Optical Configuration of a HAN Cell for Reflective Displays

Seo Hern Lee[1], Mi Kyoung Jang[1], Jin-Kwan Jeong[1], Kwan-Young Han[1], Tae-Hoon Yoon[1,2], and Jae Chang Kim[1,2]

[1]Department of Electronics Engineering, Pusan National University, Pusan, Korea
[2]Research Institute of Computer, Information and Communication, Pusan National University, Pusan 609-735, Korea

Abstract

We propose an optical configuration of a hybrid-aligned nematic liquid crystal cell for reflective displays by which we can achieve wide viewing angle and uniform reflection spectrum.

1. Introduction

The role of reflective liquid crystal displays(LCDs) is becoming more and more important for lightweight, thin, and low-power-consumption applications such as portable information and communication systems. Considerable efforts using the modes of various types have been devoted to reflective LCDs. Generally, in order to achieve high information density displays, high brightness, high contrast and wide viewing angle are needed. 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] have been designed. For a wide viewing angle, the methods such as multi-domain alignment and reflective fringe-field switching(FFS) mode have also 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 advantages that 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 of using a HAN cell for reflective LCDs, it has the weak points that viewing angle is narrow and dispersion property is poor. Therefore, the research to improve the viewing angle and the dispersion property has been prompted, but the configuration to satisfy both two characteristics has not been studied. So, we propose an optical configuration to be able to improve the viewing angle as well as the dispersion property.

At first, we investigate the conventional configurations to improve the viewing angle and the dispersion characteristics. However, we find that the configuration satisfying wide viewing angle and high contrast are not achieved with only one biaxial film(first and second configuration) because an attempt to improve viewing angle or dispersion property is trade-off relation. As a result, we present 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

2.1 The configuration to improve viewing angle

Figure 1 shows the configuration using one biaxial film. LC material is placed between two substrates coated to induce homeotropic and planar orientations, respectively.

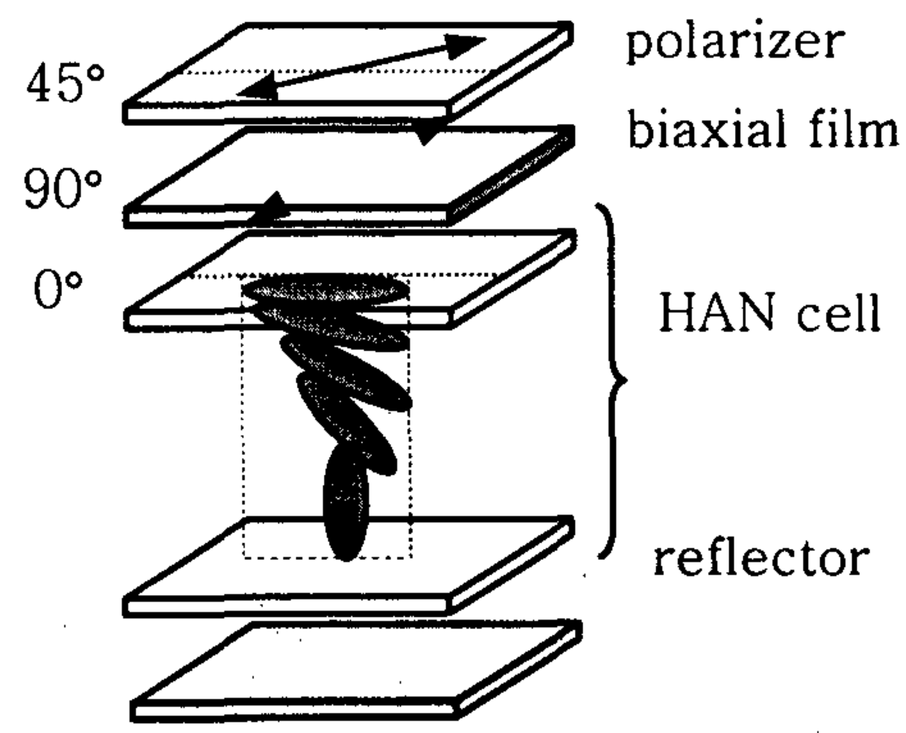

Fig. 1. The configuration to improve viewing angle using one biaxial film.

