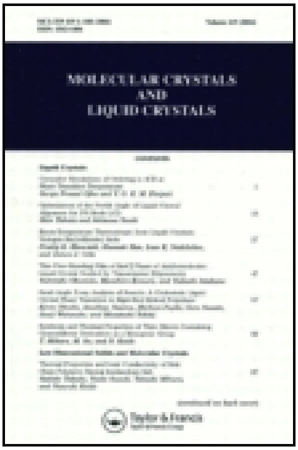

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Field Sequential LCD using Organic El Backlighting

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We have proposed a new field sequential full-color display composed of an optical compensated birefringent (OCB) mode, p-Si TFT LCD panel and a multicolored organic electro luminescent device (OEL). In this display system, each merits of the LC device with high-resolution capability and the OEL device with high-speed response are combined.

In addition, by using synchronously scan method, we could realize the field sequential display with a conventional TFT panel. We fabricated a trial display and confirmed its promising characteristics as a field sequential full-color display in the next generation.

Keywords: field sequential; OCB mode; TFT panel; organic EL

1.INTRODUCTION

We have proposed a field sequential display composed of Organic EL (OEL) backlight and OCB-mode [1] liquid crystal cell, and demonstrated a full color display. [2] We call this display as EL-backlight field-sequential-LCD (ELC). In addition, we have improved this LCD by using synchronized scan method, and have made it possible to decrease the scanning speed, which allowed to apply the conventional TFT to the field sequential LCD. We call this display as synchronized scan ELC (SS-ELC).

In this paper, we report the properties of this SS-ELC which we have made as trial.

2.SYNCHRONIZED SCAN METHOD

In the case of conventional field sequential LCD, whole area of the backlight flush at once. [3] So, to keep time for the LC response of the last addressed line, the sub-field frequency of the LCD is required to be high enough. For example, in the case of the frame frequency of the display is 60Hz, the sub-field frequency of the LCD becomes over

Table.1 Time assignment of the field sequential display

Parameter	conventional	synchronized scan
Scan (adress) whole area of LCD (Sub-field frequency of LCD)	0.93msec (1080Hz)	5.6msec (180Hz)
LC response	3.5msec	3.5msec
Backlight flushing	1msec	2msec
Frame frequency of display	60Hz	60Hz

1000Hz, and the conventional a-Si TFT panel can't be driven such a high frequency.

In the case of SS-ELC, OEL backlight is composed of many lines of R, G, B and light just under the LCD panel and synchronous to LCD addressing. Accordingly it is no longer necessary to scan whole area of LCD in a short time and the frame frequency of the LCD is only 3 times of the display. Table.1 shows the time assignment of the conventional and synchronized scan method field sequential display. We have been able to realize the field sequential display using conventional TFT panel by synchronized scan method.

3.FABRICATION OF THE PROTOTYPE DISPLAY

The structure of the display is shown in Fig.1.

The LC panel indicates a monochrome high-resolution image. Table.2 shows the specifications of the LCD panel. To make response time short enough for the field sequential display, we modified the conventional poly-Si TFT panel to the OCB-mode. Table.3 shows the response time of this panel.

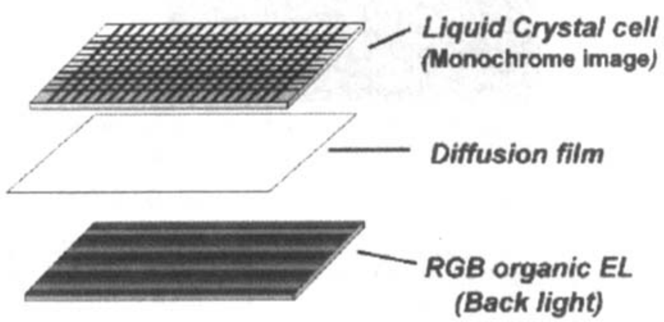

Fig.1 Structure of the display

See Color Plate VI at the back of this issue.

