Optical Configuration of a HAN Cell for Reflective Displays

Seo Hern Lee[a], Mi Kyoung Jang[a], Jin-Kwan Jeong[a], Tae-Hoon Yoon[ab*], and Jae Chang Kim[ab*]**

Abstract

We propose a new optical configuration of a hybrid-aligned nematic liquid crystal cell for reflective displays, which consist of a biaxial film for obtaining wide viewing angle and a half-wave film for achieving high contrast. As a result, we can achieve wide viewing angle of (80(for the horizontal direction and (50(for the vertical direction and uniform reflection spectrum.

Keywords : hybrid-aligned nematic liquid crystal cell, wide viewing angle, high contrast, reflective LCD

1. Introduction

The role of reflective liquid crystal displays (LCDs) is increasing in light weght lightweight, thin, and low-power-consumption applications, especially in portable information and communication systems. Considerable efforts using the modes of various types have been devoted to developing reflective LCDs. In order to achieve high information density displays, high brightness, high contrast and wide viewing angle are must be achiered. The one-polarizer mode has been considered as a suitable structure for high brightness[1]. To obtain high contrast, reflective LC cells using a wide-band quarter-wave film[2] or exhibiting the wide-band property without a wide-band film[3] was designed. For a wide viewing angle, methods such as multi-domain alignment and reflective fringe-field switching(FFS) mode have been proposed[4].

In this work, we introduce an optical configuration for single-polarizer reflective LCDs using a hybrid-aligned nematic cell. This cell has the following merits; the effective birefringence is low, leading to fabrication yield and the rising time is short because half of the molecules are already rotated in the direction imposed by the field. However, in the case where a HAN cell is used for reflective LCDs, it has some weak points such as viewing angle is narrow and dispersion property is poor. Therefore, the researches to improve the viewing angle and the dispersion property has been alone, but the configuration to satisfy both two characteristics has not been studied. Here, we propose an optical configuration that will allow the viewing angle as well as the dispersion property to be improved.

At first, we investigated the conventional configurations to improve the viewing angle and the dispersion characteristics. However, we found that the configuration satisfying wide viewing angle and high contrast could not be achieved with only one biaxial film (first and second configuration) because an attempt to improve viewing angle or dispersion property is a trade-off relation. As a result, we presented an optimized configuration by adding a half-wave retardation film to obtain good dispersion as well as wide viewing angle properties.

2. Conventional Configurations using a HAN Cell

Fig. 1 shows the configuration using one biaxial film[5]. LC material is placed between two substrates

Manuscript received March 20, 2003; accepted for publication June 20, 2003.
This work was supported by Pusan National University Research Grant.
This work was performed by the Advanced Backbone IT Technology Development Project supported by the Ministry of Information & Communication in the Republic of Korea and partly by the fund of the Pusan National University Supporting Organization.
*Member, KIDS; **student Member, KIS
Corresponding Author : S. H. Lee
a. Department of Electronics Engineering, Pusan National University, Pusan, 609-735, Korea.
b. Research Institute of Computer, Information and Communication, Pusan National University, Pusan 609-735, Korea.
E-mail : seohern@hanmail.net **Tel** : +51 510-1700 **Fax** : +51 515-5190

