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CHROMATIC CONTRAST AS A CRITERION FOR EVALUATION OF PIGMENTED LIQUID CRYSTAL DISPLAYS

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ABSTRACT - Color changes upon the application of a voltage in multicolor type of guest-host liquid crystal devices is described by using a chromatic contrast. It is shown that the chromatic contrast is a better quantitative parameter for comparing pigmented liquid crystal displays than the perceived contrast ratio. A method of theoretical estimation of chromatic contrast for an individual composition of liquid crystal devices is proposed.

Electrooptic effects in liquid crystals can display information in color. Some of the more practical display schemes employ the guest-host effect.[1] Such pleochroic dye liquid crystal displays are generally characterized by the order parameter or the contrast ratio. As Bloom and Priestley[2] showed both these descriptions are useful in determining the orientation of the dye but they are inadequate for evaluating pleochroic dye liquid crystal displays. They introduced a perceived contrast ratio (PCR) that included the relative spectral efficiency for photopic vision to achieve a better characterization of the color modulations in liquid crystal display devices. However, the modified version of the contrast ratio for colored liquid crystal displays by Bloom and Priestley is still insufficient because the PCR values do not specify any changes in colors.[3] This problem is especially important if one is trying to describe not only a color modulation but also color changes upon the application of a voltage to the liquid crystal cell.[3,4] The color changes in liquid crystal displays, upon application of the voltage, appear in the case of multicolor devices.[3,4]

The purpose of this note is to elaborate on a quantitative characterization of color change. For that purpose we introduce a chromatic contrast (CC). We also propose a method of theoretical estimation of chromatic contrast for dyes in the nematic liquid crystals. This estimated chromatic contrast (ECC) indicates a maximal value of chromatic contrast that can be obtained in practice for an individual dye and liquid crystal matrix composition.

In order to determine the chromatic contrast the CIE chromaticity coordinates of individual colors were obtained using their transmission spectra and the method described in the literature.[5] The CIE coordinates of colors were then transformed (according to Breckenridge and Schaub transformation[6]) into the Rectangular Uniform Chromaticity Scale (R.U.C.S.). The chromatic contrast is defined as the difference of the distance between the R.U.C.S. coordinates which describe the two colors. In the case of bi-color liquid crystal displays the chromatic contrast means the difference between R.U.C.S. coordinates of the display color in the electric field-off and field-on states.

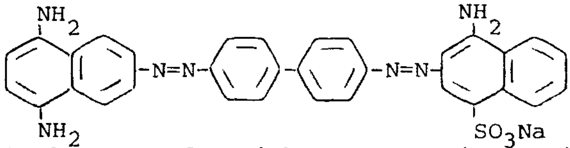
The estimated chromatic contrast is calculated as above taking the following assumptions: (1) an order parameter, (S), of dye used reaches maximal value (in nematic liquid crystals S = 0.70); (2) knowing the type of liquid crystal matrix and using the first assumption, changes in the transmission spectrum of the dye upon applying the voltage can be calculated according to the equation given by Schadt.[4] Such estimated chromatic contrast gives us the maximum value for the dye used and the liquid crystal matrix. Therefore, from one side the calculated chromatic contrast value might be used as a useful indicator for evaluation of the individual dye-liquid crystal compositions and from the other side, this value gives us information on the quality obtained in practice of liquid crystal displays.

We have used two types of liquid crystal displays: the first one was realized by combining an external polyvinyl alcohol (PVA) sheet with an oriented pleochroic dye and a 90° twisted nematic liquid crystal cell with another pleochroic dye.[3,7] The second type of liquid crystal display consisted of the two special dyes in a liquid crystal matrix. One of them was a pleochroic dye with a high degree of orientation and the second was an unoriented one (the degree of orientation was equal null). The color change depends on the voltage - induced variation of the polarized absorption of dichroic dye. It is important to point out that both types of liquid crystal displays do not require polarizers and in both types of colored displays a large variety of color combinations are possible depending on the dyes used.

As a nematic host matrix a biphenyl-pyrimidine mixture (RO-TN-403) in the first type of liquid crystal display and RO-TN-103 in the second one, both from Hoffman La Roche, were used. The PVA sheets were prepared as described elsewhere.[8]

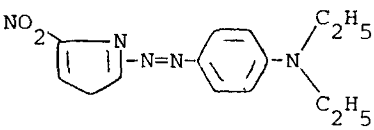
The following pigments were used:

1. The Congo Red with absorption maxima at 516 and 546 nm was located in PVA,



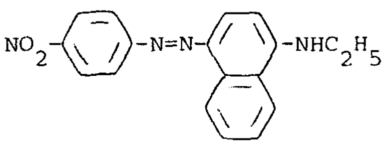
Congo Red

2. The blue azo-dye with an absorption maximum at 600 nm was located in liquid crystal matrix of both types of displays,



Blue Dye

3. The red dye with an absorption maximum at 556 nm which has a very low degree of orientation in the nematic liquid crystal matrix (S = 0.03) was used as an unoriented dye in the second type of display.



Red Dye

The cells used for both types of displays consisted of two glass plates into which SiOx was evaporated at an angle 30° to the horizontal to give a homogeneous liquid crystal alignment.[9] Thickness of the liquid crystal cell was 10 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.

Table I shows the values of chromatic contrast obtained from the experimental data (CC) and from the calculation (ECC). In this table we also show the values of PCR for the displays investigated.

TABLE I

The values of chromatic contrast (experimental and calculated data) and the perceived contrast ratio.

Type of Display	Chromatic Contrast		PCR
	CC	ECC	
I	35	38	1.00
II	13	18	1.73

The visual appearance of both displays have shown that the off-state color is determined by the mixture of dyes, whereas in the on-state the color is dominated by Congo Red in PVA or unoriented red dye in the second type of our display. Therefore, one can observe an obvious change of display colors from purple to red. These subjective viewer observations are in agreement with values of chromatic contrast, whereas PCR values are completely inadequate. The value of PCR equal to unity means that the applied voltage (off-on-state) does not change the color of the display. From Table I it can be seen that the PCR values are very close to unity and even more, the first type of our display which in practice (and in CC values) has better color changes and gives smaller values of PCR than the second one.

The results indicate that in multicolor displays (to color change descriptions) the chromatic contrast should be used as a basic quantitative parameter for the characterization of the order switching property of the liquid crystal display devices.

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