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Residual d.c. characteristics in the in-plane switching liquid crystal display by the capacitance–voltage hysteresis method on a polymer surface

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In this research, the image-sticking property of the in-plane switching (IPS)-liquid crystal display (LCD) with residual d.c. voltage on a rubbed polyimide surface was studied. The voltage holding ratio (VHR) and residual d.c. voltage were measured by the capacitance–voltage hysteresis method in the IPS-LCDs. It was found that the VHR increased with increasing specific resistivity of fluorine-containing LCs. The residual d.c. voltage decreased with increasing concentration of cyano-containing LCs. The residual d.c. voltage is thus decreased by the high polarity of cyano-LCs.

1. Introduction

The in-plane switching-liquid crystal display (IPS-LCD) used for desktop monitors is required to have high resolution, wide viewing angle, vivid colour performance, and no image sticking [1]. Rubbed polyimide (PI) layers are used to obtain uniform LC alignment and a high pretilt angle [2–5]. It is well known that the PI layer influences the electrical properties of LC cells such as voltage holding ratio (VHR) and residual d.c. voltage. It is also commonly understood that the residual d.c. voltage is related to image sticking, where a ghost image remains after the display signal changes, when the image has been displayed for a long time. Recently, residual d.c. voltages of the LCs on rubbed PI layers have been proposed as a possible cause of image sticking [6–8]. This, however, has not yet been reported in the literature; this paper examines the findings on these phenomena.

2. Experimental

Figure 1 shows the structure of the IPS-LCD used in this study. The electrode width used as 10 μm; electrode distance was 20 μm. The electrode was formed by MoW.

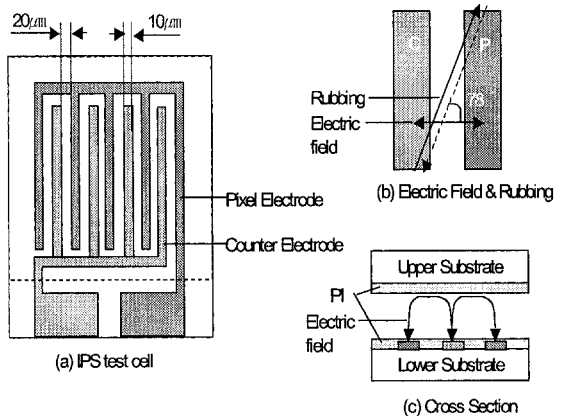

Figure 1. Structure of the IPS-LCD.

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The PI (Al-1051; for low pretilt, JSR Co., Ltd.) films were formed on ITO (indium tin oxide) coated glass substrates by curing at 180°C for 1 h. The rubbing direction was 78° to the electric field on the PI surfaces, as shown in figure 1 (*b*). The IPS-LCDs were assembled with anti-parallel structure; cell thickness was 4.7 μm. The LCs used (from the Chisso Corp.) had positive dielectric anisotropy, and the fabricated IPS-LCD was in the NB (normally black) mode. The table shows the physical properties of the LCs.

The VHR characteristics were measured using the VHR measurement system (VHRM103, Autronic Co., Ltd.) as shown in figure 2. The pulse width, frame frequency, and data voltage were 40 μs, 60 Hz, and 1.0 V, respectively. VHR measurements were performed 20 times, and average values were obtained. The measurement temperatures were 25, 50 and 70°C. Residual d.c. voltages were measured using an LCR meter (4284A, Hewlett Packard Co., Ltd.) as shown in figure 3.

3. Results and discussion

Figure 4 shows the VHR properties of the IPS-LCDs with different cyano-LC (from E. Merck) concentrations on rubbed PI surfaces. It can be seen that the VHR decreases with increasing temperature. A similar behaviour in an LC cell with anti-parallel structure on rubbed PI layers has been reported [6]. Also, it is clear that the VHR decreases with increasing cyano-LC concentration. The same effect in IPS-LCDs on rubbed PI layers has been reported [6].

VHR properties of IPS-LCDs with fluoro-LCs of different specific resistivities on rubbed PI surfaces are shown in figure 5. The VHR decreases with increasing temperature; it also decreases with decreasing specific resistivity of the fluoro-LC. The VHR was about 95% at above 10^{11} Ω cm, and 83% at 10^{10} Ω cm.

