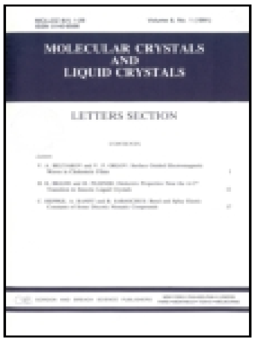

Molecular Crystals and Liquid Crystals

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

Macroscopic Alignment Control of Liquid Crystal Molecule in Optical Film for 3D Display

Moon Soo Park, Shin Young Kim & Soo Young Ryu

To cite this article: Moon Soo Park, Shin Young Kim & Soo Young Ryu (2014) Macroscopic Alignment Control of Liquid Crystal Molecule in Optical Film for 3D Display, Molecular Crystals and Liquid Crystals, 605:1, 275-280, DOI: 10.1080/15421406.2014.917501

To link to this article: http://dx.doi.org/10.1080/15421406.2014.917501

Published online: 15 Dec 2014.

Mol. Cryst. Liq. Cryst., Vol. 605: pp. 275–280, 2014

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2014.917501

Macroscopic Alignment Control of Liquid Crystal Molecule in Optical Film for 3D Display

MOON SOO PARK,* SHIN YOUNG KIM, AND SOO YOUNG RYU

IT&Electronic Materials R&D, LG Chem, Ltd., Daejeon, Korea

The optical film made of liquid crystal molecules can have useful anisotropic optical properties by controlling the alignment of molecules. In order to apply those films to commercial display, we have to know the way to control the thickness, appearance, refractive index, adhesion, and many properties in macroscopic scale. In this presentation, we show how can we control alignment of liquid crystal molecules in macroscopic scale and make the Film Patterned Retarder (FPR^{TM}) used in the polarization type stereoscopic 3D-displays.

Keywords Liquid crystal; reactive mesogen; photo alignment; 3D display; film patterned retarder

Introduction

With the growth of the display industry including LCD, there has been significant development in functional optical films capable of adjusting the polarization of light. Polymer stretched optical films and liquid crystal optical films offer various functions such as a wide viewing angle, brightness enhancement, and three-dimensional image display. In particular, liquid crystal optical films are very thin compared to polymer stretched optical films and can be turned into retardation films having diverse functions. For instance, a quarter wave plate (QWP) that converts linear polarized light into circular polarized light is produced when rod-like liquid molecules are used to obtain a planar aligned liquid crystal film with a thickness of 1 μm. Liquid crystal alignment is made possible by creating an anisotropic electron distribution on the surface of the alignment layer through rubbing or photoalignment. [1–4] The liquid crystal molecules are aligned according to the electron distribution and undergo self-assembly to fabricate a well-aligned liquid crystal layer of a few um thickness. They then form a thin liquid crystal optical film with stiffening from exposure to UV light.

Meanwhile, 3D TVs have developed rapidly in recent years following the success of 3D movies like Avatar. Binocular disparity is used to achieve 3D effects. Fig. 1 shows the principles behind the representation of 3D images in a 3D TV. A full HD TV with 1,080

This paper was originally submitted to *Molecular Crystals and Liquid Crystals*, Volume 594, Proceedings of Optics of Liquid Crystals 2013.

*Address correspondence to Moon Soo Park, 188, Moonji-ro, Yuseong-gu, Daejeon, 305-738, Korea. E-mail: pcartoon@lgchem.com

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gmcl.

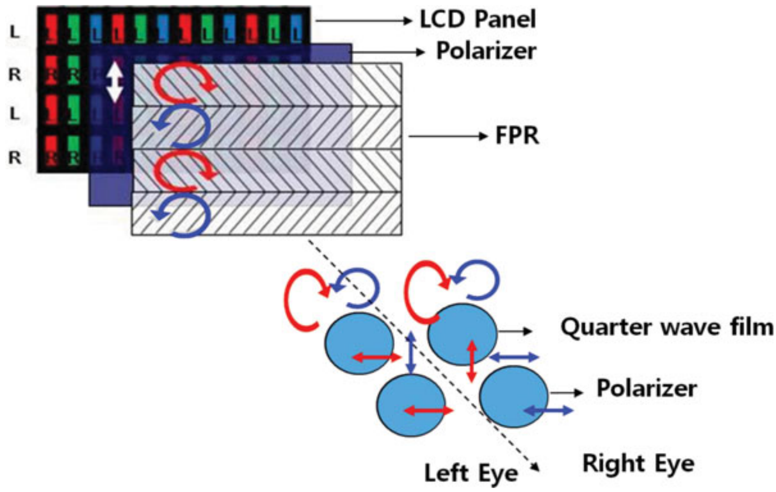

Figure 1. Mechanism of 3D image recognition through Film Patterned Retarder in 3D TV.

