13.5: A Color STN-LCD with Improved Contrast, Uniformity, and Response Times

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Abstract: A novel approach to obtain a fast responding STN LCD is described.
Response times are reduced to less than 50ms for 1/240 duty operation without sacrificing sharp threshold behaviour, using a low viscosity nematic mixture.
Driving method is also investigated to avoid the contrast reduction, which comes from the "frame response" phenomena in fast-responding LCDs. A multi-line selection method, where 2 or more scanning lines are selected at a time, is proved to be a promising candidate to overcome the problem.
A 5.7" diagonal color STN LCD with improved contrast, uniformity and response times has been developed, using the new nematic mixture and the driving method as well.

INTRODUCTION

STN LCD has been used in various applications. However, the application has been limited to those which allow relatively slow response properties.
Basic principle of improving response times has been already proposed, such as adopting thinner cell gap, low viscosity nematic liquid crystal material with high optical anisotropy, small K33/K11 of LC material and so on.<1> However, there has been few practical applications so far, since the fast responding property has not been compatible with high contrast in high duty operation due to mismatch of liquid crystal properties, as well as the so-called "frame response" phenomena.
The frame response phenomena is observed in fast responding LCDs, where the response time is comparable to the period of addressing waveform. In the Alt-Pleshko technique, a high voltage pulse is applied to each scanning line once in a frame, and the applied voltage is optimized to give the highest ON/OFF ratio of RMS voltage. But the fast responding LCD responds to the high voltage pulse in the addressing waveform, even though the RMS voltage is lower than the threshold voltage, and also the fully ON state is not maintained during the non-selected period. Therefore, fast response has not been compatible with high contrast, especially for high duty operation.
This paper describes recent progress in liquid crystal material for fast responding STN and a new driving method to avoid the frame response phenomena.
A 5.7" diagonal color STN LCD with improved contrast, uniformity and response times has been developed, using the new LC mixture and the new driving method as well.

TECHNIQUE

A. Liquid crystal material for fast responding STN

Basic approach to obtain fast response is to use a thinner cell gap(d). This requires larger optical anisotropy(Δ n) of liquid crystal material, since Δ n·d is usually kept constant in the STN.
Tolanes, stilbenes, biphenyls and phenyl pyrimidines are typical compounds, which have high Δ n. Assuming that response time is proportional to (viscosity;η)/(cell gap)^2, liquid crystal compounds can be evaluated by a figure of merit;η / n^2.
Figure 1 shows a comparison of typical compounds. Tc (nematic-isotropic transition temperature) has to be taken into account to evaluate the figure of merit, since high Tc material tends to have high viscosity. As far as viscosity and Δ n are concerned, there is a possibility to improve the response time by the factor of 5 to 10 compared to the conventional mixture, whose response time is approximately 200 ms.
In designing liquid crystal mixture for the STN, elastic properties are also important. The ratio K33/K11 affects the response time as well as the sharpness of threshold characteristics. The larger K33/K11 gives better sharpness which leads to high contrast, but degrades the response time. Therefore, the new mixture is designed to have a similar K33/K11 to the conventional mixture.
Physical properties of the new mixture are listed in Table 1. It is designed for approximately 4 μm cell of double layered STN mode.
The average response time is 50 ms for 1/240 duty operation, which is applicable to video display.
Sharpness characteristics are almost the same as the conventional mixture, and thus it can show a similar multiplexability.

B. Frame response phenomena in the fast responding STN

Figure 2 shows the frame response phenomena in the fast responding STN in which the new liquid crystal mixture is used. In case of the Alt-Pleshko technique, liquid crystal molecules respond to each high voltage pulse, and the activated state (ON-state) is relaxed

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during the half- or non-selected period. This phenomena decreases the luminances of ON state, and increases the luminance of OFF state, even though the applied RMS-volatge is below the threshold. Figure 3 shows voltage-transmission curves for various frame frequency.

High frame frequency is one of the easiest ways to get rid of the problem. Using 400 Hz, the frame response phenomena can be fairly suppressed as shown in the figure. However, 400 Hz is too high for practical applications , since the high frequency causes the serious nonuniformity problems. It should be pointed out that the thinner cell gap of the fast responding STN leads to a larger capacitance, and it makes the nonuniformity problems more serious than the conventional condition.

The bias voltage, which is usually selected to give the highest selection ratio of RMS voltage, can be also optimized to give the highest contrast ratio. (Fig.4) The higher bias voltage the smaller frame response. <2,3,4,5>

However, these techniques are not successful in the extremely fast responding STN.

