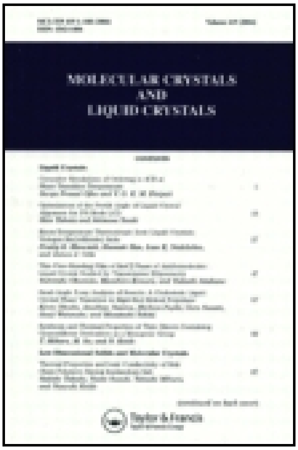

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VOLTAGE HOLDING RATIO AND RESIDUAL DC PROPERTY OF THE IPS-LCD ON RUBBED POLYMER LAYERS BY VOLTAGE-TRANSMITTANCE HYSTERESIS METHOD

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Voltage holding ratio (VHR) and residual DC phenomena for the in-plane switching (IPS)-liquid crystal display (LCD) on a rubbed polyimide (PI) surface were investigated. It was found that the VHR of the IPS-LCDs on the rubbed PI layer increased with increasing concentration of cyano LC and specific resistivity of fluorine LCs. Also, the residual DC voltage in the IPS-LCD by voltage-transmittance (V-T) hysteresis method decreased with increasing cyano concentration of LCs. The residual DC voltage of the IPS-LCD can be improved by high polarity of LCs. Finally, the new residual DC voltage measurement of the IPS-LCDs by light minimum/maximum method is proposed.

Keywords: cyano LC; in-plane switching liquid crystal display; nematic liquid crystal; polyimide; residual DC voltage; specific resistivity

INTRODUCTION

Nowadays, thin-film-transistor (TFT) liquid-crystal displays (LCD) are widely used, such as notebook computers, mobile phone, and monitors because they have excellent quality of resolution. However, LCD performance has not been satisfied because of the narrow viewing angle.

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Previously, some techniques have been proposed to improve the viewing angle characteristics, such as the film-compensated twisted nematic (TN) cells [1], optically compensated birefringence (OCB) cells [2], in-plane-switching (IPS) cells [3], and multidomain vertical-alignment (MVA) cells [4]. Also, the fringe field effect using a slit-patterned electrode [5.6] and protrusion [4] have been reported to improve the viewing angle. IPS-LCD used for desktop monitors is required to have high resolution, wide viewing angle, vivid color performance, and no image sticking [7]. It is well known that the PI layer influences the electrical properties of LC cells such as VHR and residual DC. It is commonly understood that residual DC has some relation with image sticking. The image remains even after the display signal changes when the voltage is applied for a long time. Recently, the residual DC voltages of the NLCs on the rubbed PI layers have been proposed by many researchers [8–10]. But, the residual DC in the IPS-LCD on the rubbed PI layers has not been yet reported.

In this work, we report on the residual DC characteristics of the IPS-LCD by V-T hysteresis method and new light minimum/maximum method on the rubbed PI surface. Also, the VHR characteristics of the IPS-LCDs on the rubbed PI surface were studied.

EXPERIMENTAL

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

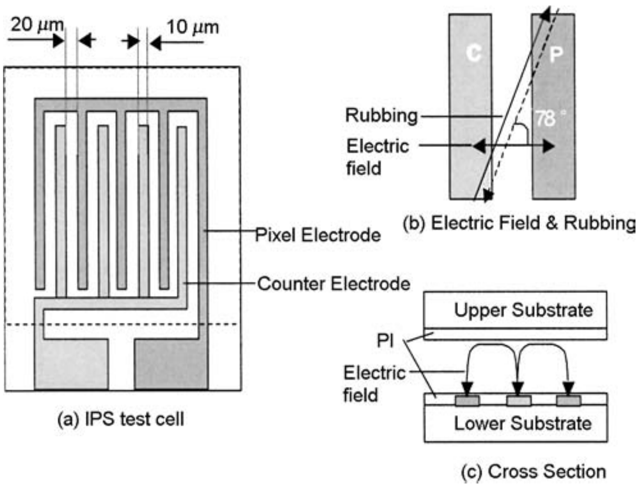

FIGURE 1 Structure of the IPS-LCD.

formed by MoW. The Pi (AL-1501; for low pretilt, JSR Co.) films were formed on ITO (indium-tin-oxide) coated glass substrate by curing at 180°C for 1 hr. The rubbing [11–14] was treated by 78° to the electric field on the PI surfaces as shown in Figure 1(b). The IPS-LCD was assembled by anti-parallel structure. The cell thickness was 4.7 μm. NLCs used had positive dielectric anisotropy. The IPS-LCD fabricated was NB (normally black) mode.

