A new WV Film for Fast-Response-time OCB-LCD-TVs

Yoji Ito, Ryouta Matsubara, Yoshiaki Hisakado,
Hiroyuki Mori, and Keiji Mihayashi
Flat Panel Display Materials Research Laboratories, Fuji Photo Film Co., Ltd., 210, Nakamura,
Minamiashigara-shi, Kanagawa, 250-0193, JAPAN

Abstract

We have successfully commercialized a novel optical compensation film, OCB-WV film, for OCB-LCD-TVs which has fast response time and wide viewing angle. The OCB-WV film consists of a 45degree-aligned discotic layer and a high Rth biaxial TAC film, which is suited for a roll-to-roll polarizer manufacturing process. This OCB-WV has brought out the excellent features that OCB intrinsically has, making next-generation fast-response LCD-TVs possible and free from image blurring in conjunction with an impulsive driving scheme.

1. Introduction

Liquid crystal displays (LCDs) have been widely used for car-navigation system, camcorder, note-book PCs and monitors. Recently LCDs have been ready to be applied for TV use, and need not only wide-viewing angle but also fast-response time. The response time of conventional LCDs is not fast enough for TV applications. Conventional LCDs are inferior to CRTs in displaying motion pictures because, whereas a CRT displays pictures in a series of pulse light-emission, a LCD has slow response time and a hold-type driving scheme, resulting in blurring over consecutive frames. It is known that LCDs with an impulsive-type driving scheme improve blurring(1) *but require LC response time of less than 5 ms.*

The OCB mode is the only nematic-type LCD mode known, so far, to have the fastest response time. OCB-LCDs have long been reported mainly in academic conferences for many years(2)~6)*. It was not until quite recently that OCB-TVs were commercialized.*

Some of the main reasons are follows: OCB is sensitive to retardation fluctuation of the cell and the optical compensation films because of a birefringence mode. OCB-LCDs require a complicated structure of optical compensation to obtain a wide viewing angle. To develop the OCB-WV films, we had to overcome the following difficulties:

(1) Optical control of the TAC film, which plays an important role in optical compensation, as well as a protective film.

(2) Highly control of the hybrid-aligned PDM layer to fit the bend alignment of LC in black-state OCB cell.

(3) Suitability to roll-to-roll process in polarizer production lines.

We have successfully developed a novel OCB-WV film, which realizes the yield-up without changing the polarizer production process.

2. Structure of OCB-WV

Figure 1 shows the structure of an OCB cell in the black state. The OCB mode has a bend alignment of LC as hybrid aligned LC stacked together. A pair of the OCB-WV films, as a whole was designed to 3-demensionally compensate the bend alignment structure of the LC layer of the OCB cell.

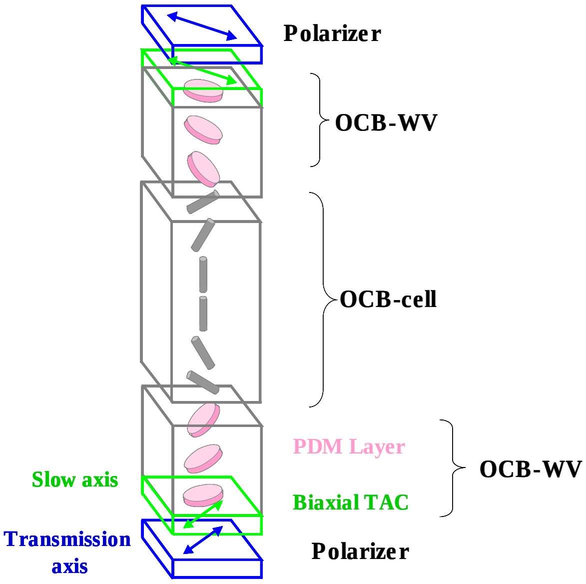

Fig.1 Cross sectional view of OCB cell with OCB-WV
(Simplified and idealized description)

The OCB-WV requires a high Rth value for the biaxial TAC film with the slow axis parallel to the transmission axis of the polarizer and a hybridly-aligned PDM (Polymerized Discotic Materials) layer with the alignment direction parallel to the cell rubbing direction. By optimizing the cell and film parameters, light leakage from cross-nicole polarizers at oblique incidence can also be minimized to be wide viewing angle.

3. How to realize of its structure

3.1 Biaxial TAC

3.1.1 Control of Rth

It is well known that TAC films tend to have a low Rth value, and that it is very difficult to control the birefringence due to the configuration of TAC molecules, which has three side chains perpendicular to the main chain.

A new technology of controlling the Rth value of TAC film has successfully been developed. To produce TAC films, a TAC solution is cast on a metal substrate, peeled off from the substrate, and dried. In the course of forming a film, TAC molecules tend to align in the film plane. We synthesized a new chemical compound that has large optical anisotropy and is capable of aligning parallel with TAC molecules in the film. The new additive controls the Rth value of TAC films (Figure 2).