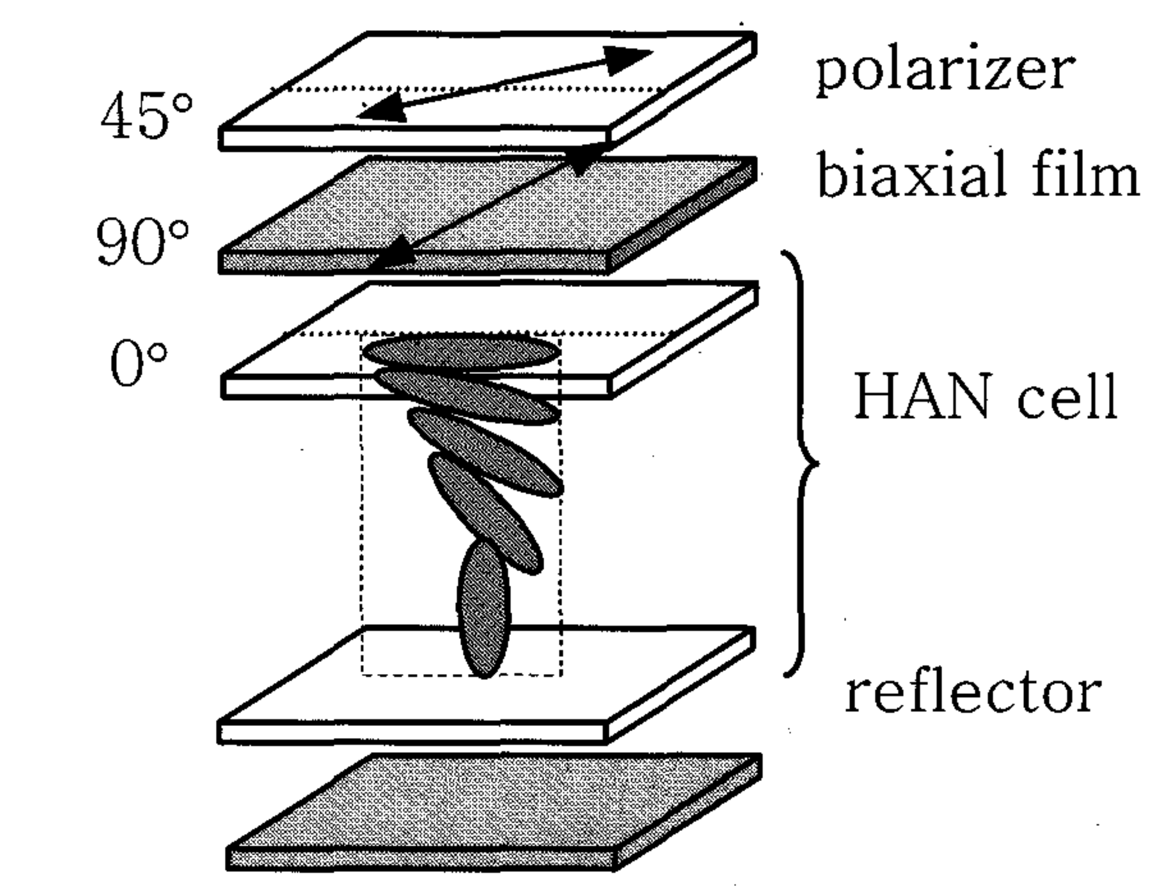

Fig. 1. The configuration to improve viewing angle using one biaxial film.

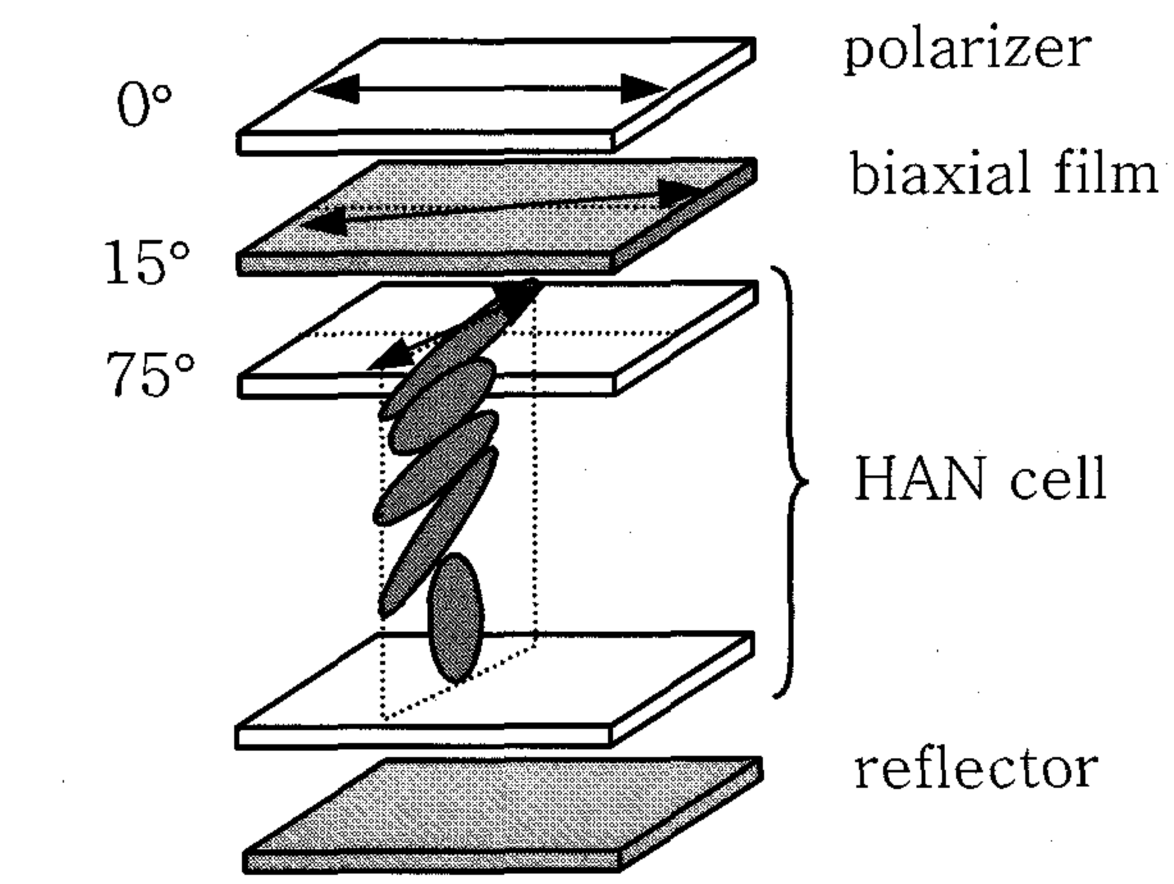

Fig. 4. The configuration to improve dispersion property using one biaxial film.