vertical pixel lines displays linear polarized images for the left and right eye in its even-numbered and odd-numbered lines respectively. A film pattern retarder (FPR) is placed for exact matching with the pixel lines, converting images for the left and right eye into left handed circular polarized light and right handed circular polarized light. When viewed through polarized glasses, images in the even-numbered pixel lines reach the left eye while images in the odd-numbered pixel lines arrive at the right, thus delivering 3D images to viewers. FPR can be implemented in films with reactive mesogen and photoalignment patterning. The quality of 3D images is determined by the accuracy and uniformity of liquid crystal alignment on the macroscopic scale.

Film Patterned Retarder and Crosstalk

Figure 2 shows that the FPR is comprised of a rod-like reactive mesogen aligned at 45 degrees and 135 degrees on top of a transparent polymer matrix with no retardation and coated with a 0.2 μm photoalignment layer. When linear polarized light with an optical axis

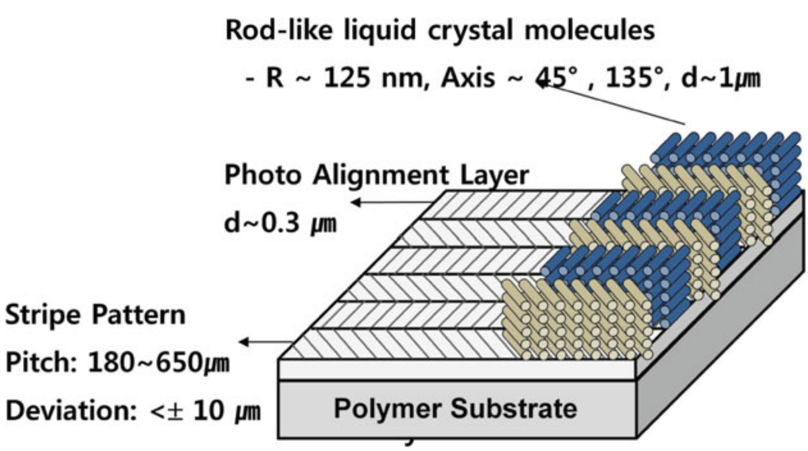

Figure 2. Film Patterned Retarder structure.

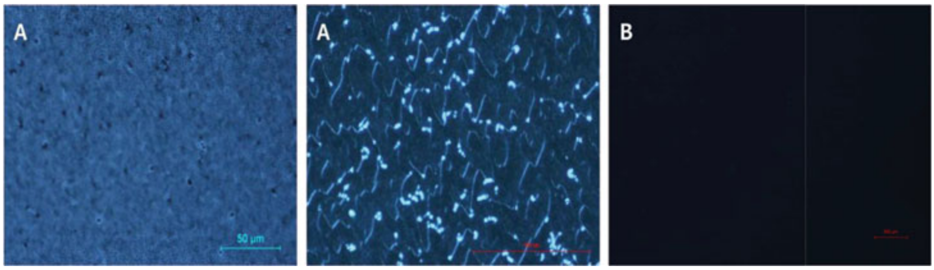

Figure 3. The polarized optical microscopic images of LC films (A) the bad alignment image of one-component system under uneven drying conditions (Left: center of drying zone, Center: side of drying zone), (B) the good alignment image of three-component system.

of 0 or 90 degrees passes through the FPR, patterns aligned at 45 and 135 degrees form the right handed circular polarized light and left handed circular polarized light. Observations through 3D glasses attached to the polarizer at 45 and 135 degrees reveal that the QWP only passes left or right handed circular polarized light. The eye sees two overlapping images when the left and right circular polarized light are passed through. Crosstalk refers to the amount of overlapping and serves as an indicator of 3D image quality. To reduce crosstalk to less than 1%, the optical axis and retardation value of the liquid crystal layer of FPR must coincide with that of 3d glasses. At the boundary of patterns aligned at 45 and 135 degrees, there is a disclination zone in which the optical axis of liquid crystal molecules cannot be defined by 45 or 135 degrees. The width of this boundary must be minimized as it increases crosstalk with random polarization. The size and optical axis of patterns are determined by various mechanical factors such as exposure mask, exposure system, and polarization degree of the light source. Thus, a low crosstalk value on the macroscopic scale and thereby high 3D image quality can be achieved by optimizing actual process conditions or the composition of liquid crystal solution, so as to minimize the boundary width and maximize the uniformity of retardation.

