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Investigation of alignment direction in wide view film and rubbing angle of twisted nematic liquid crystal display mode

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Wide view (WV) film is an important material in the polariser. It is a hybrid-aligned, discotic liquid crystal (DLC) on an alignment layer on the tri-acetyl cellulose film, which is used as compensation film in twisted nematic (TN) mode liquid crystal display (LCD). The relation between the alignment direction of the DLC in the WV film and the rubbing direction of the polyimide on the glass substrate in the TN mode LCD was investigated. The results indicated that the contrast ratio (CR) of the TN mode LCD can be increased by adjusting this angle . When an 88° rubbing angle was used in this work, the CR of the TN mode LCD could reach 1000:1 and the horizontal and vertical viewing angles were 170 and 160°, respectively.

Keywords: wide view film; contrast ratio; alignment direction; rubbing angle; twisted nematic mode liquid crystal display

1. Introduction

Twisted nematic (TN) liquid crystal displays (LCDs) are widely used in monitors, mobile phones, cameras, car navigation systems, televisions and so on (*1*, *2*). For the TN mode LCD, the polariser is a critical component and there are several layers in the polariser, which include the protection film, the tri-acetyl cellulose (TAC) film, the uniaxially polyvinyl alcohol (PVA) layer, which dispersed dichroic absorbing iodine or crystal particles, the wide view (WV) film, the pressure sensitive adhesive and the release film (*3*). The layer structure is shown in Figure 1. The WV film (also called the compensation film) is used for enhancing the viewing angle region of the TN-LCD. It is a discotic liquid crystal (DLC) (disc-like molecule) material, which is coated on a hybrid alignment layer on the TAC film (*4–8*). The material of the DLC is one of the triphenylene derivatives, which has a disc-like shape, high birefringence and is cross-linking. For the hybrid structure, the discotic molecules in the vicinity of the alignment surface tend to align with the molecular plane parallel to the alignment layer surface, while the molecules in the vicinity of the air surface tend to align with the molecular plane almost perpendicular to the air surface, as shown in Figure 2. The WV film can compensate three-dimensionally the birefringence of the TN liquid crystal (LC) in the LCD cells in the black state, and light leakage is suppressed in all viewing directions (*9*). Therefore, the contrast ratio (CR) and the viewing angle performance of the LCDs are enhanced.

When the WV film is applied to the TN mode LCDs (*10*, *11*), the relation among the alignment direction of the DLC in the WV film, the absorption axis of the PVA layer and the rubbing direction of the polyimide (PI) on the glass substrate is shown in Figure 3. In general, the rubbing direction on the top glass substrate (colour filer, CF substrate) is 45° and the rubbing direction on the bottom glass substrate (thin film transistor glass substrate) is 135°, which are both observed from the protection film to the release film of the polariser on the top glass substrate. In industry, the PVA layer is manufactured by the polariser producer and the absorption axis direction of the PVA layer is fixed during the polariser manufacturing process. The WV and TAC films are adhered to the PVA layer using a roll-to-roll lamination process (*12*). If the angle between the alignment direction of the DLC layer in the WV film and the absorption axis of the PVA layer varies, the performance of the LCDs would be changed. We fixed the absorption axis of the PVA layer and varied the angle of the alignment direction of the DLC layer in the WV film. We investigated the relation between the alignment direction of the DLC layer in the WV film and the rubbing direction of the PI of the LCD, through adopting the different alignment direction of the DLC layer and

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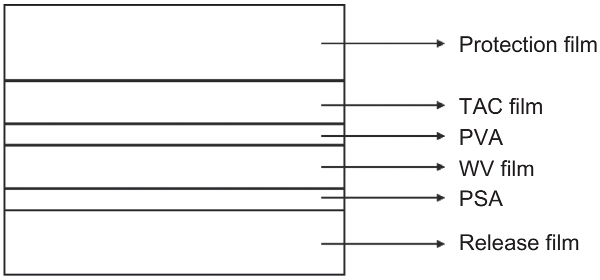

Figure 1. Layer structure of the polariser.

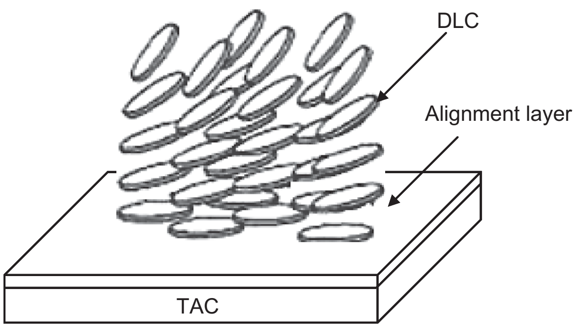

Figure 2. Structure of the wide view film.