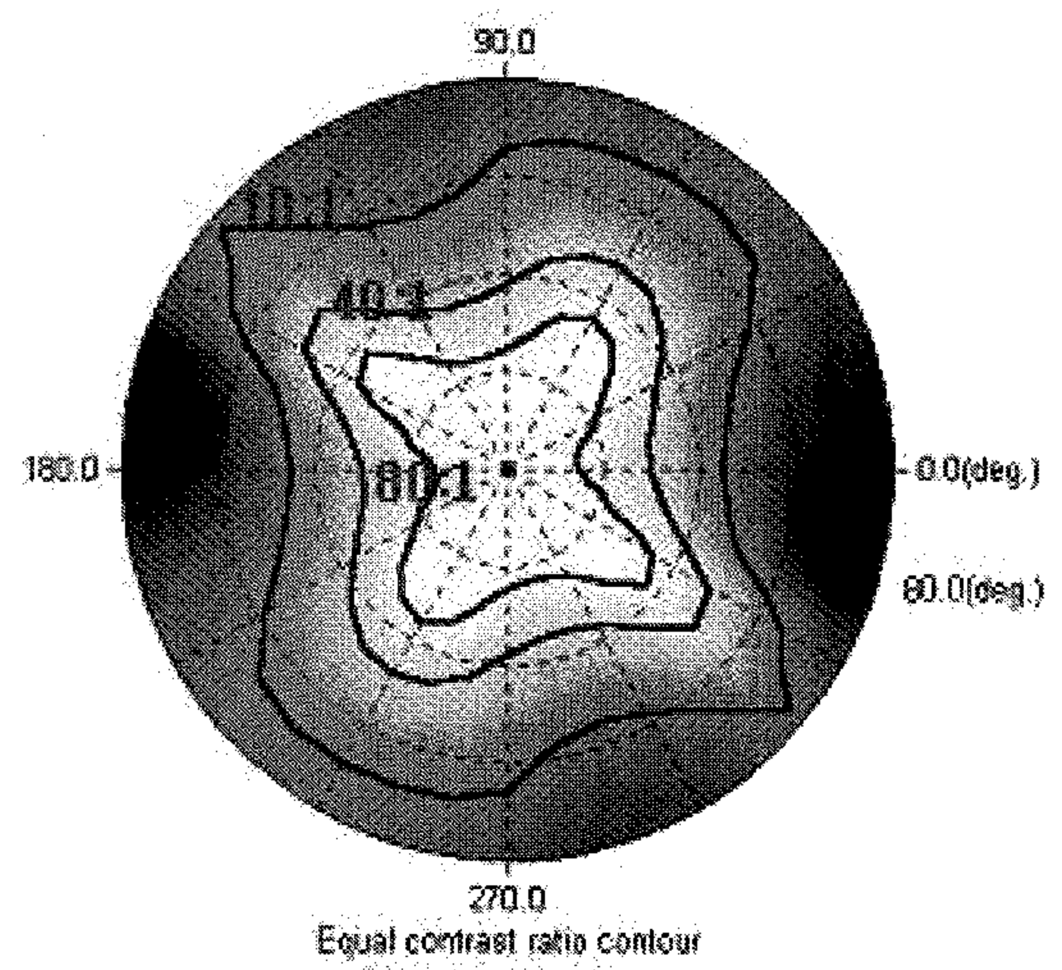

Fig. 2. Contrast ratio contour for the configuration of Fig. 1.

