Development of High-Performance ASV-LCDs Using Continuous Pinwheel Alignment (CPA) Mode

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Abstract

We developed Advanced Super View (ASV) LCDs using Continuous Pinwheel Alignment (CPA) mode. ASV-LCDs are proposed to realize high-performance displays having wide viewing angles, high brightness, high contrast and fast response. The new CPA technology can be used in various LCD applications such as TV sets, PC monitors, and portable monitors for amusement.

Introduction

Recently, as prices for LCDs drop, signs are emerging of burgeoning demand for their use in TVs. However, to overtake CRTs, LCD devices must offer higher overall display performance including wide viewing angles, high luminance, and fast response time. Currently, there are numerous reports regarding the use of IPS (in-plane switching)[1)] and MVA (multi-domain vertical alignment)[2)3)] modes to provide LCDs with wider viewing angles. Compared to conventional TN (twisted nematic) mode, either of these display modes can achieve excellent viewing angle characteristics and contrast without suffering from grayscale reversal phenomena. But neither approach also provides adequate light utilization efficiency, and there are additional problems in that, to clearly delineate the domain space by means of a structure that forms multiple domains within a single pixel, multi-domain vertical alignment modes require a process that causes shape effects and electrical field effects to be manifested on both the upper and lower substrates, and thus the fabrication process becomes complex as a result.

By contrast, we have proposed Super View LCDs with improved viewing angle characteristics, and ASV (Advanced Super View) LCDs, which feature not only wider viewing angles, but also high overall display characteristics. At this time, we have developed a new enhanced version of our ASV-LCDs intended for use in TV sets and monitors. In this design, a continuous multi-domain radially tilting alignment within the pixels is achieved merely through an ingenious design for the electrode configuration on one substrate side. We call this new alignment technology "Continuous Pinwheel Alignment," and in addition to the process being simple, it enables the fabrication of high-performance LCDs having display parameters rivaling CRTs. Here, we report on the development of a 20-inch ASV-LCD for TVs using this technology.

1. Continuous Pinwheel Alignment (CPA mode)

If a closed domain is formed on one substrate side, a stable alignment can be obtained merely by controlling the electric field on that substrate side. Consequently, we formed multiple sub-pixel electrodes within a single pixel. **Fig. 1** illustrates the liquid crystal molecule alignment and the configuration of the sub-pixel

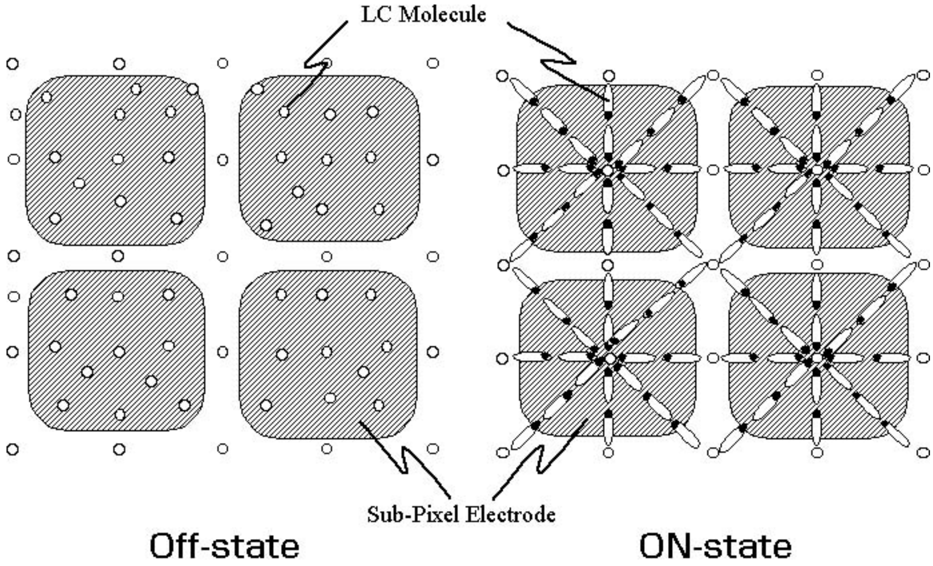
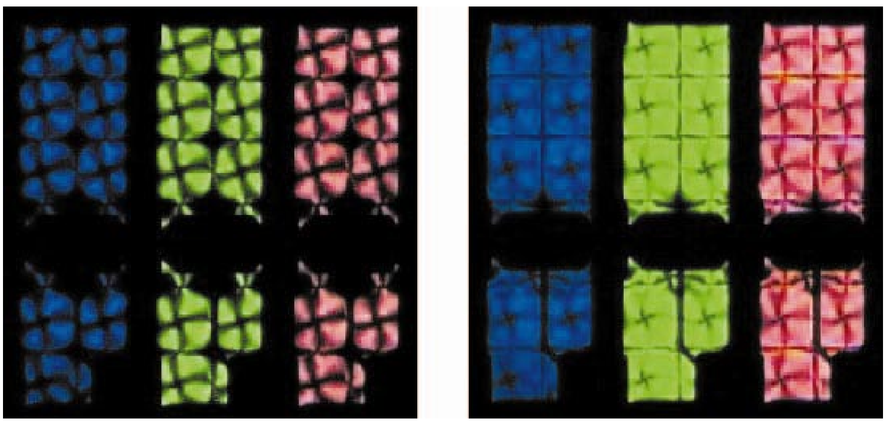


