Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

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Version of record first published: 18 Oct 2010

To cite this article: Geetha G. Nair, D. S. Shankar Rao, S. Krishna Prasad, S. Chandrasekhar & Sandeep Kumar (2003): Electrooptic and Viewing Angle Characteristics of a Display Device Employing a Discotic Nematic Liquid Crystal, Molecular Crystals and Liquid Crystals, 397:1, 245-252

To link to this article: http://dx.doi.org/10.1080/714965605

Mol. Cryst. Liq. Cryst., Vol. 397, pp. 245/[545]–252/[552], 2003

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400390214176

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ELECTROOPTIC AND VIEWING ANGLE CHARACTERISTICS OF A DISPLAY DEVICE EMPLOYING A DISCOTIC NEMATIC LIQUID CRYSTAL

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Recently we developed [1] a novel liquid crystal display device employing discotic nematic material. This device exhibits the following improvements over a conventional twisted nematic (TN) display device using a calamitic nematic material. The device (i) is simple to fabricate and (ii) has excellent viewing angle characteristics showing a wide and symmetric viewing angle profile, (iii) has much less difference in the pixel capacitance between the ON and OFF states resulting in reduced cross talk problem. However the response time of the device is slower than conventional TN devices. An obvious solution to this problem is to reduce the viscosity of the material. To achieve this we have doped, in small concentrations, a long chain alkane compound to the parent room-temperature discotic nematic material. Systematic studies show that both the switch ON and switch OFF response times show a significant decrease, i.e., the device switches faster, in the case of the mixtures. It should be mentioned that wide and symmetric viewing angle characteristics remain unaffected by the addition of the dopant material. However both the switch ON and switch OFF response times are still an order of magnitude slower compared to that of conventional TN devices. Considering the fact that these response times are not very different from those for the STN displays, the achievement of symmetric and wide viewing angle characteristics with a simple fabrication process makes this device quite interesting. To make them attractive enough to be considered for commercial applications new materials with faster response have to be developed. Efforts in this direction are underway in our laboratory.

Keywords: discotic nematic liquid crystal; electro-optics; wide-viewing angle; long chain alkane

INTRODUCTION

One of the major problems affecting the liquid crystal displays is the limited viewing angle characteristics. Various methods have been suggested to improve the viewing angle characteristics. Some of them are (i)

the multi-domain technique [2–5], (ii) the introduction of an optical compensator to reduce the amount of light leakage in the dark state [6–8], (iii) the application of an electric field parallel to the plane of the substrates by means of in-plane electrodes on one of the substrates [9–11], (iv) the so called "amorphous" TNLCD [12,13] etc. All these methods have been proposed to improve the conventional display devices, employing calamitic liquid crystalline materials, i.e., liquid crystals composed of rod-like molecules. Recently we developed [1] a novel LCD that is based on a discotic nematic material. The principal merit of this device over the conventional TNLCD is that it gives a wide and symmetrical viewing angle profile with no reversal in the contrast ratio. It also eliminates the need for alignment of the liquid crystalline molecules by mechanical rubbing or photo-alignment, and further results in a significant reduction in the difference in the pixel capacitance between the ON and OFF states. However the major drawback of this device is the slow response on both switch ON and switch OFF times. A possible way to get faster switching material is to reduce the viscosity. To achieve this we mixed, in small concentrations, a long chain alkane to a room temperature discotic nematic material that was recently reported from our lab [14]. The results of these studies reported in the present article, show that both the switch ON and switch OFF response times exhibit a significant decrease, i.e., the device switches faster, in the case of the mixtures. We also have studied the viewing angle characteristics of the device and find that the wide and symmetric viewing angle characteristics remain unaffected by the addition of the dopant material.

EXPERIMENTAL

The parent discotic nematic material (RTDNM) used in the present studies shows a nematic phase at room temperature. The chemical structure of RTDNM is shown in Figure 1. The isotropic to discotic nematic phase transition temperature has a large width occurring over a range of 81.5°C to 75°C. The reason for the large width of the isotropic to nematic phase transition is that the material contains a mixture of large number of stereoisomers with each isomer exhibiting different clearing temperatures. A detailed discussion about this and the synthetic procedure of the material is described elsewhere [14]. We have carried out studies on pure RTDNM as well as the two mixtures of RTDNM with a long chain alkane *viz.*, octadecane. The mixtures are 4.9% and 10% (by weight) of octadecane with RTDNM.

The electro-optic response and the viewing angle characteristic measurements were performed using a fully automated Display Measuring System DMS 501, from Autronic Melchers, Germany.

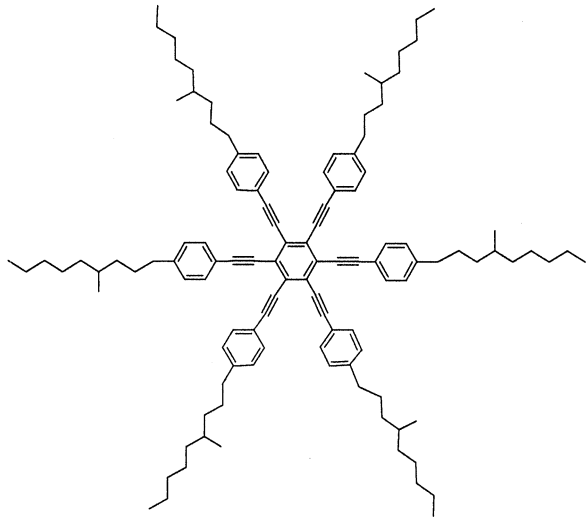

FIGURE 1 Chemical structure of RTDNM.

