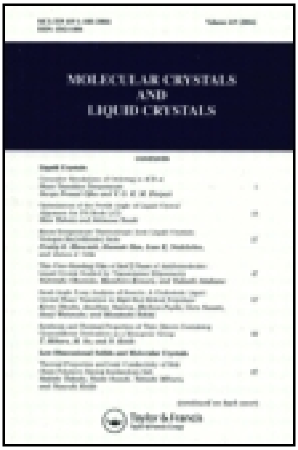

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Color Matching of Guest-Host Liquid Crystal Displays

Hidehiro Seki [a], Taketoshi Uwano [a] & Tatsuo Uchida [b]

[a] Hachinohe Institute of Technology, 88-1, Aza-Ohbiraki, Ohaza-Myoh, Hachinohe-City Aomori, 031-8501, Japan

[b] Tohoku University Graduate School of Engineering, 05, Aza-Aoba, Aramaki, Aoba-Ku, Sendai-City, Miyagi, 980-8579, Japan

Version of record first published: 04 Oct 2006

To cite this article: Hidehiro Seki, Taketoshi Uwano & Tatsuo Uchida (1999): Color Matching of Guest-Host Liquid Crystal Displays, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 331:1, 415-421

To link to this article: http://dx.doi.org/10.1080/10587259908047541

Mol. Cryst. Liq. Cryst., 1999, Vol. 331, pp. 415-421
Reprints available directly from the publisher
Photocopying permitted by license only

Color Matching of Guest-Host Liquid Crystal Displays

HIDEHIRO SEKI[a], TAKETOSHI UWANO[a] and TATSUO UCHIDA[b]

[a]*Hachinohe Institute of Technology 88–1, Aza-Ohbiraki, Ohaza-Myoh, Hachinohe-City Aomori, 031–8501 Japan and* [b]*Tohoku University Graduate School of Engineering 05, Aza-Aoba, Aramaki, Aoba-Ku, Sendai-City, Miyagi, 980–8579 Japan*

A bright reflective LCD without a backlight is a key device for portable information systems. The guest-host LCDs use absorption effect of dichroic dyes and have a wide viewing angle cone. So that, complicated designs of optical compensation in birefringence or optical rotatory power modes have no use of the GH-LCDs. Black and white color of the GH-LCDs works as a light shutter of a full color display with micro-color filters and achromatic color must be displayed precisely. Then it is necessary to mix dyes for achromatic display in the GH-LCDs. In this work, the design was carried out with the Newton-Raphson method in order to obtain the optimum dye concentration. As a result, the relationship between the dye concentration and the optical property was clarified. The process gives us a helpful guideline in fabrication of the reflective color LCD and it is expected that the precise color matching improves the quality of GH-LCDs.

Keywords: Liquid-Crystal; Reflective Display; Colorimetric Design; Guest-Host LCDs; Lambert-Beer's law; Newton-Raphson Method

Introduction

A bright reflective LCD without a backlight is a key device for portable information systems. The guest-host LCDs use absorption anisotropy effect of dichroic dyes and have a wide viewing angle cone [1]. So that, the GH-LCDs does not need complicated designs of optical compensation in birefringence or optical rotatory power modes. One of the applications of GH-LCDs is a black and white display which works as a light shutter of a full color reflective display with micro-color filters. Then it is necessary to mix dyes for achromatic display. In this work, the colorimetric design is examined with the Newton-Raphson method in order to obtain optimum dye concentrations for achromatic color.

Newton-Raphson method for color matching

It is shown in FIGURE 1 that the absorbances $\log T_{\parallel}$ and $\log T_{\perp}$ of guest-host liquid crystal are proportional to dye concentration and electrode spacing [2]. $T_{\parallel}$ and $T_{\perp}$ are transmittances of the incident linear polarized lights whose electric vectors are parallel and perpendicular to the molecular orientation. This means that the Lambert-Beer's law is able to apply to the GH-LCDs and the wavelength dependence of absorption coefficient of dichroic dye is measured, any optical characteristic of the GH-LCDs is able to be calculated.

