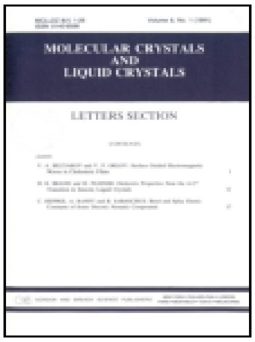


Taylor & Francis
Taylor & Francis Group

Molecular Crystals and Liquid Crystals

ISSN: 1542-1406 (Print) 1563-5287 (Online) Journal homepage: http://www.tandfonline.com/loi/gmcl20

Optical Properties of the Retro-reflective Polarization Film Fabricated by Stacking Anisotropic and Isotropic Materials

Dong Bin Yeo, Dae Soo Kim, Kyung Chan Heo, Yong Gil Kim, Bo Suk Kang & Chul Gyu Jhun

To cite this article: Dong Bin Yeo, Dae Soo Kim, Kyung Chan Heo, Yong Gil Kim, Bo Suk Kang & Chul Gyu Jhun (2015) Optical Properties of the Retro-reflective Polarization Film Fabricated by Stacking Anisotropic and Isotropic Materials, Molecular Crystals and Liquid Crystals, 612:1, 238-244, DOI: 10.1080/15421406.2015.1031994

To link to this article: http://dx.doi.org/10.1080/15421406.2015.1031994

Published online: 06 Jul 2015.

Mol. Cryst. Liq. Cryst., Vol. 612: pp. 238–244, 2015

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2015.1031994

Optical Properties of the Retro-reflective Polarization Film Fabricated by Stacking Anisotropic and Isotropic Materials

DONG BIN YEO,[1] DAE SOO KIM,[1] KYUNG CHAN HEO,[1] YONG GIL KIM,[1,2] BO SUK KANG,[2] AND CHUL GYU JHUN[1,3,*]

[1]Department of Digital Display Engineering, Hoseo University, Asan, Chungnam, Korea
[2]CoreOptix Asantechno Valley, Seogok-ri, Dunpo-myeon, Asan, Chungnam, Korea
[3]School of Green Energy & Semiconductor Engineering, Hoseo University, Asan, Chungnam, Korea

As Liquid Crystal Display (LCD) market with ultra-high definition is growing, high contrast ratio and high light efficiency are required. The anisotropic reflective film can improve light efficiency of the back light unit of LCD TV due to the retro-reflective polarization film, which is named as the double brightness enhanced film fabricated by stacking an optically anisotropic and isotropic layer. We have calculated the transmittance, the reflectance and the polarization degree of the proposed film with respect to the layer number. We also demonstrate the optical performance of the anisotropic reflective film.

Keywords: Retro-reflectvie; polarization degree; multi-layer; anisotropy

1. Introduction

Recently, Liquid Crystal Display (LCD) market is need for technology that has fast response time, high contrast ratio, and high light efficiency. In this perspective, LCD TV was using optical film in back light unit (BLU) for higher light efficiency. For these reasons, optical film has been actively carried out studies. This BLU is composed of a lamp, a reflective sheet, a light guide plate, and a prism sheet etc. for enhancing brightness. Dual brightness enhancement film (DBEF) that is used for an optical film in BLU is stacked several hundred layers of film with a thickness of less than 100 nm. This film increases the optical efficiency of the BLU [1]. Based on this result, the brightness enhancement of more than 50% in the current has been reported because a specific polarized light is passed, the remaining light is recycled again.

