Design of the OCB mode for the Wide Viewing Angle LCD

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Abstract

Parameters of a biaxial compensation film and a liquid crystal cell for the optically compensated bend mode LCD with wide viewing angle were optimized. For practical approach, we calculated the optical refractive indices of a retardation film when thickness of a retardation film was fixed at 50 ㎛. Furthermore, we also optimized optical parameters of LC cell when parameters of a retardation film were different with designed values, because the biaxial compensation film with exact designed values was very difficult to fabricate. In experiments, we achieved the wide viewing angle of over the ± 60 degrees by using a biaxial compensation film with a practical thickness value.

Introduction

AM (Active Matrix) LCDs have been applied to TVs and computer displays widely, because of their excellent electro-optical performances. However, at an oblique angle, serious problems such as degradation of a contrast or an inversion of the gray scale occur in AMLCDs that generally used TN (Twisted Nematic) mode. Recently, some improvements for the wide viewing angle characteristic have been reported, for example OCB (Optically Compensated Bend) mode, AFLCD (Anti-Ferroelectric LCD) and multi-domain alignment cell, etc. Among the above examples, the OCB mode was proposed by T. Uchida in 1993, and many research reports have been published in recent years. Unfortunately, there are a cost increment by a additive film and a power consumption from the bias voltage of the splay-to-bend transition voltage, but it has attracted much attention for the solution of the conventional LCD mode because of its simple configuration, wide viewing angle and fast response characteristics [1,2,3].

In this paper, we optimized parameters of a LC cell and a retardation film for the OCB mode LCD with wide viewing angle characteristic. To obtain the practical value of parameters, we calculated optical viewing characteristics at 50 ㎛ film thickness. We also fabricated the OCB mode cell and evaluated the viewing angle characteristic.

Design of the OCB mode

The OCB mode consists of a bend alignment LC cell and a biaxial compensation film that are sandwiched between two polarizers as shown in Fig. 1.

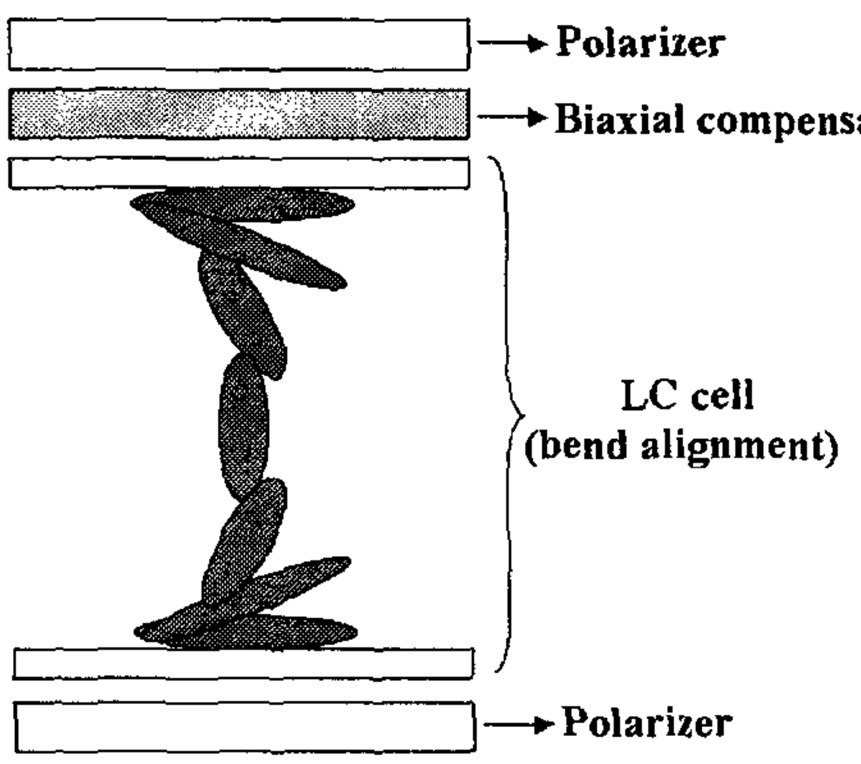


Fig. 1. Configuration of the OCB mode.