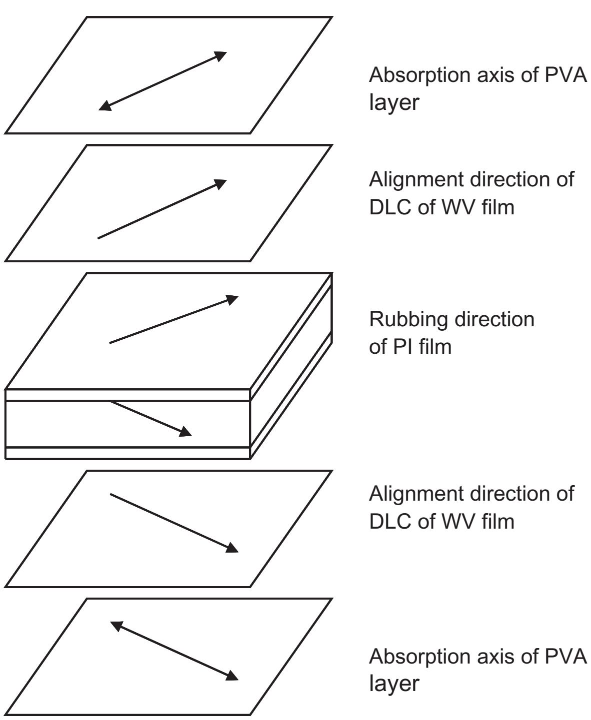

Figure 3. Directions of the discotic liquid crystal in a wide view film, the absorption axis of the polyvinyl alcohol layer and the rubbing direction of the polyimide on the substrate.

the rubbing angle of the PI. The experimental results, such as the CR and viewing angle, are reported. Good performance of the TN-LCDs was achieved.

2. Experiments

The WV film adopted in this experiment was a third generation compensation film called a 'WV-EA' type (*13*, *14*). It is suitable for the large size, wide-aspect-ratio TN-LCD mode. The angle between the alignment direction of the DLC in the WV film and the absorption axis direction of the PVA layer is defined as Θ_W, as shown in Figure 4. Figure 4 is a top-view scheme from the protection film to the release film of the polariser. Θ_W is given by

$$\Theta_{\mathrm{W}} = \theta_{PVA} - \theta_{\mathrm{W}V}. \tag{1}$$

θ_{PVA} is the absorption angle of the PVA layer and θ_{WV} is the alignment angle of the DLC in the WV film. If $\theta_{PVA} < \theta_{WV}$, $\Theta_{\mathrm{W}} < 0$, while $\Theta_{\mathrm{W}} > 0$ when $\theta_{PVA} > \theta_{WV}$. The rubbing direction of the PI and the rubbing angle $\theta_{\mathrm{rubbing}}$ is defined as in Figure 5.

To investigate the relation between the alignment direction of the DLC in the WV film and the rubbing

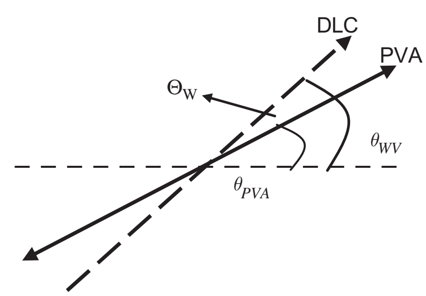

Figure 4. Angle between the direction of alignment of the discotic liquid crystal in a wide view film and the direction of the absorption axis of the polyvinyl alcohol layer.