Table I shows the physical properties of the NLCs (from Chisso Co.). The VHR characteristics were measured using the VHR measurement system (VHRM103, Autronic Co.) as shown in Figure 2. The pulse width, frame frequency, and data voltages were 40 μs, 60 Hz, and 1.0 V, respectively. VHR measurements were performed 20 times. Average values were obtained from these measurements. The measurement temperatures were 25°C, 50°C, and 70°C. The residual DC voltage was measured using the LCD evaluation system (LCD7000, Otsuka Co.) as shown in Figure 3.

Also, the residual DC voltage was measured using LCD evaluation system (LCD7000, Otsuka Co.) and oscilloscope as shown in Figure 4. We measured the offset voltage in minimizing of the flicker. The residual DC voltage was evaluated as shown in Figure 5. The V_{com} offset voltage was measured by minimizing or maximizing the light. The measurement methods are as follows: (a) We measured the light minimum value of or offset voltage before stress. The light minimum or offset voltages were measured by applied voltage from -1.5 V to $+1.5$ V on a oppose electrode. The pixel electrode was applied AC 4 V at 25 Hz. (b) The stress was applied in the LC cell for 1 h at 50°C. The applied voltages were AC 5 V and DC 10 V for driving voltage of LC cell and offset voltage, respectively. (c) The two electrodes were shorted between the pixel electrode and the oppose electrode for 1 min at 20°C. (d) In order to stabilize LC cells, we applied the AC 5 V

TABLE I Physical Properties of NLCs (from Chisso Co.)

NLC	Δn (25°C,589 nm)	Δε (1 kHz, 25°C)	Tni (°C)	η (mPas) (at 20°C)	ρ (at 25°C)	γ (mPas) (at 25°C)	CN (wt%)
C5023	0.075	7.2	72.0	18.9	$>1\times10^{13}$	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

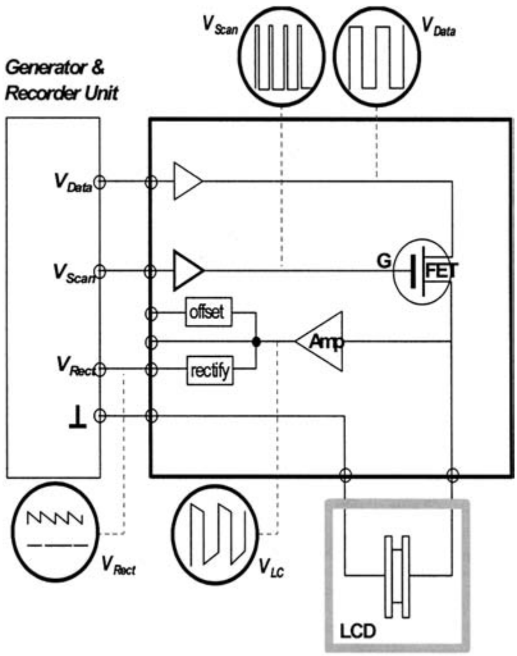

FIGURE 2 Measurement system of VHR.