Retardation and Uniformity

The retardation value of liquid crystal films is derived from multiplying the thickness of the liquid crystal layer and birefringence. This is approximately 130 nm for QWPs, which convert linear polarized light into circular polarized light. If the retardation values deviate by more than 5%, the difference in brightness will lead to non-uniformity when seen through polarized glasses. Assuming that the birefringence value is 0.13, we can form a uniform QWP using 1 μm liquid crystal film. Precise coating technology is required to obtain uniform liquid crystal films that are 1 μm thick. Reactive mesogen molecules can be melted with an organic solvent to get a uniform solution with a viscosity lower than 10 cps. Using a bar coater or slot die coater, this low-viscosity RM solution can form a 1um liquid crystal film with less than 5% deviation in thickness at a speed of 20 m per minute on a 1∼2 m film matrix. After coating, some non-uniformity in temperature and air volume is unavoidable in the drying process. If the maximum temperature difference between the center and sides of a drying oven is 20 degrees, it is necessary to design a liquid crystal solution with a nematic temperature range to ensure uniform liquid crystal alignment characteristics. Generally, liquid crystal solutions consist of a reactive mesogen, solvent, photo initiator, and additive. Liquid crystal alignment defects may be caused by a number of factors including impurities, defects on the matrix surface, and non-uniformity in

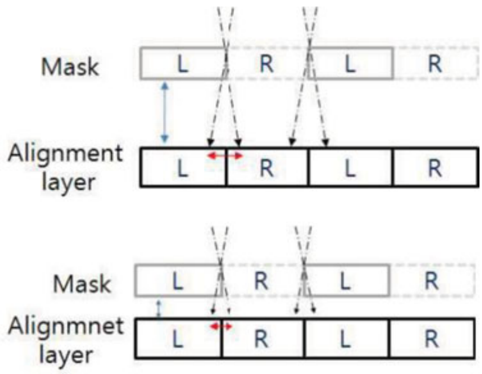

Figure 4. Difference of boundary (disclination line area) width according to distance (gap) between mask and alignment layer.

the drying process. These defects arise from non-uniform concentration on the micro scale due to convection during drying, which partially forms a disclination line. At a partially high concentration, a highly soluble solution can reduce the generation of a disclination line. Fig. 3 is the polarized microscopic image of solutions with A and B involving one and three types of RM respectively. Composition B has a broader nematic range compared to A, and remains highly soluble at high concentrations. Both A and B exhibit uniform alignment characteristics in the center, but only B maintains uniform alignment characteristics at the sides where the temperature is 20 degrees higher. In actual production, solutions can be designed to allow mild drying in the drying oven by mixing various solvents, thus producing 1∼2 m uniform liquid crystal QWP films with a retardation deviation of 5% or less.

Minimizing of Boundary Width Between L and R Areas

Photoalignment offers the advantage of easily creating liquid crystal alignment patterns using a mask. When the photoalignment layer is exposed to polarized UV light, an electron distribution is formed either vertically or horizontally due to three reactions: dissociation, cyclization, and isomerization. Liquid crystal molecules are then aligned accordingly. Using

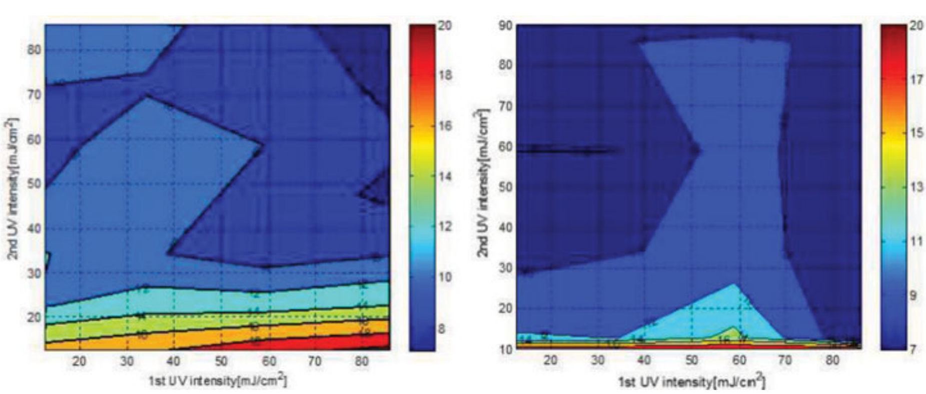

Figure 5. Disclination line width according to UV power at distance of 250 μm and 150 μm.