In this study, we investigated the optical characteristics of the retro-reflective polarizing film to substitute the DBEF these films [2]. When stacking the optical thickness of one quarter to the center wavelength of visible light (550 nm), the films indicating a polarization

*Address correspondence to Chul Gyu Jhun, Department of Digital Display Engineering, Hoseo University, Asan, Chungnam 336-795, Korea; E-mail: cgjhun@hoseo.edu

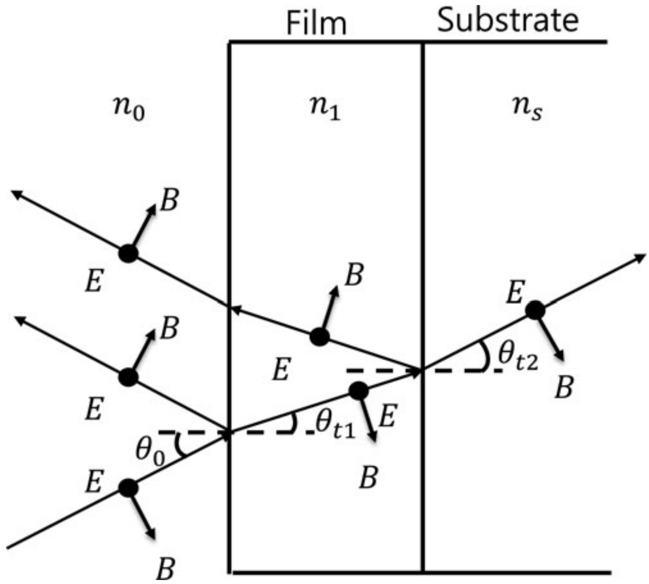


Figure 1. Structure of multilayer.

can be fabricated by using both Polyimide (PI) revealing an optical isotropy and Reactive mesogen (RM) having an optical anisotropy.

2. Simulation Results

In this research, we were alternately stacked quarter of the wavelength of visible light alignment film having optical isotropy and RM having an optical anisotropy. In order to examine the degree of polarization, the films were designed 1 pair, 10 pairs, 20 pairs, 50 pairs of stacking PI layer and RM layer, respectively and it can be simulated by using a refractive index (SE-3140n, Nissan Chemical Industries) of RM and PI (HCM-008, HCCH). The refractive index for *e*-wave (extra ordinary) and *o*-wave (ordinary) are 1.6768 and 1.5114, respectively. The refractive index of the PI is 1.671.

From the boundary condition of the electric field and magnetic field at on boundary as shown in Fig. 1 [3–5], the electric and magnetic fields relations can be represented in matrix form [5] as:

$$\begin{bmatrix} E_a \\ B_a \end{bmatrix} = \begin{bmatrix} cos\delta & \frac{isin\delta}{\gamma} \\ i\gamma sin\delta & cos\delta \end{bmatrix} \begin{bmatrix} E_b \\ B_b \end{bmatrix}. \tag{1}$$

For a multilayer with arbitrary layer number, N, An overall transfer matrix, which represents the entire multilayer stack is the production of the individual transfer matrix as:

$$\begin{bmatrix} E_a \\ B_a \end{bmatrix} = \left\{ \prod_{j=1}^{N} \begin{bmatrix} cos\delta & \frac{isin\delta}{\gamma_j} \\ i\gamma_j sin\delta & cos\delta \end{bmatrix} \right\} \begin{bmatrix} E_N \\ B_N \end{bmatrix} \tag{2}$$

The 2 × 2 matrix is called the transfer matrix of the film and generally represented by

$$\mathcal{M} = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix}. \tag{3}$$

Using the relationship between electric field and magnetic field and reflection and transmission coefficients, Eqs. (2) and (3) may be written as:

$$\begin{bmatrix} E_0 + E_{r1} \\ \gamma_0 (E_0 - E_{r1}) \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \begin{bmatrix} E_{t2} \\ \gamma_s E_{t2} \end{bmatrix}, \tag{4}$$

where $\gamma_i = n_i \sqrt{\varepsilon_0 \mu_0} cos\theta_i$ for TM mode and $\gamma_i = \frac{n_i \sqrt{\varepsilon_0 \mu_0}}{cos\theta_i}$for TE mode. γ_0 and γ_s are related to the refractive index of the air and substrates. From the above transfer matrix, the reflection coefficient and the reflectance can be obtained

$$\mathrm{r} = \frac{\gamma_0 m_{11} + \gamma_0 \gamma_s m_{12} - m_{21} - \gamma_s m_{22}}{\gamma_0 m_{11} + \gamma_0 \gamma_s m_{12} + m_{21} + \gamma_s m_{22}} \tag{5}$$

$$\mathrm{R} = \frac{1}{2} \left(\mathrm{R}_{//} + \mathrm{R}_{\perp} \right) \tag{6}$$