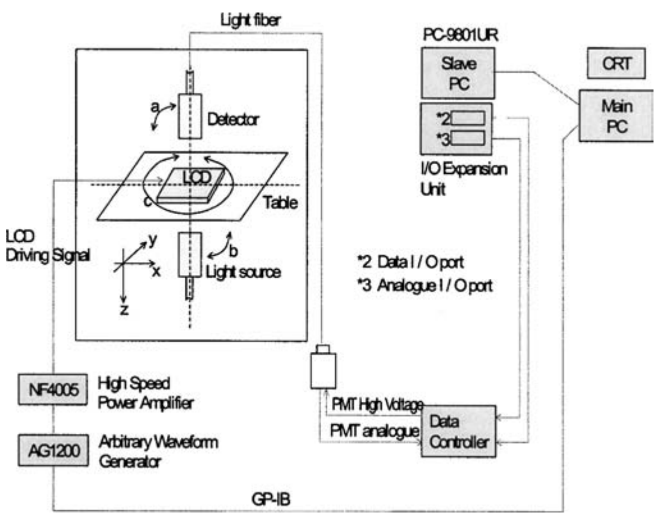

FIGURE 3 Measurement system of V-T hysteresis.

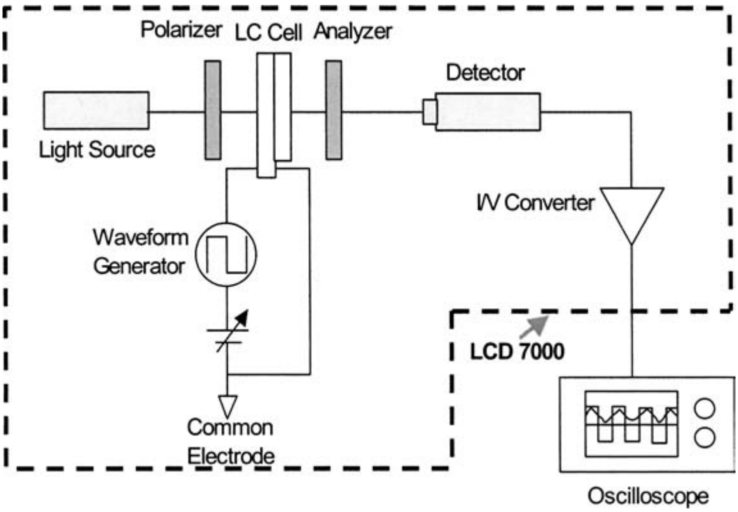

FIGURE 4 Measurement system of flicker minimizing method.

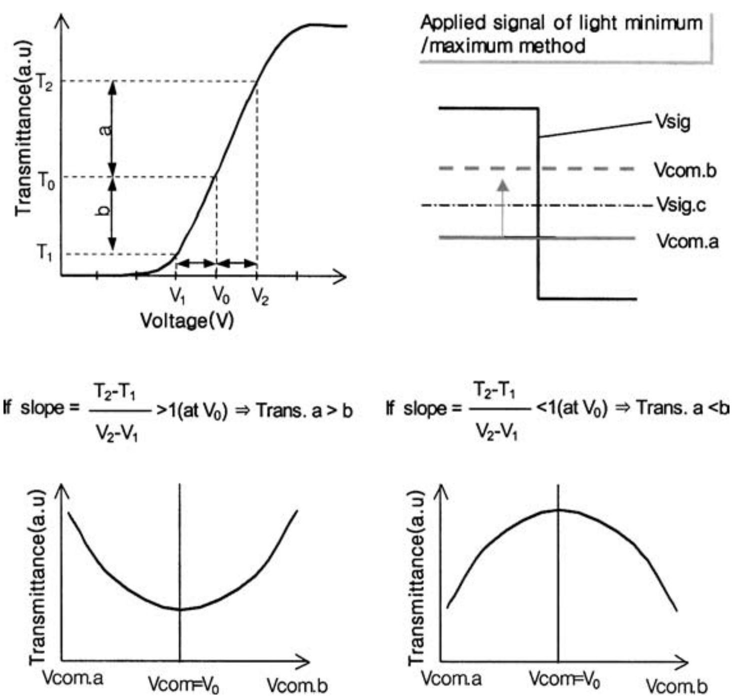

FIGURE 5 Priniciple of measurement in light minimum/maximum method.

(30 Hz) in the IPS-LCD for 10 min. (e) The offset voltage was measured after stress. (f) We defined the residual DC voltage by deduction value between before the stress and the after stress.