Fig. 1 Schematic illustrations of CPA mode.

electrodes. The sub-pixel electrodes are square-shape with rounded corners, and are arranged in a regular pattern with a fixed distance between them. In the OFF state, the liquid crystal molecules, which have a negative dielectric constant anisotropy, are aligned vertically with respect to the substrate surface (homeotropic alignment). When a voltage is applied to the liquid crystal layer between one sub-pixel electrode and its opposite electrode on the other substrate side (ON state), the liquid crystal molecules are set in motion by the fact that a diagonal electric field is being generated. This causes the liquid crystal molecules to tilt over and lie down oriented toward the center of the sub-pixel electrode. As a result, a radially tilting alignment state can be attained at each sub-pixel electrode. No domain boundaries are generated in doing so because the shape of the liquid crystal molecules is continuously distorted between the sub-pixel electrodes. We have dubbed this alignment configuration, "Continuous Pinwheel Alignment (CPA)." **Photo 1(a)** shows the alignment configuration when a voltage has been applied to the liquid crystal layer. By using CPA technology in this way, we have been able to form a uniform array of multiple radially tilting alignments having identical configurations across the entire display region, and have achieved a wide-viewing angle LCD offering a high level of display quality.



(a) ECB (electrically controlled birefringence)   (b) Reverse-TN (twisted nematic)

Photo 1 Optical texture under the electrical field 6V.

2. Improvement of Transmittance

2.1 Higher luminance and wider viewing angles based on reverse TN technology

In LCDs, wide-viewing-angle characteristics are readily attained using CPA mode because the liquid crystal molecules tilt in all directions. However, as shown in **Photo 1(a)**, two types of regions exist-ones in which light in a pinwheel-like shape passes through and is visible above the sub-pixels, and others in which no light passes through at all. Thus, attaining satisfactory transmittance is a difficult problem.

We resolved this problem by combining CPA mode with a reverse TN system. In the reverse TN system, adding a chiral compound to the liquid crystal makes it possible to constructively utilize optical rotation rather than birefringence to alter the optical characteristics when a voltage is applied to the liquid crystal layer, enabling light to be used with much greater efficiency. **Photo 1(b)** shows an alignment configuration using the reverse TN mode. Compared to **Photo 1(a)**, light also passes through regions in which no pinwheel-shaped light is transmitted. In conventional approaches, almost no light is transmitted when the liquid crystal molecule is tilted in a horizontal or vertical orientation with respect to the polarizing axis of the polarizers, but by using optical rotation, light is transmitted in all directions in which the liquid crystal molecules tilt. In this manner, we implemented the white display using a configuration close to twisted nematic alignment configurations in the cell thickness direction the same as in the past, and implemented the black display using the vertical configuration. This enabled the achievement of an LCD having high transmittance when the display is white, and because the liquid crystal orientation when black has a uniform vertical configuration, an LCD also having high contrast.

2.2 Super High Aperture (SHA) technology

The addition of Super High Aperture (SHA) technology[4)] on the TFT substrate to CPA technology worked to boost the aperture ratio of the display, and attain higher transmittance.

The radially tilting alignment configuration is achieved by controlling an electrical field, and thus, it tends to be affected by the electrical fields of the source and gate bus lines. This SHA technology forms the pixel electrodes using ITO (indium tin oxide) on top of an interlayer dielectric. This approach not only improves aperture ratio, but it also serves to reduce the effect on liquid crystal orientation from electrical fields generated by the source and gate bus lines, making it possible to achieve a more stable radially tilting alignment configuration.