C. Driving method for the fast responding STN

In the conventional Alt-Pleshko technique each scanning line is selected once in a frame period. But it would be expected to provide a similar effect to the high frequency method, if multiple scanning lines are selected at a time.

Several methods, using the multiple line selection (MLS) technique, have already been proposed, using twisted nematic LCDs. <6,7> Improved hybrid addressing technique (IHAT), which has the same selection ratio as the Alt-Pleshko technique(APT),is one of the most promising methods among them. Major advantages of the method are reduction of driving voltage, good uniformity of the display and higher address-duty ratio as compared to the APT. The higher address-duty ratio does not affect the selection ratio of RMS voltages, but it would suppress the frame response phenomena in the fast responding STN. We adopted the IHAT with some modification for driving the fast responding STN.

A comparison of the wave forms is shown in Fig.5. Three scanning lines are selected at a time in the MLS, and thus the number of high voltage pulses is 3 times of the APT.

Figure 6 shows frequency dependence of contrast ratio, using a MLS method which has the same selection ratio of RMS voltage as that of the APT. Here, N is the number of scanning lines and l is the number of scanning lines selected simultaneously. Contrast ratio is about 40 to 60 in the MLS, while the conventional method can not give sufficient contrast in low frequency region as shown in the figure.

D. 5.7" diagonal color STN LCD

A 5.7" diagonal color STN LCD has been developed, using before-mentioned techniques. Specifications are listed in Table 2.

Number of scanning line is 240, and it corresponds to 1/240 duty in the APT.

Driving condition has not been optimized in this sample, and contrast ratio is lower than the potential value shown in Fig.6, because suitable driver LSIs are not available at the moment.

However, the color purity is fairly good. Figure 7 shows a comparison of chromaticity diagrams for the MLS and the APT. Frame frequency is 90 Hz in the MLS and 200 Hz in the Apt.

Uniformity of luminance is also superior to the conventional technique owing to the new driving method.

Conclusions

Response time of the STN LCD is improved down to 50 ms through the development of a new liquid crystal mixture. However, the fast response causes the so-called "frame response" phenomena, which decreases contrast ratio.

A multiple line selection method is a promising candidate to overcome the frame response problem. Contrast ratio is improved approximately two times as compared to the conventional Alt-Pleshko technique.

A 5.7" diagonal color STN with improved response times, contrast and uniformity has been developed, using the new liquid crystal mixture and the new driving method for fast responding LCDs.

ACKNOWLEDGMENT

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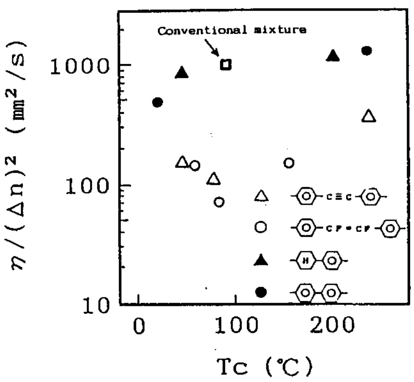


Fig.1 A comparison of the figure of merit of several nematic compounds.

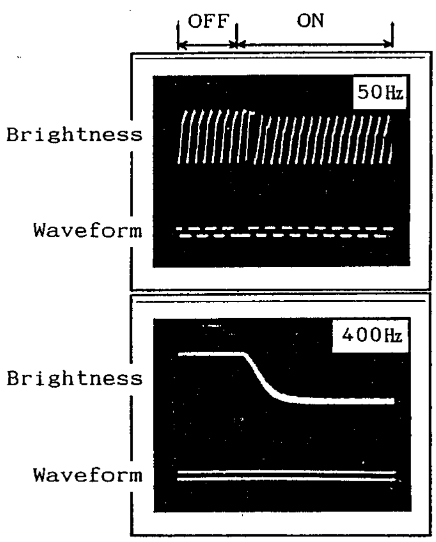


Fig.2 Frame response phenomena in the fast responding STN.

Table 1 Physical properties of the liquid crystal mixture.

Optical anisotropy (589nm)	0.237
Tc	86.7 ℃
Viscosity	12.1 mm^2/s
K11	$13.4 * 10^{-12}$ N
K33	$19.2 * 10^{-12}$ N
K33/K11	1.44
ε ⊥	3.7
ε	9.5
Δ ε / ε ⊥	1.5

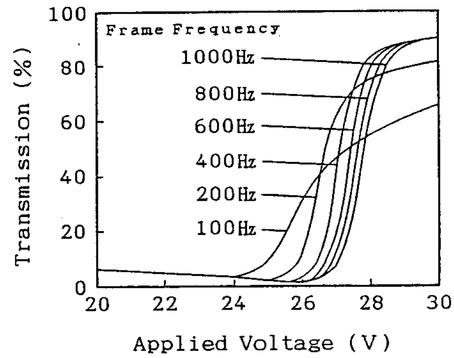


Fig.3 Applied voltage dependence of transmission.