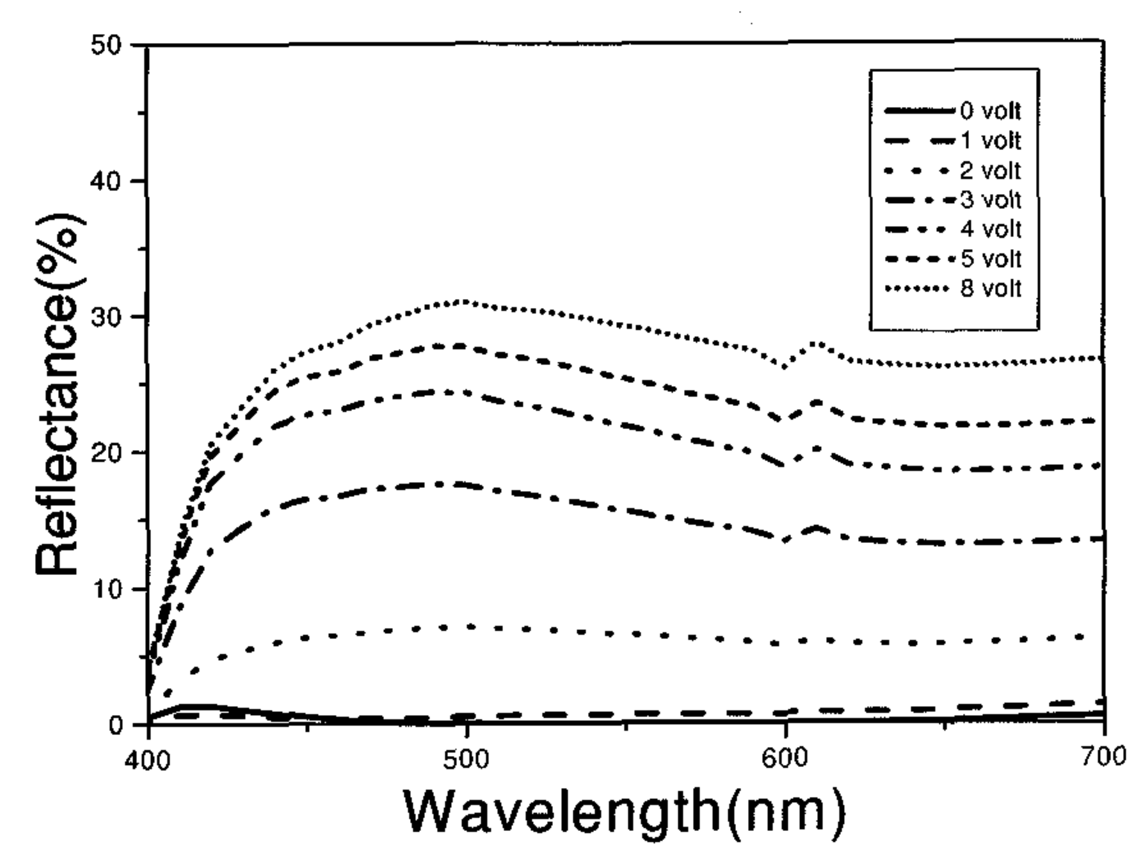

Fig. 5. Reflectance as a function of wavelength for configuration of Fig. 4.

