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A hybrid aligned nematic reflective liquid crystal display driven by a fringe-field

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We have designed a novel reflective nematic liquid crystal (LC) cell driven by a fringe electric field, in which the LCs are hybrid aligned in the initial state. Due to the hybrid alignment of the LC, the effective retardation value of the cell is greatly reduced when viewed in the normal direction and such a cell retardation value of 0.28 μm equals a quarter wave plate viewed in the normal direction. This means that the new reflective device can have a large cell gap of greater than 3 μm, which is advantageous when manufacturing the cell and, in addition, the device shows excellent electro-optic characteristics.

1. Introduction

Reflective liquid crystal displays (R-LCDs) are widely used in small size LCDs for mobile information tools (MITs) [1, 2]. Recently, several approaches, such as the reflective twisted nematic (R-TN) [3], vertical field-driven homogeneous cells (ECB) with a dual colour filter structure [4, 5], reflective optically compensated bend (R-OCB) [6], reflective in-plane switching (IPS) [7, 8] and fringe-field switching (R-FFS) [9] with homogeneous alignment (HA) of the LC in the initial state have been introduced. In general, reflective LCDs consist of a single polarizer, a compensation film, a LC medium with a retardation value of $\lambda/4$ and a reflector. In order for the LC medium to have its retardation value of $\lambda/4$, the cell gap (d) should be very small, about 2 μm, since the lowest birefringence of the LC is larger than 0.06 at present. The low d causes a problem in manufacturing and a decrease in yield ratio since non-uniformity of an image can easily be caused by particles larger than 2 μm.

This paper will examine the results of an investigation on a hybrid aligned nematic (HAN) cell driven by a fringe electric field as a reflective display, and its electro-optic characteristics. In the device, the optimal cell retardation value is about 0.28 μm, equal to $\lambda/4$ viewed effectively at a normal direction, which means that the cell gap can be as high as about 4 μm. This allows a better processing margin than the other devices.

2. Cell structure and switching principle of the fringe-field driven reflective HAN mode

Figure 1 shows the cell structure of the HAN cell driven by a fringe-field. As shown, the LCs are hybrid aligned in the OFF state. The device has electrodes on the bottom substrate, both a common electrode acting as a plane and a slit-form pixel electrode, with a measurable distance between them. A passivation layer is positioned between the common and the pixel electrodes. The detailed electrode structure is the same as reported previously [10]. With this electrode structure, a fringe electric field is generated when a voltage is applied; the hybrid aligned LCs do rotate over the whole electrode surface with bias voltage, although the deformation of the LCs is slightly dependent on the electrode position. An optical compensation film of $\lambda/2$ is inserted between the polarizer and LC to improve the dark state.

To obtain the optical design and calculate electro-optic characteristics, a computer simulation using the 2×2 extended Jones matrix was used [11]. For the simulation, we used a LC characterized by $\Delta n = 0.074$ at $\lambda = 550$ nm, $\Delta\varepsilon = -4.0$, $K_{11} = 13.5$ pN, $K_{22} = 6.0$ pN, $K_{33} = 15.1$ pN. The rubbing direction (θ) of the bottom substrate, which is the optic axis of the LC, was 12° against the horizontal component (E_y) of the

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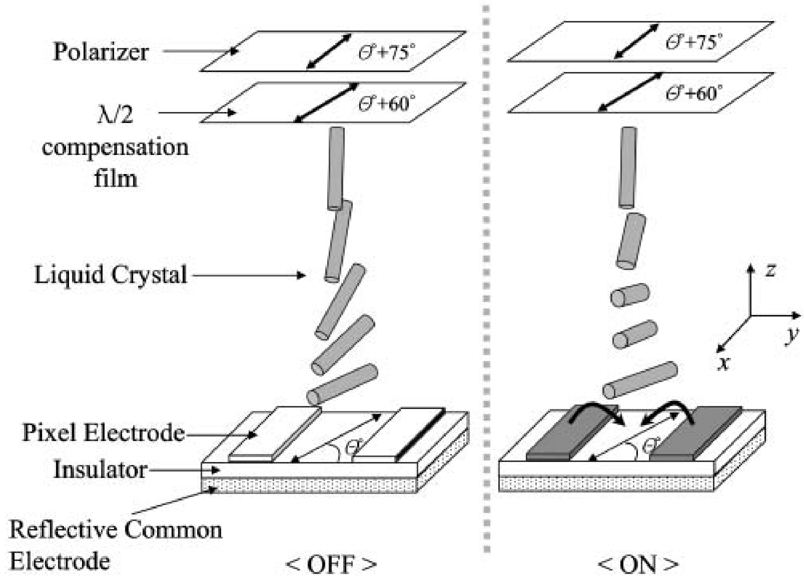

