Jpn. J. Appl. Phys. Vol. 36 (1997) pp. 6523–6524
Part 1, No. 10, October 1997

Short Note

Color Filters with Negative Birefringence for Liquid Crystal Display Use

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(Received January 11, 1997; revised manuscript received June 2, 1997; accepted for publication June 3, 1997)

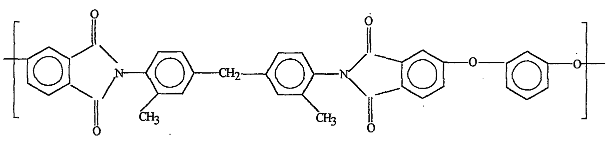
We have developed a special color film with negative birefringence, which can work as a color filter and a viewing angle extension film for liquid crystal displays (LCDs). A high-performance polyimide (PI), which can be dissolved in the usual organic solvent and shows negative birefringence after lamination, was synthesized to fabricate the film. By mixing PI with suitable proportions of green, blue or red pigment in the solvent, then laminating them onto a glass substrate, we obtained color films with good transmission spectra and suitable chromatic coordinates. The results of our experiments show that the color filters still have negative birefringence but a little lower than that of the pure PI film. and can therefore work as compensation films for normal white twist nematic liquid crystal displays (TN-LCD).

KEYWORDS: negative birefringence, color filter, liquid crystal display

All twist nematic liquid crystal displays (TN-LCD) suffer from poor viewing angle performance caused by the difference in path length through the liquid crystal layer between light rays viewed at high angles as compared to those viewed at near-normal angles. To overcome this problem, research workers have proposed many methods such as multi-domain TN-LCD,[1)] amorphous TN-LCD,[2)] Curvature Aligned TN-LCD[3)] and film-compensated TN-LCD.[4)] Among of these, film-compensated TN-LCD becomes the most convenient method and, since some PI films with high negative birefringence were developed,[5)] it has a higher display performance. However, as we know, adding extra films to a LCD will lower the efficiency of the light source. Another problem is that the birefringence of compensated film cannot match that of liquid crystal precisely throughout the visible wave band. Thus one uniform film cannot fulfill the optimum conditions for all wavelengths.

Color filters are another important issue in the field of LCD technology. To realize full color display, a filter with color pattern which includes a number of trichromatic segments has to be formed onto one of the LCD substrates. If we incorporate both the color filter and negative birefringence into one film, the problems would be solved and the cost of the product would be lowered. We know that such a incorporation is possible because some PIs have been used as the matrix in commercial color filters, and the thickness of these color filters is close to that of the compensation film. Furthermore their positions in LCDs are neighboring. Based on the above consideration, we have synthesized a oil-soluble polyimide whose thin films show negative birefringence. Using this PI as the matrix, we have successfully fabricated color films that have good transmission and suitable chroma, and the effect of the color films on the viewing angle of TN cells is similar to that of pure polyimide films.

PI with the following structure formula were synthesized in our lab. They can be dissolved in organic solvents such as N,N dimethylformamide, N,N-dimethyl acetamide and trichloromethane. Their thin films are transparent over the entire visible wave bands and the refractive indices of pure PI films are $n_o = 1.6421$, $n_e = 1.6130$ respectively with $\Delta n \approx 0.03$ for $\lambda = 632.8$ nm obtained using the optical waveguide method. Their birefringence characteristics arise from the rigid molecular structures which intend to lie along the plane which is parallel to the substrate in the thin film case and conjugated phenyl rings. The PI were used as the matrix material of the color films in our experiments.



The structure formula of PI used in our experiments

The structure formula of PI used in our experiments N,N-dimethyl acetamide was used as a solvent.

The red pigment provided by Shanghai Pigment Developing Institute (China) is oil-soluble (Color Index 12150). The fine green (Color Index 74260) and blue pigments (Color Index 74160) were provided by Shenyang Chemical Industry Academy (China). The pigments were dispersed in separate N,N-dimethyl acetamide solutions of PI. The proportions of the mixtures were listed in Table I. The mixtures were individually coated onto the glass substrate by roller, then cured in a thermal box at 60°C for 2 h and 150°C for 1 h to form color

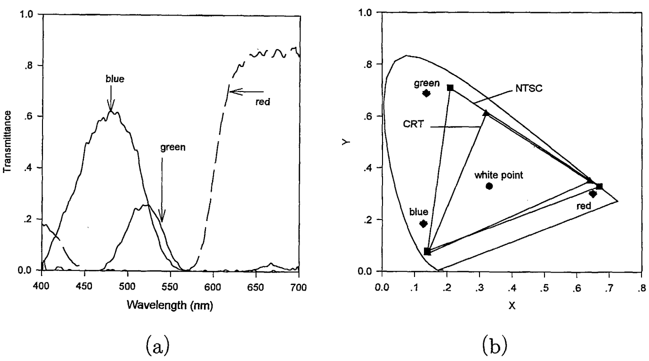


Fig. 1. The transmission spectra and chromatic coordinates of the color films (a) the transmittance spectra of the color films. (b) The coordinates of the color films in chromatic diagram (CIE1931) ▲ and ■ indicate the coordinates of the trichromatic in CRT and NTSC criteria respectively.