The transmission axes of the entrance and exit polarizers are perpendicular to each other. And these are 45° and -45° on the direction which the LC directors lie. The compensation component, a biaxial compensation film is located between the LC cell and the exit polarizer, and the slow axis (SA) of the film is perpendicular to the rubbing direction.

In the design of the OCB mode LCD, it is the most important to calculate the optimized parameters of the biaxial compensation film. There are four values, i.e., three refractive indices of principal axes (n_x, n_y and n_z) and a thickness of the film (D). We can calculate these values from the conventional design rule [1]. However, in a conventional theory, it was failed to notice a practical value of the film thickness. The parameters by a conventional calculation were not suitable for the fabrication because the designed thickness is always much smaller than a practical value. So we proposed the new design method of the optimized parameters of a biaxial compensation film for the OCB mode.

At first, we decided the thickness of the film, and here we used 50 ㎛ that is the most popular value. Then we could select two values, n_x and n_y, from equation (1).

$$n_y - n_x = \frac{1}{D}\left[\int_0^d \frac{n_o n_e}{\sqrt{n_o^2 \cos^2\theta(z) + n_e^2 \sin^2\theta(z)}}dz - n_o^2 d\right] \quad (1)$$

Where d is the cell gap, n_o and n_e are the refractive indices of the liquid crystal. And $\theta(z)$ is the deformation profile of the LC directors at specific voltage. Finally, we could deduce the value n_z from an iterative calculation, which showed the most similar angular dependence to that of ideal values.

We also researched the parameters of a LC cell for the enhanced optical characteristics in the OCB mode. There are three values for a LC cell, i.e., cell gap, anisotropy of refractive indices of liquid crystal and pretilt angle. We could find that there was a trade-off between the brightness of the ON state and a viewing angle property. In case of higher cell gap, lower anisotropy of refractive indices and lower pretilt angle, the brightness of the ON state was higher, however a viewing angle characteristic was degraded. We selected the cell parameters with the best optical characteristics by comparison. The optimized parameters of the OCB mode are shown in table 1. The optical characteristics that were calculated by extended 2 × 2 Jones method [4], are shown in Fig. 2.

Experiment

We fabricated the OCB mode cell by using the biaxial compensation film (Nitto-Denko) with Nz = 1.41, $|n_x - n_y|D$ = 390 nm. This film was not a designed one. Actually, in a fabrication of the OCB mode cell, it is hard to get the biaxial compensation film that is exactly coincident with designed parameters. So the design method of the LC cell from the parameters of the film was needed. The parameter, *Nz*, is a value that presents an angular dependence of the film. It is a ratio of the refractive indices of the three principal axes, but it is not a proper value. Though two retardation films have same *Nz* values, if the refractive indices are different each other, angular dependences of the two films are not same. So we measured the parameters of the biaxial compensation film: n_x = 1.47, n_y = 1.4778, n_z = 1.4668, D = 50 ㎛. Then we optimized parameters of the LC cell: LC material ZLI-1557 (E. Merck), cell gap 9 ㎛, pretilt angle 1° , off-target voltage 2.25 V.

