액정 디스플레이에서 편광판의 빛샘 모델링

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Modeling the light leakage of a polarizer in a liquid crystal display

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Introduction

A liquid crystal display (LCD) is composed of a liquid crystal cell and two polarizers, which are assembled to produce a final device by using pressure sensitive adhesive (PSA) layers [1]. The polarizer includes polarizing elements such as an iodine-based compound aligned in a constant direction by stretching a polyvinyl alcohol (PVA)-based film, and the polarizing element is protected using a triacetyl cellulose (TAC) film.

The aforementioned films have different physical, chemical, and optical characteristics, since the films are prepared from materials that have different molecular structures and compositions. When a liquid crystal display is used for a long time, the stress resulting from the dimensional changes of the films causes severe light leakage in the black state from the LCD [2]. Therefore, the analysis of the stress distribution in each layer of the polarizer is very important in controlling the light leakage [3]. In this work, a mathematical model is developed for calculating the stress distributions of the PSA and TAC layers and compared with experimental data. In addition, the nonlinear effect of the PSA modulus is considered in modeling the light leakage of the polarizer.

Modeling the stress distribution in a polarizer

Fig. 1 shows the schematic diagram of a polarizer adhered to a glass panel by using a PSA. The dotted and solid lines represent the initial and deformed shapes of the polarizer and PSA, respectively. The domains of the multi-layered structure are divided into sub-elements. In this work, the polarizer and PSA are considered as elastic solids. In each sub-element, the deformations of the polarizer and PSA are determined by force balance between the polarizer and PSA layers. The equations of the force balance in each element are obtained as follows:

$$tE_{POL}\frac{\delta L_2-\delta L_1}{L_0/n}=tE_{POL}\frac{\delta L_1}{L_0/n}+\left(\frac{L_0}{n}\right)G_{PSA}\frac{\delta L_1}{d} \qquad \text{(element 1)}$$

$$tE_{POL}\frac{\delta L_3-\delta L_2}{L_0/n}=tE_{POL}\frac{\delta L_2-\delta L_3}{L_0/n}+\left(\frac{L_0}{n}\right)G_{PSA}\frac{\delta L_2}{d} \qquad \text{(element 2)}$$

$$\cdots$$

$$tE_{POL}\frac{\delta L_n-\delta L_{n-1}}{L_0/n}=tE_{POL}\frac{\delta L_{n-1}-\delta L_{n-2}}{L_0/n}+\left(\frac{L_0}{n}\right)G_{PSA}\frac{\delta L_{n-1}}{d} \qquad \text{(element n-1)}$$

$$tE_{POL}\frac{\Delta L_{free}}{L_0}=tE_{POL}\frac{\delta L_n-\delta L_{n-1}}{L_0/n}+\left(\frac{L_0}{n}\right)G_{PSA}\frac{\delta L_n}{d} \qquad \text{(element n)}$$

where n is the number of sub-elements, δL_i the deformation of the polarizer in each element i, t the thickness of the polarizer, E_{POL} the Young's modulus of the polarizer, L_0 initial half length of the polarizer, ΔL_{free} the shrinkage of the polarizer when it is not adhered to the glass panel, G_{PSA} the shear modulus of the PSA, and d the thickness of the PSA.

We solve simultaneously the system of equations for δL_i, which are used for the calculation of the anisotropic stress distribution in each layer. The light leakage in the polarizer is proportional to the birefringence of each layer, which is caused by the anisotropic stress.

