Development of HR-TFT(High Reflective -TFT)

Kozo Nakamura*
Hisakazu Nakamura*
Naofumi Kimura*

* Engineering Development Dept.2, LCD Laboratories, TFT LCD Development Group.

Abstract

HR-TFT has been developed which consists of super high aperture ratio (Super HA), micro reflective structure (MRS) and RGB micro color filters optimized for reflective color LCD. Two types of HR-TFT have been fabricated. One is guest host (GH) type with high brightness, the other is high contrast reflection (HCR) type with high chroma. The HR-TFT has excellent chracteristics, extremely low power consumption, and is very thin and light in weight because of non back light system. The HR-TFT is one of the most promising displays for mobile computer, still camera, video movie and so on.

Introduction

With excellent features of thinness, lightweight and low power consumption, LCDs have extended their application from small size displays such as calculators and watches to large size displays such as word-processors and personal computers. In order to keep up with rapidly increasing demand in the mobile information market, the LCDs will require higher performance of the very low power consumption which allow the long duration time with battery operation. The conventional transmissive LCDs, however, did not satisfy these requirements because of built-in backlight system. Under such circumstances, reflective LCDs which use ambient light have been drawing much attention from researchers. They envision the reflective LCDs as a promising display for mobile information tools, and further for outdoor use such as still cameras and video

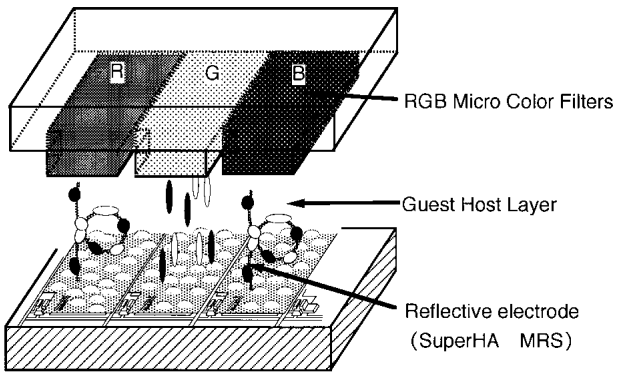

Fig. 1 Structure of the panel. [GH type]

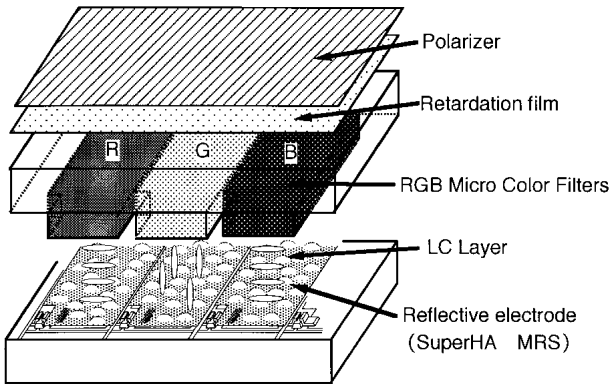

Fig. 2 Structure of the panel. [Polarizer type]

movies due to its excellent visibility under sunlight. Most of the existing reflective LCDs, however, are black-and-white displays, and the reflective color LCDs which are satisfactory in terms of brightness and a number of colors have not been realized yet.

Now, by applying the Super HA and the MRS technologies with optimized RGB micro color filters, we have developed a prototype of HR-TFT which displays excellent quality images.

1. Panel structure

Figures 1 and 2 show the structure of our newly developed HR-TFT, GH(Guest Host) type and HCR(High Contrast reflection)type respectively. Super HA(Super High Aperture ratio) and MRS(Micro Reflective Structure) technologies are applied to the reflective electrode in both types. As a result, we have successfully realized a high aperture ratio and a high reflectance which result in sufficient brightness without a backlight system.

1·1 Super HA

Figure 3 illustrates the Super HA structure. We adopted the reflective pixel on passivation structure to obtain a high aperture ratio and placed reflective electrode inside the cell to avoid parallax- the occurrence of incident light and reflected light passing through different pixels. This is caused by the thickness of the glass substrate when the reflector is attached outside of the panel. This parallax results in mixed color reproduction which becomes a serious problem for high definition color display in particular. To achieve higher reflectance, we used aluminum as the reflective electrode.