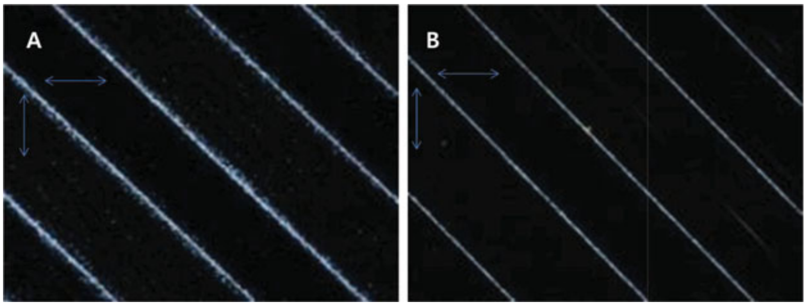

Figure 6. The polarized optical microscopic images of FPR (A) FPR coated with one-component system had bad LC alignments and broad boundary lines, (B) FPR coated with three-component system had good LC alignment and narrow boundary lines.

a high-sensitivity photoalignment material with cyclization or isomerization as its main mechanism is recommended since photo dissociation requires a relatively high amount of energy and strong UV light leads to thermal deformation of the polymer film substrate. For FPR to form stripe patterns aligned at 45 degrees (R area) and 135 degrees (L area), parts of the R and L areas may be exposed to polarized light, or R followed by part of L, or L followed by part of R. Regardless of the order of exposure, the boundary of R and L will be exposed more than once. When exposed on a continuously moving film, a distance greater than the magnitude of vibration must be acquired between the alignment layer and the mask. As shown in Fig. 4, the overlapping area between L and R increases with the distance between the mask and the alignment layer. The boundary faces competition between alignment in 45 degrees and 135 degrees. If neither direction is dominant, a disclination line is formed and results in indistinct polarization. This raises the crosstalk value and deteriorates the 3D image quality. Conditions that minimize the width of the boundary between patterns must be identified because it is difficult to achieve full uniformity in the gap and exposure energy on the macroscopic scale.

With TAC film as a substrate and LG Chem's photoalignment materials, a 0.2 μm photoalignment layer was formed and subject to pattern exposure at 45 degrees and 135 degrees. The boundary width between patterns was measured by varying the gap between the alignment layer and mask, and the intensity of pattern exposure. For a gap of 250 um, the width was less than 10 μm if the exposure intensity at 135 degrees was set to 30 mW/cm^2. For a gap of 150 μm, the width was less than 10 um under all conditions. As such, the boundary width can be kept below 10 μm um even with 10% deviation if the gap is 200 um and the intensity is 40 mW/cm^2 at 135 degrees (see Fig. 5).

Meanwhile, the overlapping area between 45 degrees and 135 degrees has a mixed electron distribution in the two directions. If the liquid crystal composition reacts sensitively to a small alignment effect, we can reduce the occurrence of undefined disclination lines. Fig. 6 shows that A and B have different boundary widths for the same gap and exposure conditions. B, which is a mixture of three RMs, has a narrower width than A, which implies that B is more sensitive than A.

Conclusion

FPR is a 3D film with liquid crystal molecules aligned in order at 45 degrees and 135 degrees. To achieve uniform 3D characteristics, the retardation and optical axis should be uniform on the macroscopic scale, and the boundary width between patterns must be minimized. Despite some degree of non-uniformity arising from FPR manufacturing conditions, it is possible to produce FPR with uniform 3D characteristics through optimization of liquid crystal composition and exposure conditions.

References

[1] Collings, P. J., Ed. (1990). *Liquid Crystals*, IOP Publishing, Ltd.: Bristol.
[2] Collings, P. J., Patel, J. S., Eds. (1997). *Handbook of Liquid Crystal Research*, Oxford University Press: Oxford.
[3] Schadt, M., Schmitt, K., Kozinkov, V., Chigrinov Jpn, V. (1992). *J. Appl. Phys*, *31*, 2155–2164.
[4] lchimura, K. (2000). *Chem. Rev*, *100*, 1847–1873.