LCD master(Shintech, Inc.) as a calculation engine is used to determine the optical properties. The simulated result is shown in Fig. 2. We find that viewing angle of ±80° for the horizontal direction and

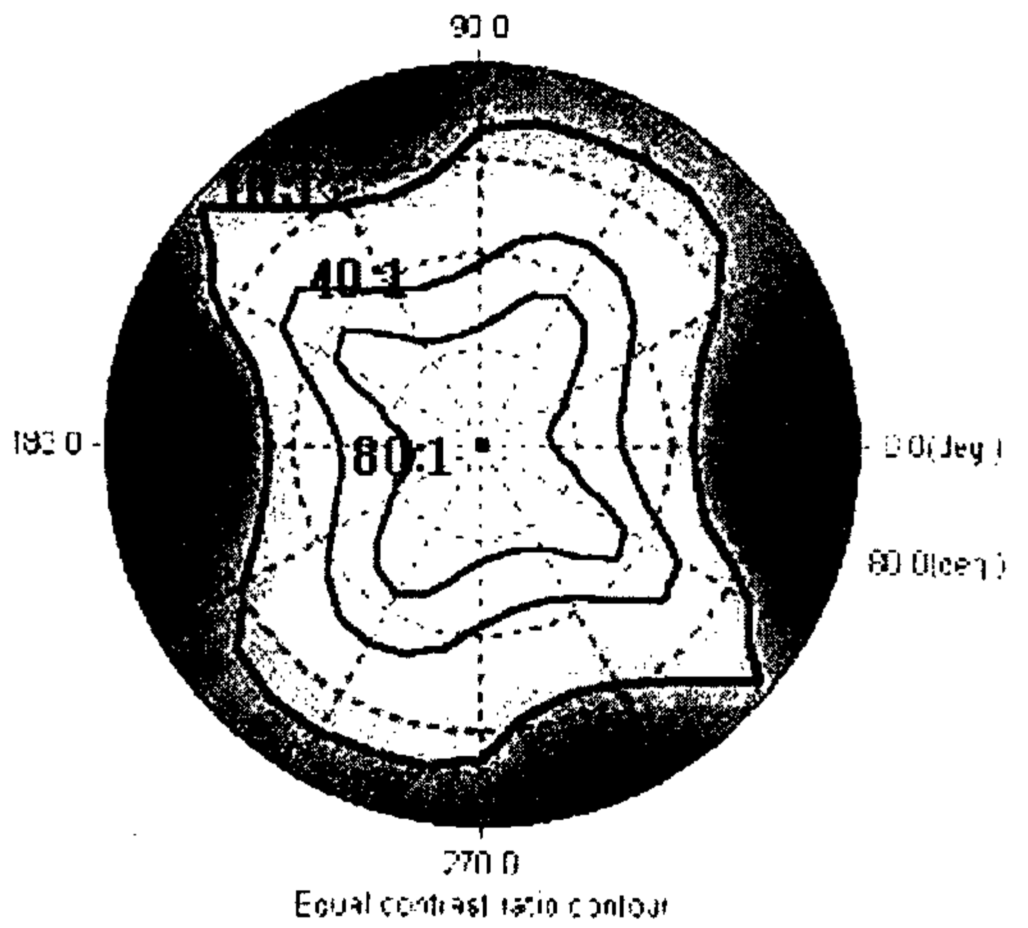

Fig. 2. Contrast ratio contour for the configuration of Fig. 1.