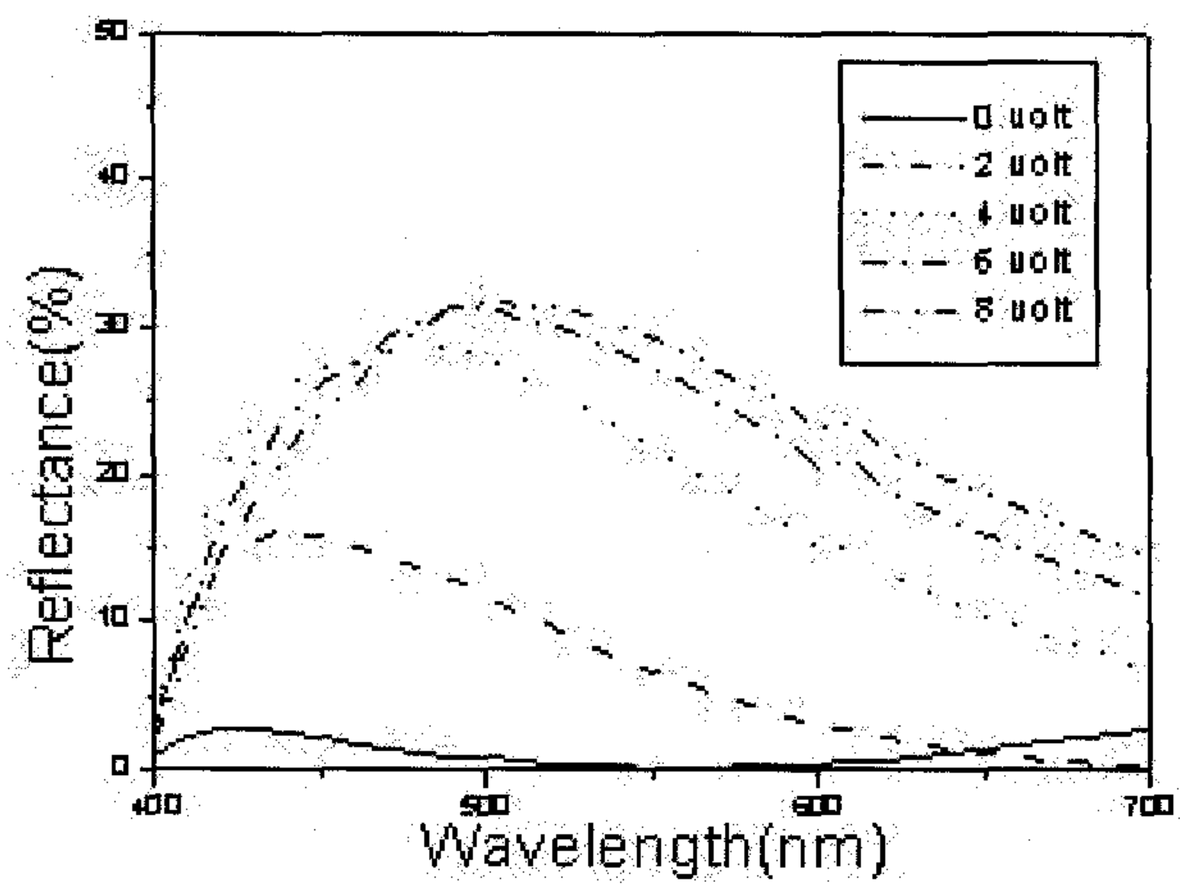

Fig. 3. Reflectance as a function of wavelength for the configuration of Fig. 1.

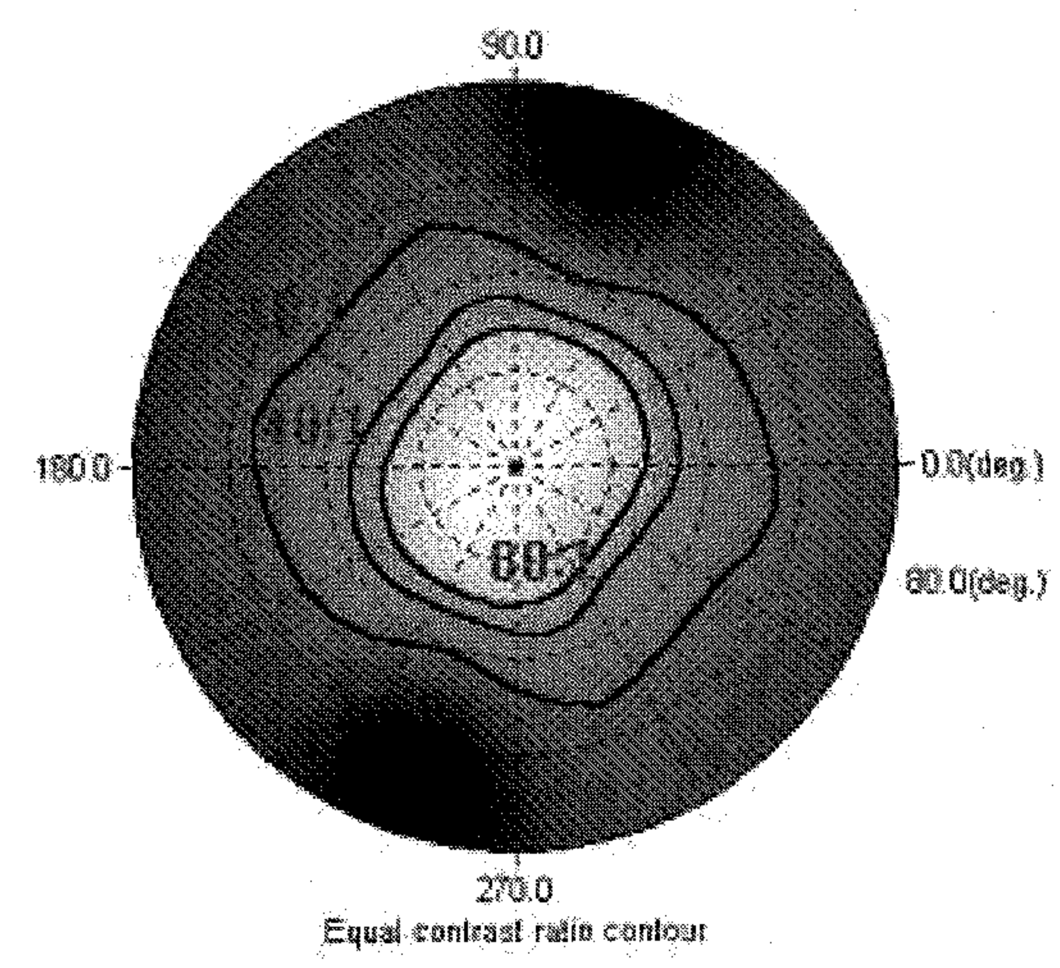

Fig. 6. Contrast ratio contour for the configuration of Fig. 4.

coated to induce homeotropic and planar orientations, respectively. LCD master (Shintech, Inc.) was used as a calculation engine to determine the optical properties. The simulated result is shown in Fig. 2. We found that the viewing angle of ±80 ° for the horizontal direction and ±60 ° for the vertical direction were obtained, but dispersion characteristics for the entire visible range were poor, as shown in Fig. 3.