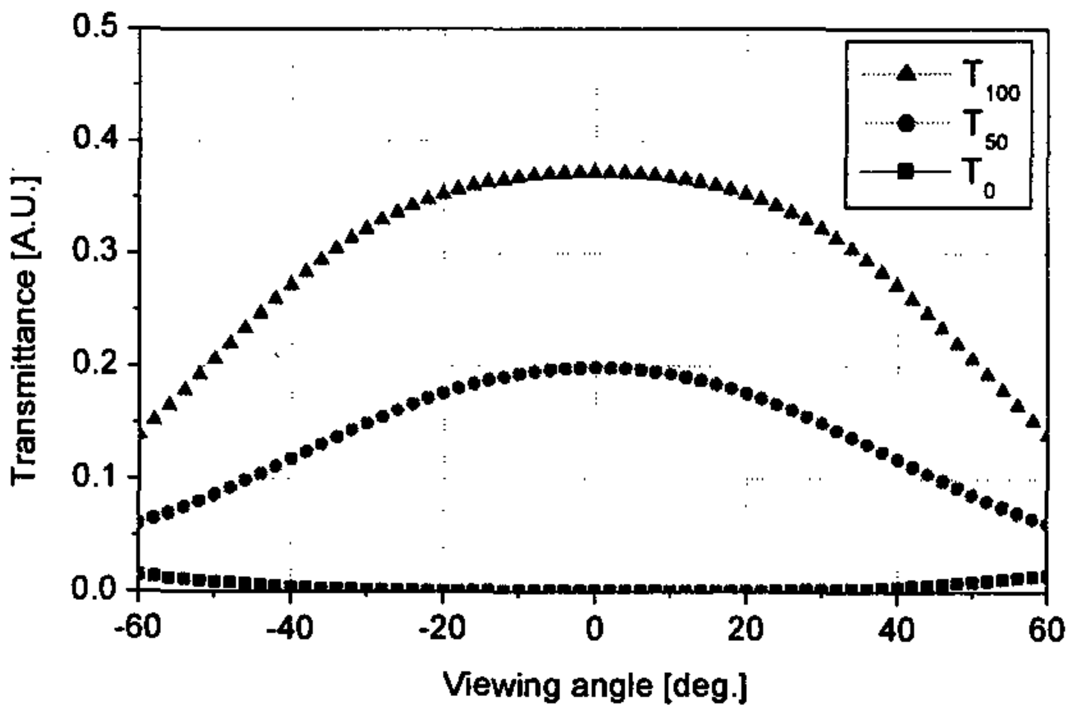
As above design specifications, we fabricated the OCB mode cell and measured its optical characteristics as shown in Fig. 3 and Fig. 4.

Result

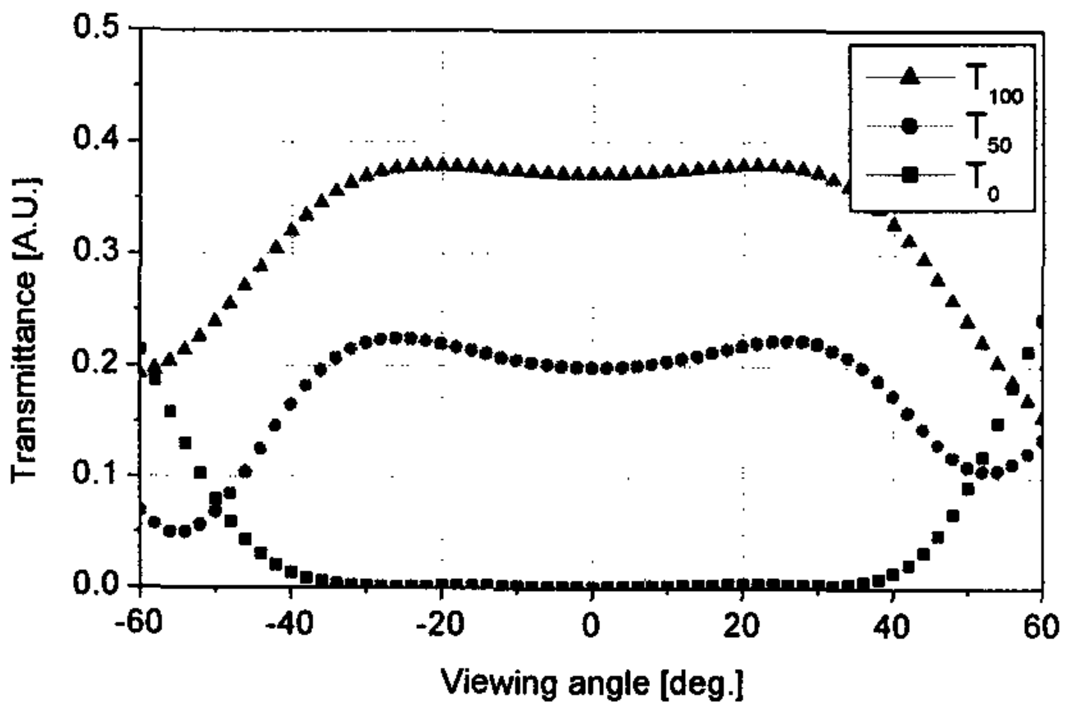
We achieved the wide viewing angle characteristic. In horizontal direction, it showed a viewing angle of more than ± 60° , even in vertical direction, a viewing angle in the vicinity of ± 50° .

