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Effect of Dye Concentration on the Chromatic Contrast of Pigmented Liquid Crystal Displays

Zdzislaw Salamon [a] & Danuta Bauman [a]
[a] Institute of Physics, Poznan Technical University, Piotrowo 3, 60-965, Poznan, Poland
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EFFECT OF DYE CONCENTRATION ON THE CHROMATIC CONTRAST OF PIGMENTED LIQUID CRYSTAL DISPLAYS

ZDZISLAW SALAMON AND DANUTA BAUMAN
Institute of Physics, Poznan Technical University,
Piotrowo 3, 60-965 Poznan, Poland

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ABSTRACT - Studies of the dependence of chromatic contrast on the different type of liquid crystal matrix, various dyes and their concentrations in the bicolor liquid crystal devices were made. Results have indicated the most favorable circumstances to obtain a bicolor display with the best visual appearance.

The liquid crystal (LC) display device using guest-host interactions has attracted interest recently because of display of color and wide viewing angle. However, in order to construct a competitive cell with the twist nematic display device[1] in terms of brightness and contrast ratio, one must take a number of factors into consideration.[2]

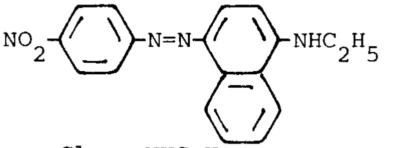
The authors have investigated the color changes upon application of voltage in multicolor type of guest-host liquid crystal displays.[3] As we have recently shown[3] a chromatic contrast is a main parameter for a quantitative characterization of such color change and to describe a visual appearance of colors.

The chromatic contrast depends (1) on an optical order parameter and appropriate surface boundary conditions; (2) on the absorption of the dye used (it means that if the thickness of the liquid crystal cell is kept constant the chromatic contrast depends on the concentration of dye; (3) on a separation of the absorption bands of the dyes used in the case of multicolor cells.[3,4]

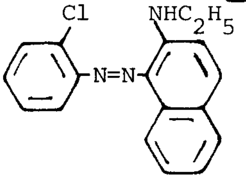
Two types of liquid crystal cells were used. The first one was a 90° twisted nematic LC cell with a pleochroic dye. The following LC matrices were used to this type of display: E7, K15, K18, K24 (from BDH) and RO-TN-403 (from Hoffman-LaRoche).

The second type of display consisted of two dyes in the nematic LC matrix E7. One of the dyes was a pleochroic dye with a high degree of orientation, whereas the second was an unoriented one. As a pleochroic dye the one of anthraquinones (D16 from BDH) was used. This blue anthraquinone dye with an absorption maximum at 596 nm was located in LC matrices of both types of displays. The red dyes with absorption maxima at 556 nm (R-556) and at 520 nm (R-520) which have a very low degree of orientation in the nematic LC matrix ($S \approx 0.03$) were used as the unoriented dyes in the second type of display.

R-556



R-520



The cells used for both types of displays consisted of two glass plates into which SiO_x was evaporated at an angle 30° to the horizontal to give a homogenous LC alignment.[5] Thickness of the LC cell was 20 μm. In all experiments the propagation direction of light was perpendicular to the electrode surfaces. Both sample and reference displays were operated in parallel in the electrooptical experiments.

The chromatic contrast (CC) and an estimated chromatic contrast (ECC) were obtained as described elsewhere.[3]

Table I shows the values of the order parameter S and chromatic contrast CC. These results were done with the first type of LC display and with D16 at the concentration of 1.3 wt%.

TABLE I

Values of Order Parameter and Chromatic Contrast of the Pleochroic Dye D16 in Different LC Matrices

LC matrix	S	CC [R.U.C.S.]*
E7	0.60	34
K15	0.52	31
K18	0.48	30
K24	0.50	33
RO-TN-403	0.55	32

*Unity of Rectangular Uniform Chromatocity Scale[6]

As it is seen from Table I the best optical parameters give the cell with E7 matrix. Therefore, for this cell the measurements on the influence of dye concentration on the chromatic contrast and optical degree of orientation were done. The results are shown in Figure 1.