Another configuration to improve dispersion property is shown in Fig. 4. Based on the previously proposed wide-band property[3], this configuration was composed of a linear polarizer with its transmission axis at 0°, a biaxial film with its slow axis at 15°, and an LC layer with its input director axis at 75°. As a result, as shown in Fig. 5, we could obtain a good dispersion property for the entire visible range. However the viewing angle was narrower than the former structure, as shown in Fig. 6, because this structure focused on improving the dispersion, which in turn removes the merit of the biaxial film. From this, we could confirm that it is impossible to obtain a wide-viewing angle as well as a high contrast from the configuration using only one biaxial film.

3. The Optimized Configuration with a Wide Viewing Angle as well as a High Contrast

We investigated two conventional configurations. We found that the attempt to improve viewing angle and dispersion property is trade-off relation. Therefore, we present an optimized configuration by adding a half-wave retardation film to obtain good dispersion as well as wide viewing angle properties.

Fig. 7 shows the optimized configuration using λ/2 film and an effective λ/4 LC configuration. The effective λ/4 LC configuration could be obtained with the biaxial film of λ/2 retardation and an LC layer of λ/4 retardation. The polarizer angle was set at the x-axis. A biaxial film was located between the LC cell and the polarizer, and the slow axis of the film was perpendicular to the rubbing direction. Birefringence at normal direction of the biaxial film was designed to be a half-wave retarder.($|n_x-n_y|D=275$ nm, where n_x and n_y are the refractive indices of the biaxial film parallel to the x-and y-axes, respectively, and D is its thickness.) By variating the n_z value, which is the refractive index of the biaxial film parallel to the z axis, we could optimize the viewing angle. The optimized parameters of the biaxial film obtained from the simulation data and specification of liquid crystal used in simulation is shown in Table 1.

Table 1. The simulation parameters of the liquid crystal and the optimized parameters of the biaxial film.

Liquid crystal	***RDP-81003***
Cell gap	4.3μm
Upper pretilt angle	3°
Bottom pretilt angle	89°
Biaxial film	Nz=0.88

We found that wide-band condition could be satisfied, which presents a good dispersion property. We found that viewing angle was wider than the structure of Fig. 4 due to the role of the biaxial film. As shown in Fig. 8, we can see that viewing angles of ±80 ° for the horizontal direction and ±50 ° for the vertical direction were achieved, and dispersion characteristics for the entire visible range were the same as shown in Fig. 5, due to the wide-band property.

4. Design of Biaxial Film

In designing these configurations, it is necessary to find the optimized parameters of the biaxial compensation film. The parameters that need to be calculated are three refractive indices of principal axes(n_x , n_y and n_z) and the thickness of the film(D). In the conventional technique, the calculated thickness was always much smaller than a practical value[6]. So, we used the design method to be able to make use of the practically known film thickness. Once we find the film thickness (D), the birefringence at the normal direction of the biaxial film can be designed to become a half-wave retardation. Canseguently, we can obtain normally black state with an LC layer of a quarter-wave retardation by simply calculating $|n_x-n_y|$ value at normal direction. And then, by using the obtained $|n_x-n_y|$ value, we could deduce the value n_z from an iterative calculation. The optimized parameter is 0.88 for Nz as shown in Table 1.

