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Wide viewing angle and fast response time using a novel vertical-alignment-pi cell mode on a homeotropic alignment layer

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Wide viewing angle and fast response time using a novel vertical-alignment-π cell mode on a homeotropic alignment layer

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We have developed a novel vertical-alignment (VA)-π cell mode that provides a wide viewing angle and fast response times for a negative dielectric anisotropy nematic liquid crystal on homeotropic polyimide surfaces. Good voltage–transmittance curves and low driving voltages were achieved with the novel VA-π cell mode without negative compensation film. Iso-viewing angle characteristics were also successfully observed. A fast response time of 31.7 ms for the novel VA-π cell mode was also measured.

1. Introduction

Thin film transistor (TFT)-liquid crystal displays (LCDs) are widely utilized in information displays such as notebook computers, monitors, and televisions because they have excellent resolution quality. However, TFT-LCD performance has been unsatisfactory due to a narrow viewing angle and slow response times. Several methods for improving the viewing angle have been proposed, among these are the addition of birefringence films [1], the domain divided twisted nematic [2], the in-plane-switching mode [3], and multi domain vertical alignment (MVA) mode [4, 5]. The MVA-LCD is eventually expected to achieve a wide viewing angle, fast response time, and high contrast ratio; however, the division of each pixel into multi-domains and a fringe field are required. The optically compensated bend mode has been introduced to try to improve the narrow viewing angle and response time [6]. Unfortunately, this mode may have some difficulties in controlling the LC conformation and pretilt angle. A fast response time for TFT-LCD is particularly required to achieve a high quality image over a large area.

In this work, we report the viewing angle and fast response time characteristics of a negative dielectric anisotropy NLC using a novel VA-π cell mode on a homeotropic polyimide (PI) layer.

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2. Experimental

In these experiments, JALS-696-R2 was used for the homeotropic alignment layer. The PI films were coated on indium tin oxide (ITO) coated glass substrates by spin-coating, and were imidized at 180°C for 1 h. The thickness of the PI layers was 500 Å. The PI films were rubbed using a machine equipped with a nylon roller (Y_o-15-N, Yoshikawa Chemical Industries Co., Ltd.). The definition of the rubbing strength (*RS*) is given in previous papers [7–10]. The *RS* was 187 mm for the medium rubbing region. The LC layer thickness of the novel VA-π cell was set at 4.25 μm. NLC used negative dielectric anisotropy. The voltage–transmittance (V–T), viewing angle, and response time measurements for the novel VA-π cell were observed at room temperature (22°C).

3. Results and discussion

Figure 1 shows the schematic diagram of the novel VA-π cell mode without negative compensation film, in the off- and on-states. In the off-state, the LC directors are aligned vertically to the glass substrates. Under crossed polarizers and in the normal viewing direction, there was an ordinary wave and no phase retardation to modulate the light polarization. Therefore, the off-state of the novel VA-π cell mode was very dark in the normal direction. In the on-state, in order to be perpendicular to the electric anisotropy, we require pre-tilt to reorient. The effect of the pretilt is to align the stable

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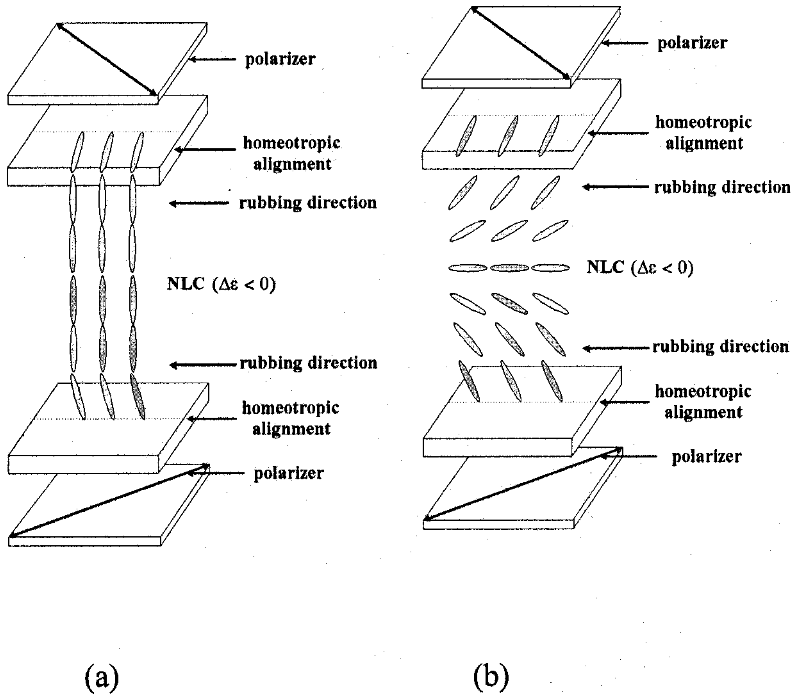

Figure 1. Schematic diagram of the novel VA-π cell mode without negative compensated film in the off-state (*a*) and on-state (*b*).

