf{v}_p$ represents the mean velocity of particle p, S_p is the production rate for particle p and μ_p is the mobility or drift coefficient of particle p. They are functions of the reduced electric field E/P, where P is the total pressure in the cell. For neutral particles, the drift coefficient is equal to zero. For electrons and positive ions, the drift coefficient is negative and positive respectively. The coefficient D_n is the diffusion coefficients of particle p. It is determined by Einstein's equation.

$$\frac{D_p}{\mu_p} = kT_p \qquad (2),$$

here p indicates electron and positive ions, k is Boltzmann's constant and T_p is the temperature of the particle p. The diffusion coefficient of neutral particles is equal to that of the corresponding positively charged particles.

Equation (1) and (2) are coupled with Poisson's equation

$$\nabla \cdot (\nabla V) = -\frac{e(n_p - n_e)}{\varepsilon} \qquad (3),$$

where e is the charge of an electron and ε is the permittivity.
A Monte Carlo model is used to describe the radiation and absorption process of resonance photons [6,7] in our study. The distribution of photons on the phosphor layer in discharge cell is calculated.

3. Simulation results

3.1 Addressing process

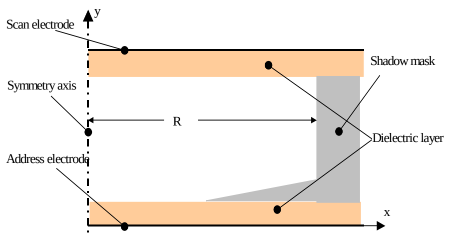


Figure 3 Cross section of discharge cell

The discharge characteristics in the addressing period are calculated first. During the addressing period, a negative voltage pulse is applied to the scan electrodes, one by one, while a positive data pulse is applied to the address electrodes according to the video input signal. A 2-D calculation has been done to visualize the addressing process. The cross section of the discharge cell is shown in Figure 3. Only one half-cell is considered in the calculation because of the symmetry of the structure.
Figure 4 shows the discharge process in addressing period. Different from normal ACC PDP, the shadow mask causes an extremely non-uniform electric field in the discharge space, i.e. the electric field is stronger at the edge of the shadow mask holes while weaker at the center than in the case of normal non-conductive barrier ribs. For active pixels with addressing pulses, ignition happens easily at the edge because of the strong electric field there. Then, charged particles move rapidly to the center to induce the opposed discharge as shown in Figure 4. After the address discharge, wall charge is built up on the surface of dielectric layers according to the input signal. So, the discharge characteristic in SM-PDP is that it's a kind of non-uniform opposed discharge.

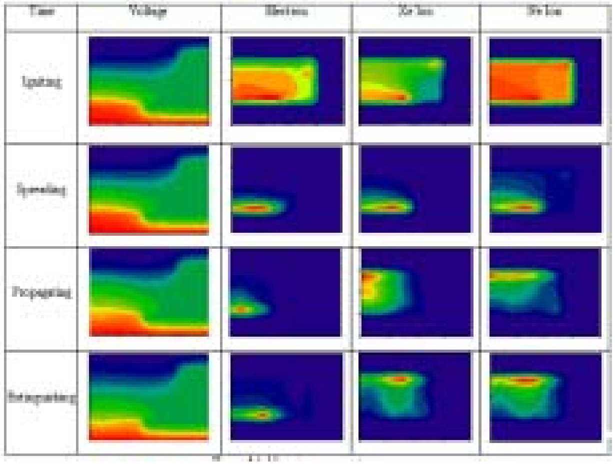
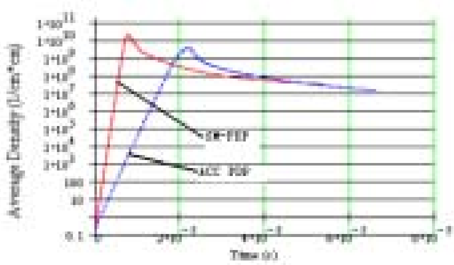


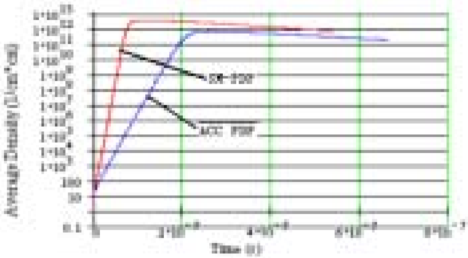
Figure 4 Addressing process of SM-PDP

3.2 High response frequency

As the metal shadow mask has been introduced into the discharge space, the discharge becomes a non-uniformity field discharge. The simulation results show that the SM-PDP has an advantage of higher speed address as shown in Figure 5. With the same address voltage, the ignition of an SM-PDP is much faster than that of an ACC PDP because of the stronger electric field caused by the conductive shadow mask. A 1.5 μs addressing speed is realized in our 34" and 25" SM-PDP panels.