3. Performance of 20-inch LCDs for TVs

The display parameters of a 20-inch LCD designed for use in TV sets are shown in **Table 1**. The development of a high-transmittance LC panel and a high-intensity backlight enabled us to achieve a module luminance of 450 cd/m^2, as well as a front contrast ratio of 500:1. **Fig. 2** shows the viewing angle characteristics of the ASV-LCD, and **Fig. 3** the viewing angle dependencies of brightness as a parameter of various grayscales. By combining polarizers and optical compensation films, we obtained wide viewing angles with contrast 10 or better over a range of 170° in all directions, and

Table 1 Specifications of the 20-inch diagonal LCD for TV.

Contrast (front)		Better than 500:1
Viewing angle contrast 10:1	Up/down	170°
	Right/left	170°
	Tilted	170°
Viewing angle grayscale dependency		Good
Viewing angle color shift		Good
Temperature characteristics	Grayscale dependency	Good
	Color shift	Good
Response rate	Full grayscale ($\tau_r + \tau$)	15 ms

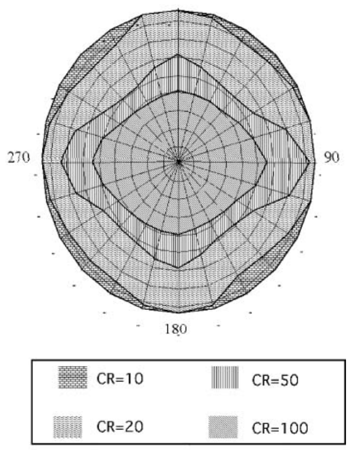


Fig. 2 Viewing angle characteristic of ASV-LCD.

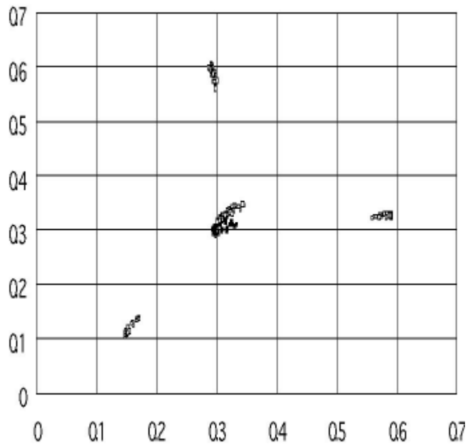


Fig. 4 Color shift of RGB, white and black at polar angle 60° around various azimuth.

contrast 30 or better in a range of 170° up/down and right/left. **Fig. 4** shows the viewing angle color shift characteristics. Changes in color rendition characteristics dependent of viewing angles are very small compared with conventional wide viewing angle technology. Plus, we are able to achieve fast response of under 15 ms, making it possible to provide an LCD appropriate for moving-image applications.

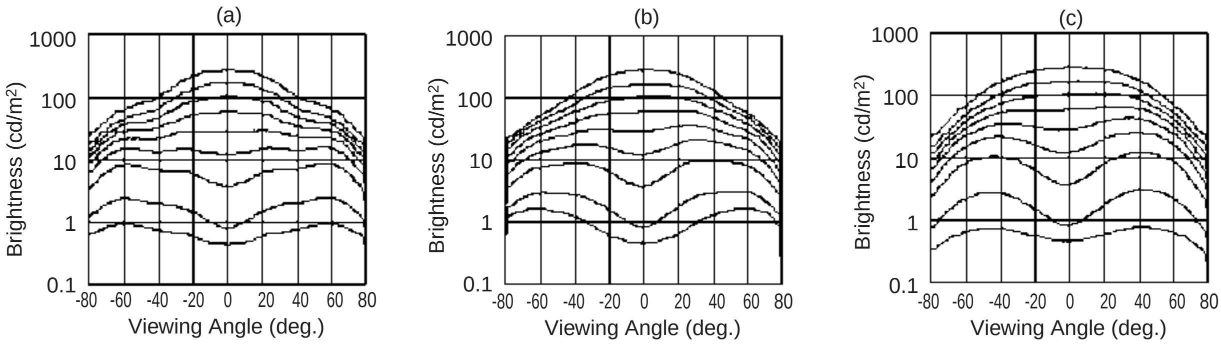


Fig. 3 Viewing angular dependences of brightness as a parameter of various grayscales.
(a) Bottom to top (b) Bottom left to top right (c) Left to right

Conclusions

By using a relatively simple structure to control vertically oriented liquid crystals, i.e., controlling the electrical field only on one substrate side, a wide-viewing-angle LCD was obtained with promising possibilities for mass production. In addition, by adopting a reverse TN mode, transmittance was improved over conventional wide-viewing-angle LCDs. The application of these technologies enabled the realization of a high-performance LCD which combined wide viewing angles, high luminance, high contrast, and fast response rate. In the future, such LCDs can be expected to find application in a wide variety of products, including monitors, TV sets, and game machines.

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