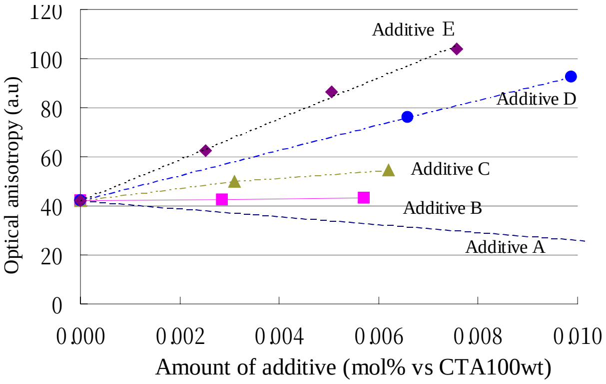

Fig.2 Optical anisotropy of TAC vs. amount of additive

3.1.2 Control of in-plane Re

The in-plane retardation of the biaxial TAC films plays an important role in improving the viewing angle of a pair of cross-polarizers. To control the in-plane retardation of the biaxial TAC film, we introduced a new inline tenter-stretching equipment, which stretches the film in the lateral direction.

One of the problems of tenter-stretching is the “bowing” phenomenon, which deviates the slow axis of the film in the shape of a bow.

When a polymer film is stretched, it is generally contracted in the orthogonal direction to the stretching direction. In the case of tenter-stretching, the center of the film tends to be contracted more than a edge of its film, as shown in Figure 3. By releasing the film from tenter clips before the film is contracted, we can avoid the bowing.

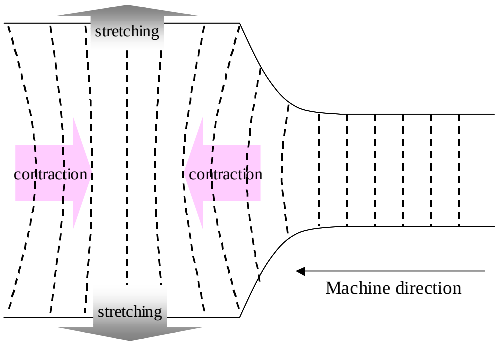

Fig3. Schematic of tenter-stretching

3.2 PDM layer

3.2.1 Hybrid alignment

Discotic molecules must be aligned in a hybrid way to compensate the bend cell[7)].

It is important to align the PDM layer to make an angle of 45 degrees with the longitudinal direction of the film roll. This makes a roll-to-roll process possible in polarizer production lines. The OCB-WV film can directly be laminated onto a stretched PVA film to make a polarizer.

It is also important to reduce the fluctuation of the alignment direction of the PDM layer. It was found that air-flow in the heated-air drying process of the PDM layer affects the PDM alignment direction in a model experiment, as shown in Figure 4. To solve this problem, two new technologies were developed. One is to use a new compound which increases viscosity of the discotic material at the discotic nematic phase. The other is to control the air-flow by introducing a new equipment.

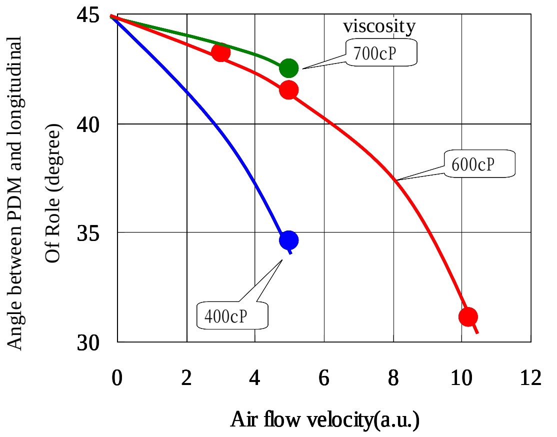

Fig.4 Air-flow Velocity dependence of PDM direction

4. Optical design of OCB-WV

To determine the optical parameters of the OCB-WV film, a numerical simulation approach was employed, as explained below.

(1)Δnd of the OCB-LC cell was optimized. At given optical parameters of the OCB-WV film, light leakage at oblique incidence in the black state was minimized.

(2)At temporarily determined parameters, we checked optical characteristics, such as transmittance, viewing angle, gray scale inversion, and so on. Figure 5 shows that black luminance of optimized cell at a front versus each several kinds of optical parameters of OCB-WV. It was found that light-leakage decreased, as PDM_Re became small.

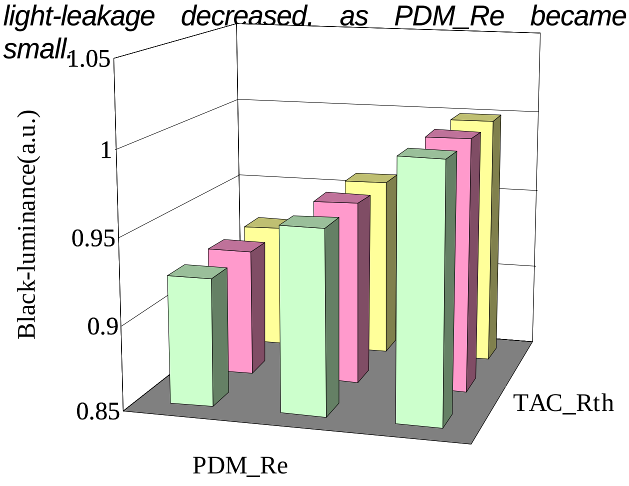

Fig5. Black luminance of optimized cell at a front versus optical parameters of OCB-WV.