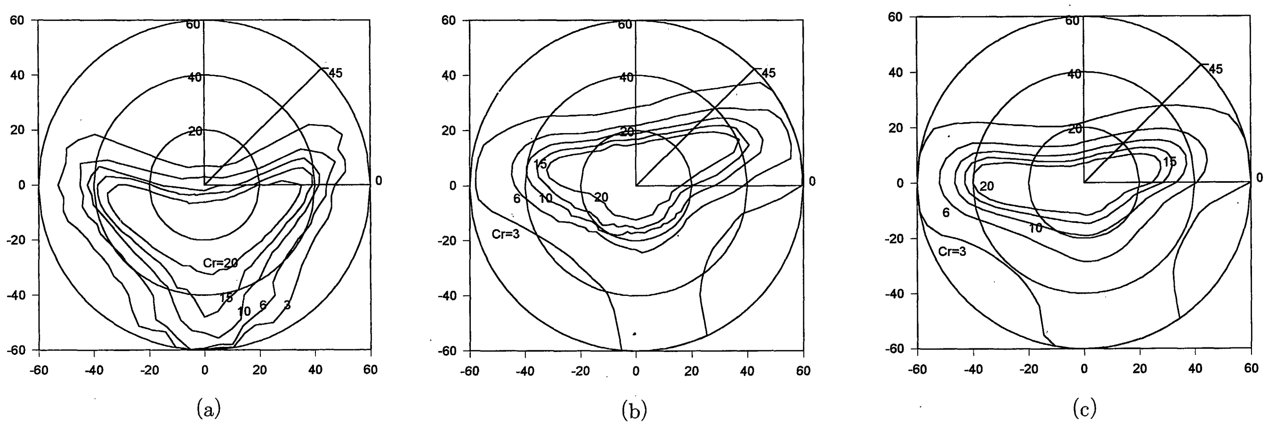


Fig. 2. The Iso-contrast curves of the cells (a) the normal TN cell with $d \times d_{\text{eltn}} = 0.159$, (b) the cell with one PI film on its back and red color film on its front, (c) the cell with double PI films.

Table I. The proportional contents of solutions.

	Red (C.I. 12150)	Green (C.I. 74260)	Blue (C.I. 74160)	PI
Solvent	86.1%	85.1%	85.4%	85.0%
PI	11.0%	11.3%	11.1%	15.0%
Pigment	2.9%	3.6%	3.5%	—

films. The transmission spectra and chromatic coordinates were measured using an LCD Parameters Tester developed by the North LCD R&D Center of China. The results are shown in Fig. 1. We can see from Fig. 1(a) that the transmission spectra of the red color films is excellent but that of the green and blue color films is not so good. The shift in transmission peaks, caused by the intrinsic characteristics of the pigments indicates that they cannot completely satisfy the conditions required for LCD use. However this does not alter basic principles and the transmission spectra can be adjusted by selecting the pigments carefully. The chromatic coordinates (CIE 1931) of the color films were shown in Fig. 1(b). For comparison, the required coordinates of the cathode radiation tube (CRT) and the National Television System Committee (NTSC) criteria for color displays, are also marked. We can see that the coordinates of our red film are close to those of the NTSC criteria which are usually adopted for color LCDs. The refractive birefringence of red film is about 0.02 for $\lambda = 632.8$ nm as indicated by waveguide method, which is lower than that of pure PI film. This is due to the relative lower content of PI in the color film. Unfortunately, the refractive birefringence of green and blue color films cannot be obtained using the same method because they absorb red light.

90° TN cell with a $d = 7.01\,\mu$m gap were fabricated using conventional method and injected into commercial liquid crystals, E70($\Delta n = 0.227$ for $\lambda = 589.6$ nm), provided by Tqinghua LC Corp. of China. The viewing angle characteristics of a conventional TN cell, a TN cell with double PI films on both sides and a TN cell with one PI film on its back and one color film on its front were analyzed with an LCD Parameters Tester. Figure 2(b) is the Iso-Contrast ratio curve of the TN cell with the red color film at the front and the PI film at the rear. The TN cell with blue and green color films had similar results. For comparison, the Iso-Contrast Ratio curves of the normal TN cell and the TN cell with double PI films are shown in Figs. 2(a) and 2(c) respectively. We can see that the last two samples have extended viewing angles that are similar to each other. This indicates that the color film can also work as a compensation film with negative birefringence.

In conclusion, we have proposed a new LCD-use color filter with negative birefringence, and have described how we fabricated it. Using a special PI synthesized in our Laboratory, and three color pigments, we developed color films with excellent transmission spectra and good achromatic coordinates. Further analysis of our results shows that the color films perform the additional function of extending the viewing angle of normal-white TN cells, similar to that performed by compensation films with negative birefringence.

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