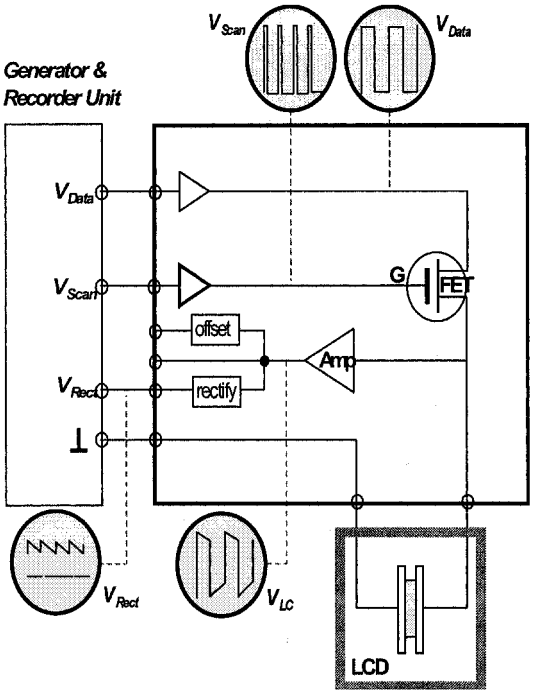

Figure 2. VHR measurement system.

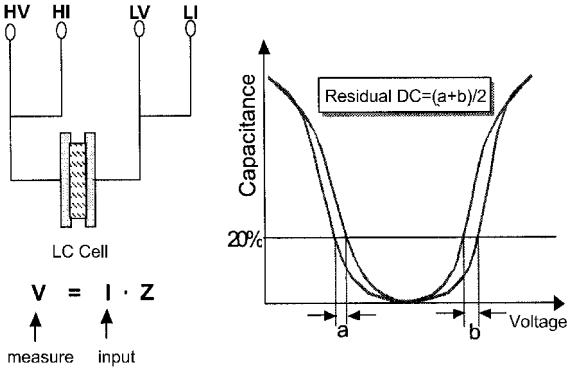

Figure 3. C-V hysteresis measurement system.

Table. Physical properties of NLCs used in this study.

NLC†	Δn (25°C, 589 nm)	$\Delta\varepsilon$ (1 kHz, 25°C)	T_{NI}/°C	η/mPa s (at 20°C)	ρ (at 25°C)	γ/mPa s (at 25°C)	[CN]/wt%
C5023	0.075	7.2	72.0	18.9	$>1 \times 10^{13}$	90.1	0
C5048	0.075	7.3	71.6	17.9	5.4×10^{12}	88.8	5
C5049	0.075	7.3	71.5	18.3	2.9×10^{12}	84.3	10
C5050	0.075	7.2	71.1	18.1	3.8×10^{12}	82.4	15
C5051	0.075	7.3	70.9	18.2	9.2×10^{12}	80.2	20
C5037	0.070	6.1	70.6	18.8	9.0×10^{10}	—	0
C5038	0.070	6.1	70.5	18.8	1.0×10^{11}	—	0
C5039	0.070	6.1	70.5	18.8	8.0×10^{12}	—	0
C5040	0.070	6.1	70.5	18.8	3.0×10^{13}	—	0

†Materials from the Chisso Corp. whose coding is ZGD5023 etc.

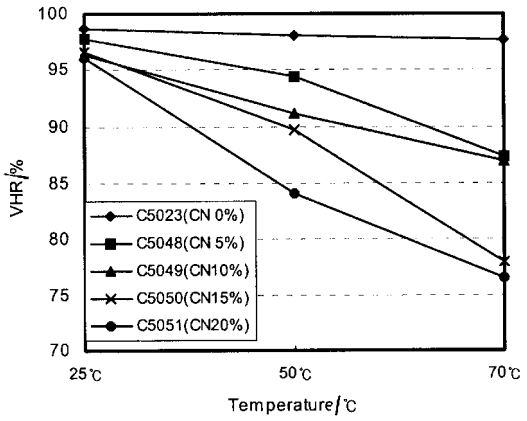

Figure 4. VHR properties in IPS-LCDs (undoped or cyano-doped mixtures from the Chisso Corp.) on rubbed PI surfaces as a function of cyano-LC concentration.