From these results it is seen that the order parameter S usually used for description of an LC display device is insufficient in the case of pleochroic dye LB displays. At the low dye concentration the order parameter reaches a maximal value whereas the chromatic contrast comes to its lowest value. The lowest value of the chromatic contrast increases with increase of pigment concentration. But increase of the dye concentration causes a small decrease of S. Therefore, from such results one can determine the range of a dye concentration in which a maximal chromatic contrast can be obtained. This problem of pigment concentration is especially important if one is trying to describe not only a color modulation but also color changes in a multicolor type of cell upon the application of a voltage to the LC cell.[3,4]

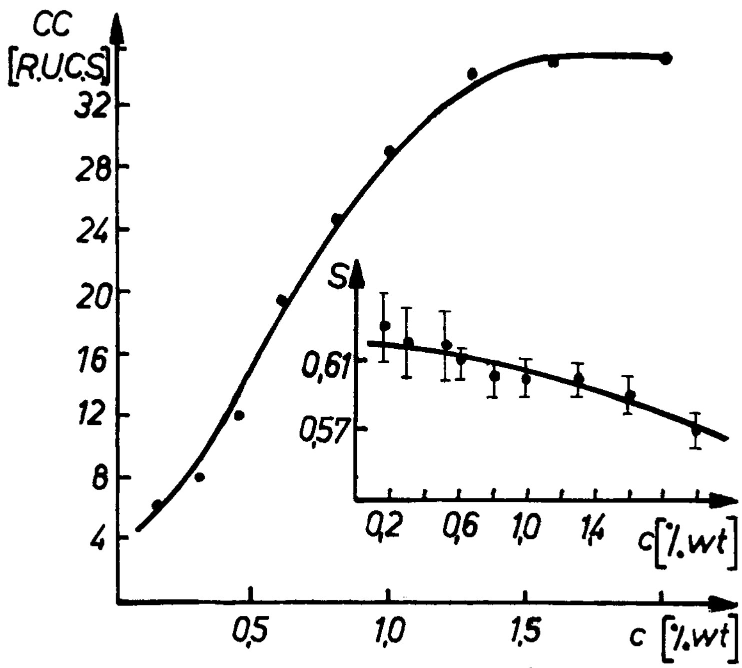


Figure 1. Plots of chromatic contrast and order parameter vs concentration of the pleochroic dye D16.

It should be noticed that in the bicolor cells a second type of used dye will influence the chromatic contrast as well. As has been mentioned above, in such situations the chromatic contrast depends on a separation of absorption bands of two dyes used and on the concentration of that second dye. In order to show an effect of separation of absorption bands on the chromatic contrast two different unoriented red dyes (R-556 and R-520) were composed with D16 in the bicolor cells. The results are shown in Table II.

TABLE II

Values of Chromatic Contrast and Estimated Chromatic Contrast for the Bicolor Cells with D16 (at Concentration 0.8 wt%) and Red Dyes (at Concentration 0.4 wt%)

Bicolor cell with:	CC [R.U.C.S.]	ECC [R.U.C.S.]
R-556 + D16 in E7	13	16
R-520 + D16 in E7	19	24

It can be clearly seen that the cell with D16 and R-556 (separation of absorption bands equals 40 nm) gives lower values of CC and ECC than that with D16 and R-520 (separation equals 76 nm).

Figure 2 shows the changes of chromatic contrast caused by variation in a red pigment concentration for display with D16 and R-520 in E7 at two different concentrations of D16.

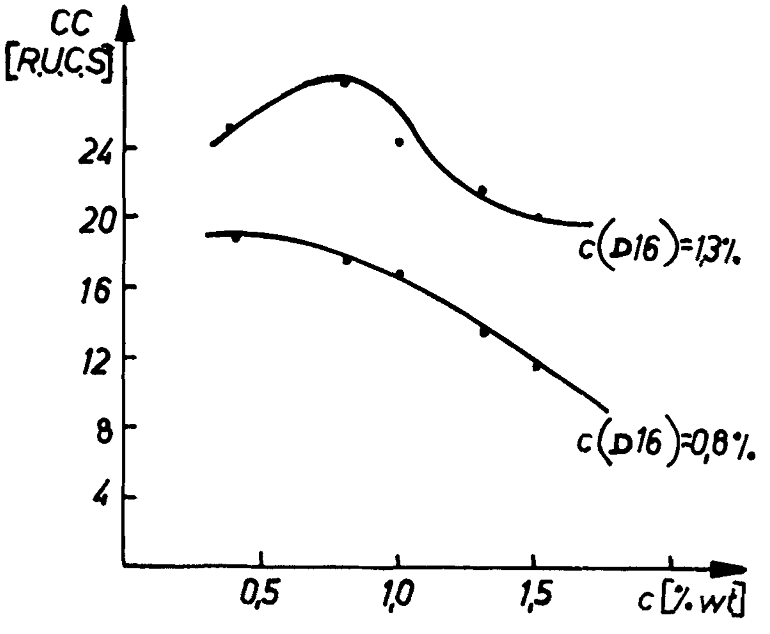


Figure 2. Plots of chromatic contrast vs concentration of the red dye (R-520).

Having results from Figure 1, one has an optimum concentration (about 1.3 wt%) of the pleochroic dye (D16). Such concentration of D16 has given another range of optimum concentration (about 0.8 wt%) of the second type of dye (R-520) in the biocolor display.

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