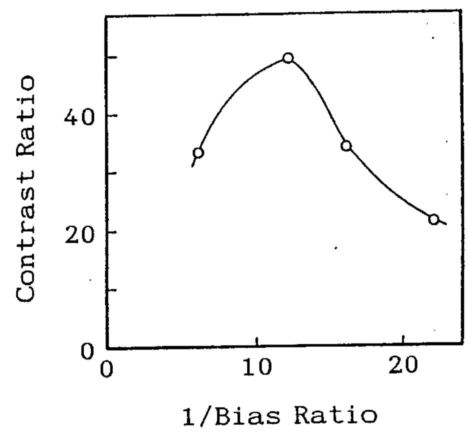
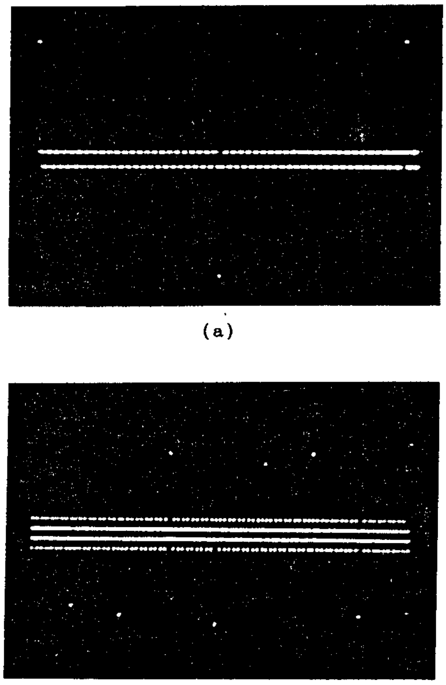


Fig.4 Bias ratio dependence of contrast ratio. Frame frequency is 90 Hz.

Table 2 Specifications of the 5.7" color STN

Number of dot	320 * 3(R,G,B) * 240
Pixel pitch	285 μm
Driving method	MLS method N = 240
Response time	50 ms (average)
Contrast ratio	15 : 1



(a)

(b)

Fig.5 Typical wave forms.
(a) APT, (b) MLS

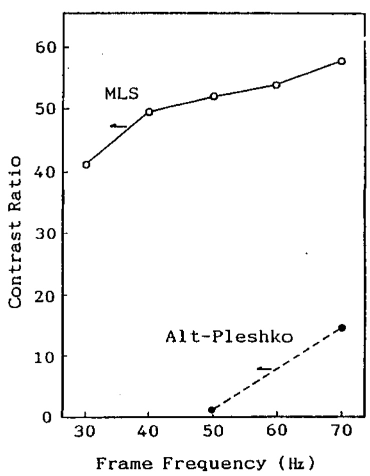


Fig.6 Frequency dependence of contrast ratio

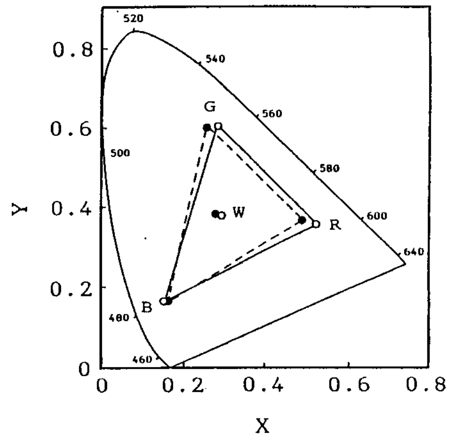


Fig.7 Chromaticity diagrams of the 5.7" color STN.
● APT (200Hz), ○ MLS (90 Hz)

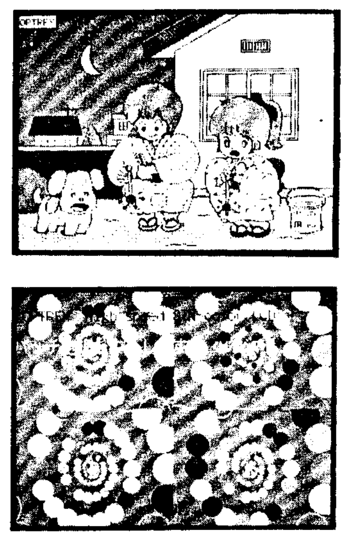


Fig.8 Photographs of the 5.7" color STN

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