LC director field symmetrically. With this transition, the light was transmitted. Symmetric LC director fields can reduce the grey scale inversion over a large viewing angle.

Figure 2 shows the *V–T* characteristic of the novel VA-π cell without negative compensation film on a homeotropic PI surface. An excellent *V–T* curve was measured; however, light leakage in the off-state was observed. Usually, light leakage can be compensated for by utilizing a negative compensation film. The *V–T* characteristic of a conventional VA cell on a homeotropic PI surface is shown in figure 3; again, an excellent *V–T* curve was obtained. Table 1 shows the threshold voltage for the novel VA-π cell and a conventional VA cell on homeotropic PI surfaces. It is seen that the threshold voltage of the novel VA-π cell was almost the same as that of the conventional VA cell.

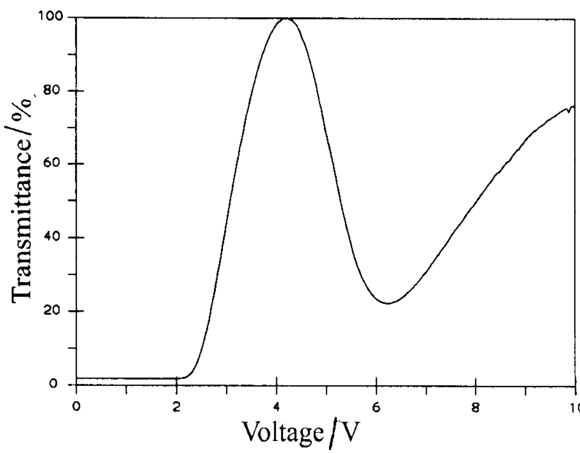

Figure 2. *V–T* characteristic of the novel VA-π cell without negative compensation film on a homeotropic PI surface.

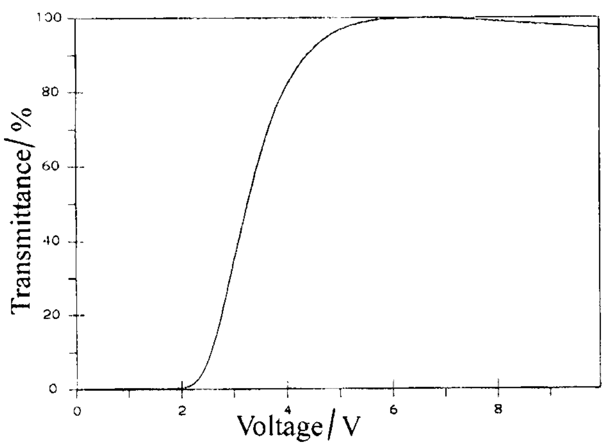

Figure 3. *V–T* characteristic of a conventional VA cell without negative compensation film on a homeotropic PI surface.

Table 1. Threshold voltage for the VA modes on homeotropic PI surfaces.

Modes	V_{10}/V	V_{90}/V
Novel VA-π cell	2.54	3.72
Conventional VA cell	2.56	4.39

Figure 4 shows the viewing angle characteristics of the novel VA-π cell without negative compensation film on a homeotropic PI surface. Iso-viewing angle characteristics were successfully observed. Additionally, viewing angle characteristics are dependent on the state of darkness; therefore a wide viewing angle can be achieved by utilizing a negative compensation film. Viewing angle characteristics measured in the conventional VA cell were asymmetric, as shown in figure 5.

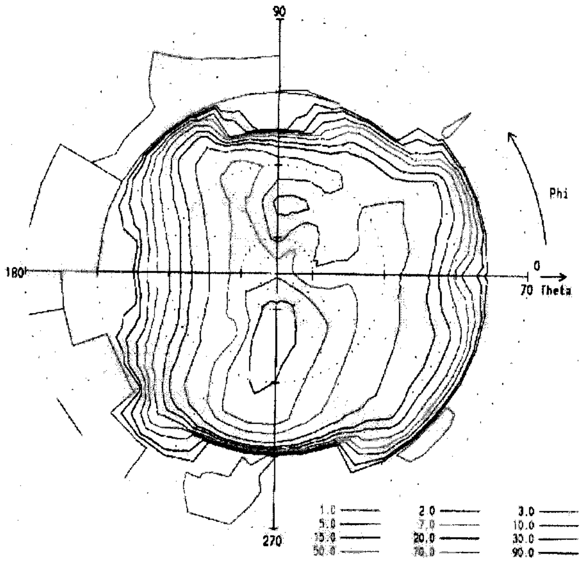

Figure 4. Viewing angle characteristics of the novel VA-π cell without negative compensation film on a homeotropic PI surface.