(a) Electron



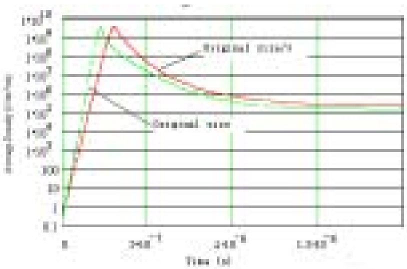
(b) Resonant Xenon

Fig.5 Comparing of discharge between SM-PDP and ACC PDP (With same addressing voltage)

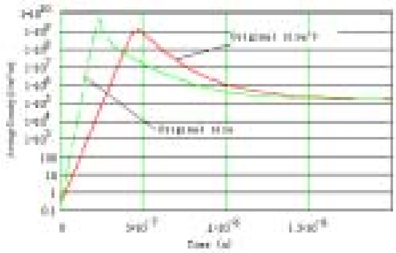
3.3 High resolution

Another advantage of the SM-PDP is that it is easy to manufacture a high resolution display because of the availability of high resolution shadow masks.

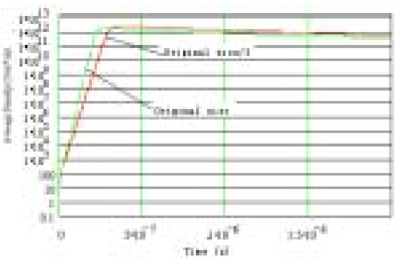
In order to investigate the influence of the cell size on the discharge, the dimensions of both SM-PDP and ACC PDP cells are reduced three times while keeping the height unchanged. The variation of average densities of electron and xenon resonance for SM-PDP and ACC PDP is given in Fig.5.



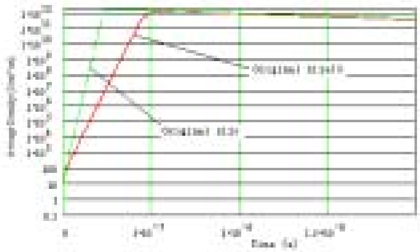
(a) Average density of electron in SM-PDP



(b) Average density of electron in ACC PDP



(c) Average density of xenon resonance in SM-PDP



(d) Average density of xenon resonance in ACC PDP

Figure 5 Variation of average density of electron and xenon resonance as the cell size reduced

The discharge is getting weaker when the size decreases for both SM-PDP and ACC PDP. However, the variation for the SM-PDP is much less than that for the ACC PDP. This means that the discharge behavior of a SM-PDP is less affected by the size of the discharge cell in certain range. In other words, good discharge performance can be realized easily with an SM-PDP at high resolution or for small size displays, which have a smaller pixel size.

Table 1 Photon on phosphor in SM-PDP and ACC PDP

Structure	Shadow mask (%)	ACC PDP (%)
Original size	53.58	51.4
Original size/3	65.00	47.6

The photon distribution in the discharge cell is also calculated. Table 1 shows the UV-photons (%) hitting the phosphor layer in the SM-PDP and ACC PDP when changing the size of cell. It can be seen that as the size reduces, the photons hitting the phosphor layer increase for SM-PDP and decrease for ACC PDP. Hence, the efficacy will be better in an SM-PDP than that in an ACC PDP for high resolution.

3.4 Influence of the width of scan and address electrode

The influence of the width of scan and address electrode on the discharge process has been investigated with 3D simulation. Fig. 6 shows the variation of the maximum average density value of electron with the width of the scan and address electrode. It can be seen that the maximum average density values of electron increase as the width of the electrodes increases. This is caused by the increase of the electric field.

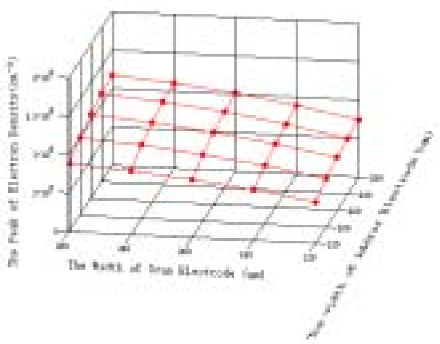


Fig.6 The Maximum Average Density Value of Electron

Fig.7 shows the variation of discharge efficiency with the width of scan electrode and address electrode. When the width of electrode changes from 120µm to 200µm the efficiency increases 3.1% and when the width of electrode changes from 200µm to 280µm the efficiency increases only 0.8%. In other words, the discharge efficiency increases as the width of electrode increases at first and then gets saturated. This means that the width of the scan and address electrodes should be selected properly to get high discharge efficiency.