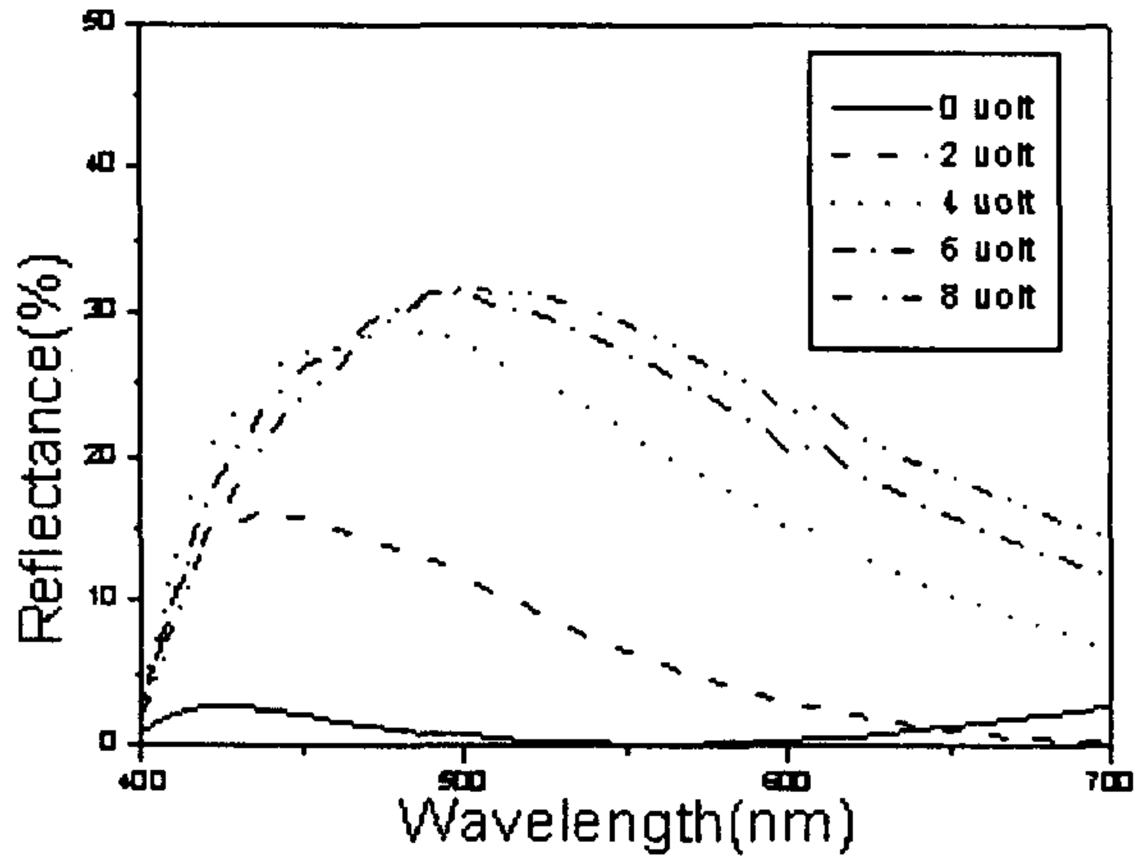

Fig. 3. Reflectance as a function of wavelength for the configuration of Fig. 1.

±60° for the vertical direction are obtained, but dispersion characteristics for the entire visible range are poor, as shown in Fig. 3.

2.2 The configuration to improve dispersion property

Another configuration is shown to improve dispersion property in Fig. 4. By the previously proposed wide-band property[3], this configuration is composed of a linear polarizer with its transmission axis set at 0°, a biaxial film with its slow axis set at 15°, and an LC layer with its input director axis set at 75°. As a result, as shown in Fig. 5, we can get a good dispersion property in the entire visible range, but viewing angle is narrower than the former structure as