RESULTS AND DISCUSSION

1. VHR Characteristics

Figure 6 shows the VHR properties of the IPS-LCD with different cyano LCs concentrations on the rubbed Pi surfaces. It is shown that the VHR decreases with increasing temperature. A similar behavior in the LC cell with anti-parallel structure on the rubbed PI layers has been reported [8]. Also, it is clearly observed that the VHR decreases with increasing cyano LC concentrations. The same effects in the IPS-LCD on the rubbed PI layers has been reported [8].

VHR properties of the IPS-LCD with different specific resistivities of the fluorine LCs on the rubbed PI surfaces are shown in Figure 7. The VHR decreases with increasing temperature. Also, the VHR decreases with decreasing specific resistivity of fluorine LCs. The VHR was about 95% at above $10^{11}\,\Omega$cm. But the VHR was 83% at $10^{10}\,\Omega$cm.

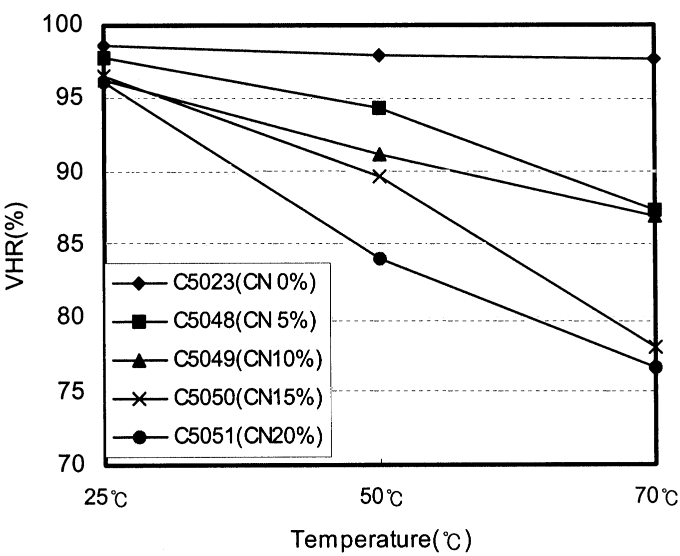

FIGURE 6 VHR properties in the IPS-LCDs on the rubbed PI surfaces as a function of cyano LCs concentrations.

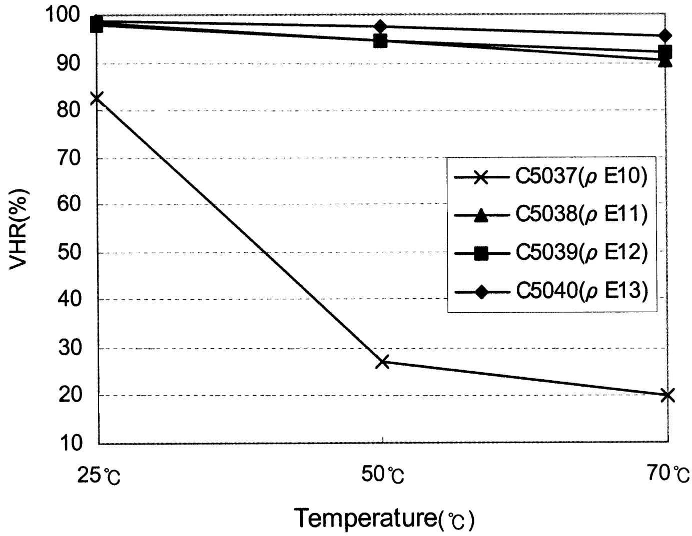

FIGURE 7 VHR properties in the IPS-LCDs on the rubbed PI surfaces as a function of specific resistivity of fluorine LCs.

2. Residual DC Characteristics by V-T Hysteresis Method

Figure 8 shows the V-T hysteresis properties in the IPS-LCDs with different cyano NLCs concentrations on the rubbed PI surfaces. It is clearly observed that the transmittance hysteresis of the IPS-LCD decreases with increasing cyano NLC concentrations. Table II shows the residual DC voltage in the IPS-LCDs with different cyano NLCs concentrations by V-T hysteresis method on the rubbed PI surfaces. The residual DC voltage in the IPS-LCD decreases with increasing cyano NLC concentrations.