Figure 1. Cell structure and configuration of the LC of the reflective HAN mode driven by a fringe electric field in the OFF and ON states.

fringe electric field, and the surface tilt angle was 2°. On the top substrate, the LCs were vertically aligned. For calculation, the transmittances for the single and parallel polarizers, and the compensation film of $\lambda/2$ were assumed to be 41, 35 and 100%, respectively.

Several configurations to realize the fringe electric field-driven R-HAN are possible [12, 13]. One solution for achieving a good dark state is that when the polarizer axis is in horizontal direction as the reference angle, the slow axis (θ_F) of the film can be $\pm15°$ and the optic axis (θ_L) of the LC can be $\pm75°$. In other words, when the rubbing direction of the bottom substrate is 12°, the slow axis of the film and the polarizer axis make angles of 72° and 87°, respectively, as shown in figure 1.

The switching principle can be understood as follows: with no voltage applied, linearly polarized incident light passing through the polarizer in a normal direction changes the polarization direction to 57° after passing through the compensation film, since the angle between the polarizer and the film is 15°; next, the linearly polarized light makes a 45° angle with the LC and, as a result, becomes circularly polarized after passing through the LC; finally, the reflected light passes through the LC and the film once again becomes linearly polarized with a changed polarization direction of 90° and, thus, the polarizer blocks the light. When a voltage is applied, the LC director rotates over the whole surface area, giving rise to reflectance. A white state can be obtained when the LC director rotates by 45° because the optic axis of the LC and direction of the linearly polarized light are coincident in the same position, so that the polarization state is not changed when passing through the LC.

3. Results and discussion

First, we calculated the effective retardation value of the HAN cell. By constructing a cell consisting of a polarizer and the hybrid aligned LC, with their optic axes making an angle of 45° to each other, the reflectance was calculated as a function of $d\Delta n$ at a wavelength of 550 nm, as shown in figure 2. Here, d was varied at a fixed Δn. As indicated, the reflectance is zero when the values are 0.28 μm and 0.87 μm, which are the first and second minimum conditions. The result suggests that when the cell retardation value is

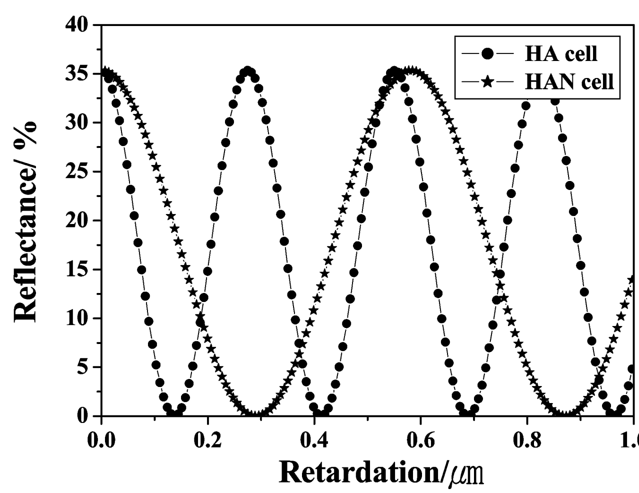

Figure 2. Calculated reflectance as a function of cell retardation value.