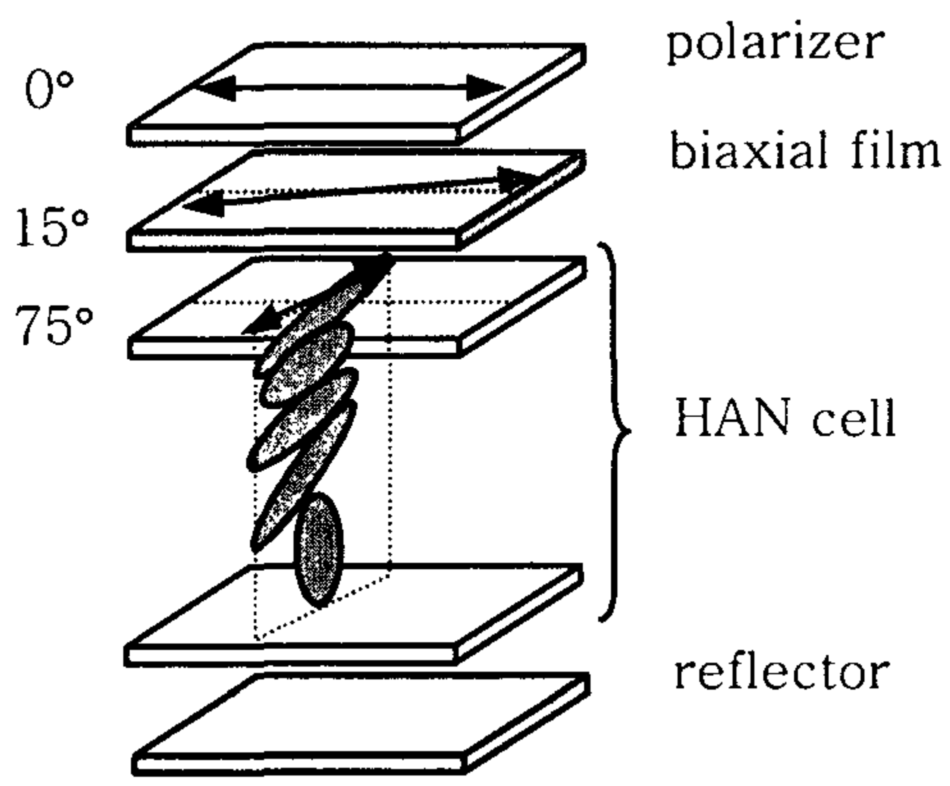

Fig. 4. The configuration to improve dispersion property using one biaxial film.