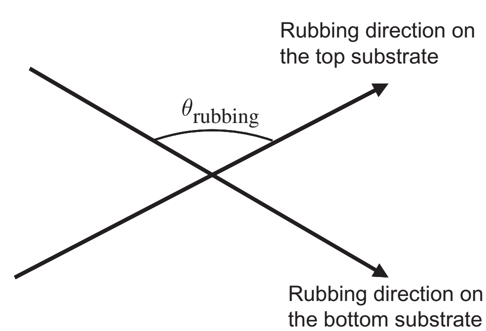

Figure 5. Rubbing angle in the twisted nematic liquid crystal display mode.

direction of the PI, the polariser with fixed absorption axis and different Θ_W was attached to the 19 inch (16:10) TN-LCD mode panels. The value of Θ_W varied from 0 to –0.8° and the different rubbing angles $\theta_{rubbing}$ (i.e. 87°, 89° and 91°) were adopted in the experiment. The rubbing directions on the top and bottom glass substrates were both changed (inwards or outwards with the same magnitude) when a different rubbing angle was obtained. The performance of the sample panels, such as CR and viewing angle, was measured by the BM-5A (Topcon) and CA-210 display colour analyser (Konica Minolta).

The CR was calculated by $CR = L_{255}/L_0$, where L_{255} is the luminance of grey level 255 and L_0 is the luminance of grey level 0. The viewing angle is the angle at which the CR is greater than 10:1. The CR uniformity of the samples is given in this paper. We think it can reflect the influence of the change in alignment directions of the DLC in the WV film and TN LC in the cells. The definition of CR uniformity, CR_{uni}, is

$$CR_{uni} = \frac{CR_{max} - CR_{min}}{CR_{max}} \times 100\%. \quad (2)$$

Here, CR_{max} is the maximum CR and CR_{min} is the minimum CR in the test points. The lower this value is, then the better the uniformity. The height and width of the sample panel is H and W, respectively, and the positions of the test points are shown in Figure 6. For five-point CR uniformity, the test points used are labelled points 1–5. For nine-point CR uniformity, the test points used are labelled points 1′-9′. The point 5(5′) is the centre of the panel.

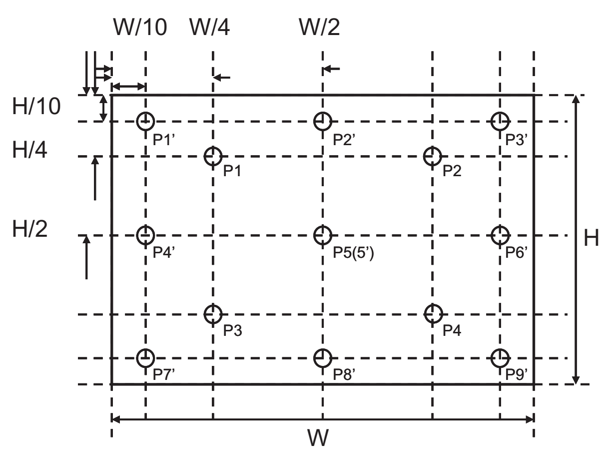

Figure 6. Positions of the test points of the liquid crystal display samples.

3. Results and Discussions

The centre CR of each sample is measured and the average result is shown in Figure 7. The centre CR specification of the experimental panel production is 800:1. From Figure 7, it can be seen that the centre CR were both above 800:1 for the samples with an 87° and 89° rubbing angle, while the centre CR was lower than 700:1 for the samples with a 91° rubbing angle. The centre CR of samples with an 87° $\theta_{rubbing}$ was always better than those with an 89° and 91° rubbing angle for all Θ_W from 0 to –0.8°, which exhibited better tolerance of the centre CR performance. The centre CR of some of the samples with an 89° $\theta_{rubbing}$ is close to 800:1. They show higher variance, which is not suitable for the manufacturing process.

The photograph of the sample with an 89° $\theta_{rubbing}$ and –0.6° Θ_W in the black state is shown in Figure 8(a). From this picture, it can be seen that the luminance in the centre region was higher than that in other regions. There is some 'grey-scale inversion' in the centre region. The measured data of the gamma curve indicate that the grey-scale inversion occurred at the fourth grey level, that is, the luminance of the fourth grey level was the lowest. So this is the reason that the centre CR becomes low. Other samples with a low centre CR also have grey-scale inversion.