Table.2 Specifications of the LCD panel

Parameter	Specification
Effective Viewing area diagonal	10.0cm (4.0inches)
Effective Viewing area dimensions	80.16×60.00mm
Numbers of dots	320×3×240
Dot pitch	0.0835×0.250mm
Color arrangement	RGB stripe

Table.3 Response Time of LC Cell

Rise Time (msec)	3.7
Decay Time (msec)	0.9

We have made the OEL backlight with RGB horizontal stripe and flush synchronously to LCD addressing. Furthermore, we have stacked diffusion film between the backlight and LC panel to shade off the stripe shape. Table.4 and figure 2 show the specifications and the photograph of the Organic EL backlight. It is confirmed that the diffusion film successfully shade off the stripe on the backlight.

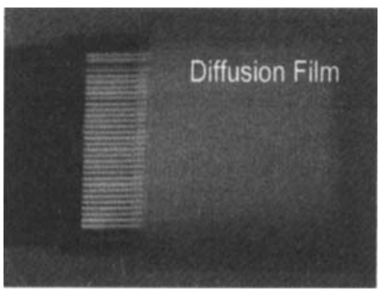

Fig.2 photograph of the backlight with diffusion film
See Color Plate VII at the back of this issue.

Table.4 Specification of the Organic EL Backlight

Parameter	Specification
Lighting area dimensions	90 × 70mm
Pixel size	0.55 × 70mm
Number of lines	96(32 × 3)
Line pitch	0.73mm

Figure 3 shows the block diagram of the driver circuit. This circuit receives video signal and drive the LCD and organic EL synchronously.

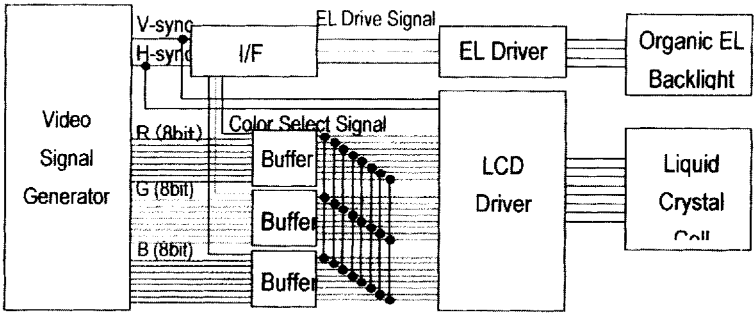

Fig.3 block diagram of the driver circuit

4. CHARACTERISTICS OF THE DISPLAY

Display images of the test-fabricated SS-ELC are shown in Fig.4.

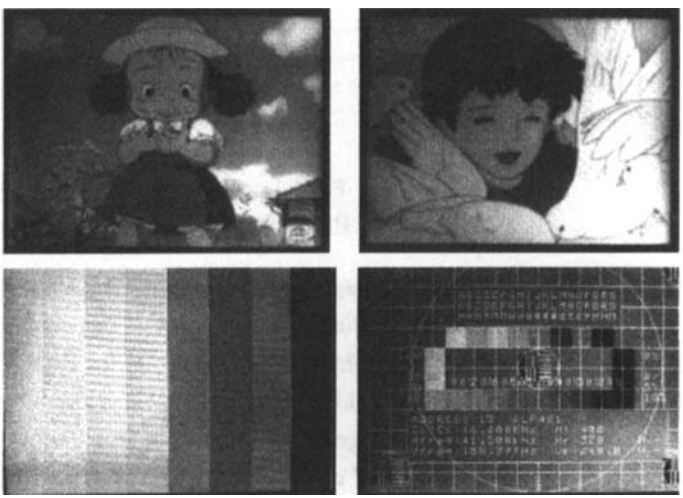

Fig.4 photographs of the test-fabricated display
See Color Plate VIII at the back of this issue.

We have confirmed that color tone was sufficiently uniform thanks to synchronous scan method, and that color performance was satisfactory.

Figure 5 shows the luminance of the display. The luminance of position B is rather lower than position A. This difference is caused by a slightly voltage-drop due to the resistance of the electrode of the backlight. Furthermore, figure 5 indicates that the luminance of the display is about 12% of the backlight, and the transmittance of the diffusion film and LCD is 70% and 17%. The transmittance of LCD depends on the transmittance of polarizer, retardation, and aperture ratio of the LCD. In the case of our LCD, transmittance of the polarizers were about 35~40% and aperture ratio of the LCD was about 60~65%. In addition, the factor of transmittance on the retardation of our LCD was about 70%. Considering these values, the total transmittance of the LCD mentioned above is reasonable at this moment.