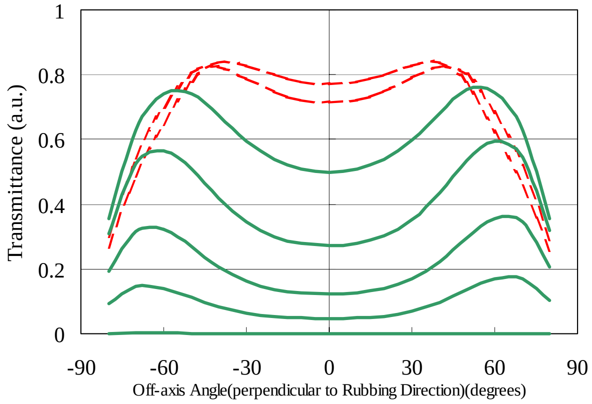

Fig.6 Viewing-angle dependence of gray-scale luminance (Δnd of OCB-cell:770nm)

Furthermore, we found that gray-scale inversion was seen in the high transmittance region, as shown in Figure 6, if Δnd of the OCB-cell was too large(red broken curves in Figure 6).

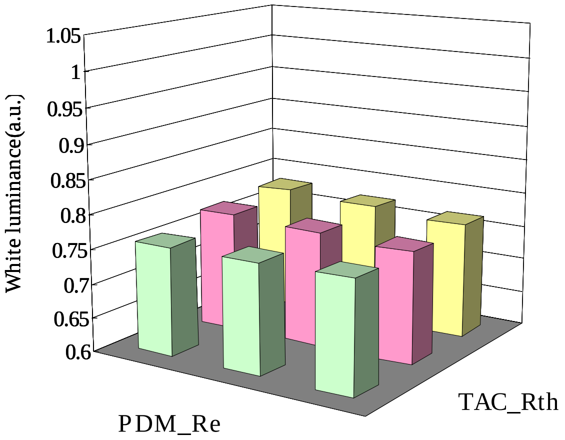

Fig.7 White luminance of optimized cell at a front versus optical parameters of OCB-WV, considering gray-scale inversion.

Figure 7 shows that white luminance at a front versus each several kinds of optical parameters of OCB-WV, considering gray-scale inversion. Surprisingly, white luminance is almost independent of the optical parameters of OCB-WV.

Our simulation concludes that the lowest Re of the PDM layer in the range of considered cell gaps and black voltages provides the best performance for LCD-TV applications.

We believe that OCB is a strong candidate for general purpose LCD-TVs that have a wide screen.

5. Conclusion

The OCB-WV film that we have commercialized will lead to the OCB-TV with a fast response time less than 5ms, which is an unreachable target for the VA mode or the IPS mode even if an over driving scheme is employed. The OCB-TV is free from image blurring especially when an impulsive driving scheme is combined. The development of OCB-WV film and the introduction of OCB-TVs into the market should play an important roll in the rapid growth of the LCD-TV market. The OCB-TV film developed is basically based on the technologies developed for the TN-WV film but was far difficult to realize because it should have a large Rth value for the TAC film and an optimized PDM layer. The TAC film also has a biaxial property with in-plane retardation perpendicular to the longitudinal direction. The biaxial TAC film, in combination with the PDM layer, minimizes light leakage at oblique incident angles, maximizing the viewing angle performance. The 45degree-aligned PDM layer as well as the biaxial TAC film enables a roll-to-roll polarizer manufacturing process, leading to a very low defect level and high yield. The OCB-WV film should offer a high performance LCD-TV with a reasonable cost.

We will continue our effort to make OCB-WV more and more sophisticated and hopefully to make OCB-LCDs the de facto standard LCD-TVs.

6. Acknowledgements

The authors would like to thank the people who have provided technical support in commercializing the OCB-WV.

7. References

[1] T. Kurita, SID'01Digest. p.986 (2001).

[2] P.J. Bos and K.R. Koehler/Beran Mol. Cryst. Liq. Cryst., 113, p. 329 (1984).

[3] Y. Yamaguchi, T. Miyashita and T. Uchida, SID '93 Digest p. 277 (1993).

[4] H. Nakamura, K. Miwa, M. Noguchi, Y. Watanabe, J. Mamiya, J. Watanabe, Y. Nishiura and Y. Shinagawa, SID'98Digest. p. 143 (1998).

[5] K. Kumagawa and A. Takimoto, SID'02Digest p. 1288 (2002).

[6] Ting-Jui Chang and Po-Lun Chen, IDW'03Digest. p. 78 (2003).

[7] H. Mori, M. Nagai, H. Nakayama, Y. Itoh, K. Kamada, K. Arakawa and K. Kawata, SID'03 Digest p. 1058 (2003).