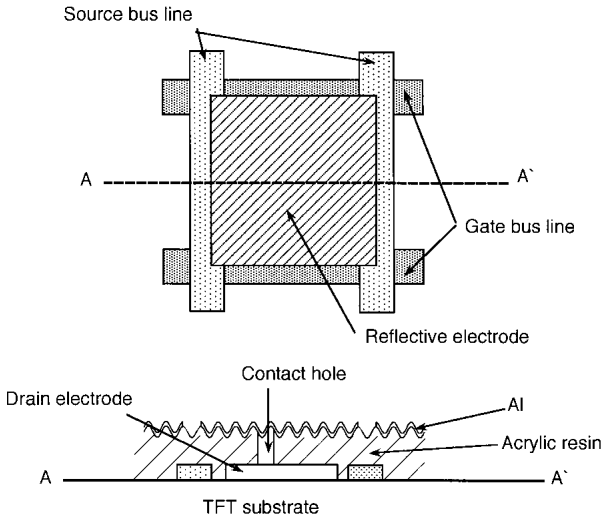

Fig. 3 "Super-HA" structure.

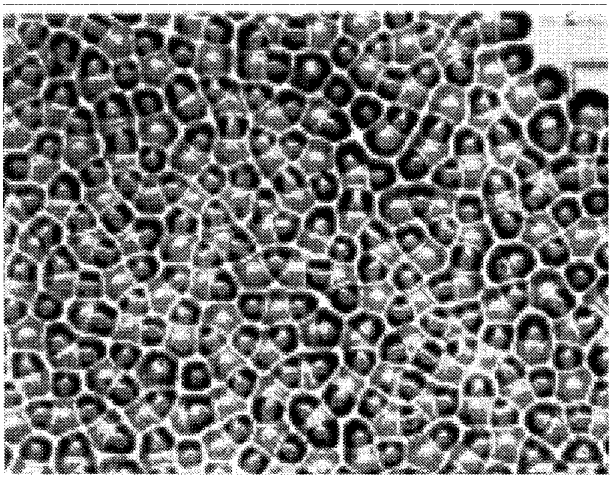

Fig. 4 Micro scope photograph of "MRS".

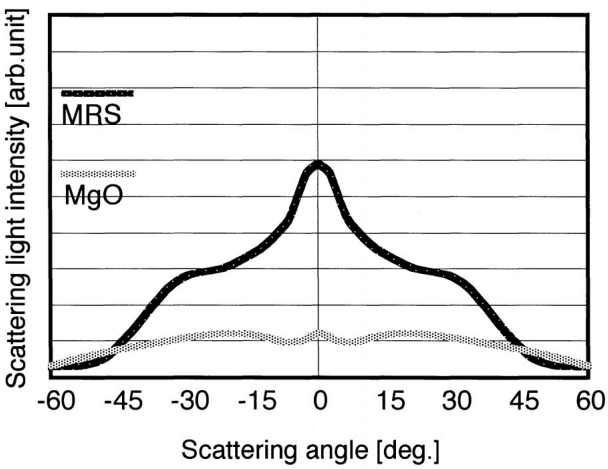

Fig. 5 Angular dependence of reflectance of the reflective electrode.

1·2 MRS

Figure 4 shows a microscopic photograph of the MRS. The surface of this reflective electrode consists of a number of projections which are randomly aligned to avoid coloration caused by light interference. Furthermore, the shape of these projections is optically designed to diffuse incident light efficiently. **Figure 5** shows the angular dependence of the reflectance of the reflective electrode with the MRS. Within 45 degrees from the normal direction of the panel, higher reflectance is yielded from the MRS than from the standard white(MgO).

2. Optimization of GH mode and color filters

Not only brightness but also chroma is an essential factor in the designing process of reflective color LCDs. The chroma of a reflective color LCD is generally determined by the contrast ratio of the display mode as well as the color purity of the color filters. In other words, vivid color can be displayed by using a display mode with high contrast ratio and high color purity of color filters. The brightness trades off the contrast ratio in the case of the GH type, and the same is true of the interrelation between the color purity and transmittance of the color filters. Then we simulated the value of the chroma and reflectance of the LCD panel in order to optimize optical properties of the GH layers and transmittance of the color filter.

Table 1 shows the properties of the three types of GH layers. Here, the reflectance and the contrast ratio of the GH layer depend on dye concentration. We simulated the relationship between the reflectance in the white state and the chroma in the blue, green and red by

Table 1 Properties of GH layer for simulation.