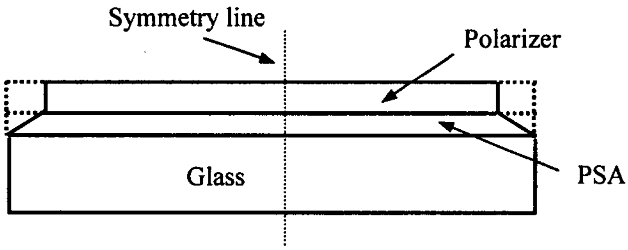


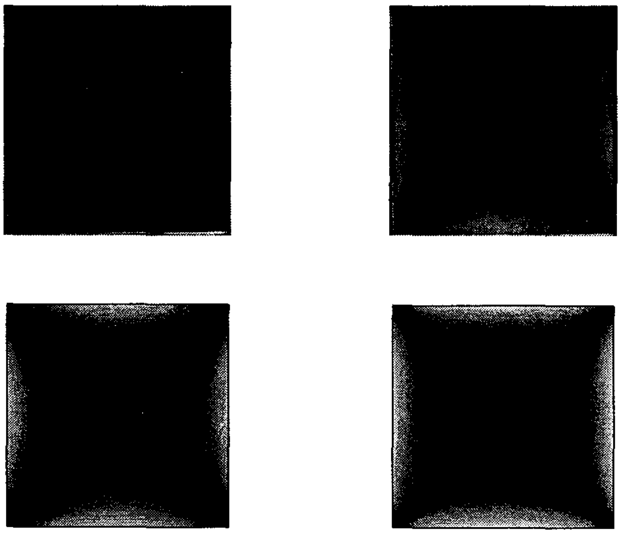
Fig. 1. The schematic diagram of the polarizer adhered to the glass panel by using the PSA.

Results and Discussion

Fig. 2 shows the comparison between the experimental light leakage and the model prediction of the anisotropic stress distribution in the polarizer for the PSAs having different shear modulus. The model parameters used in the prediction are given in Table 1. The model predicts well the pattern of the light leakage in the polarizer. The intensity of the light leakage increases with increasing the modulus of the PSA. However, the area of the light leakage in the polarizer for the case of high modulus PSA is smaller than that of low modulus PSA. That is, the anisotropic stress is concentrated near the edge of the polarizer for the case of high modulus PSA. Fig. 3 shows the anisotropic stresses from the center to the edge of the polarizer along the symmetry line. The anisotropic stress of PSA2 decreases more steeply than that of the PSA1.

To see the effect of the polarizer shrinkage on the light leakage, we calculate the anisotropic stress for the polarizers having different shrinkages. The shrinkage of the polarizer used in the model predictions are 0.005 and 0.007, respectively. As shown in Fig. 4, the shrinkage of the polarizer affects significantly on the light leakage of the polarizer. Because the anisotropic stress is caused by the dimensional change of the polarizer, it is important to control the shrinkage of the polarizer to decrease the light leakage.

The results of this work indicate that the developed model can be used for optimizing the stress distribution and for controlling the light leakage in the polarizer.



(a) (b)

Fig. 2. The experimental light leakage pattern and the model prediction of anisotropic stress in the polarizer (a) PSA1, (b) PSA2.

Table 1. The parameters used in the model prediction.

L_0 (cm)	n	ΔL_{free}	E_{POL} (Pa)	t (μ)	G_{PSA1} (Pa)	G_{PSA2} (Pa)	d (μ)
9	100	0.005	1.8x10^9	110	3.3x10^3	7.0x10^3	25

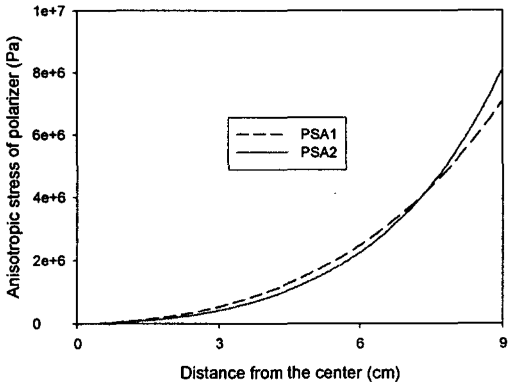
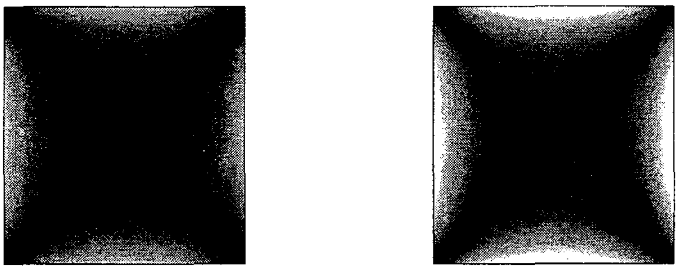


Fig. 3. Anisotropic stresses from the center to edge along the symmetry line in the polarizer.



(a) (b)

Fig. 4. Effect of the polarizer shrinkage on the light leakage (a) shrinkage=0.005, (b) shrinkage=0.007.

References

1. Satas, D. (Ed.), 1999, Handbook of Pressure Sensitive Adhesive Technology, Satas & Associates.

2. Sohn, S., 2003, Various ways to control the bulk properties of pressure sensitive adhesives, *J. Adhesion Sci. Technol.*, **17**, 703.

3. Suhir, E., 2003, Bimaterial assembly with a low modulus bonding layer at the ends, *J. Appl. Phys.*, **93**, 3657.