37.1: A 31-in.-Diagonal Full-Color Surface-Discharge ac Plasma Display Panel

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ABSTRACT

A 31-in.-diagonal full color ac-plasma display panel was made in experimental basis. This used a reflection-type three-electrode surface discharge technique. A 64 gray level full color TV image is achieved. A display capacity is 640x480 pixels . A pixel pitch is 1.0 mm. A sub-pixel pitch is 0.5 mm. The white peak area luminance is 64 cd/m2 at the sustain frequency of 30 kHz.

OBJECTIVE AND BACKGROUND

The full color ac plasma display has now reached at a practical stage beyond a trial stage because a three color plasma display panel has already been mass produced in 1990. (1) Since in 1966 when the AC-plasma display was invented, it have been studied and manufactured in many laboratories and companies. In the late 1980s the mass production of 640x480 or 640x400 PDPs was started for computer terminals. Now the plasma displays and liquid crystal displays are the main flat display devices. Furthermore, color plasma displays become a most expected device to realize a direct-view wall hanging HDTV due to features such as a simple process appropriating to make a large panel, a good display quality because of self emitting, a quick response ,and a wide viewing angle . We have been studying the color plasma display, i.e. presenting a full dot color plasma display with the surface discharge ac plasma display in 1980 and inventing the three electrode type surface discharge plasma display panel and succeeding to produce the commercially available three color display for stock market in 1990 with the reflection-type three-electrode surface-discharge (RTSD) technique. (2),(3) Although the application of the product was restricted to a special application , or a stock exchange display , it was necessary to satisfy the demands such as high luminance ,long life, i.e. more than 10,000 hours , high reliability , and stability which are the main subjects to be solved for realizing the HDTV. As a result, technical innovation which promises a larger size wall hanging TV than a 20-in.-diagonal display was performed. Our next subjects were realization of color TV technology and of a large size display technology. The color TV image with surface discharge ac plasma displays has already been demonstrated by Mr. Yokozawa with a 128 level gray scale on a 5 inch plasma panel.(4). However, there is no report on demonstrative proof of realizing a 256 gray scale on ac-plasma display panels with 1000 horizontal display lines. In the conventional sub-field method , a very high driving frequency is needed. But, this method is not appropriate for an ac-plasma display due to the response time, life ,power consumption, and driving component.

In this paper, we propose a new driving technique for gray scale and demonstrate a color TV image on a 31 inch diagonal panel to show the possibility of realization of HDTV with the device.

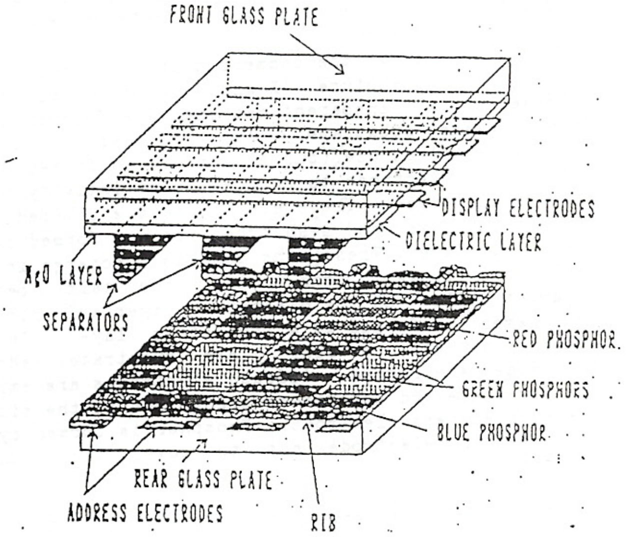


Fig. 1 Panel structure of 31-in.-diagonal PDP

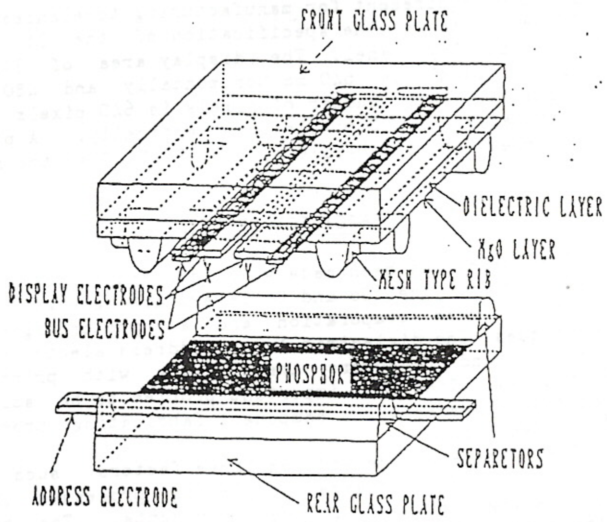


Fig. 2 Panel structure of comercially available 3-color PDP.