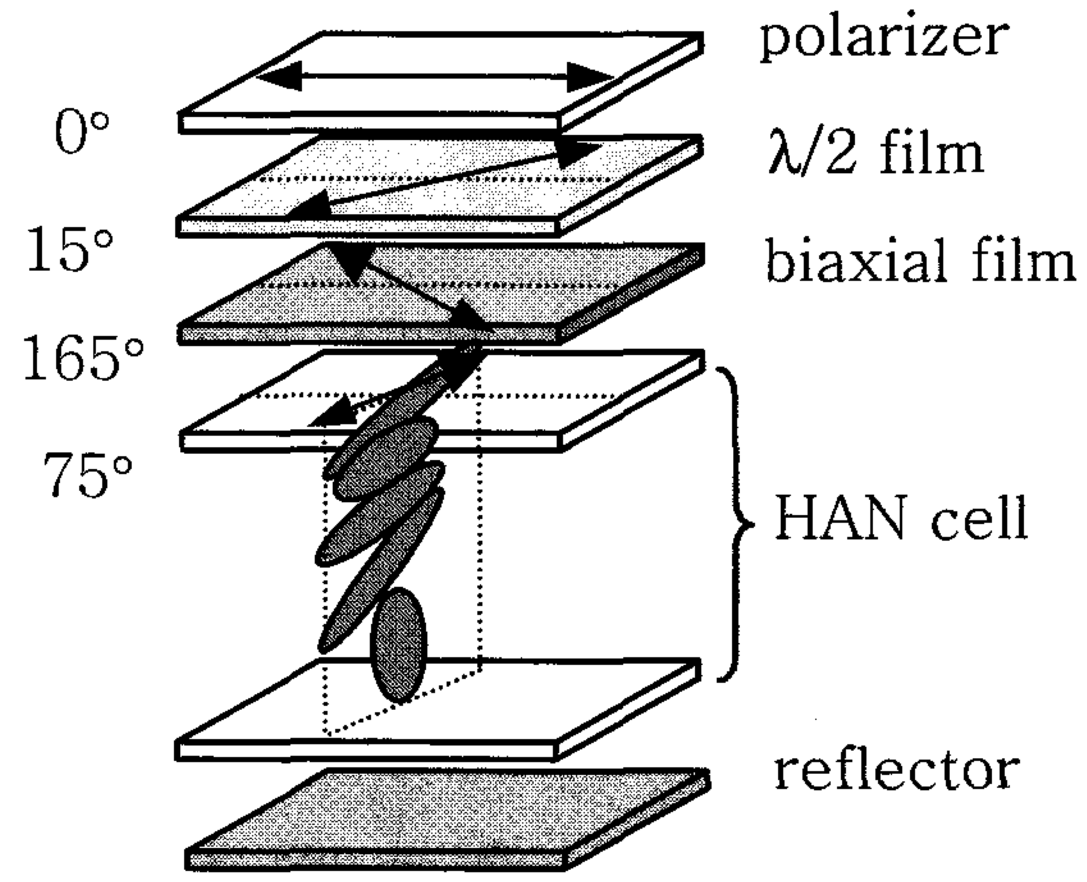

Fig. 7. The optimized configuration using one biaxial film and λ/2 film.

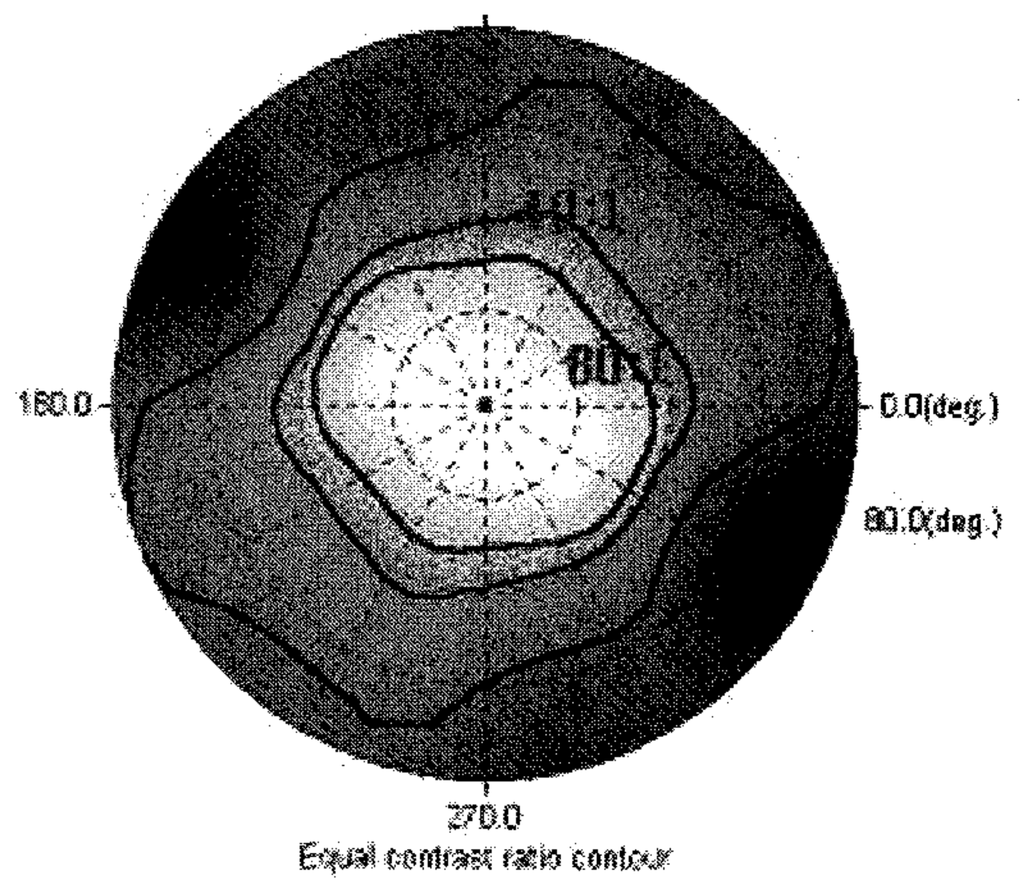

Fig. 8. Contrast ratio contour for the optimized configuration.