Type	Reflectrance	Contrast ratio
Type 1	42%	6
Type 2	46%	5
Type 3	57%	3

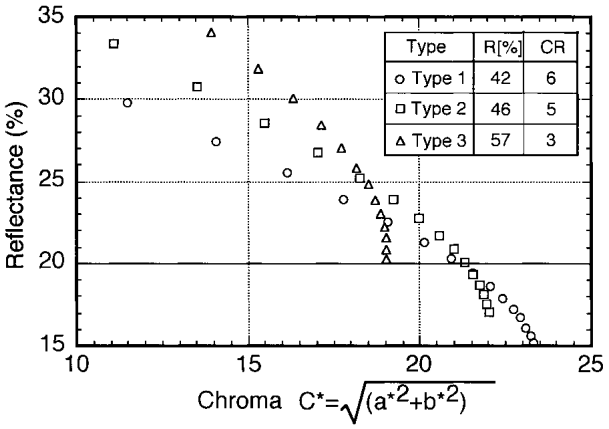

Fig. 6 Characteristic of reflectance and C*. [Blue]

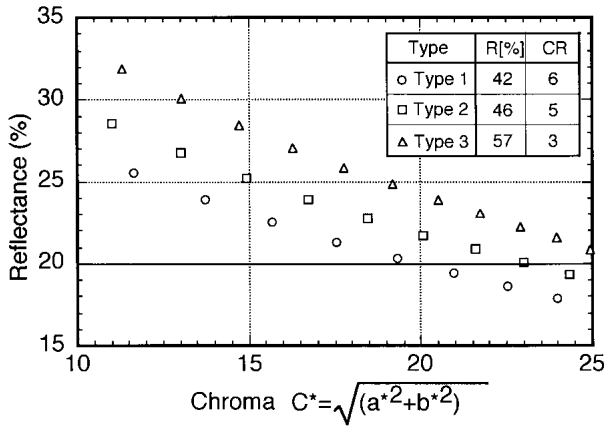

Fig. 7 Characteristic of reflectance and C*. [Green]

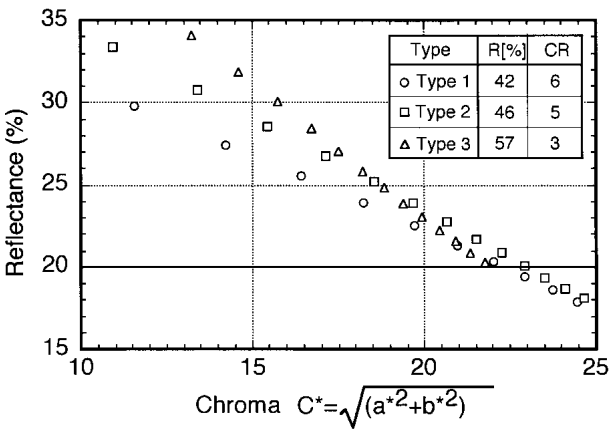

Fig. 8 Characteristic of reflectance and C*. [Red]

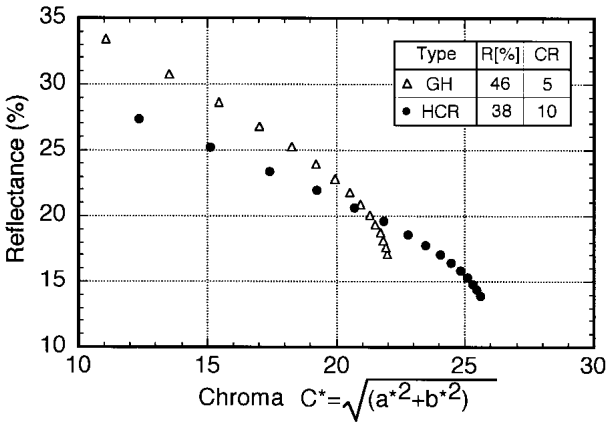

Fig. 9 Characteristic of reflectance and C*. [Blue]

