Transflective SFT (Super Fine TFT) Panel Display

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Abstract

In the context of the current trend in the advancement of digital TV technologies, there is an increased demand for our wide viewing angle range and transflective liquid crystal modules. In order to meet this demand, NEC LCD Technologies has developed two main technologies; a) our original compensation technology to solve display issues that the color tone is reversed between reflection and transmission modes when employing the IPS LCD (liquid crystal display) mode, and b) a fine comb-shaped electrode processing technology for unevenly surfaced reflectors. Wide-angle transflective SFT (Super-Fine-TFT) LCD panels have been developed as a result of these technologies. The transflective SFT LCD panel features superior characteristics in terms of improved transmissivity and reduced thickness compared to the conventional transflective LCD panel. It is expected that it will soon be employed for high grade mobile LCD monitors.

Keywords

SFT, transflective, visibility under extraneous light, wide view angle range, high contrast, IPS mode, reflector

1. Introduction

The transflective LCD panel, which mounts a reflector inside the liquid crystal cell, has superior visibility characteristics under extraneous light so that it is widely employed for compact LCD panels, especially the ones employed for mobile products. Moreover, with regard to the recent advancement in digital TV technologies, the demands for a wide viewing angle range and for high contrast have been increasing with regard to transflective LCD panels. To meet such demands, we have developed a transflective SFT (Super-Fine-TFT) panel that features wide angle viewing range characteristics using the IPS (In-Plane Switching) liquid crystal mode, which also has a transflective operational capability.

2. Transflective SFT Technology

2.1 Conventional Technology

(1) Transflective Technology

Transflective technology enables the LCD panel to function in the transmissive mode while the backlight is turned on and in the reflective mode by using ambient light when the backlight is turned off. In order to realize this technology, pixels inside the panel are divided into transmissive and the reflective areas. By forming a reflective surface with uneven faces in the reflective area, the reflective performance has been improved. NEC LCD Technologies possesses an SR-NLT (Super-Reflective Natural-Light-TFT) technology featuring a high reflective performance that makes use of our original reflector design technology.

(2) SFT Technology

With vertical electrical field modes such as the TN (Twisted Nematic) mode, black color is displayed while the liquid crystal molecules are shifted 90 degrees vertically, so that the viewing angle becomes narrow and a high contrast performance cannot be achieved. On the other hand, in the IPS mode, the liquid crystal molecules rotate inside a substrate only when a voltage is applied, so that the liquid crystal molecules do not shift to 90 degrees vertically. This process results in a superior viewing angle and a transmissive display performance that features high contrast. NEC LCD Technologies possesses an SFT technology that utilizes our original IPS mode.

2.2 Fusion of SFT and Transflective Technologies

In order to employ the IPS mode featuring superior transmissivity for the transflective type LCD, there are two issues; one is of an optical nature and the other is a pixel structure matter. We have solved these issues by adopting the following methods.

(1) Optical Technology Issues

When a transflective LCD panel in the IPS mode is configured with an optical arrangement similar to the ordinary transmissive mode, the dilemma is presented that the color tone of display is reversed between transmissive and reflective modes. With the transmissive mode, a “normally black display” is obtained that displays black without the need to apply a voltage and white display when a voltage is applied. In the reflective mode, a “normally white display” is obtained that displays white without applying voltage and a black display when applying a voltage.
The vertical electrical field mode has solved this reversal issue by employing an optical compensation film (wide-band quarter-wave retardation plate). However, the quarter-wave retardation plate converts the light into circularly polarized light when it enters the liquid crystal and such light has no sensitivity to the horizontal rotation of liquid crystal so that it cannot be employed in the horizontal electrical mode. Therefore, another method is required to solve this display tone-reversal issue in order to drive the transflective LCD module in the IPS mode. We have solved the issue by employing our original compensation technology. Moreover, this technology uses only ordinary thin polarization plate, which is also adopted for the transmissive LCD panels without using an optical compensation film, so that a reduction in the thickness of the LCD panel compared to that of the conventional transflective panel is achieved.