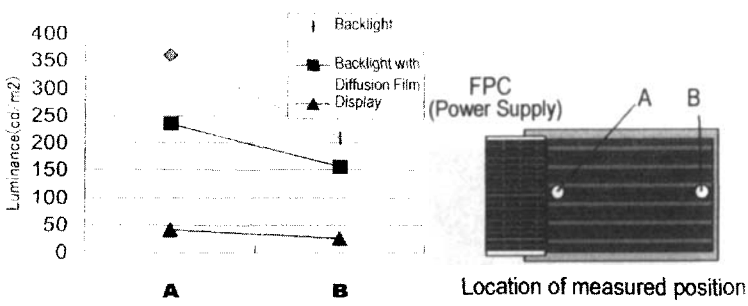

Fig.5 Luminance of the display

See Color Plate IX at the back of this issue.

Figure 6 shows chromaticity diagram of the display. The color purity is not so good because of insufficient color purity of the organic EL backlight. In addition, we found that the color purity of the display was worse than that of the backlight. We think this is caused by the capacitance change after voltage application. Figure 7 shows the principle of the color decline of color purity, which is caused by the

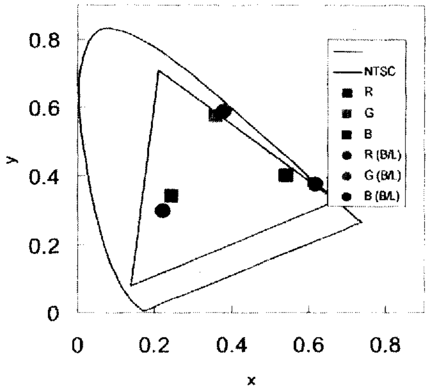

Fig.6 chromaticity diagram of the display
See Color Plate X at the back of this issue.

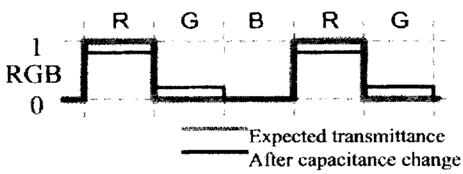

Fig.7 principle of the color deviation
See Color Plate XI at the back of this issue.

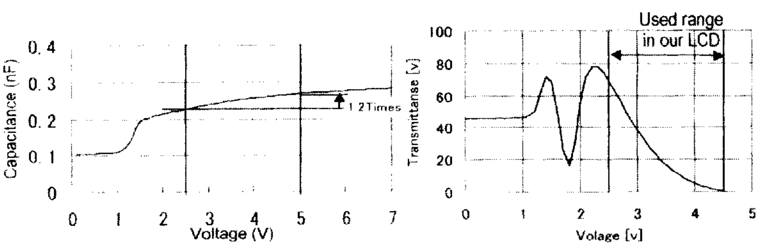

Fig.8 C-V and V-T characteristics of the OCB cell

capacitance change of liquid crystal due to the response of its molecular alignment. Figure 8 shows an example of voltage-capacitance property and voltage-transmittance property of the OCB-mode cell. When the red color is displayed in this LCD, applied voltage to the LCD is about

2.5V for the red sub-field about 5V for the green and blue sub-fields. In this situation, the capacitance at 5V is 1.2 times higher than that at 2.5V.

As a result, the transmittance is deviated from the aimed value. The direction of the color shift as shown in figure 6 agree well with the direction predicted by the abovementioned consideration.

5. CONCLUSION

We have successfully fabricated a dot-matrix type field sequential display composed of p-Si TFT, OCB-mode LCD and RGB-OEL backlight. The OEL with stripe RGB structure was driven with synchronization with the LCD-scanning. It was confirmed that the satisfactory color performance was obtained, although a slight color shift occurs due to the capacitance change by liquid crystal response. Each of these voltages is sequentially applied to the LCD pixel during gate-on time of the TFT (about 20μs in our LCD) and then it is cut off until the next sub-field. The liquid crystal alignment responds after it, and the capacitance changes, which causes shift of the stored voltage.

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