PANEL STRUCTURE AND SPECIFICATION

The structure of the experimental 31-in.-diagonal panel is different from the commercially available three color panel in some details. Figure 1 shows the experimental panel structure. The pair of display electrodes, X and I, are formed on the front glass substrate. These electrodes are made of a Cr-Cu-Cr multi-layer. These are covered by dielectric layer. The separators are formed on the dielectric layer perpendicular to the display electrodes in order to isolate the discharge coupling between adjacent cells. These are covered by a MgO layer.

On the other glass substrate, the rear glass, the address electrodes are formed. The mesh type ribs are formed on the electrodes. Phosphors are formed in the mesh type rib. The phosphor materials are Zn_2SiO_4:Mn for green, $(Y.GA)BO_3$:Eu for red, $BaMgAl_{14}O_{23}$:Eu for blue, respectively. Gap between two substrates are about 100um and a Ne+Xe gas mixture is filled in this space.

Figure 2 shows the commercially available three color panel structure. X and Y display electrodes composed of a transparent material are formed on the front glass substrate. An auxiliary Cu-Cu-Cr multilayer electrode (bus electrode) is formed on the transparent electrode to reduce the resistivity of the display electrode. These electrodes are covered by a dielectric layer and mesh type ribs are formed on the dielectric layer. These ribs confine discharge in each cell and prevent from color cross-talk between adjacent cells. On the dielectric layer and ribs, a MgO layer is formed as a protecting layer. On the other substrate, a rear glass substrate, address electrodes are formed. Address electrodes are exposed to gas space and separators are formed at the side of the each address electrode. Phosphor is formed by the side of an electrode not to cover the address electrodes.

The difference between the 31-in.-diagonal panel and the commercially available panel is as follows.

1. The display electrodes are made with opaque metal materials in the 31-in.-diagonal panel since they are patterned much easier than transparent materials for experimental panel.

2. To realize a higher resolution than the three color panel, the structure in which the address electrodes are covered by phosphors is introduced to relax the requirement for manufacturing torelances.

Table 1 shows the specification of the 31 inch plasma display panel. The display area of 31inch diagonal panel is 640 mm horizontally and 480 mm vertically. The number of pixels is 640 pixels for horizontally and 480 pixels for vertically. A pixel is formed with 4 sub-pixels, i.e. RGBG. Then the sub-pixel pitch is 0.5 mm.

	SPECIFICATION
Display Area	31.5 in. (640 mm x 480 mm)
Number of pixels	640 H x 480 V
Number of sub-pixels	1280 H x 960 V
Pixel pitch	1.0 x 1.0 mm
Sub-pixel pich	0.5 x 0.5 mm
Sub-pixel arrangement	RGRG GBGB
Panel thickness	6 mm
Area luminance (White)	65 cd/m² (29 kHz)
Contrast (Dark room)	> 40:1
Gray scale	64 levels (With dither) 16 levels/pixel (4 sub-fields)
Driving voltage	Sustain 160 V Address 80 V
Power consumption	250 W typ.

Table 1 - Specification

FABRICATION PROCESS

The panel has been made with thin and thick film technologies. The Cu and Cr layers are made with an electron beam evaporation and a photorithgraphy techniques. The dielectric layer, address electrodes, ribs and phosphors are all made with printing technology. The most important problem to be solved was the tolerance while component fabricating process and assembling.

The torelance depends on three factors such as panel structure, change in firing processes, and fabricating process of the components. The both structures that electrodes are covered by phoshors and that mesh type ribs are formed on the electrodes are introduced to relax the tolerance required of the phosphor fabrication process. The glass substrate of soda-lime float-glass is pre-fired before any processes to reduce the deformating shrinkage in the following firing processes. Particular attention is paid to the printing process. To reduce the extension of the screen mask while printing, a specific printing mask was adopted.