(2) Pixel Structure Issues

A reflector inside the LCD panel adjusts the incident light, when it incomes with the angle of approximately 30 degrees, to the outgoing light with the angle of between 0 to 15 degrees. In order to carry out this adjustment, the angle of inclination of the concavity and convexity on the reflector must be at 4 to 6 degrees. However, in the IPS mode, the liquid crystal molecules are not driven uniformly because of an uneven surface. To solve this issue a flat layer is formed on the rough reflector surface and comb-shaped pixel electrodes are mounted on it (**Fig. 1**).

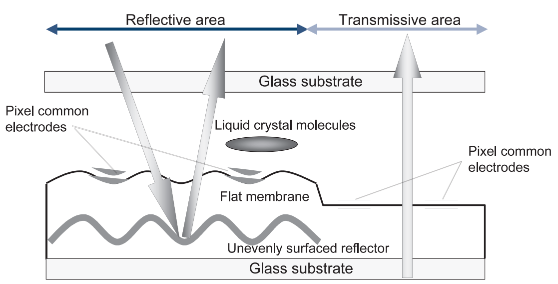


Fig. 1 Transflective SFT panel structure.

The uneven layer consists of approximately 1µm steps at the most but the steps can be reduced to 0.2µm or less by introducing a planarization layer on top of the uneven surfaced reflector.
Currently, acrylate is being employed for the flat membrane. However, it is generally difficult to construct patterns of comb-shaped electrodes on an organic membrane such as acrylate. Moreover, gaps between liquid crystal cells are smaller in the reflection field compared to those in the transmissive field, so that it is required to introduce gaps between the comb-shape pixel electrodes to an even finer degree in order to achieve a drive voltage equal to that of the transmissive field. We have developed a comb-shaped electrode forming process that forms finer gaps on a flat membrane.

3. Display Performance

3.1 Panel Specifications

NEC LCD Technologies has developed a 3.5”QVGA transflective SFT LCD panel using the above mentioned technologies. **Table** below indicates the specifications of the newly developed panel and compares them with those of our conventional transflective panel products.

3.2 Transflective SFT Panel Characteristics

(1) Transmissive Mode

The transmissive contrast ratio of the transflective SFT panel is 400 to 500:1, which is greatly superior to that of our conventional transflective panel, which is 150:1. **Fig. 2** shows the transmissive viewing angle characteristics of the transflective SFT panel. The viewing angle range depending on contrast has achieved over 170 degrees under the condition of CR>10, which shows that a wide viewing angle range has been achieved.

(2) Reflection Mode

Fig. 3 shows the reflective ratio and reflective contrast of the

Table 3.5”QVGA transflective SFT panel specifications.

Item	Transflective SFT (Newly developed product)	Conventional transflective product
Number of colors	262k	←
Transmissive contrast	400 – 500:1	150:1
Transmissive view angle (CR>10)	Vertical>170 degrees Horizontal>170 degrees	Vertical>70 degrees Horizontal>70 degrees
Transmissive luminance	250 cd/m^2	220 cd/m^2
Reflective ratio	15%	15%