In this experiment, the display mode of the samples was normally white, so the centre CR was very sensitive to luminance in the dark state. The WV film used for improving the transmittance of the dark state compensates the retardation of the LC, which suppresses light leakage. The idealised of the WV film and TN LC is proposed (*15*), and a simplified compensation principle is shown in Figure 9. For the TN LC, it has an alignment structure continuously changing from the homogeneous alignment near the PI

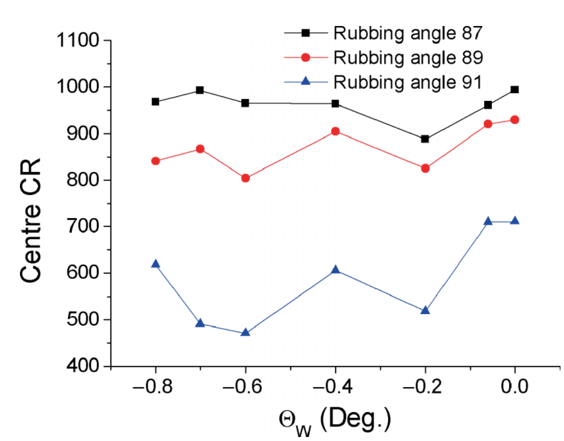

Figure 7. Centre contrast ratio of the sample with different $\theta_{rubbing}$ and Θ_W.

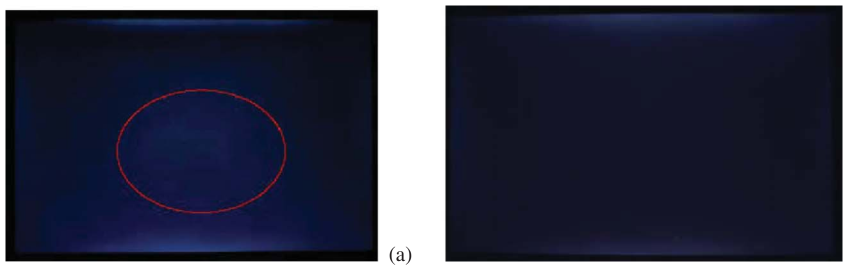

Figure 8. Photograph of the sample: (a) θ_{rubbing} = 89° and Θ_W = –0.6°; (b) θ_{rubbing} = 88° and Θ_W = –0.4°.

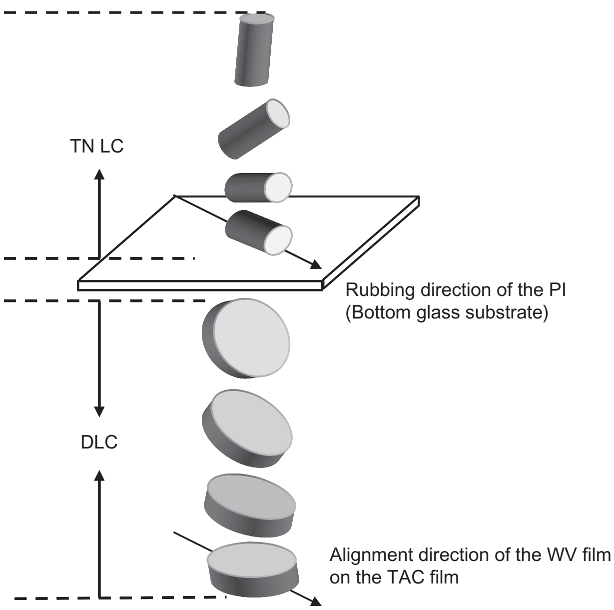

Figure 9. Compensation principle for the twisted nematic mode liquid crystal display using a wide view film.

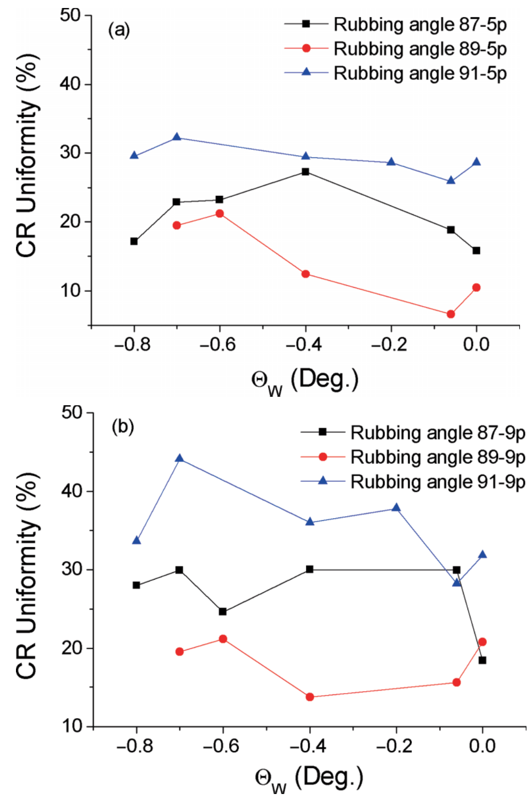

Figure 10. Contrast ratio uniformity of samples: (a) five points; (b) nine points.