Usually, plural dyes are mixed for achromatic color in GH-LCDs. In order to obtain the objective color, the concentration must be determined precisely. Scheffer suggested that the Newton-Raphson method is useful for this purpose

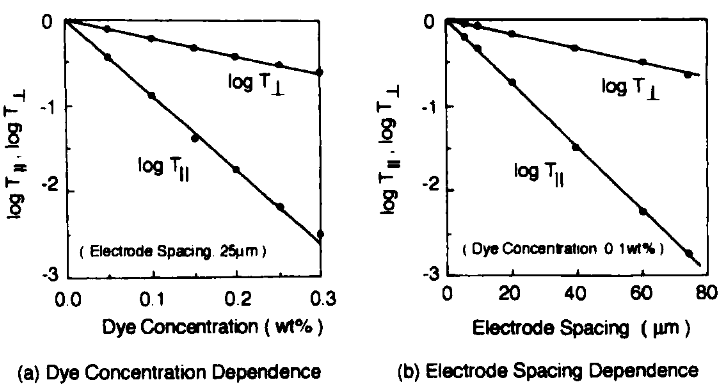

FIGURE 1 Lambert-Beer's law in guest-host liquid crystal display [2].

[3]. The concept of colorimetric design with Newton-Raphson method is shown in FIGURE 2. Considering the relation between dye concentration and tri-stimulus values, the following equation could be derived from the Newton-Raphson method.

$$[C]_{n+1} = [C]_n + [D]^{-1}([X]_a - [X]_n) \tag{1}$$

$$\begin{bmatrix} C_Y \\ C_M \\ C_C \end{bmatrix}_{n+1} = \begin{bmatrix} C_Y \\ C_M \\ C_C \end{bmatrix}_n + \begin{bmatrix} D_{11} & D_{12} & D_{13} \\ D_{21} & D_{22} & D_{23} \\ D_{31} & D_{32} & D_{33} \end{bmatrix}^{-1} \left(\begin{bmatrix} X_Y \\ X_M \\ X_C \end{bmatrix}_a - \begin{bmatrix} X_Y \\ X_M \\ X_C \end{bmatrix}_n \right)$$

Where $[C]_n$ is a set of arbitrarily dye concentrations, $[C]_{n+1}$ is that of improved dye concentrations, $[X]_n$ is that of tri-stimulus values at the dye concentrations $[C]_n$, the elements of $[X]_a$ are tri-stimulus values for the objective color. $[D]$ is a 3*3 matrix whose elements are the nine partial derivatives $D_{ij} = \partial X_i / \partial C_j$ evaluated for $[C]_n$. Considering Heilmeier type GH-LCDs, partial derivatives are expressed as follows,

$$D_{ij} = \frac{\partial X_i}{\partial C_j} = -\frac{100 \ln 10 \, d \int_{360}^{830} \bar{x}_i(\lambda) s(\lambda) k_j(\lambda) T(\lambda) d\lambda}{\int_{360}^{830} \bar{x}_2(\lambda) s(\lambda) d\lambda}. \tag{2}$$

The optimization process of dye concentrations is done as follows. At first,

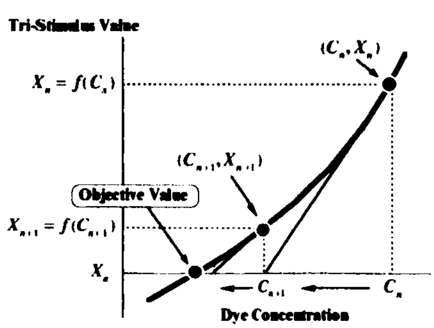

FIGURE 2 Concept of colorimetric design with Newton-Raphson method [3].

arbitrary dye concentration $[C]_n$ is given. Tri-stimulus values $[X]_n$ for $[C]_n$ is compared with the objective values $[X]_a$. If they does not match with, modified dye concentrations $[C]_{n+1}$ are calculated by the above formula. These processes are repeated until the dye concentrations for $[X]_a$ are obtained.

SIMULATION RESULTS

For example, mixing of three kinds of dyes is considered. The absorption maximum wavelength of the dyes are 450, 550 and 700nm, and full width at half height is 100nm. FIGURE 3 and 4 shows the dye concentration and tri-stimulus value change in optimization process using the Newton-Raphson method. Ach-

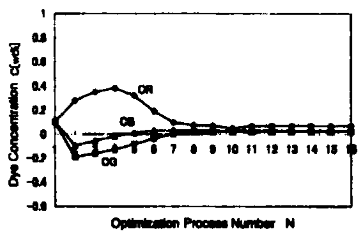

FIGURE 3 Dye concentration change in optimization process for tri-stimulus values (X=Y=Z= 50%).