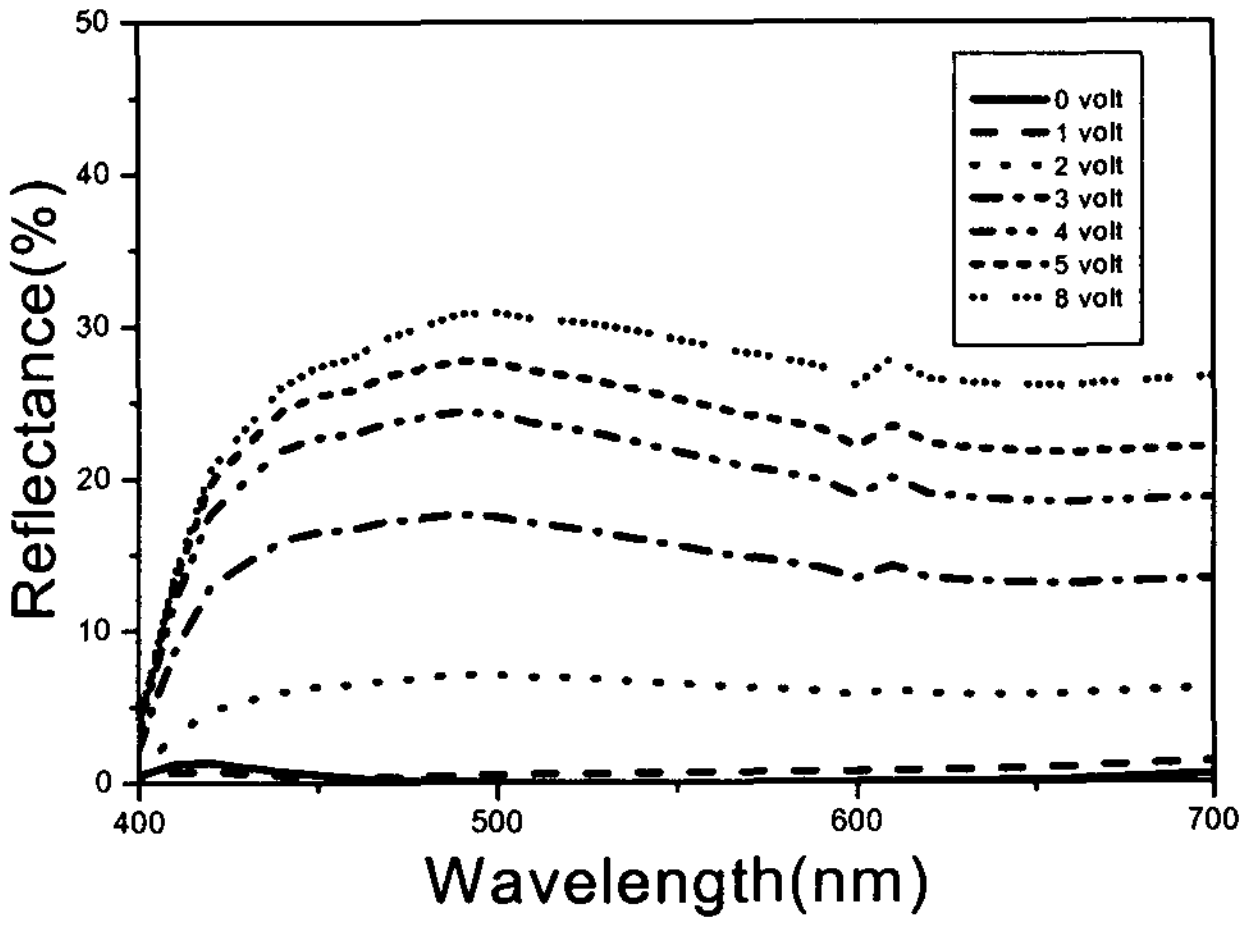

Fig. 5. Reflectance as a function of wavelength for configuration of Fig. 4.

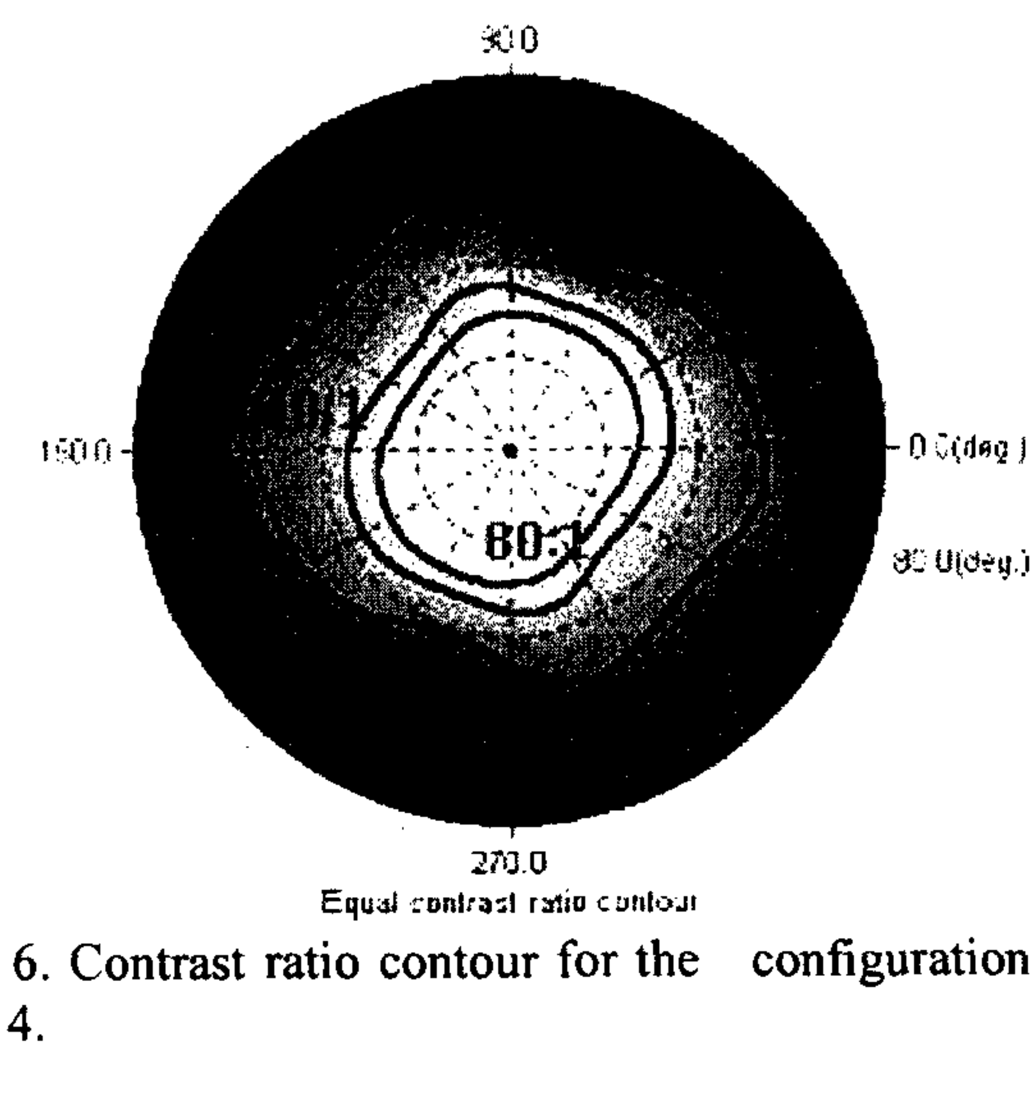

Fig. 6. Contrast ratio contour for the configuration of Fig. 4.