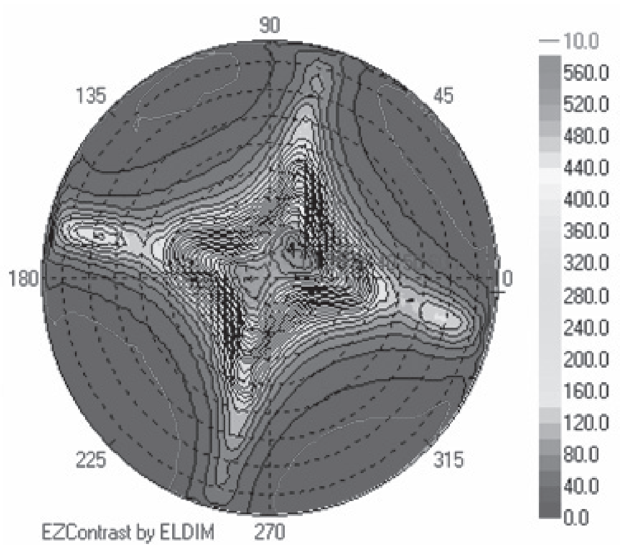
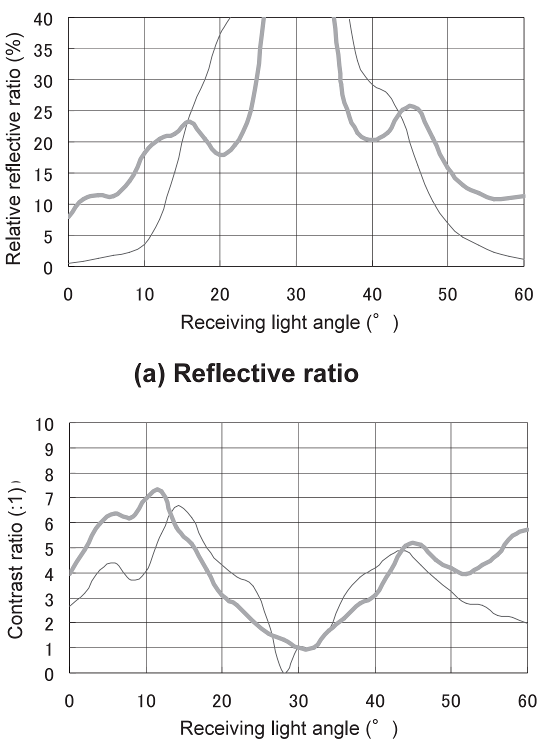


Fig. 2 Transmissive viewing angle characteristics of transflective SFT panels.



(a) Reflective ratio

(b) Reflective contrast ratio

Bold line - unevenness inclination angle: 6 degrees
Fine line - unevenness inclination angle: 3 degrees

Fig. 3 Reflection characteristics of transflective SFT panels.

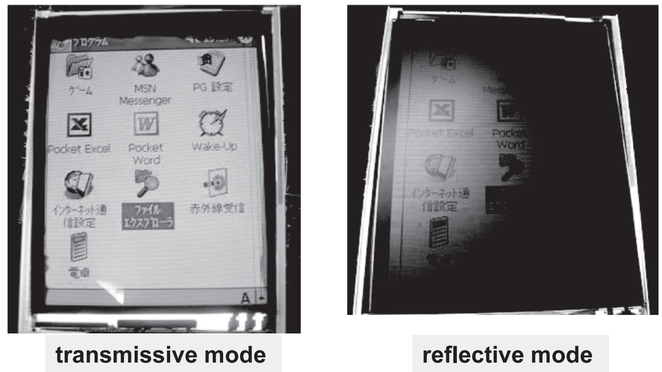


Fig. 4 Display image of a transflective SFT panel.

outgoing angle (θ) against an incident angle of 30 degrees. Under the conditions of an incident angle of 30 degrees and an outgoing angle of 10 to 15 degrees, a reflective contrast of 5 to 7:1 is achieved. This value is inferior to those of conventional products that are generally 10:1 or greater. However, the reflective ratio maintains a high value by having as a feature the reflector designs that have been accumulated using original SR-NLT technologies (**Fig. 4**).

(3) Thickness

Our original compensation technology enabled transflective panel operation without employing an optical compensation film. This strategy resulted in the employment of the polarizer that is usually used for a transmissive LCD panel and which is 60% thinner than a polarizer used for the conventional transflective panel. Due to this innovation a reduction in the thickness of the panel module has been achieved.

4. Conclusion and Future Development

The transflective SFT LCD panel employing the IPS LCD mode, which had hitherto been difficult to achieve, became possible as a result of our development of the original compensation method, which aimed at solving the display reversal issue between the reflective mode and the transmissive mode and of the introduction of a planarization layer on the uneven surfaced reflector.

The transflective panel developed by NEC LCD Technologies has achieved a greatly enhanced performance in the field of wider viewing angles and reduced thicknesses compared to conventional products. We intend to apply the transflective SFT panel, which offers a superior legibility performance and transmissive display characteristics under extraneous light to small-size applications such as mobile monitors, etc. In future, we intend to further improve reflective contrast values by modifying the reflective comb-shaped electrodes and the reflective liquid crystal processes in the reflective field.

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