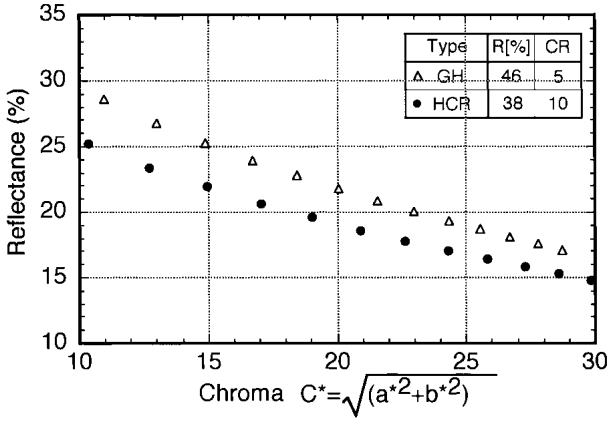

Fig. 10 Characteristic of reflectance and C*. [Green]

exchanging the GH type and the transmitance of the color filter. In this simulation we considered the light leakage caused by the incomplete black sate and used an additive mixing system. The chroma is defined by following formula: $C^*=(a^{*2}+b^{*2})^{1/2}$, which is standardized in the CIE 1976. **Figures 6,7 and 8** show the simulated results. Furthermore, we have additionally obtained the fact in terms of the visibility that at least 20% of reflectance is required to realize practical display performance under typical room light conditions in the case of using our reflector. The type 2 GH layer gives maximum chroma to the blue and red colors when the reflectance is 20%. Based on these results, we have adopted the type 2 GH layer.

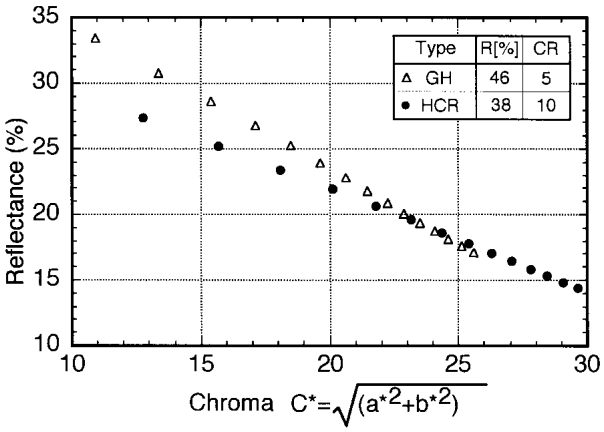

Fig. 9 Characteristic of reflectance and C*. [Red]

Table 2 Specification of HR-TFT.

Display mode	GH type	HCR type
Display size	16.4 cm (6.5 inch)	←
Dot format	640[H] x 240[V]dots	←
Drive system	Active drive (a-Si)	←
Number of color	4096	260.000
Contrast ratio	5:1 (0 to 30 deg.)	10:1
Brightness	33%(0 to 30 deg.;ref.MgO)	30%
Response time	80 ms [on and off] 150 ms [gray scales]	50 ms [on and off] 80 ms [gray scales]
Power consumption	200 mW	←

3. Comparison between GH type and HCR type

The HCR type has just one polarizer. **Figures 9,10 and 11** show the relationship between the reflectance in the white state and the chroma in the blue, green and red by changing the transmittance of the color filter in the HCR type panel. The characteristic of the GH type (type2) is also plotted in the same figures to be compared to the HCR type. When the

Photo 1 Typical display image of the HR-TFT.

reflectance is high, the HCR type gives less chroma than the GH type. On the other hand, when the reflectance is low the opposite result is gained. In the case of HCR type, it is not appropriate to sacrifice the chroma by raising the transmittance of the color filters in order to increase the reflectance. Therefore, chroma should be prior to brightness in HCR type.

4. Specifications of HR-TFT

Table 2 shows the specifications of the HR-TFT. The GH type uses absorption of dye for its display, thus offering a wider viewing angle. Its brightness value is 33%(MgO ratio), against which the HCR type cannot be competitive. The HCR type, however, offers better performance in contrast ratio and also in response speed. Therefore, the GH type is more suitable to the applications which display graphic information such as mobile computers, while the HCR type is more suitable for the applications which display video pictures such as still cameras and video movies. **Photo.1** shows a typical display image of the HR-TFT with HCR type.

Conclusion

We have successfully developed a high-definition HR-TFT by adopting various technologies, such as super HA, MRS and optimum condition for LC layer and the transmittance of the color filters. The HR-TFT dose not have a built-in backlight system, which allows for long-duration operation with batteries and reduction in size and weight. Its display images have become sufficient in respect of brightness and a number of colors. The HR-TFT will create a new market not only in mobile information devices field but also in a entire mobile field as well, and thus is regarded as a promising device in the LCD industry.

Acknowledgments

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