shown in Fig. 6 because this structure focused on improving the dispersion removes the merit of the biaxial film. Therefore, we can confirm that we can.not 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 and 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.

Figure 7 shows the optimized configuration using λ/2 film and an effective λ/4 LC configuration. The effective λ/4 LC configuration can be obtained with the biaxial film of λ/2 retardation and an LC layer of λ/4 retardation. The polarizer angle is set at x axis. A biaxial film is located between the LC cell and the polarizer, and the slow axis of the film is perpendicular to the rubbing direction. Birefringence at normal direction of the biaxial film is designed to be a half-wave retarder.($|n_x-n_y|D=275nm$, 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 the variation of n_z value, which is the refractive index of the biaxial film parallel to the z axis, we can 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.

We find that wide-band condition is satisfied, which presents a good dispersion property. We find that viewing angle is wider than the structure of Fig. 4 due to the role of the biaxial film. As shown in Fig. 8, we find that viewing angles of ±80° for the horizontal direction and ±50° for the vertical direction are obtained, and dispersion characteristics for the entire visible range are the same as shown in Fig. 5 because of the wide-band property.

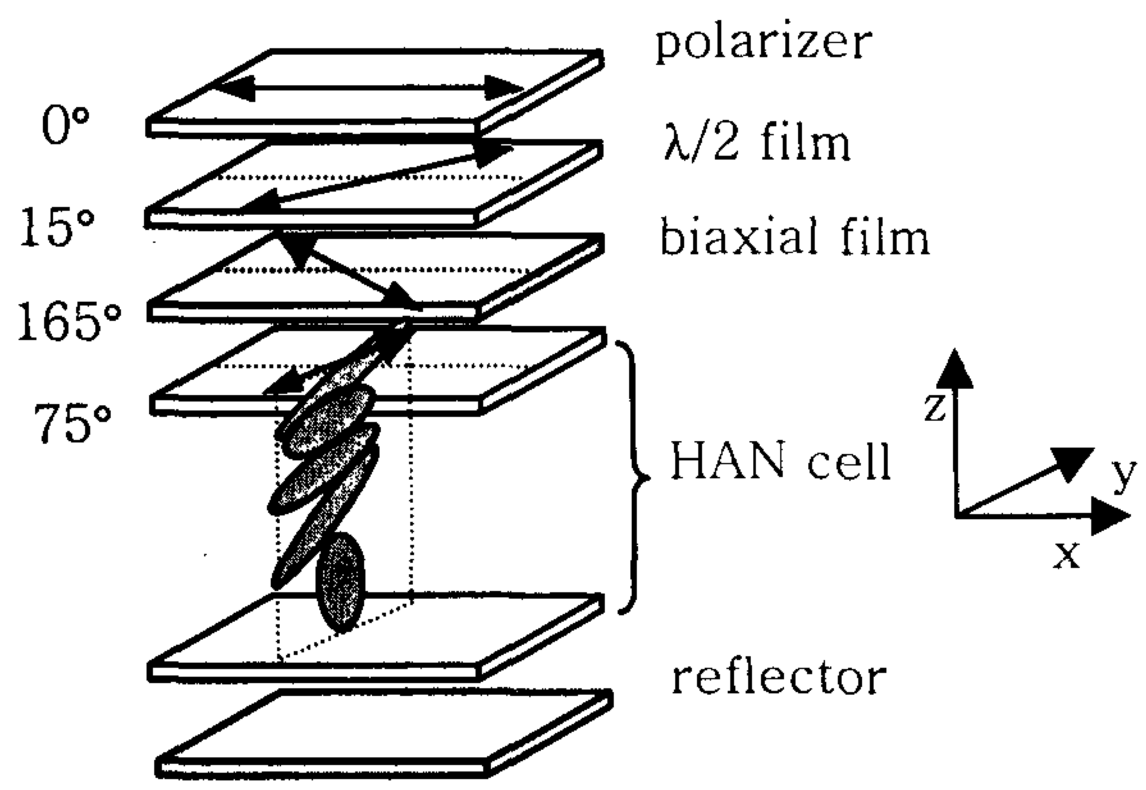

Fig. 7. The optimized configuration using one biaxial film and λ/2 film .

