# Recent Development of Optically Compensated Bend (OCB) Mode TFT-LCD

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## Abstract
*Toshiba Matsushita Display Technology (TMD) has firstly succeeded in mass production of OCB (Optically Compensated Bend) mode liquid crystal display panels which have excellent moving picture quality almost the same as CRT. We have newly developed 32-inch diagonal HD (1366× 768 pixels) panels using OCB mode and low temperature p-Si TFT (LTPS) array substrates. High performance of brightness of 600 cd/m$^2$ and contrast ratio of 600 : 1 was obtained by using pseudo-impulse driving method to insert a black period between continuous two frames, and also by using blinking backlight method. Furthermore,* moving picture response time *(MPRT) 6.5ms has been obtained by optimization of black insert driving and backlight blinking, without the great sacrifices of contrast ratio and luminance.*

## 1. Introduction
Recently, the needs for TFT LCD-TVs have dramatically increased by the expansion of the digital-TV market. LCD-TVs have lots of advantages of high resolution, low power consumption, light weight, slim size and so on. However, they have some drawbacks for TV application, especially motion image blur which results from slow response time and hold-type driving method is most acute problem. Motion image blur is recognized easily by becoming a large screen, and the difference with CRT becomes remarkable.

Toshiba Matsushita Display Technology (TMD) achieved the best performance of moving picture quality as LCD by concentrating some specific technologies, and succeeded in the mass production of 23-inch diagonal OCB(Optically Compensated Bend) mode HD-TV panel for the first time in the world. In this paper, OCB mode liquid crystal technology and the low temperature poly silicon technology that applies to the 32 inch panel are referred [1]. In addition, the liquid crystal driving method and the backlight control method to improve the moving picture quality are described [2].

## 2. OCB Mode TFT-LCD with high speed response

### 2.1 Bend Transition Technology
Among practical LCD modes using nematic liquid crystals, OCB mode which was proposed in 1993 can provide advantages of fastest response and wide viewing angle [3][4][5].

However, this OCB mode requires complete transition from initial splay to bend alignment in all pixel of the LCD. It was one of the most difficult problems to put OCB mode LCD to practical use to establish the method of bend transition.

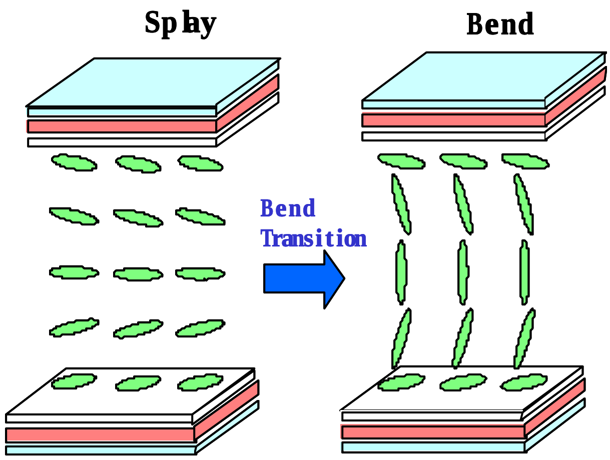


Figure 1. Splay to bend transition in OCB cell

To solve this problem, we have developed a new bend transition method using electrical twist field that induced right and left twist alignments [6]. We adopted a new pixel structure that generates horizontal field to make the twist alignment. Figure 2 is a concept chart of driving scheme and the pixel structure. Zig-zag shaped pixel electrodes are made of

ITO, and zig-zag area is formed above black matrix in the every pixel. The horizontal electric field is applied between the zig-zag pixel electrodes.

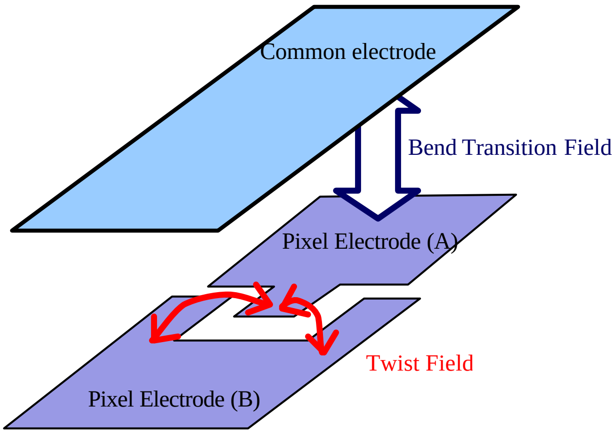


Figure 2. The electric fields to induce bend transition and pixel structure for the new bend transition method using lateral twist field

After the power supply is turned on, the bend transition field is applied to a common electrode, and this field promotes the bend growth. At the same time, the horizontal field is applied in the zigzag electrode. The horizontal field makes both right- and left- twist alignment.

