Image Sticking Resistant Liquid Crystal Display Driven by Fringe Electric Field for Mobile Applicaitions

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We propose image sticking resistant liquid crystal display (LCD) driven by fringe electric field for mobile application. For use of an alignment layer with polyamic acid (PA) type without cross link agent, impurity ions absorbed on the alignment layer easily discharge irrespective of liquid crystal (LC) because there is not any cross link agent which prevents discharging the ions, resulting in that image sticking easily disappears. For a panel with use of an alignment layer with polyimide (PI) type, time dependant flicker value is less than 2 dB and very steady while it is more than 10 dB and dramatically changes for a panel with the PA coated. From the result, we can know the PA coated panel without cross link agent has advantage in fast discharge of impurity ions when voltage is off, which is very favorable to an approach to image sticking free LCD driven by fringe electric field for mobile devices.

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Recently, mobile devices such as personal digital assistants, digital still cameras, and mobile smart phone with high resolution are widely developed as a result of their increasing demand in the market.[1,2] These mobile displays require high image qualities like wide viewing angle, high transmittance, and low dynamic range. In-plane switching mode is the representative with wide viewing angle but it has low transmittance. On the other hands, fringe field switching mode has both high transmittance and wide viewing angle. These LC modes driven by in-plane field[3–5] have excellent electro-optic characteristic but asymmetrical electric field is generated in a bottom substrate when a voltage is applied. As a result, residual direct current (DC) is strongly formed in the bottom substrate. And also, impurity ions produced during manufacturing the liquid crystal display (LCD) are still trapped on the alignment layer due to this residual DC even though a voltage is eliminated.[6,7] Actually, we can easily recognize transmittance difference between normal area and abnormal area of which the displayed image is affected by degree of the ion's absorption as image sticking. Therefore, it is absolutely needed to solve this problem for these modes driven by in-plane field with high image quality. Further, as for mobile device of these modes with small pixel size, the image quality is sensitively affected by the residual DC or noise signal near pixel edge so that the small size LCDs are more vulnerable to the image sticking than other applications. Therefore, it is very important to optimize and design materials like LC and especially alignment layer for minimizing the image sticking.

In this paper, we measured the image sticking, residual DC, and time dependent flicker according to the materials like LCs or alignment layers to optimize a panel with excellent image quality. From the result, we proposed the image sticking resistant LCD driven by fringe electric field for mobile application.

Figure 1 shows the top and side views of this mode for mobile application. The electrode structure is like as follows. It has a planar common electrode and slit pixel electrodes on the bottom substrate. The pixel electrode with patterned slits exists with a width (w) and a distance (l'). The w and l' are designed to be 3 and 5 μm, respectively, which are commercially used.[8,9] With this structure, the fringe electric field having both horizontal and vertical component is generated with a bias voltage. The slit angle (SA), θ is 0° and the rubbing direction is given to horizontal direction to make an angle of $-7°$ with respect to the horizontal component of the fringe field. Pretilt angle is 2° and the cell gap (d) is 3.8 μm. LCs (supplied by Merck and Chisso) for mobile application are used. Alignment layers are polyimide (PI) type (supplied by JCR) and polyamic acid (PA) type (supplied by Nissan Chemicals) which are respectively with and without crosslink agent. Here, the LCs and materials of alignment layer employed have their physical properties as shown in Tables I and II. With this cell structure, LC molecules are homogeneously aligned with their optic axis parallel to the transmission axis of the bottom linear polarizer. The bottom polarizer is crossed to the top one. As a result, it shows normally black in an initial state and transmittance becomes maximal while the LC directors are rotated close to 45° by fringe electric field.