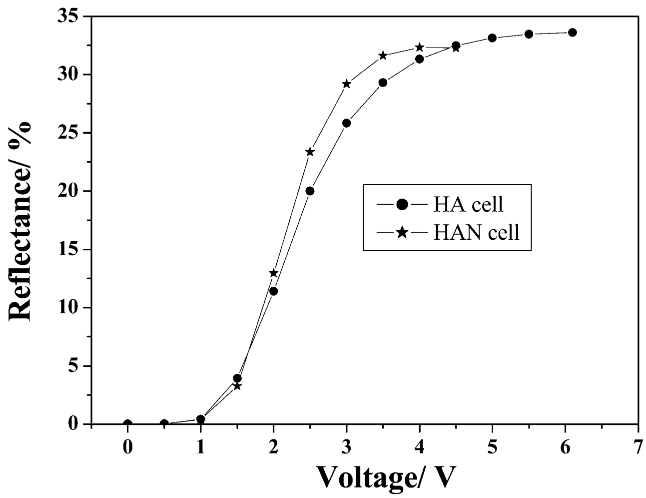

Figure 3. Comparison of calculated voltage-dependent reflectance curve, in fringe-field driven HA and HAN modes.

0.28 μm at a normal direction, its effective retardation equals $\lambda/4$, which is 137.5 nm; thereby, resulting in a dark state in such a cell configuration. Consequently, when the cell retardation value was 0.28 μm with a birefringence value 0.074 of the LC, a cell gap of 3.8 μm was chosen to give a cell retardation value of $\lambda/4$. This higher cell gap, larger than those used in other devices such as ECB, R-IPS, and R-FFS with homogenous alignment, is advantageous in manufacturing the cell.

Figure 3 shows calculated voltage-dependent reflectance curves of the HAN cell driven by a fringe-field and compares them with the HA cell driven by a fringe-field. The reflectance of the HAN cell is about 32%, i.e. the light efficiency of the device is sufficiently high at 91% and about the same as that in the HA cell. The driving voltage of the HAN cell is slightly lower than that of the HA cell since the LCs are aligned vertically on the top substrate and thus free to rotate in any direction.

Figure 4 shows wavelength dependent reflectance in the dark and white states, with and without the $\lambda/2$ compensation film. In the dark state, leakage is well suppressed in the whole range of visible wavelength with the help of the compensation film; and the wavelength dependency of the white state for the HAN cell with the film is slightly changed, showing less wavelength dependency than that of the HAN cell without the film. Now, it is important to obtain a good dark state, not only at a normal direction but also at an oblique viewing direction, for the realization of high image quality in every direction. Figures 5 (*a*) and 5 (*b*) show a dark state at four different azimuthal directions up to a polar angle of 80°, without and with the compensation film, respectively. As shown, with the compensation film the dark state is well preserved at any viewing direction. This indicates that although a reflective display with a LC of $\lambda/4$ is possible, the compensation film is absolutely necessary for obtaining a good dark state, since it cannot be achieved using only the LC due to wavelength dispersion [13].

Next, grey scale inversions of the six grey levels at four azimuthal directions, were studied as shown in figure 6. At directions in the cross-sectional plane from 45° to 225° and the vertical plane, grey scale inversion does not exist, but directions in the horizontal plane and cross-sectional plane from 135° to 315° show grey scale inversion at a polar angle of over 50°. Figure 7 shows the iso-contrast contour of the device at 550 nm. A contrast ratio greater than 5 exists at a polar angle of over 50° in any direction.

We fabricated a test cell to obtain the electro-optic characteristics, with $d = 3.3$ μm, and using the LC with $\Delta n = 0.089$ at 589 nm, $\Delta\varepsilon = -3.7$ and $\gamma = 110$ mPa s. The voltage-dependent reflectance curves were measured for