Neglecting energy loss, the optical transmittance of the multilayer thin film can simply be obtained

$$\mathrm{T} = 1 - R \tag{7}$$

For *e*-wave whose electric field oscillates parallel to the optic axis of the RM material, we calculated the transmittance of 10 pairs, 20 pairs, 50 pairs of stacking PI layer and RM layer. The calculated transmittance were shown in Fig. 2. Figure 3 shows the calculated transmittance of *o*-wave whose electric field oscillates perpendicular to the optic axis of the RM material.

3. Experimental Results

The experiments were conducted while varying the solvent ratio in the solution and coating conditions in order based on the results of the simulation to produce the optical thickness of a quarter wave plate.

First, 0.02 g of the photo-initiator was mixed into 7 g of cyclopentanone. 1 g of HCM-008, which is RM (reactive mesogen), was also mixed the cyclopentanone with photo-initiator. We coated this mixture on the substrate at 4500 rpm for 15 s, which yields 80 nm thickness.

On the other hand, 2 g of SE-3140 which is an alignment material. Alignment material was coated with thickness of 80 nm at 6000 rpm for 15s. The thickness was measured by

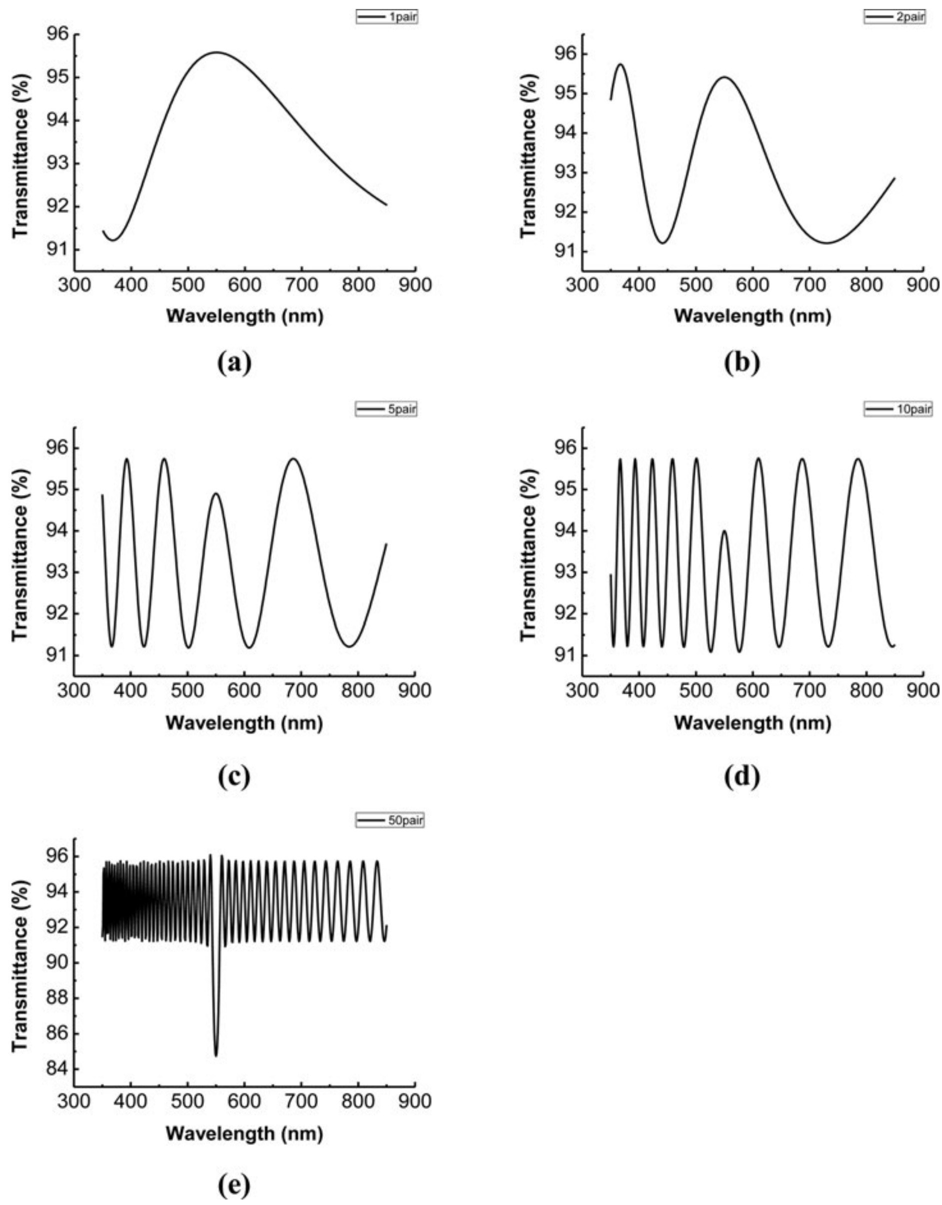


Figure 2. Transmittance of *e*-wave depending on the number of layers: (a) 1 pair, (b) 2 pairs, (c) 5 pairs, (d) 10 pairs, (e) 50 pairs.

NV-2000 (Nano system co.) The measured thickness by NV-2000 was shown in Fig. 4. The transmittance of fabricated two layers of RM and PI was measured by the spectrometer, USB4000-XR1 (Ocean optics co.). The transmittance of *e*-wave was measured by inserting polarizer, whose transmissive axis was parallel to the optic axis of RM. The transmittance of *o*-wave was measured when the transmissive axis is perpendicular to the optic axis of RM. The degree of polarization can be obtained from the relationship between transmittance of