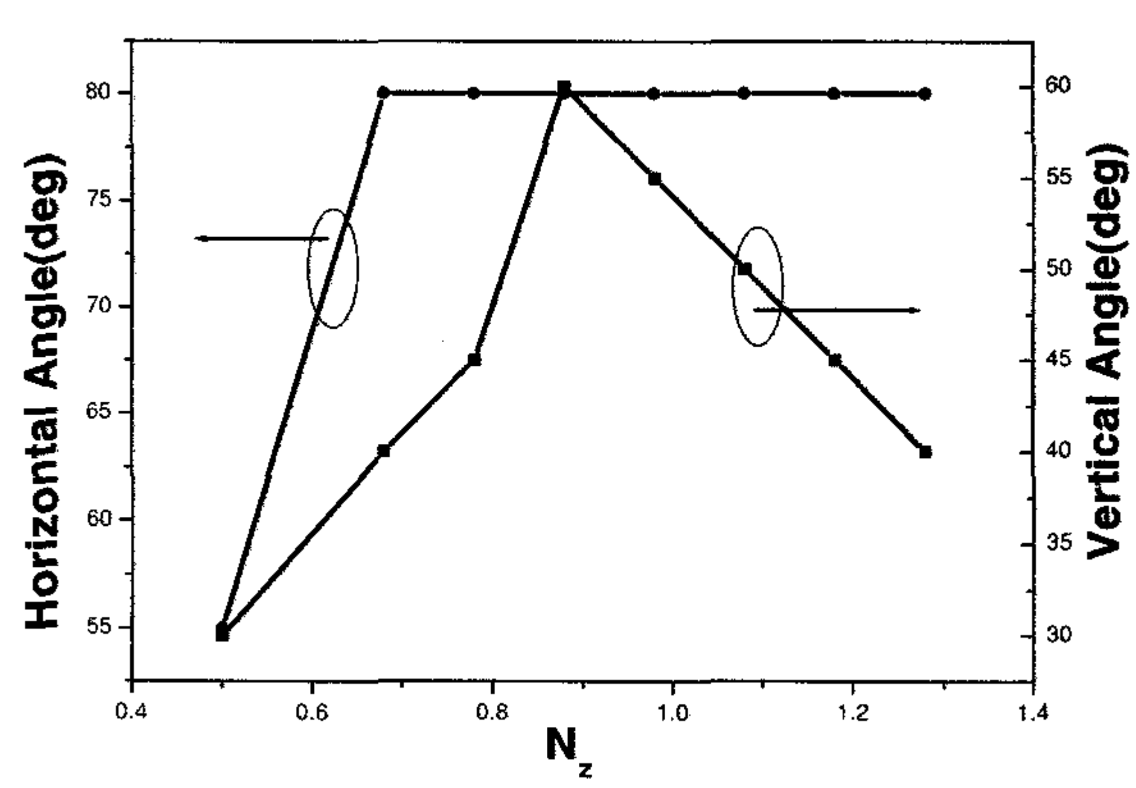

Fig. 9. Variation of viewing angle as a function of Nz

Let us now we discuss the viewing angle characteristics by the deviation of the value of Nz. In the practical implementation of these configurations, it is necessary to discuss the effect of viewing angle as a margin of the value of Nz as it is not easy to find a biaxial film design. Therefore, we investigated the variation of horizontal and vertical viewing angle as the margin of Nz. Fig. 9 shows the results of simulation for viewing angle as a function of Nz.

As shown in Fig. 9, we can see that the horizontal viewing angle (HVA) maintains 80 ° in wide range of Nz value from 0.68 to 1.28, and the vertical viewing angle (VVA) is the widest for the Nz of 0.88. So, we could confirm that the range of Nz can satisfy a HVA of ±80 ° and a VVA of above ±50 ° was from 0.84 to 1.02.

5. Conclusions

In this study, we propose a configuration to apply to a single-polarizer reflective LC cell by using a HAN cell. In a display system using a HAN cell, since the dispersion property is poor and the viewing angle is narrow, conventional configurations to improve viewing angle and dispersion property have been studied, but the structure for satisfying both wide viewing angle and high contrast has not yet been achieved. Therefore, we propose the optimized configuration so as to obtain high contrast as well as wide viewing angle by using λ/2 film and an effective λ/4 LC configuration.

References

[1] S.-T. Wu and C.-S. Wu, Appl. Phys. Lett., **68,** 1455(1996).

[2] G.-D. Lee, G.-H. Kim, S.-H. Moon, J.-D. Noh, S.-C. Kim, W. S. Park, T.-H. Yoon, J. C. Kim, S. H. Hong, and S. H. Lee, Jpn. J. Appl. Phys., **39,** L221(2000).

[3] T.-H. Yoon, G.-D. Lee, and J. C. Kim, Opt. Lett., **25,** 1547 (2000).

[4] Seung Hee Lee, Seung Ho Hong, Hyang Yul Kim, Dae-Shik Seo, Gi-Dong Lee, and Tae-Hoon Yoon, Jpn. J. Appl. Phys., **40,** 5334 (2001).

[5] T. Ishinabe, T. Miyashita and T. Uchida, SID '99 Digest, 698 (1999).

[6] T. Miyashita, P. Vetter, M. Suzuki, Y. Yamaguchi and T. Uchida, Eurodisplay '93 Digest, 149 (1993).