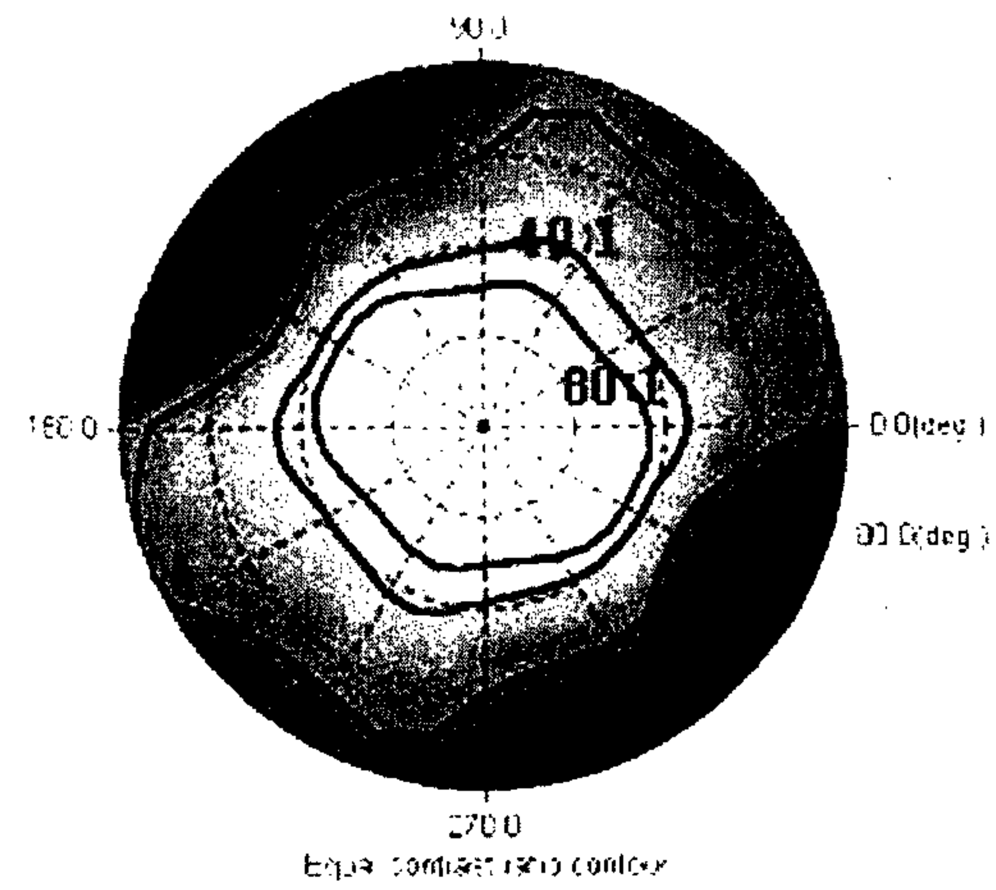

Fig. 8. Contrast ratio contour for the optimized configuration

Table 1. The simulation parameters of the liquid crystal

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

† $Nz=(n_x-n_z)/(n_x-n_y)$

4. Design of biaxial film

In the design of 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 conventional technique, the calculated thickness was always much smaller than a practical value[5]. So, we used the design method to be able to make use of the practically known film thickness. If we could find the film thickness(D), the birefringence at the normal direction of the biaxial film can be designed to become a half-wave retardation. As a result, 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.

Now we discuss the viewing angle characteristics by the deviation of the value of Nz. In the practical implementation of these configurations, since it is not easy to find a biaxial film designed, it is necessary to discuss the effect of viewing angle as a margin of the value of Nz. Therefore, we investigate 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 .