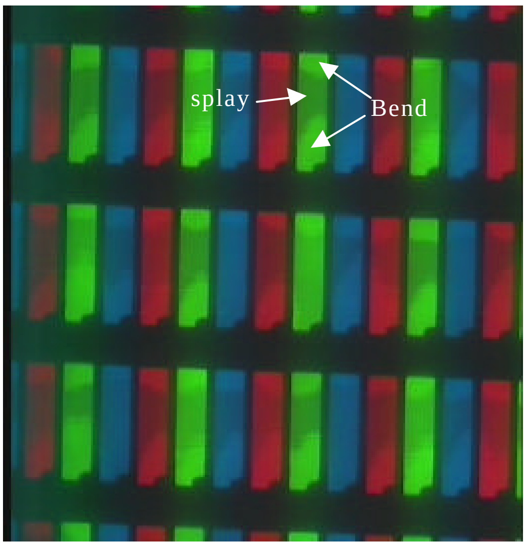


Figure 3. The photograph of the bend transition in the pixels of OCB mode LCD

When both right and left twist alignment are created, a disclination line is generated in boundary of both the twist alignments. The bend transition occurs near the disclination line, because higher-order twist alignment over 90° appears near this line.

Figure 3 show a photograph of the bend transition in the pixels of OCB mode LCD. The bend domains were generated from zig-zag electrodes under the black matrix in the every pixel. The Bend domain expanded and covered the entire pixel. The formation of bend alignment became possible by using this method within one second.

## 2. 2 32-inch LTPS HD-TV LCD using OCB Mode

Table 1 and figure 4 show specification and photograph of 32-inch LCD (1366×768 pixels) using OCB mode, LTPS array substrates and blinking backlight technology, respectively. The OCB mode can provide advantages of both high moving picture quality and wide viewing angle (>160 degrees). High performance with brightness of 600 cd/m2 and contrast ratio of 600 : 1 was obtained.

Table 1. Photograph of 32-inch LCD (1366×768 pixels) using OCB mode,

| | Specification | |
|---|---|---|
| Diagonal Size | 31.55 inch | |
| Pixel Format | 1366×768 | |
| Brightness | 600 cd/m$^2$ | |
| Contrast Ratio | 600:1 | |
| Color Temp. | 10000K | |
| Viewing Angle | Horizontal | Vertical |
| (CR>10) | >160 | >160 |
| (CR>50) | >160 | >160 |
| (?u'v'<0.02) | >160 | >160 |
| MPRT | 8.4 msec | |

To achieve high contrast ratio, not only blinking backlight technology was introduced, but also color filter materials, cell configuration, electrode structure and process conditions have been investigated. Also we have devebped newly designed compensated films and cell structure to obtain wide viewing angles of over 160 degrees both horizontally and vertically.

Clear images can be seen in any direction. Color shift was evaluated taking the gray levels into account. Viewing angles with color shift of △u'v'<0.02 were also over 160 degrees both horizontally and vertically. The reproducibility of a natural picture is also excellent.

Figure 4 Photograph of 32-inch LTPS HD-TV LCD using OCB Mode

## 2.3 LTPS Technologies

Figure 5 shows a circuit diagram of the p-Si TFT array substrate. Gate drivers and signal line selectors to reduce the number of external source drivers by a half are integrated as peripheral circuits, resulting in huge cost reduction. Scanning circuits for black insertion driving are also incorporated in built-in gate drivers. Connection reliability is improved by minimizing the size of PCB.

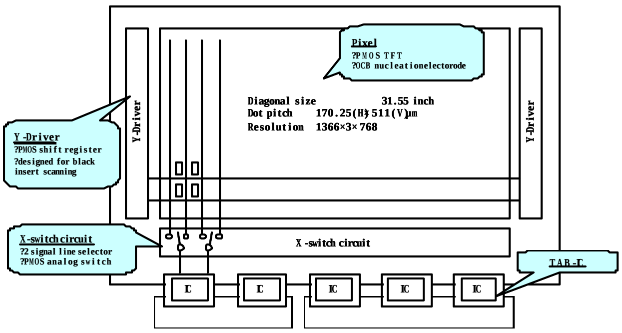


Figure 5. Circuit diagram of 32 inch–in-diagonal p-Si TFT array substrate

Figure 6 shows a cross sectional view of the pixel structure. Minimizing the size of p-Si TFT and fabricating color filter (CF) on array substrate achieve high aperture ratio of 70% that is comparable to TN LC panel. Each pixel has a component to confirm transition of OCB mode LC from spray to bend orientation.