These process techniques are usually used for the conventional mono-chrome AC-plasma display panels. In our panel structure address electrodes and phosphors are all made with thick film printing technology. And as the display electrodes are made with photolithgraphy, the deviation in discharge gap between display electrodes is less than 5 um which means that the discharge gap uniformity is kept easier than the double-substrate conventional AC-PDP. (5) As mentioned, the RTSD-PDP is an appropriate device for a large color display as same as the conventional double substrate AC-plasma display panels.

PRINCIPLE OF DRIVING TECHNIQUE FOR GRAY SCALE

One of the important subjects of the ac-plasma display panel is to realize a TV display. There was an opinion that as an ac plasma display panel requires wide operating pulses for accumulating wall charges to have an inherent memory function, it was difficult to realize a 256 level gray scale for HDTV. In the 31 inch color plasma panel , we adopted a new driving technique which promises a 256 level gray scale for HDTV.

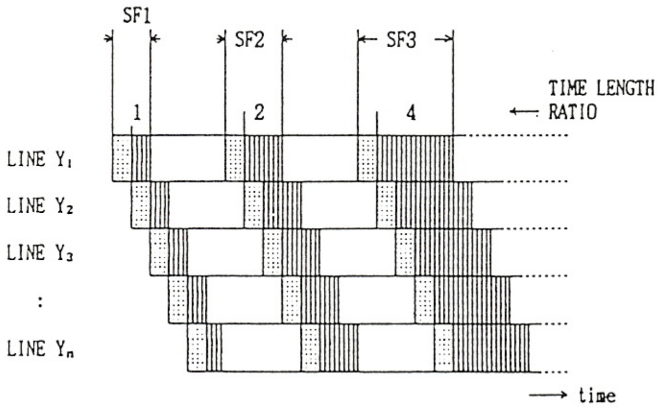
Figures 3.a and 3.b compare the conventional methods and new one. In the conventional gray scale method, a frame is divided 8 sub-fields and the number of emitting light pulses in the sub-fields are changed as 2,4,8,16,32,64,128 , and 256 times , individually. In the case of driving a panel with 1000 horizontal lines , one line has to be addressed in 2 us. Or, if the panel is divided in two parts, one line has to be addressed in 4 us. In the conventional driving method, a set of write, sustain , and erase pulses is in a sub-field and the horizontal lines are sequentially addressed with the set of pulses. And the number of sustain pulses in the individual sub-fields is decided corresponding to the intensity level. Then the driving technique with very high frequency is required. It is well known that introduction of He + Xe gas realizes a very quick response, more than 500 kHz (6), however, from the view point of practical use, problems of life, power consumption , and driving components, i.e. IC, can not be solved soon.

Then, we introduced the new driving technique as shown in fig. 3b. Although a frame is divided 8 sub-fields as same as a conventional method, the way to address pixels is different. In this method, the wall charges are formed preliminary in the pixels corresponding to the display data on the full display area at first , and then sustaining pulses are applied to full display area to display. The number of sustaining pulses is changed corresponding to the intensity of the sub-field. With the driving technique, we can address very first and display with a low sustaining frequency. This technique eliminates the problems for realization of full color TV such as power consumption by both of gas-discharge, charge and discharge current due to capacitance, and life.

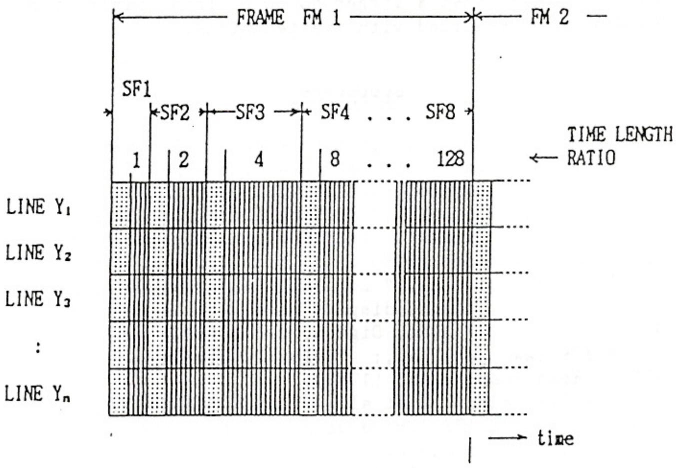
In the case of the 31 inch color plasma display with 960 horizontal lines, we realized a 16 level gray scale. A TV image corresponding to a 64 level gray scale are realized by applying both a 16 level gray scale per sub-pixel and dithered methods . The refresh rate is 60 Hz. The addressing speed per line is 3 us. The corresponding sustaining frequency is about 30 kHz.