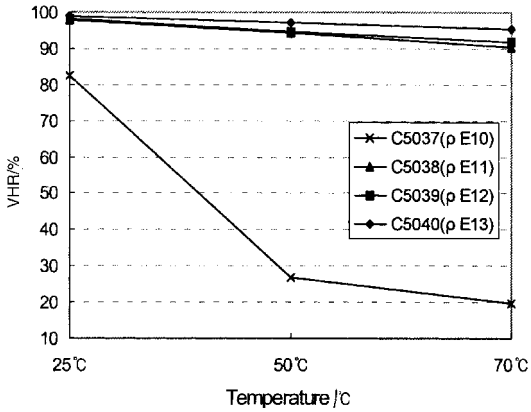

Figure 5. VHR properties of IPS-LCDs on rubbed PI surfaces as a function of specific resistivity of fluoro-LCs. The sample numbers C 5037 etc. refer to fluoro-LC mixtures from the Chisso Corp. catalogued as 2GD-5037 etc. In the figure the E10 etc. indicate the power of the value of the specific resistivity (see the table).

Figure 6 shows that the capacitance hysteresis of the LC decreases with increasing cyano-LC concentration. Figure 7 shows the residual d.c. voltage characteristics of the IPS-LCDs with different cyano-LC concentrations on rubbed PI surfaces. It can be seen that the residual d.c. voltage decreases with increasing cyano-LC concentration.

4. Conclusion

In conclusion, the VHR decreased with increasing concentration of cyano-LC and increased with specific resistivity of fluoro-LCs. The residual d.c. voltage decreased both with increasing concentration of cyano-LC and with increasing specific resistivity of fluoro-LCs. This indicates that the high polarity of cyano-LCs helps to reduce residual d.c. voltage and may improve image sticking properties in the PI layer of the IPS-LCD.

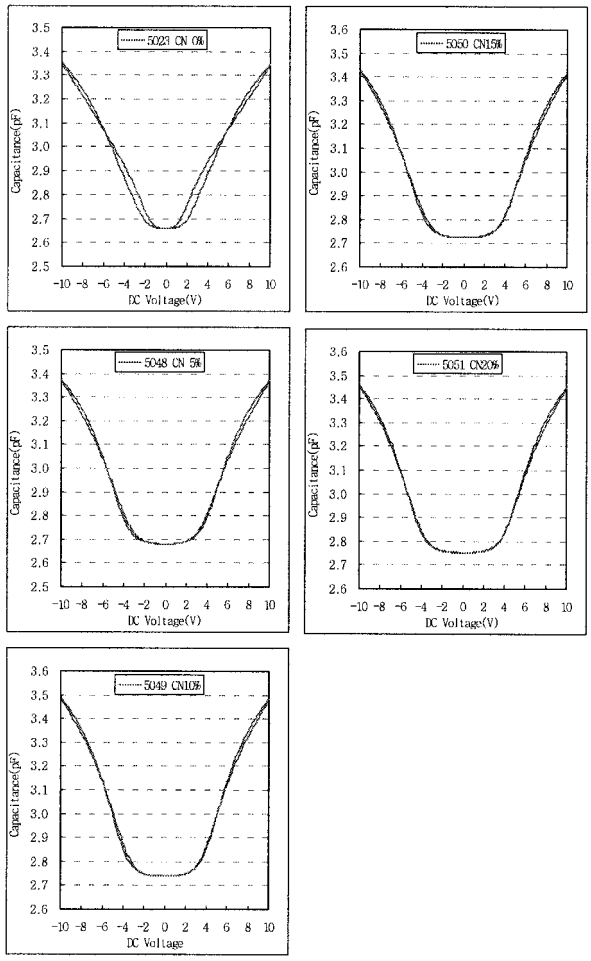

Figure 6. *C–V* hysteresis in IPS-LCDs with different cyano LC concentrations on rubbed PI surfaces.

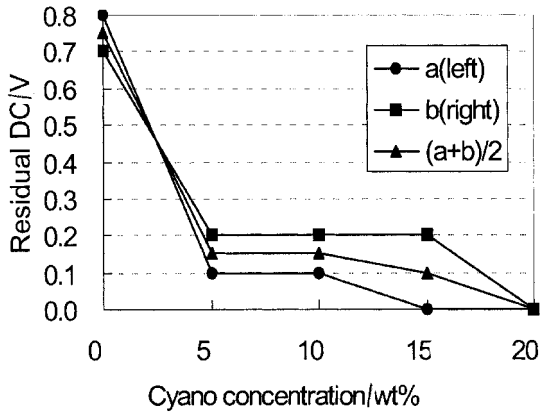

Figure 7. Residual d.c. voltage in IPS-LCDs on rubbed PI surfaces as a function of cyano-LC concentration.

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