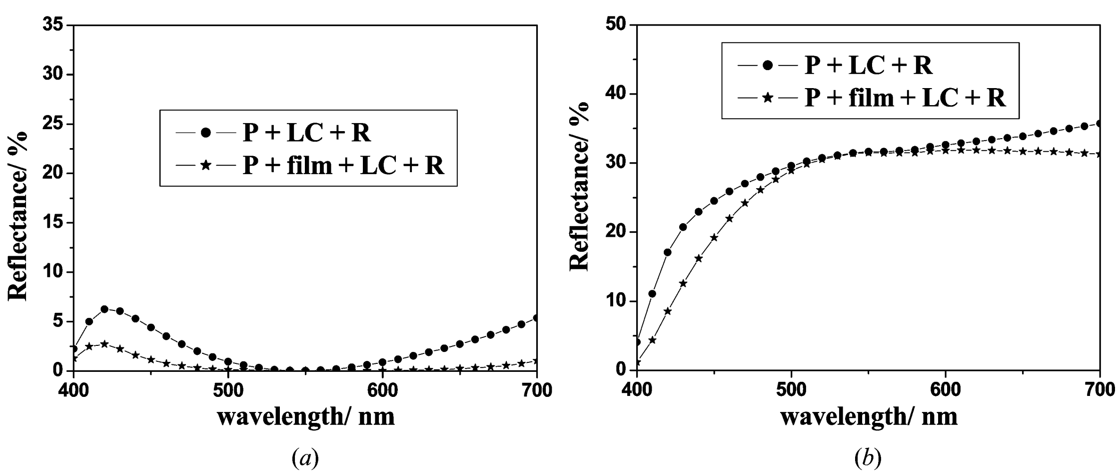

Figure 4. Wavelength dependence of (*a*) dark state and (*b*) white state, in reflectance.

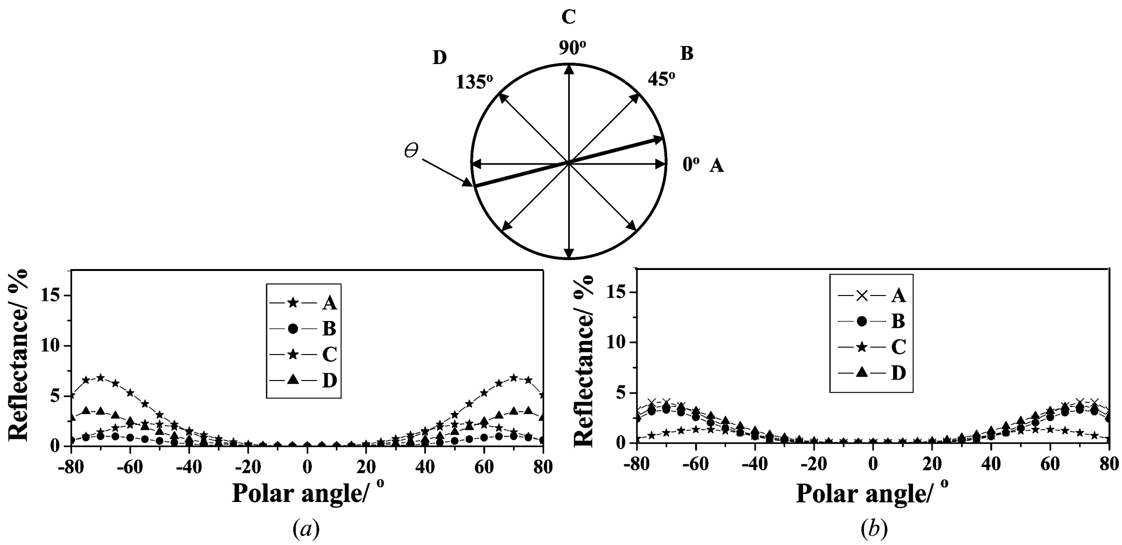

Figure 5. Leakage of light in the dark state depending on viewing directions (*a*) without, and (*b*) with a compensation film of $\lambda/2$.