Figure 9 shows the V-T hysteresis characteristics in the IPS-LCDs with different specific resistivity of fluorine NLCs on the rubbed PI surfaces. It shows that the different tendency was measured compared with cyano NLC at transmittance of 50%. The cross behavior of the transmittance was observed by up/down of DC voltage in voluntary voltage. It is considered that the residual DC was influenced by impurity of NLCs for low specific resistivity of NLC in applied DC voltage.

Therefore, we consider that the residual DC can be improved by high specific resistivity of NLC. In a previous paper, the unified model of residual DC phenomena has been proposed [9]. It was proposed that the residual DC characteristics is complex of two phenomena, one is interfacial and dipole polarization of dielectric multi-layers and the other is the electric potential of adsorbed ions on the surface between the NLC and the PI layer.

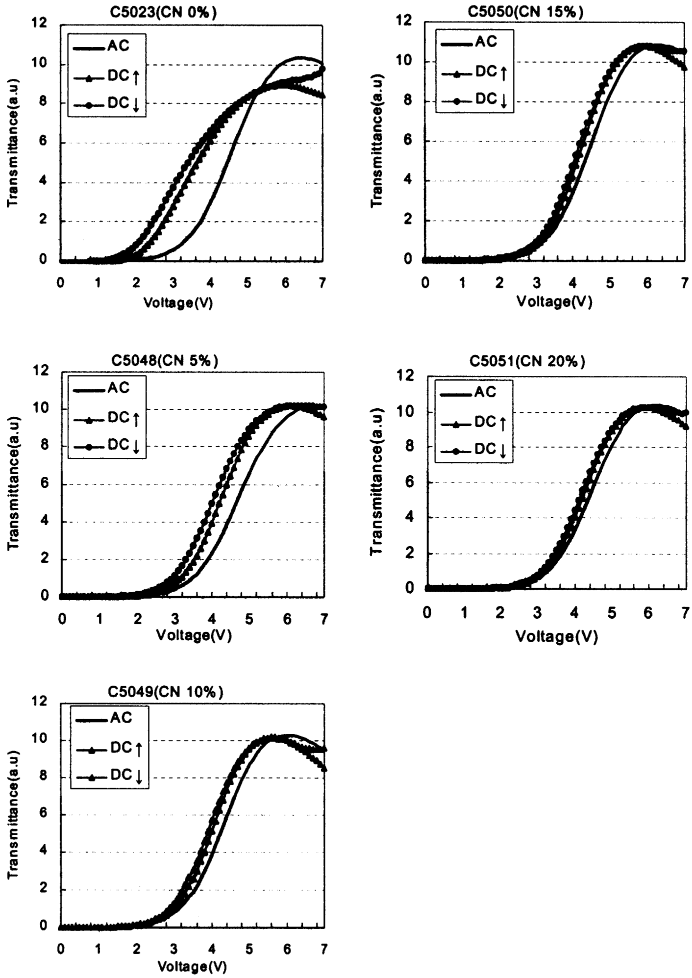

FIGURE 8 V-T hysteresis characteristics in the IPS-LCDs with different cyano LCs concentrations on the rubbed PI surfaces.

Consequently, the residual DC voltage of the IPS-LCD decreased with increasing concentration of cyano NLCs, indicating that the high polarity of cyano NLC helps reducing the residual DC voltage. Also, the residual DC can be improved by high specific resistivity of NLCs.