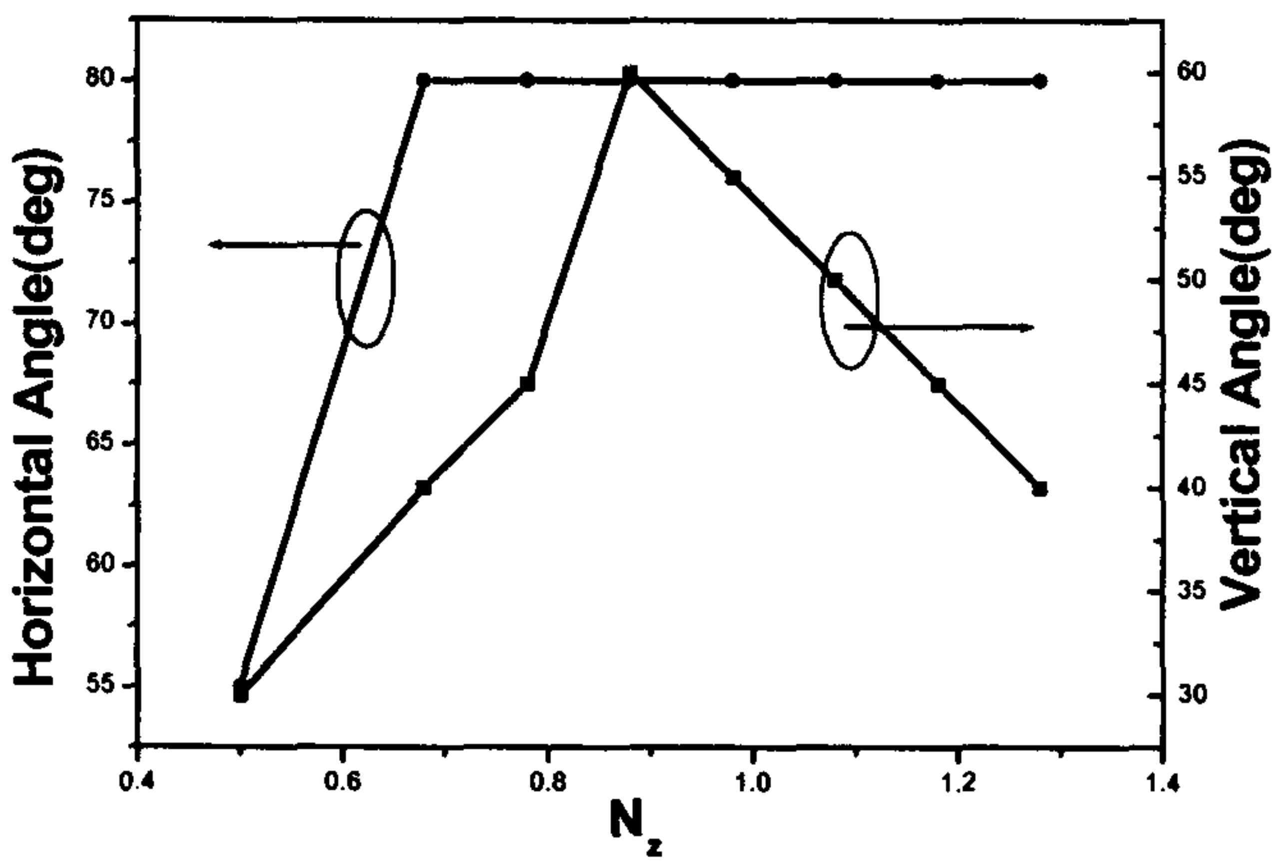

Fig. 9. Variation of viewing angle as a function of Nz

As shown in Fig. 9, we find 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 to satisfy a HVA of ±80° and a VVA of above ±50° is from 0.82 to 0.98.

5. Conclusions

In summary, we propose a configuration to be able 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 viewing angle is narrow, conventional configurations to improve viewing angle and dispersion property have been studied, but the structure to satisfy both wide viewing angle and high contrast has not been obtained. Therefore, we propose the optimized configuration to be able to obtain high contrast as well as wide viewing angle by using $\lambda/2$ film and an effective $\lambda/4$ LC configuration.

6. Acknowledgements

This work was performed by the Advanced Backbone IT Technology Development Project supported by the Ministry of Information & Communication in the Republic of Korea.

7. References

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

[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** (2000)L221.

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

[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** (2001)5334.

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