surface to the homeotropic in LC bulk along the thickness direction in the black state, so the DLC in the WV film should also have a complicated alignment structure, such as a hybrid alignment, to match the TN LC alignment and three dimensional optical compensation (*5*). In our case, when the rubbing direction in the cell and the alignment direction of DLC in the WV film were more aligned to each other, the three dimensional compensation effects were better. Gamma deviation (i.e. grey-scale inversion) occurs in the black state if these alignment directions are quite different. Therefore, for the samples with a smaller rubbing angle (such as 87° or 89°) and negative Θ_W, the CR was higher than in the samples with a larger rubbing angle (such as 91°).

Figure 10 gives the CR uniformity of the samples according to Equation (2). Five-point and nine point CR uniformity both show that the samples with an 89° rubbing angle have more uniform values than the samples with a 91° rubbing angle. The reason that CR uniformity becomes worse is that the disparity between the rubbing direction of the LC and the alignment direction of the DLC is larger.

As the viewing angle is also an important parameter for LCDs, we measured the viewing angle of the samples with different θ_{rubbing} and Θ_W, as shown in Figure 11. All samples showed a large viewing angle, which met or exceeded 170° horizontal and 160° vertical in the viewing direction. However, the samples with a 91° rubbing angle had a lower CR for most viewing angles <30°.