Table 1. Optimized parameters of the OCB mode.

n_x	1.5381	LC	ZLI-1557
n_y	1.545	Cell gap	9 ㎛
n_z	1.5317	Pretilt angle	1°
D	50 ㎛	OFF target voltage	3 V



(a) Horizontal direction



(b) Vertical direction

Fig. 2. Calculated viewing angle characteristic of the OCB cell.

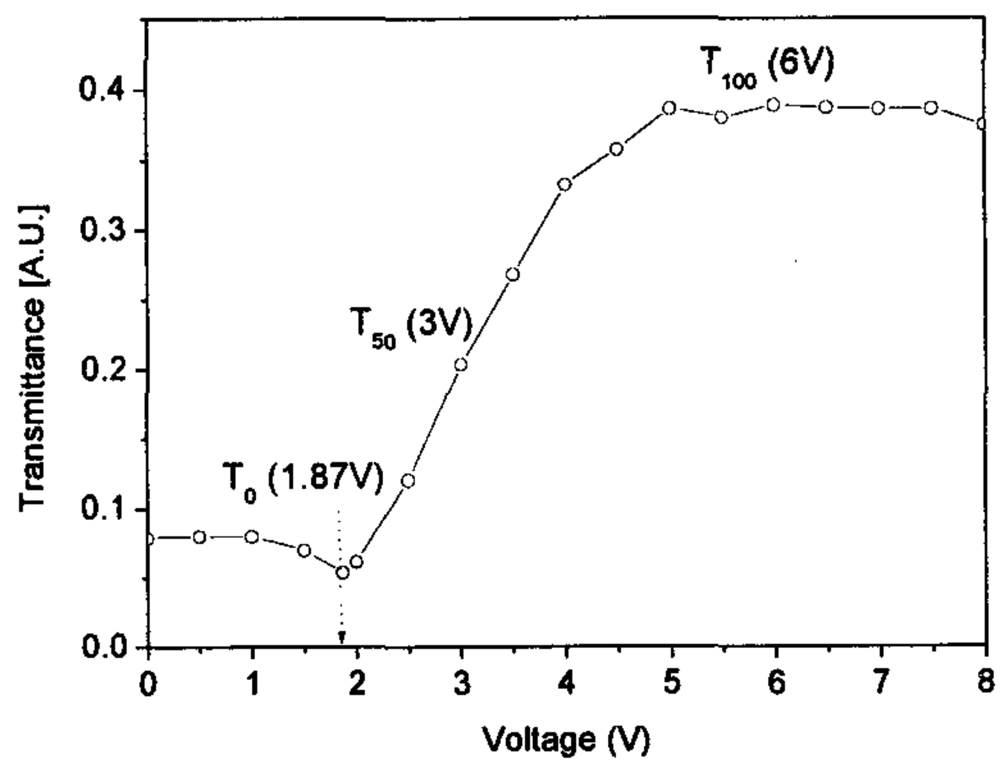