3. Flicker Minimizing Method

Figure 10 shows the offset voltage in the IPS-LCD (C5023) without cyano LCs on the rubbed PI surfaces by the flicker minimizing method. It is shown

TABLE II Residual DC Voltage in the IPS-LCDs by V-T Hysteresis Method on the Rubbed PI Surfaces

LC materials	AC	DC↑	DC↓	AC-DC↑	DC↑-DC↓
C5023(CN 0%)	4.50	3.69	3.46	0.81	0.23
C5048(CN 5%)	4.68	4.23	4.03	0.45	0.20
C5049(CN 10%)	4.25	4.00	3.90	0.25	0.10
C5050(CN 15%)	4.42	4.22	4.13	0.20	0.09
C5051(CN 20%)	4.38	4.21	4.14	0.17	0.07

that the residual DC voltage of the IPS-LCD was about 0 V. It is considered that the sensitivity of residual DC measurement in the IPS-LCD by flicker minimization was limited.

4. New Light Minimum/Maximum Method

Figure 11 shows the offset voltage in the IPS-LCD (C5023) without cyano LCs on the rubbed PI surfaces by light minimum/maximum method. It shows that the offset voltage before stress was measured 0 V, and offset

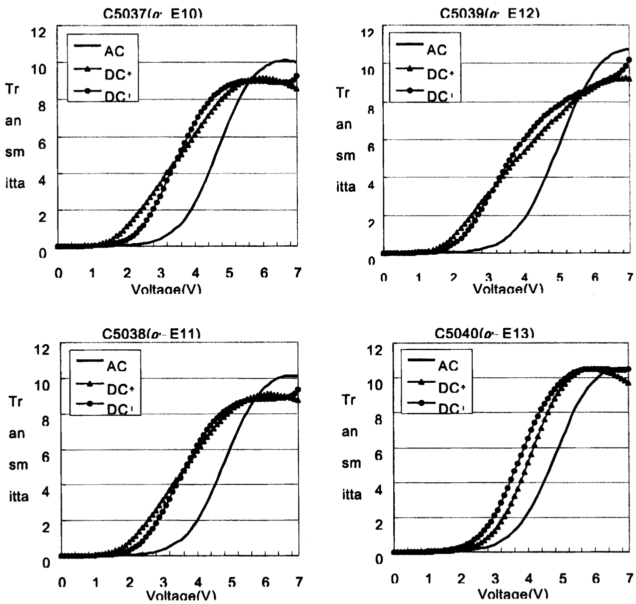

FIGURE 9 V-T hysteresis characteristics in the IPS-LCDs for fluorine LCs with different specific resistivities on the rubbed PI surfaces.

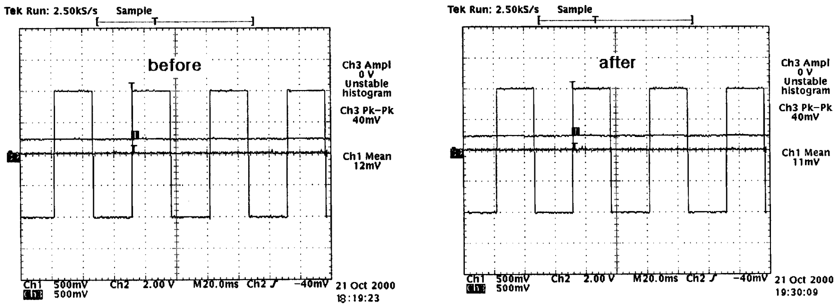

FIGURE 10 Offset voltage before and after stress in flicker minimizing method.

voltage after stress was measured about −0.1 V. Therefore, the residual DC voltage was about 0.1 V.

Table III shows the residual DC voltages in the IPS-LCDs by light minimum/maximum method on the rubbed PI surface. It is considered that the fine residual DC voltage in the IPS-LCD was easily measured. Consequently, the residual DC measurement by light minimum/maximum method compared with the flicker minimizing method and found that new measurement method of residual DC is more accurate than the conventional flicker minimizing method since the resolution level of measurement is in 0.1 V.