At first, we measured image sticking characteristics depending on LCs and alignment layer. Here, image sticking evaluation was performed as follows. We observed disappearance degree of $5 \times 5\,cm^2$ white-and-dark chess pattern in 2.0-in. quarter vedeo graphics array (qVGA) LCD panel after a given stress time, 2 h at the state of gray backgrounds which are gray 32 and 20. Full white and dark luminance is respectively, 300 and $0.5\,cd/m^2$. Each panel is designed as follows. First, A-1 is PI coated panel with LC1, A-2 is PI coated panel with LC2, A-3 is PI coated panel with LC3, A-4 is PI coated panel with LC4, B-1 is PA coated panel with LC1, B-2 is PA coated panel with LC2, B-3 is PA coated panel with LC3, and B-4 is PA coated panel with LC4.

As indicated in Fig. 2, image sticking of all PA coated panels in the gray 32 background state disappear within 1 min. On the other hands, one of PI coated panels keeps image sticking over 2 h. With this evaluation, we can see the all PA coated panels, irrespective of LCs easily disappear image sticking and also the alignment layer is more critical factor than LCs for the image-sticking.

Next, let us consider effect of alignment layer of PA type on the image sticking. Actually, PI used in this panel contains cross linking agent for the strong rubbing force.

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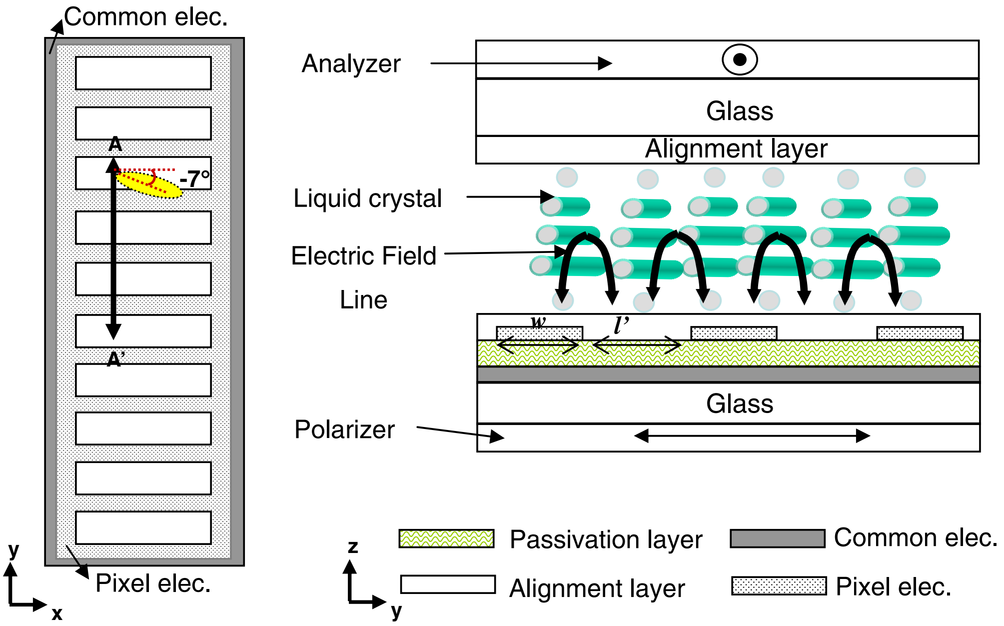

(a) (b)

Fig. 1. (Color online) Top and side views of cell structure of this mode for mobile application.

Table I. Physical properties of alignment layers.

	Polyimide	Polyamic acid
Imidization (%)	90	75
Solvent (%)	γ-BL/BC/PC = 65/5/30	NMP/BC = 80/20
Curing condition (°C/min)	220/60	220/30
Viscosity (mPa·s)	40	43
VHR (%)	99.4	99.0

Table II. Physical properties of LCs.