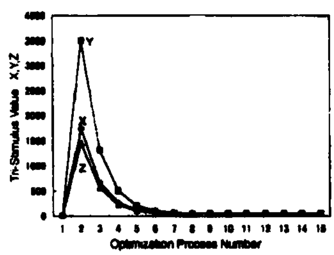

FIGURE 4 Tri-stimulus value change in optimization process (Tri-stimulus value: X=Y=Z=50%).

romatic color with tri-stimulus values X=Y=Z=50% is considering in this case. The values converge in seven or eight intervals. FIGURE 5 shows color coordinate change in the optimization process. Achromatic color of x=y=0.33 is obtained in some stages. FIGURE 6 shows wavelength dependence of transmittance at optimized dye concentration. In this case, the condition of achromatic color is given by X=Y=Z. Achromatic color is obtained though there are strong dependence on wavelength. FIGURE 7 shows tri-stimulus value dependence of optimized dye concentration for achromatic color. Achromatic color gives combination of optical dye concentration.

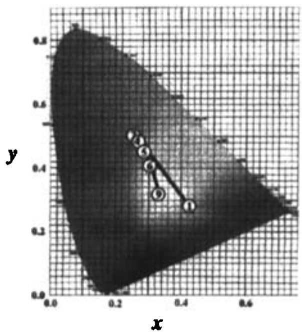

FIGURE 5 Color coordinate change in optimization process (X=Y=Z=50%).

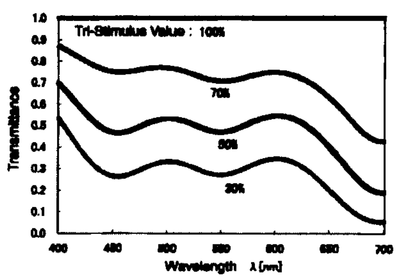

FIGURE 6 Wavelength dependence of Transmittance in optimized dye concentration. The parameters show tri-stimulus values for achromatic color (X=Y=Z).

Above mentioned case deals with off sate of GH-LCDs, in which the absorbance is maximum. At on state, the color balance must be consistent as off-state. It is generally known that the molecular orientation can be schematically expressed as shown in FIGURE 8. Therefore, for convenience, this cell can be supposed to consistent of the surface layers with parallel orientation and the bulk with perpendicular orientation. The thickness of the surface layer is expressed by d_s and d_s depends upon the applied voltage and the cell thickness. FIGURE 9 is surface layer dependence of tri-stimulus values at optimized dye concentration. It is shown that the color balance is sustained regardless of the surface layer and the applied voltage.

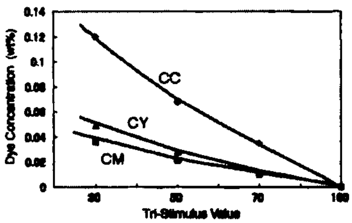

FIGURE 7 Tri-stimulus value dependence of optimized dye concentratio for achromatic color (X=Y=Z).

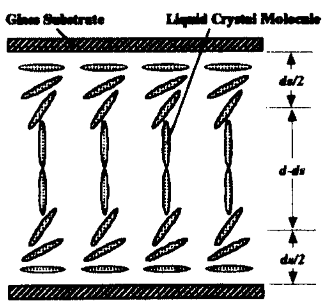

FIGURE 8 Molecular orientation under the applied voltage. d_s is effective thickness of the suraface layer [2].

CONCLUSION

Considering the characteristics of GH-cell, the colorimetric design concept is introduced with Newton-Raphson method. The accuracy and quickness of this method is verified. Conventionary, the color matching of GH-LCDs is done empirically by evaluating transmittance spectra or color coordinates x and y. A trial-and-error method is difficult for precise color control. In this paper, the concept of the colorimetric design for GH cell is examined. As a result, the process gives us a helpful guideline in fabrication of the reflective color LCD and it is expected that the precise color matching improves the quality of LCDs.

Acknowledgments

We would like to express hearty thanks to Mr. Hiroshi Okada, Mrs. Ayaka Hosoda and Naofumi Endoh in Hachinohe Institute of Techonology for research assistance.

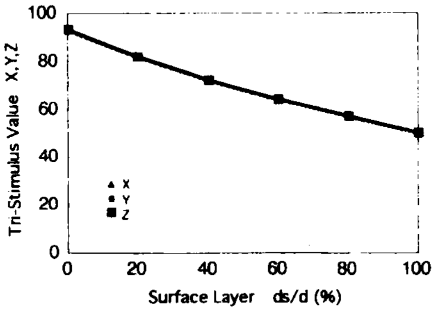

FIGURE 9 Surface Layer dependence of tri-stimulus value at optimized dye concentration.

References

[1] G. H. Heilmeir and L. A. Zanoni: Appl. Phys. Lett., 13, p.91 (1968).
[2] T. Uchida et al.: Mol. Cryst. Liq. Cryst., p.39(1977).
[3] T. J. Scheffer: J. Appl. Phys., 53(1), p.257 (1982).