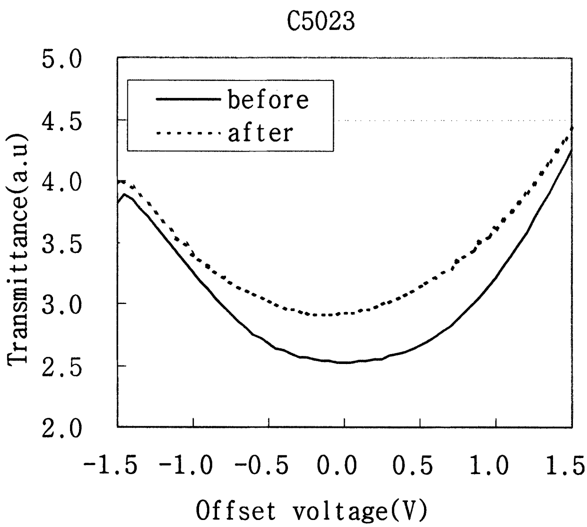

FIGURE 11 Offset voltage before and after stress in light minimum/maximum method.

TABLE III Offset Voltage and Residual DC Voltage Before and After Stress by Light Minimum/Maximum Method

LC materials	Before	After	Residual DC
C5023(CN 0%)	0.00	−0.10	0.10
C5048(CN 5%)	0.05	0.00	0.05
C5049(CN 10%)	0.20	0.05	0.15
C5050(CN 15%)	0.10	0.00	0.10
C5051(CN 20%)	0.10	0.05	0.05
C5037(ρ E^{10})	−0.10	0.10	0.20
C5038(ρ E^{11})	0.05	−0.15	0.20
C5039(ρ E^{12})	0.05	−0.20	0.25
C5040(ρ E^{13})	0.00	−0.20	0.20

CONCLUSION

In conclusion, the VHR decreased with increasing concentration of cyano LC and increased with specific resistivity of fluorine LCs. The residual DC voltage in the IPS-LCD was decreasing with increasing concentration of cyano NLCs. Also, the residual DC can be improved by high specific resistivity of NLC. Consequently, the residual DC voltage of the IPS-LCD can be improved by high polarity of cyano NLCs. Also, we proposed the residual DC in the IPS-LCD by new light minimum/maximum method. We confirmed the precision of residual DC measurement by light minimum/maximum method was good compared with the flicker minimizing method, and found that new measurement method of residual DC is more accurate than that of the conventional flicker minimizing method since the resolution level of measurement is in 0.1 V.

REFERENCES

[1] Ong, H. L. (1992). Proc. Japn Display'92, 247.
[2] Miyashita, T., Yamaguchi, Y., & Uchida, T. (1995). *Jpn. J. Appl. Phys.*, *34*, L177.
[3] Oh-e, M. & Kondo, K. (1996). *Appl. Phys. Lett.*, *69*, 623.
[4] Ohmuro, K., Kataoka, S., Sasaki, T., & Koike, Y. (1997). SID'97 Digest paper, 845.
[5] He, Z., Nose, T., & Sato S. (1997). *Jpn. J. Appl. Phys.*, *36*, 1178.
[6] Seo, D.-S. & Hwang, J.-Y. (2000). *Jpn. J. Appl. Phys.*, *39*, 914.
[7] Oh-e, M. & Kondo, K. (1998). *Liq. Cryst.*, *25*, 702.
[8] Sato, T., Sawahata, K., Endo, H., & Fukuro, H. (1998). SID'98 Digest paper, 738.
[9] Nakazono, Y., Takagi, Y., Sawada, A., & Naemura, S. (1998). IDW'98 Digest paper, 61.
[10] Fukuoka, N., Okamoto, M., Yamamoto, Y., Hasegawa, M., Tanaka, Y., Hatoh, H., & Mukai, K. (1994). AM-LCD'94 Digest paper, 216.
[11] Seo, D.-S., Muroi, K., & Kobayashi, S. (1992). *Mol. Cryst. Liq. Cryst.*, *213*, 223.

[12] Seo, D.-S., Araya, K., Yoshida, N., Nishikawa, M., Yabe, Y., & Kobayashi, S. (1995). *Jpn. J. Appl. Phys.*, *34*, L503.
[13] Geary, J. M., Goodby, J. W., Kmetz, A. R., & Patel, S. (1987). *J. Appl. Phys.*, *62*, 4100.
[14] Myrvold, B. O. & Kondo, K. (1994). *Liq. Cryst.*, *17*, 437.