	LC1	LC2	LC3	LC4
Δn	0.0967	0.0960	0.0987	0.1030
$\Delta\varepsilon$	8.3	8.8	8.2	7.8
γ_1	127	108	84	82

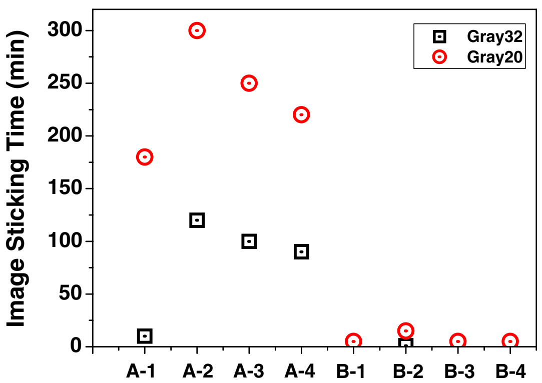

Fig. 2. (Color online) Image sticking at different LCs and alignment layers after the applied stress pattern for 2 h.

It prevents discharging of impure ions. However, in case of PA type, it does not contain them so impure ions trapped on the alignment layer discharge easily.

To confirm this result, we measured time dependent flicker in various LCs and alignment layers, as depicted in Fig. 3. We can see an interesting thing as follows. For the PA coated panel, the flicker value is changing dramatically as the time evolves. On the other hands, for the PI coated panel, the change of the flicker value within 60 sec is less than 2 dB and very steady while the value for PA coated

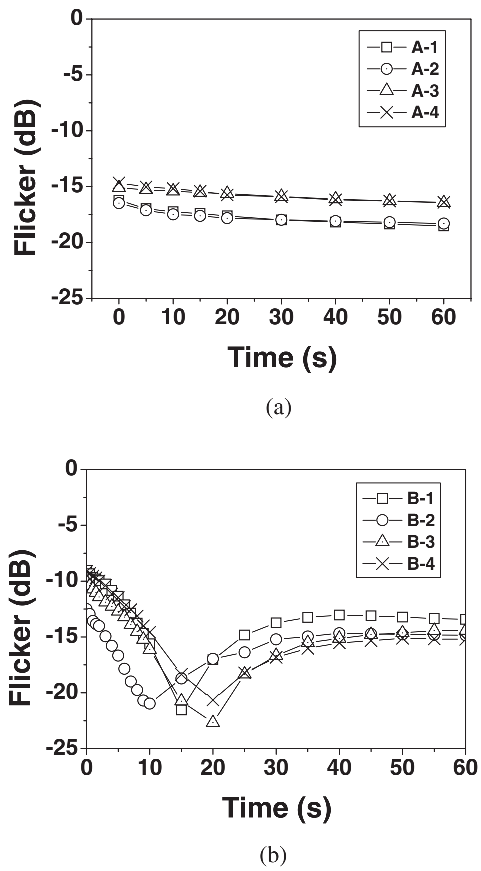

Fig. 3. Time dependent flicker at different LCs and alignment layers: (a) PI coated panels, (b) PA coated panels.

Table III. Residual DC properties of test cells depending on LCs and alignment layers, Stress: 10 V/35 min.

Cell condition	Time after DC_{off}		
	5 min	10 min	30 min
A-1	1.8	1.2	0.5
A-2	1.9	1.4	0.9
B-1	0.8	0.3	0.1
B-2	0.6	0.3	0.1

panel is more than 10 dB. From this result, we can expect fast discharging of the impure ions at the PA coated panel is occurring in which the alignment layer does not have crosslinking agent.

And also we measured residual DC depending on various LCs and alignment layers by applying DC 10 V for 35 min, and the results are shown in Table III. Residual DCs for cell A-1 and cell A-2 are 0.5 and 0.9 V, respectively while the value for B-1 and B-2 cell is only 0.1 V at the condition of 30 minute after DC_{off}. That is, the residual DC value of PA coated cell is much less than PI coated thing. We can know that the PA without cross linking agent coated cell is much favorable to discharging of impure ions.

In summary, we proposed image sticking resistant LCD driven by fringe electric field for mobile application. For PA coated panel without crosslinking agent, impurity ions absorbed on the alignment layer discharge easily because there is not any crosslinking agent which prevents discharging the ions. As a result, image sticking disappears fast. Therefore it is possible for us to approach to fabricate image sticking free LCD driven by fringe electric field for mobile application.

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