	15 in.	20 in. (3colors)	31 in.
Number of pixels	320x240	110x56	640x480
Number of sub-pixels	640x480	330x224	1280x960
Pixel Pich(mm)	1.0x1.0	2.4x3.0	1.0x1.0
Sub-pixel pich (mm)	0.5x0.5	0.75x0.8	0.5x0.5
Area luminance (cd/m²)	24 (White) (20kHz)	73 (White) (12.5kHz)	65 (White) (30kHz)
Spot luminance (cd/m²)	R: 41 G: 91 B: 19 (20kHz)	158 268 —— (12.5kHz)	135 300 50 (30kHz)

Table 2 Electro-optical characteristics of color PDPs



(a) Conventional method



(b) New method
(Address Display period separated sub-field method, ADS-sub-field method)

Fig. 3 Driving method for gray scale

CHARACTERISTICS

Table 2 shows the electro-optical characteristics of the experimental 15-in.-diagonal transmitting type three-electrode surface-discharge (TTSD) panel which was presented at the Japan display '89 held at Kyoto, commercially available 20-in.-diagonal RTSD-panels, and the 31-in.-diagonal RTSD-panel . The maximum area luminance of the white color is 65 cd/m2 for the 31-inch panel which is twice as high as the 15-inch panel, but about half of 20 inch panel. Since a pixel is composed with four sub-pixels in which each RGBG phosphors are arranged in 31-in.-diagonal panel, white color is realized with reducing the luminance of green color to half. The pixel luminance of red , blue, and green colors are 135 cd/m2, 64 cd/m2, and 300 cd/m2, respectively. As the driving frequency is 28.8 kHz, it belong s to the highest luminance level comparing to the conventional panels. The luminance should be increase comparable to the 20 inch panel if we adopt the transparent materials for display electrodes in a practical panel.

Photograph 1 shows the sample display. The 64 level gray scale TV image is shown.

CONCLUSION

This paper describes the experimental 31-in.-diagonal surface discharge color ac-plasma display panel with 640 x 480 full-color pixels . The panel is so called reflection type. The 64-level gray scale TV image is demonstrated on the panel. A new driving technique is proposed and adopted to realize a high speed addressing which promises 256 gray scale on a large size plasma display with 1000 horizontal lines. And the new driving technique has advantages not only of the possibility of the 256 level gray scale but also of reducing the sustaining frequency which solves the problems of power consumption and life. The peak area luminance of white is 64 cd/m2 at the sustaining frequency of 30kHz. The results means that the larger size color panel have almost same characteristics as small and medium size color plasma display panels, and we confirmed that a larger 50 to 60 inch panel for HDTV will be realized with the technique.

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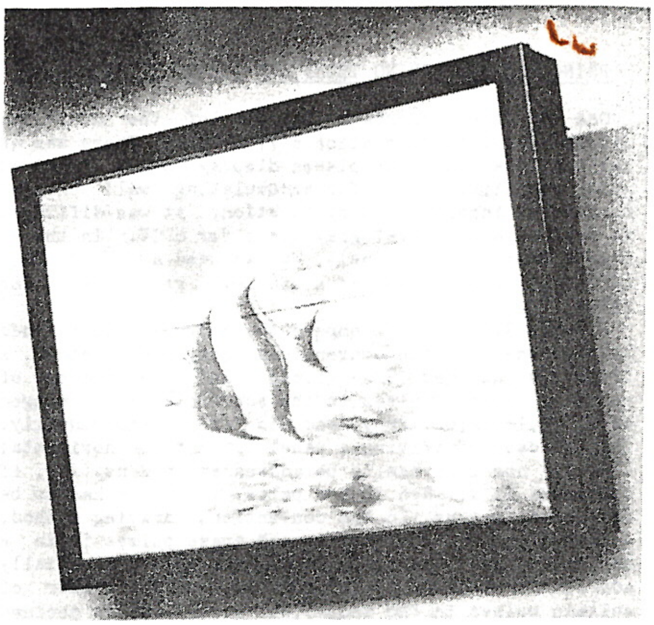

Photo. 1 Sample display of 31-in.-diagonal PDP

This figure is reproduced in color on page 1008.