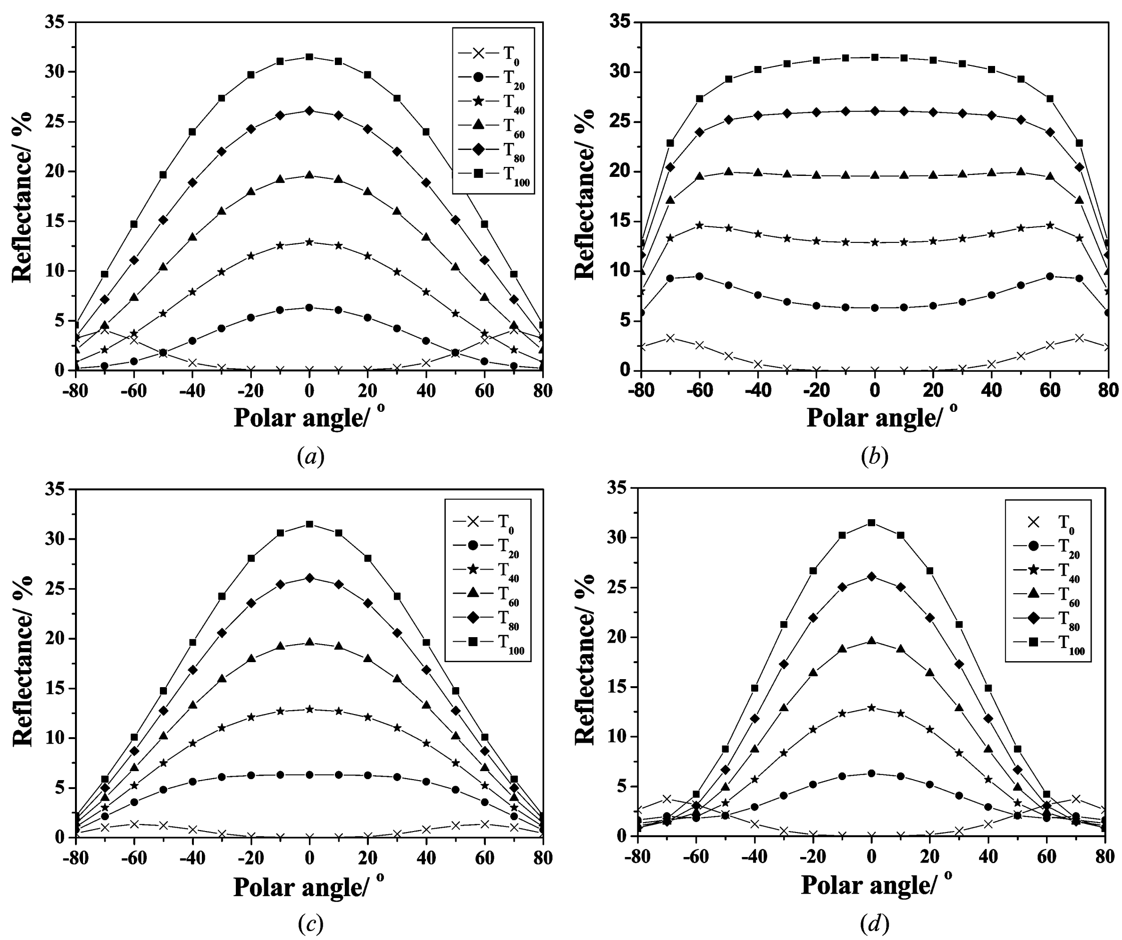

Figure 6. Viewing angle dependence of the six grey levels for different directions along (*a*) A, (*b*) B, (*c*) C and (*d*) D directions (c.f. figure 5).

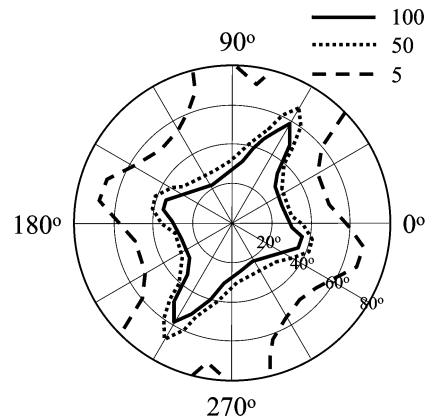

Figure 7. Iso-contrast contour dependent on the viewing angle at an incident wavelength of 550 nm in the reflective state.