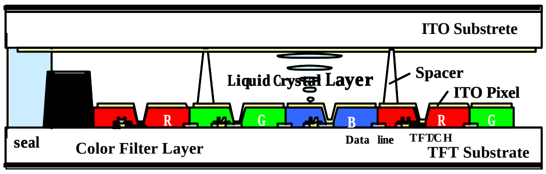


Figure 6. Cross sectional view of the panel structure

LTPS is suitable for high definition TV with the OCB mode. Because the OCB liquid crystal requires high-speed scanning to achieve fast response, excellent pixel charging capability of LTPS enables us to design the OCB mode HD panels, and it is much more difficult to design using a-Si TFT. We have newly developed LTPS, with which reliability of 60,000 hour continuous driving is confirmed.

## 2.4 Blinking Backlight Method

To improve motion blur, several backlight systems using blinking have been proposed. On the other hand, OCB mode using black data insertion which we have developed provided high performance of moving picture quality by pseudo-impulse driving to LCD. Figure 7 shows the contrast ratio and the moving picture response time (MPRT) as a function of black insert ratio using conventional backlight without blinking. Black insert ratio is defined as following expression.

$$BIR = t_b / t_f$$

where $t_b$ is period of black data and $t_f$ is period of a frame (1/60s). The MPRT decreased with increasing the black insert ratio. On the other hand, the contrast ratio monotonically decreased with increasing black insert ratio as being reported previously. When the black insert ratio was 45%, the contrast ratio and the MPRT were 320:1 and 8 ms respectively. To improve this low contrast ratio, backlight blinking has been introduced.

Backlight blinking synchronized with the display addressing reduced the brightness of black level with only a little loss of white level. Consequently, the contrast ratio of OCB mode panel using blinking backlight was higher than that of conventional hold-type backlight as shown in figure 8. This high performance of contrast ratio was accomplished by the investigation of the response times of liquid crystal and backlight and optimization of the distance between CCFL tubes and blinking timing.

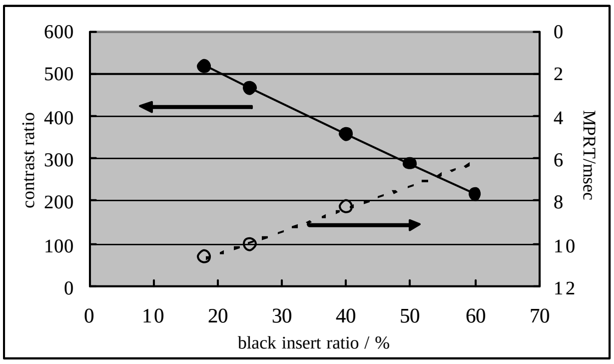


Figure 7. Contrast ratio and MPRT as a function of black insert ratio with conventional backlight without blinking .

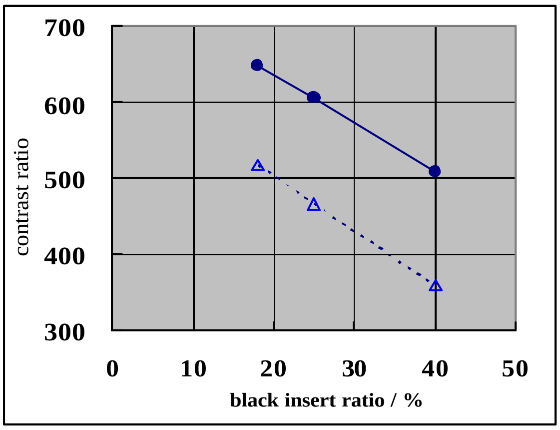


Figure 8. Contrast ratio of OCB mode panel with conventional back light and new back light using blinking as a function of black insert ratio

Figure 9 shows the MPRT as a function of contrast ratio using conventional backlight or blinking backlight. The trade-off between MPRT and contrast ratio was decreased considerably, as a result, higher performance of them was simultaneously obtained.

Optical response and normalized blurred edge time (N-BET) of the OCB panel using blinking backlight was shown in figure 10 and figure 11 respectively. By using pseudo-impulse driving method to insert black period between two successive frames and blinking backlight synchronized with the display addressing, 25% of every frame time was black state, which could be obtained by the fast response of the OCB mode.

The N-BET data between gray levels of the OCB panel was almost equal mutually, the average of which was 8.4msec.