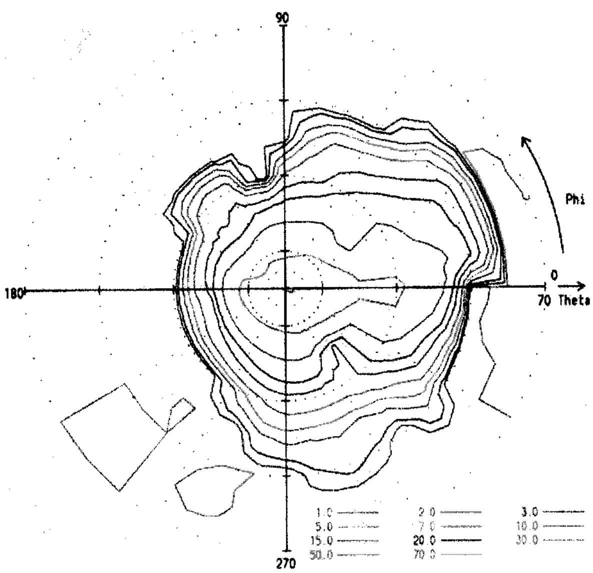

Figure 5. Viewing angle characteristics of a conventional VA cell without negative compensation film on a homeotropic PI surface.

Figure 6 shows the good response time (τ) characteristics of the novel VA-π cell. Response time characteristics, also good, for a conventional VA cell on a homeotropic PI surface are shown in figure 6. Table 2 shows the response times for the novel VA-π cell and the conventional VA cell on homeotropic PI surfaces. The response time for the novel VA-π cell mode was measured at about 31.7 ms; this was faster than that of the conventional VA cell. Consequently, both on iso-viewing angle and fast response time can be achieved by using the novel VA-π cell mode.

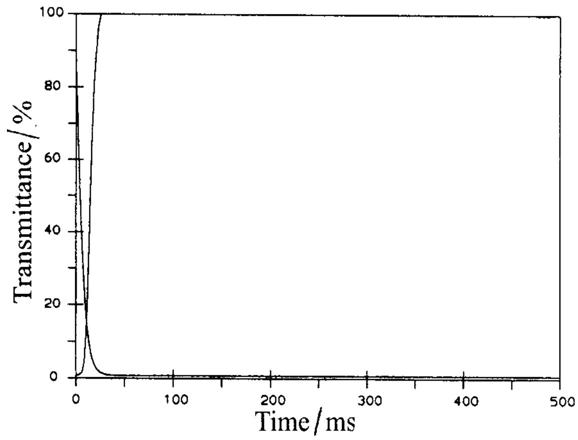

Figure 6. Response time characteristics of the novel VA-π cell without negative compensation film on a homeotropic PI surface.

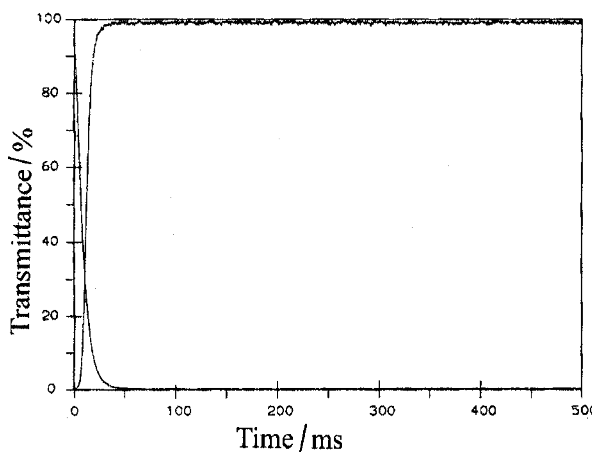

Figure 7. Response time characteristics of a conventional VA cell without negative compensation film on a homeotropic PI surface.

Table 2. Response time for the VA modes on homeotropic PI surfaces.

Modes	τ_r/ms	τ_d/ms	τ/ms
Novel VA-π cell	19.1	13.6	32.7
Conventional VA cell	18.1	18.5	36.6

In summary, we suggest that the newly developed novel VA-π cell mode on a homeotropic layer is capable of wide viewing angle and fast response time without the multi-domain accessory.

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