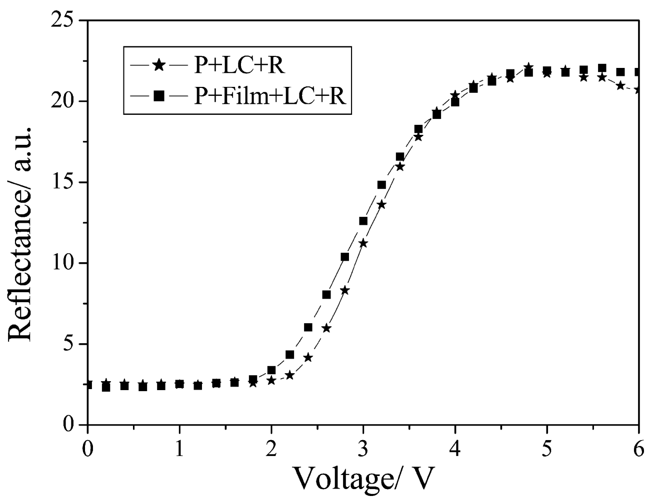

Figure 8. Measured voltage-dependent reflectance.

cells with and without a compensation film, where the incident angle of the light source was $-30°$ from the normal direction, and the light was measured at an angle of $10°$. The change in light reflectance starts at 2 V and saturates at 5 V, as shown in figure 8. The reflectivity of the dark state was less for the cell with a compensation film than for the cell without a compensation film, but the reflectivity in the white state was slightly better for the cell without compensation film.

We also measured response times of the cell: the rise time was 6.6 ms and the decay time 11.3 ms. The total response time is thus 17.9 ms, which is acceptable for normal applications. Here, the rise and decay times are defined as those in which the reflectance changes from 10 to 100% and from 100 to 10% of maximum reflectance, respectively.

4. Summary

In summary, a novel reflective display that is a fringe-field driven hybrid aligned nematic LC cell is proposed. The device allows a high cell gap, which is advantageous when manufacturing the cell, and also exhibits a wide viewing angle, without the occurrence of grey scale inversion, over a wide range of viewing angles. The cell shows a driving voltage of 5 V and a fast response time of 17.9 ms.

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References

[1] Uchida, T., Nakayama, T., Miyashita, T., Suzuki, M., and Ishinabe, T., 1995, in Proceedings of the 12th International Display Research Conference (Society for Information Display and the Institute of Television Engineers of Japan, Hiroshima), p. 599.

[2] Ogawa, T., Fujita, S., Iwai, Y., and Koseki, H., 1998, in Digest of Technical papers of 1998 SID International Symposium, Anaheim, p. 217.

[3] Shibazaki, M., Ishinabe, T., Miyashita, T., Uchida, T., Yoshida, K., Tanaka, H., and Sunata, T., 1999, in Digest of Technical papers of 1999 SID International Symposium, San Jose, p. 690.

[4] Fujimori, K., Narutaki, Y., Itoh, Y., Kimura, N., Mizushima, S., Ishii, Y., and Hijikigawa, M., 2002, in Digest of Technical papers of 2002 SID International Symposium, Boston, p. 1382.

[5] Kim, K.-J., Lim, J. S., Jung, T. Y., Nam, C., and Ahn, B. C., 2002, in Proceedings of the 19th International Display Research Conference, and the Hiroshima, p. 433.

[6] Ishinabe, T., Miyashita, T., and Uchida, T., 1999, in Digest of Technical papers of 1999 SID International Symposium, San Jose, p. 698.

[7] Sun, Y., and Wu, S.-T., 2003, *Jpn. J. appl. Phys.*, **42,** L423.

[8] Kim, H. Y., Song, I. S., and Lee, S. H., 2003, *Trans. EEM*, **4,** 24.

[9] Lee, S. H., Hong, S. H., Kim, H. Y., Seo, D.-S., Lee, G.-D., and Yoon, T.-H., 2001, *Jpn. J. appl. Phys.*, **40,** 5334.

[10] Hong, S. H., Jeong, Y. H., Kim, H. Y., and Lee, S. H., 2001, *Jpn. J. appl. Phys.*, **40,** L272.

[11] Lien, A., 1990, *Appl. Phys. Lett.*, **57,** 2767.

[12] Yoon, T. H., Lee, G.-D., and Kim, J. C., 2001, *Mol. Cryst. liq. Cryst.*, **364,** 479.

[13] Jung, T. B., Kim, J. C., and Lee, S. H., 2003, *Jpn. J. appl. Phys.*, **42,** L464.