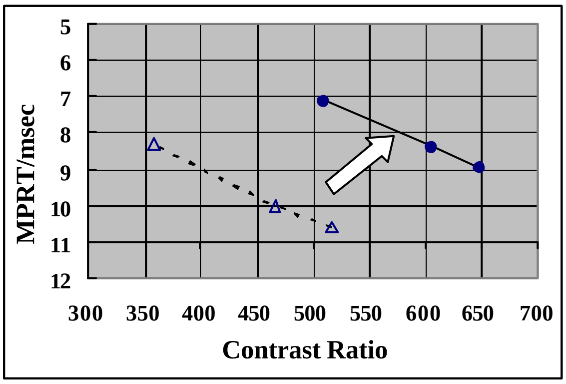


Figure 9. MPRT of OCB mode panel with conventional back light and new back light using blinking as a function of contrast ratio

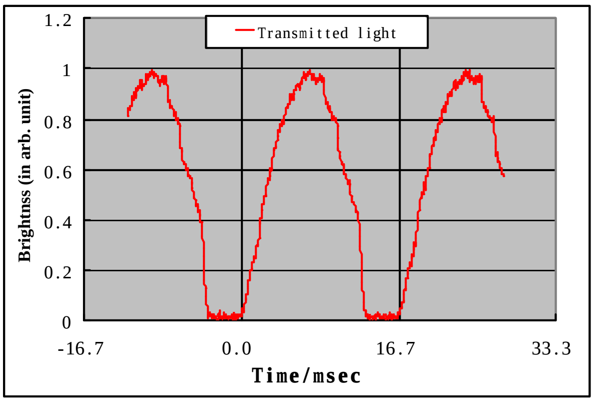


Figure 10. Optical response waveform of OCB mode panel using pseudo-impulse driving to LCD and backlight blinking

Furthermore, the appropriate selections of black insert ratio, backlight duty and backlight blinking timing respectively under a little sacrifice of contrast ratio reduce the MPRT easily. The OCB mode LCD selected mode 3 can provide higher performance of moving picture quality, the motion picture response time (6.5ms) and N-BET data between gray levels of which are shown in Table 2 and figure 12.

## 3. Conclusion

We have found the solution of the bend transition that was one of the most difficult problems to put OCB mode LCD to practical use. As a result, we have developed the 32-inch LCD using OCB mode, LTPS array substrates and blinking backlight technology which provides advantages of high moving picture quality, high contrast ratio and wide viewing angle. One most important point is the simultaneous improvement of contrast ratio and moving picture quality following the introduction of the backlight blinking synchronized with the display addressing. Another significant aspect of this system is to be able to reduce moving picture response time greatly with only little sacrifice of the contrast ratio by optimization of black insert driving and backlight blinking.

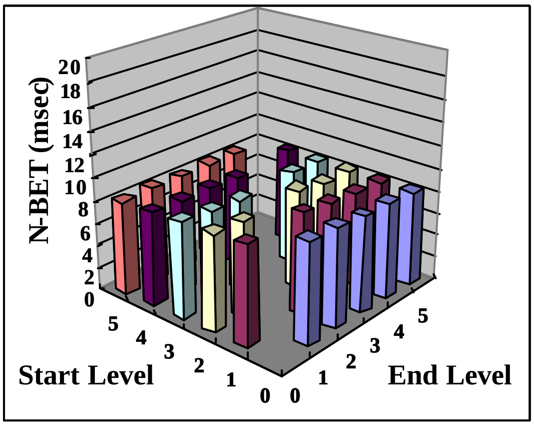


Figure 11. N-BET(Normalized Blurred Edge Time)data of the OCB panel using the pseudo-impulse driving and backlight blinking of mode 2 in table 2

Table 2. Specification of OCB mode panel using the pseudo-impulse driving and backlight blinking in several modes

| | Mode1 | Mode2 | Mode3 |
|---|---|---|---|
| Contrast Ratio | 660 | 600 | 500 |
| Brightness (cd/m$^2$) | 660 | 600 | 500 |
| MPRT (msec) | 8.9 | 8.4 | 6.5 |

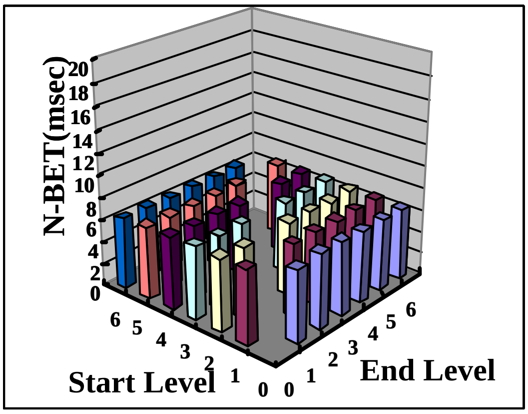


Figure 12. N-BET(Normalized Blurred Edge Time)data of the OCB panel using the pseudo-impulse driving and backlight blinking of mode 3 in table 2

## 4. References


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