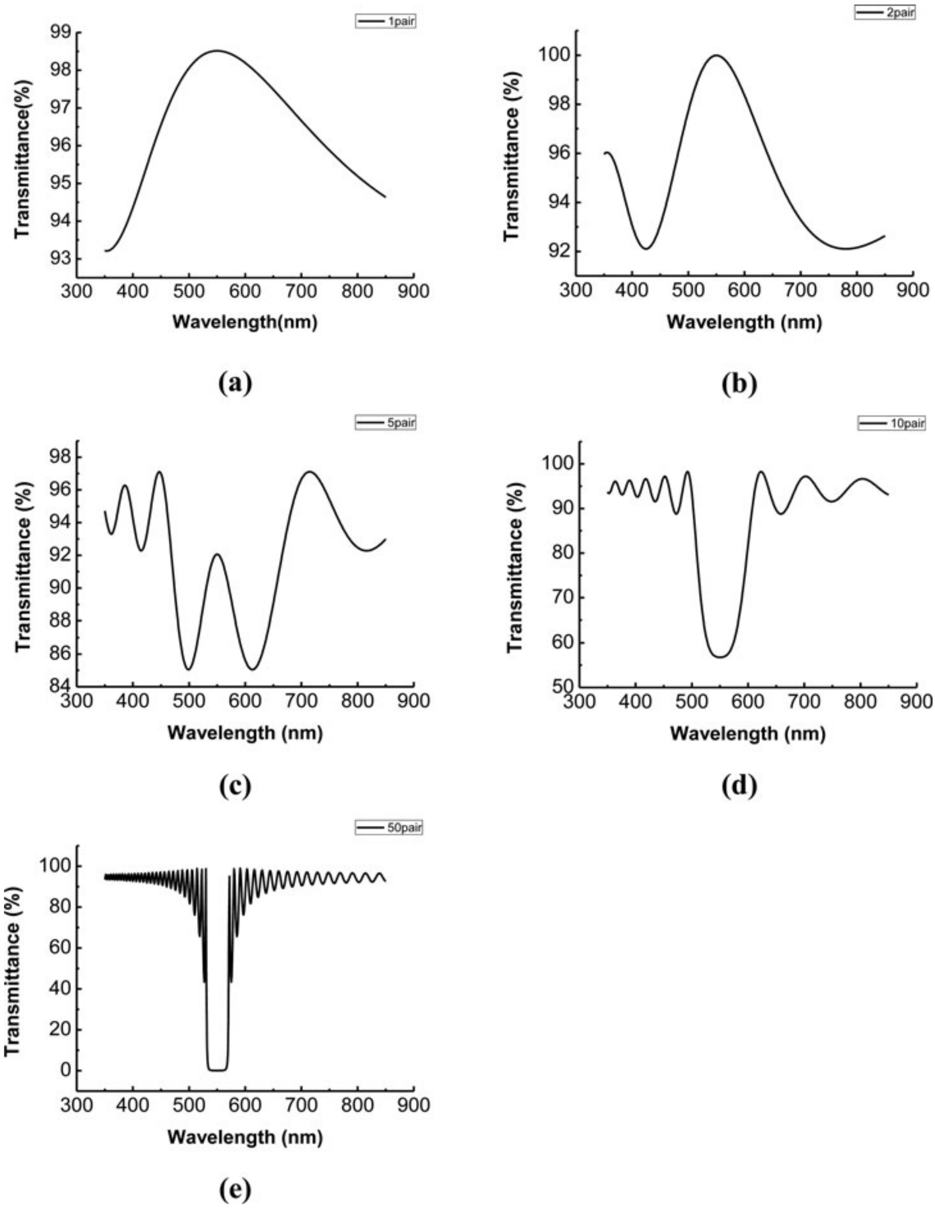
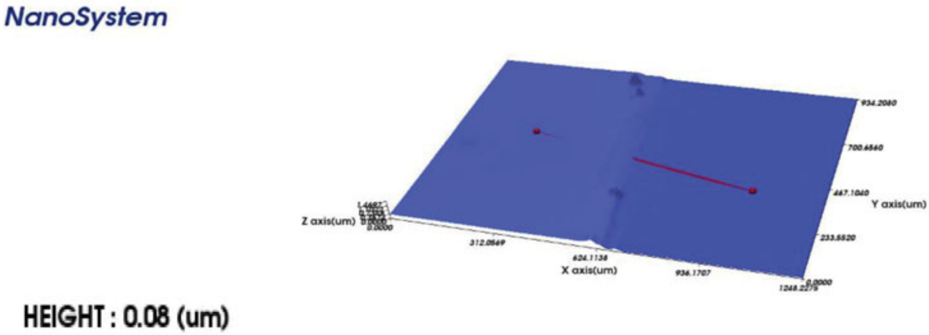