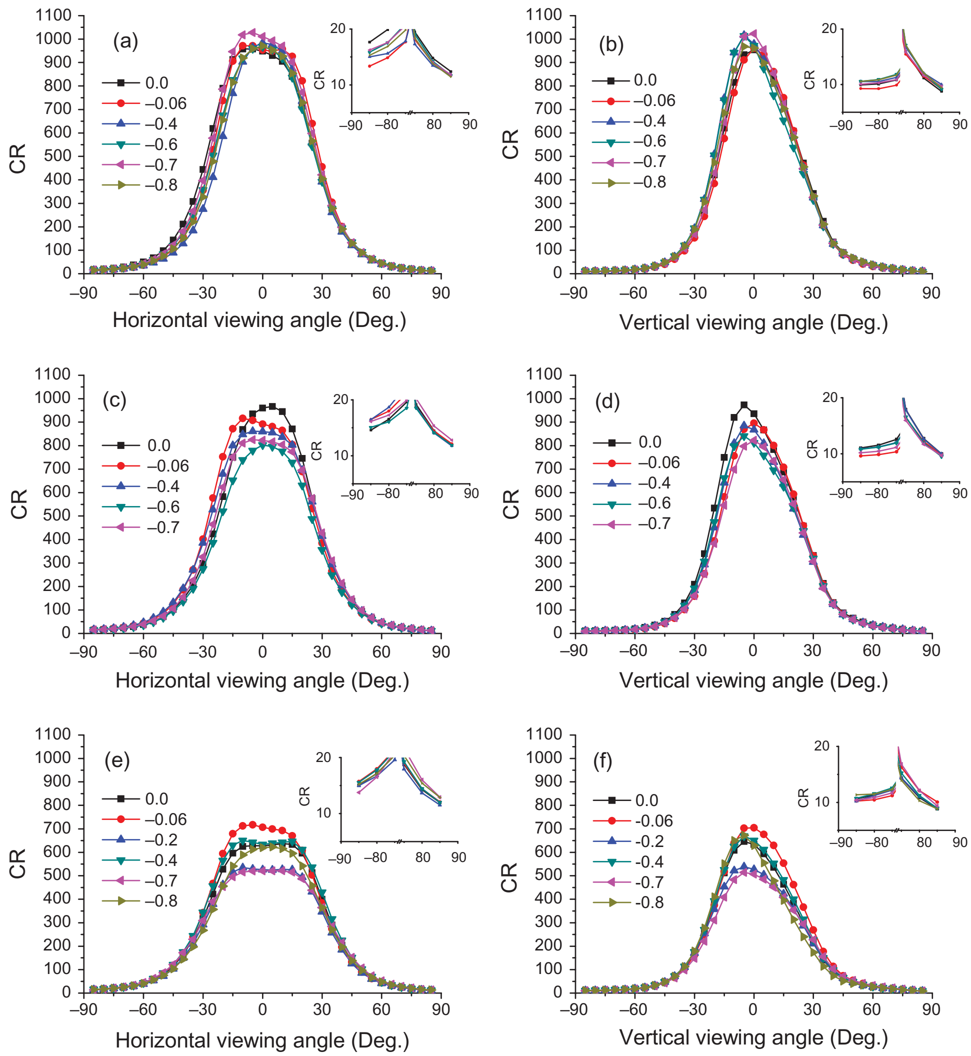

Figure 11. Viewing angles of the samples. Horizontal viewing angles: (a) $\theta_{\text{rubbing}} = 87°$, (c) $\theta_{\text{rubbing}} = 89°$, and (e) $\theta_{\text{rubbing}} = 91°$. Vertical viewing angles: (b) $\theta_{\text{rubbing}} = 87°$, (d) $\theta_{\text{rubbing}} = 89°$, and (f) $\theta_{\text{rubbing}} = 91°$.

Finally, we found that the Θ_W is usually negative from the polariser producers and the average value of the distribution is –0.4°, so the samples with an 87° or 89° rubbing angle have a higher CR. An 88° rubbing angle is preferable since the samples with an 87° angle have better CR uniformity. In addition, there is higher tolerance in the manufacturing process of the 88° rubbing angle process for the next version TN production. The picture of the new sample with an 88° rubbing angle is shown in Figure 8(b). The sample exhibited good centre CR (>1000:1) and better CR uniformity (about 15%). The measured values of the horizontal and vertical viewing angle exceeded 170° and 160°, respectively.

4. Conclusions

In this work, we studied the relation between the alignment direction of the DLC in the WV film and the rubbing direction of the PI on the substrate in the TN-LCD mode. We changed these directions, fixed the absorption axis of the PVA layer in the polariser and measured the performance parameters of the TN LCDs. The results indicated that the compensation effects of the WV film for the TN-LCD mode are good when the rubbing direction of the PI film and the alignment direction of the DLC in the WV film are aligned to each other. The samples with an 88° rubbing angle had a high CR, large viewing angle, good CR uniformity and grey-scale stability, and are more suitable for the manufacturing process.

References

(1) Wu, S.-T.; Yang, D.-K. *Reflective Liquid Crystal Displays*; John Wiley: New York, 2001.
(2) Toyooka, T.; Yoda, E.; Yamanashi, T.; Kobori, Y. *Displays* **1999**, *20*, 221–229.
(3) Lin, D.; Chao, A.; Yu, C.-H.; Jen, T.-S. *IDRC'06 Digest*, **2006**, 215–219.
(4) Yang, D.-K.; Wu, S.-T. *Fundamentals of Liquid Crystal Devices*; John Wiley: New York, 2006.
(5) Mori, H. *J. Display Technol.* **2005**, 179–186.
(6) Mori, H.; Nagai, M.; Nakayama, H.; Itoh, Y.; Kamada, K.; Arakawa, K; Kawata, K. *SID '03 Digest* **2003**, 1058–1061.
(7) Yamahara, M.; Inoue, I.; Nakai, T.; Yamada, Y.; Ishii, Y. *Jpn. J. Appl. Phys.* **2002**, *41*, 6072–6079.
(8) Yamahara, M.; Inoue, I.; Sakai, A.; Yamada, Y.; Mizushima, S.; Ishii I, Y. *Jpn. J. Appl. Phys.* **2003**, *42*, 4416–4420.
(9) Mori, H. *IDRC' 06 Digest* **2006**, 67–70.
(10) Mori, H.; Itoh, Y.; Nishiura, Y.; Nakamura, T.; Shinagawa, Y. *Jpn. J. Appl. Phys.* **1997**, *36*, 143–147.
(11) Mori, H. *Jpn. J. Appl. Phys.* **1997**, *36*, 1068–1072.
(12) Nakayama, H.; Fukagawa, N.; Nishiura, Y.; Yasuda, T.; Ito, T.; Mihayashi, K. *J. Photopolym. Sci. Tec.* **2006**, *19*, 169–173.
(13) Ito, T.; Yasuda, S.; Oikawa, T.; Ito, Y.; Takahashi, Y. *SID'08 Digest*, **2008**, 125–128.
(14) Mori, H. *IMID '05 Digest*, **2005**, 1071–1074.
(15) Mori, H.; Shinagawa, Y. *IDW '02 Digest*, **2002**, I–5.3.