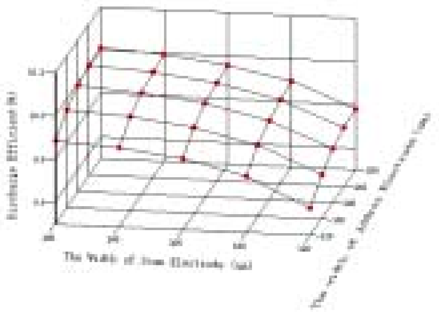


Fig.7 Discharge Efficiency of an SM-PDP Cell

3.5 Discharge process of SM-PDP obtained by ICCD

The discharge process in sustain period of 25″ SVGA800×600 SM-PDP has been studied with an Intensified CCD (ICCD). Simulation calculations have also been done to allow comparisons. Fig. 8 shows ICCD-images (λ=828 and 823nm) at different times. Since the real PDP has a slotted cell structure, the images taken by the ICCD look a little bit elliptical. It can also be seen that the IR picture looks similar to the opposed discharge process.

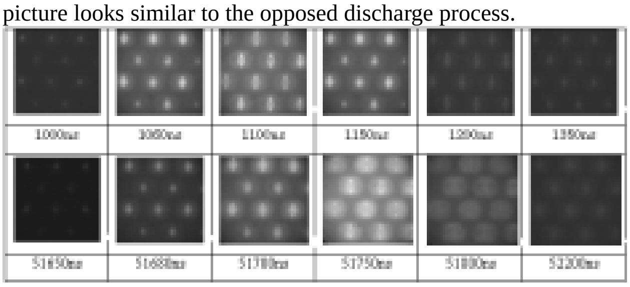


Fig. 8 Discharge process of 25" SM-PDP measured with ICCD

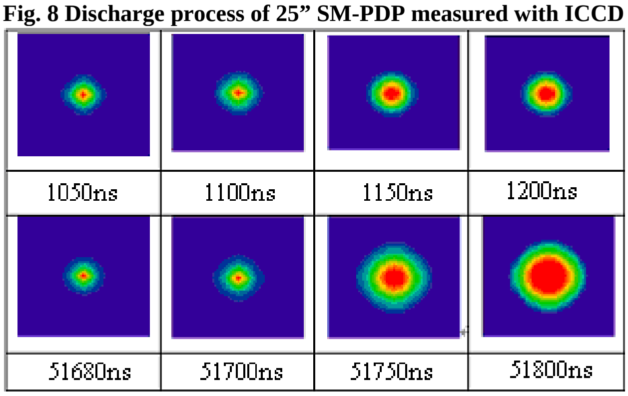


Fig. 9 Discharge process of 25" SM-PDP obtained by simulation

Fig. 9 shows the discharge process of 25″ SVGA800×600 SM-PDP obtained by simulation. The discharge processes obtained by ICCD and simulation agree nicely with each other.

Here the discharge starts at 1000ns and 51650ns, the average density of electrons arrives at maximum at 1100ns and 51700ns. The average density of electrons begins decrease at 1150ns and 51750ns, see Fig.10.

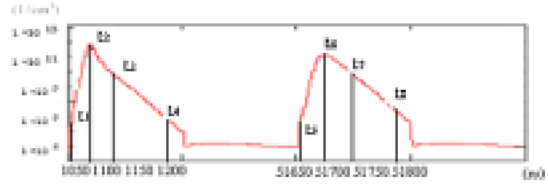


Fig.10 Variation of average density of electron with time

4. Conclusions

The discharge characteristic of the SM-PDP has been investigated using 2D- and 3D-simulations. The results show that the discharge process of the SM-PDP is similar to opposed discharge with non-uniform field. The ignition of an SM-PDP is much faster than that of an ACC PDP. It is rather easy to manufacture high resolution displays and get a good performance with SM-PDP. The width of the scan and address electrodes should be selected properly to get high discharge efficiency. The discharge phenomena obtained by simulation and measured with a fast ICCD match nicely.

5. Acknowledgements

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6. References

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