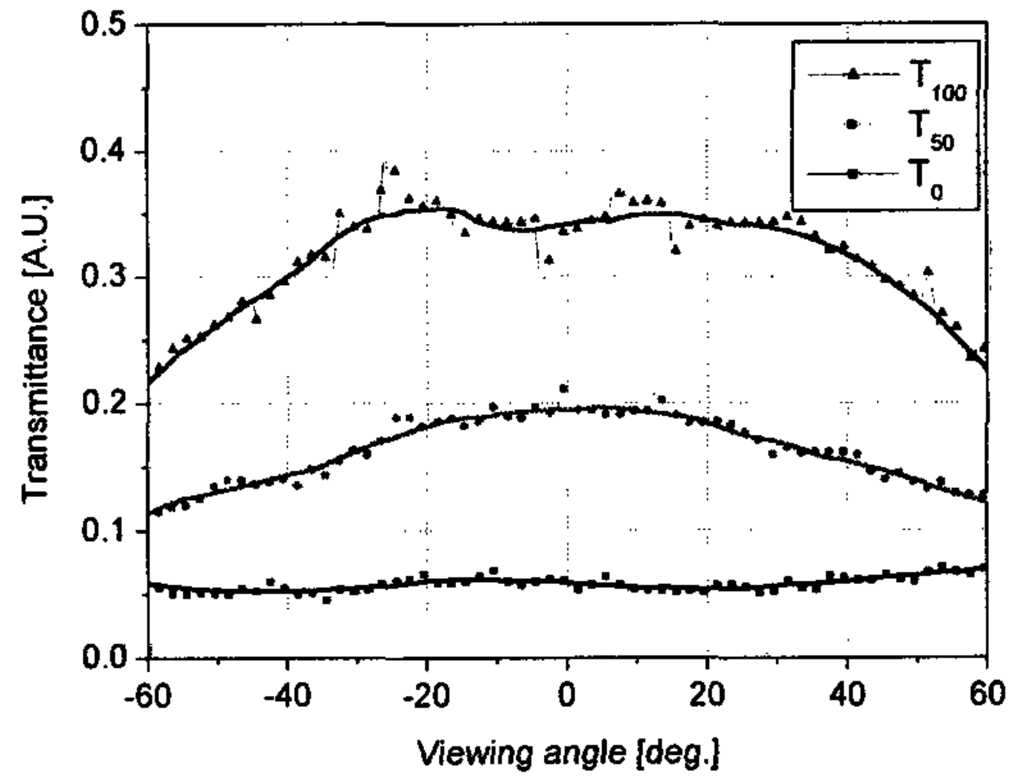
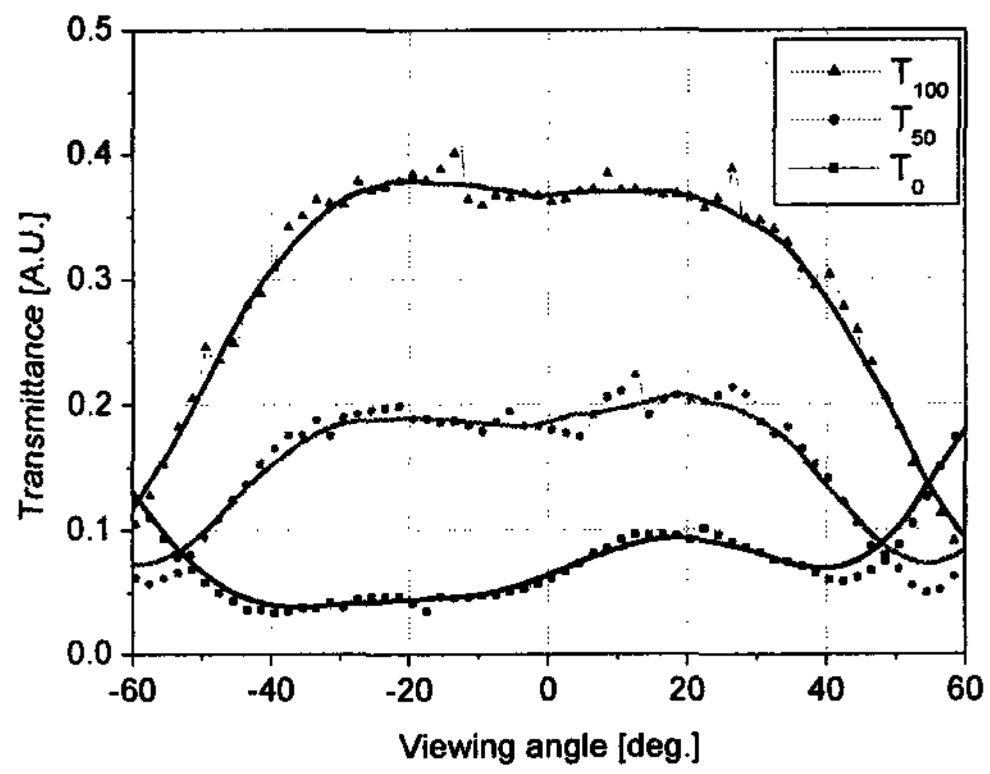


Fig. 3. Measured transmittance of the OCB cell.



(a) Horizontal direction



(b) Vertical direction

Fig. 4. Measured viewing angle characteristic of the OCB cell.

Acknowledgment

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