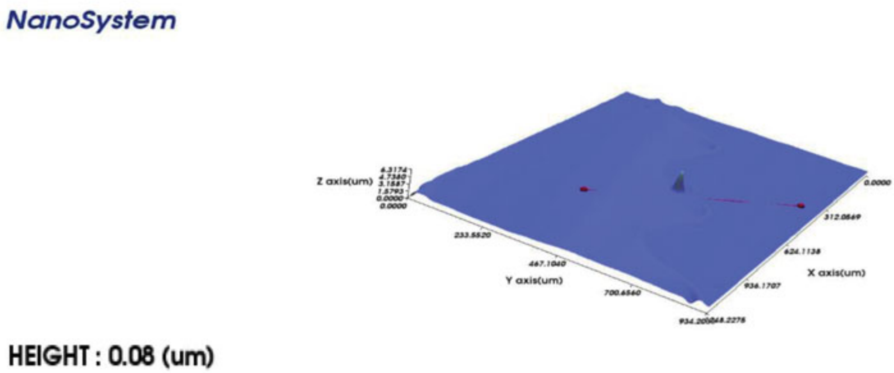
Figure 3. Transmittance of o-wave depending on the number of layers: (a) 1 pair, (b) 2 pairs, (c) 5 pairs, (d) 10 pairs, (e) 50 pairs.

e-wave and o-wave as the following equation and 13% of polarization degree was obtained as shown in Fig. 5.

$$\text{Pol} = \frac{T_o - T_e}{T_o + T_e} \tag{8}$$



(a)



(b)

Figure 4. Measured thickness of (a) PI layer and (b) RM layer by NV-2000.

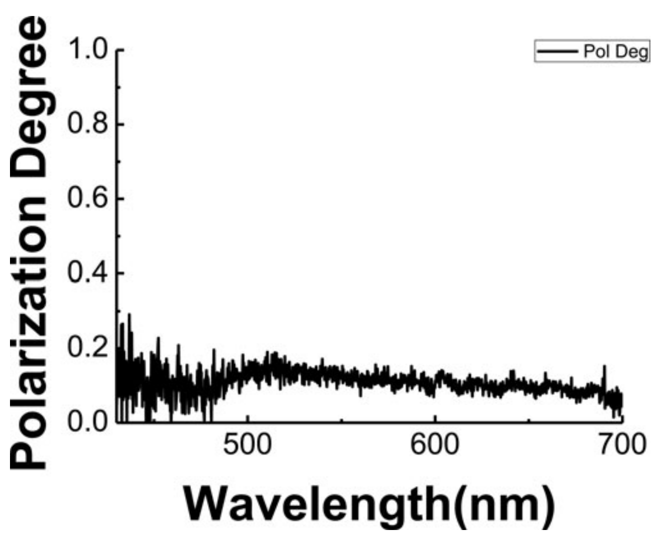


Figure 5. Measured polarization degree of the fabricated 1 pair sample.

4. Summary

We proposed a retro-reflective polarization film by stacking and optically isotropic layer and anisotropic layer. We calculated the transmittance and the polarization degree of the proposed film with respect to the layer number. To verify the effect of multi-layer on polarization, we fabricated 1 pair sample and measured the polarization degree. 13% of polarization degree was obtained from the fabricated sample.

Acknowledgment

This research was supported by the Ministry of Trade, Industry and Energy (MOTIE) through the Special Education program for Industrial Convergence.

References

[1] Boher, P., Leroux, T., Bignon, T. & Glinel, D. (2008). *SID Int. Symp. Dig. Tech. Pap*. *38*, 1517.
[2] Allen, R. C., Carlson, L. W., Ouderkirk, A. J., Weber, M. F., Kotz, A. L., Nevitt, T. J., Stover, C. A., & Majumdar, B. (2000). *U.S. Patent 6*, *111*,696A.
[3] Weber, M. F., Stover, C. A., Gilbert, L. R., Nevitt, T. J., & Ouderkirk, A. J. (2000). *Science Magazine*, *287*, 31
[4] Tyan, R.-C., Salvekar, A. A., Chou, H.-P., Cheng, C.-C., Scherer, A., Sun, P.-C., Xu, F., & Fainman, Y. (1997). *J. Opt. Soc. Am. A*, *14*, 1627.
[5] Redrotti, F. L., & Pedrotti, L. S. (1993). "Theory of Multilayer Films," Chap. 19 in *Introduction to Optics 2nd edition*, pp. 391–409. Prentice-Hall, Inc.