The sample was sandwiched between two ITO coated glass plates, with an additional coating of polyimide but with no mechanical rubbing. The thickness of the sample, defined by mylar spacers, was $\sim 2.5\,\mu m$. In the OFF state, the discs spontaneously adhere flat against the surface of the glass plates, with the director or the disc-normals, perpendicular to the surface of the glass plates. (Figs. 2(a) and 3(a)). In the ON state, when the electric field applied along the z-axis (also the substrate normal direction), owing to the negative dielectric anisotropy of the material used, the director gets oriented parallel to the surface of the glass plates.

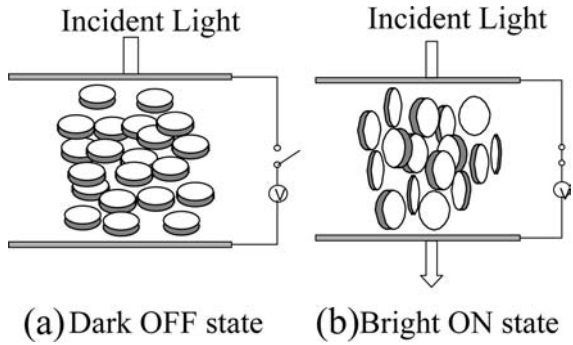

FIGURE 2 Schematic representation of the arrangement of the discs in the (a) OFF state and (b) ON states of the device.

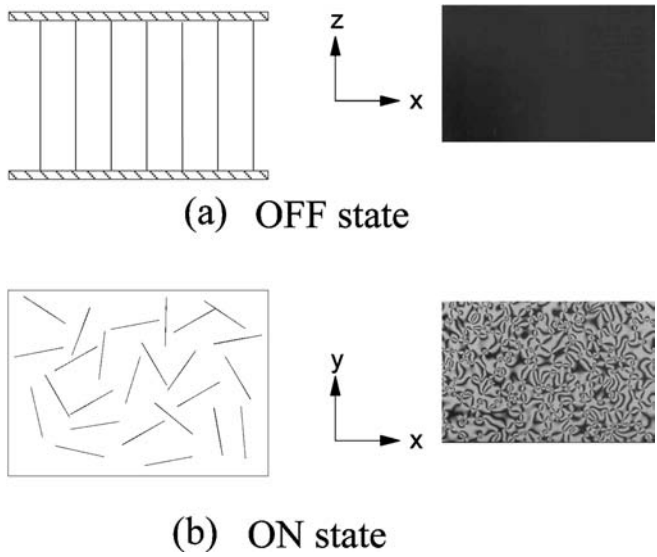

FIGURE 3 Schematic representation of the director orientation and the corresponding textures as seen under a polarizing microscope in the (a) OFF state (b) ON state. The incident light is along the z-axis. (See Color Plate XXII).

However, in the x-y plane (the substrate plane), the disc-normal orientation is completely random. (Figs. 2(b) and 3(b)). If light is incident along z-axis then, between a pair of crossed polarizers, the OFF state appears dark and the ON state bright. In the ON state, although when viewed under the microscope we see a Schlieren texture (Fig. 3(b)), the domain size is quite small ($\sim\mu$m) and therefore it is not visible to the unaided eye.

RESULTS AND DISCUSSION

Figure 4 shows the electro-optic response and the dynamic switching characteristics for pure RTDNM at room temperature (27°C). The Freedericksz threshold voltage for switching is found to be $V_{th} = 4.5$ V. The switch ON and switch OFF times have been calculated by considering the time taken for the transmitted intensity to change from 10% to 90% of its original value and vice versa. At 27°C the switch ON time is $\sim$900 ms and switch OFF time is $\sim$1700 ms. The response, especially the switch OFF is obviously very slow. In order to improve it, the viscosity of the material should be reduced. One way of achieving this is to mix it with suitable materials like for example long chain alkanes. For this purpose we doped

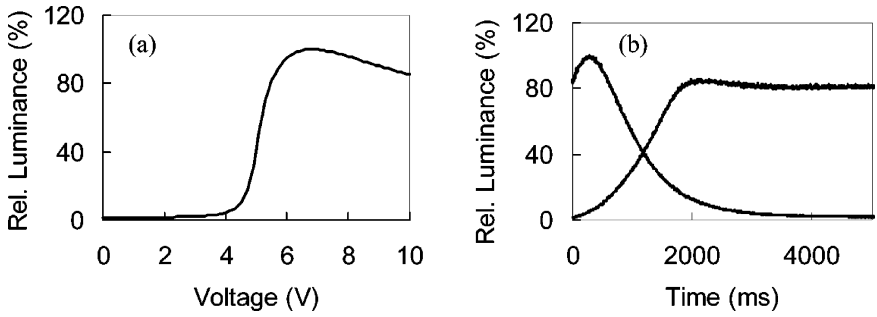

FIGURE 4 (a) Plot of light transmission as a function of applied electric field of the device employing the material RTDNM (b) Dynamic electro-optic response of the device when an electric field of 10 V, 1 kHz sine wave was applied.

the host material with a long chain alkane, viz., octadecane in small concentrations. Two different mixtures were prepared, viz., of 4.9% and 10% (by weight) of octadecane in RTDNM. It should be mentioned here that the concentration of the octadecane could not be increased arbitrarily for the reason that the discotic nematic phase becomes unstable, i.e., the isotropic temperature gets reduced drastically resulting in a narrow temperature range of the nematic phase.

It may be mentioned here that a small value for the dielectric anisotropy results in only a small change in the pixel capacitance between the OFF and ON states of the device. Such a feature would directly reduce the cross talk between the neighbouring pixels. The essence of the device is to have a discotic nematic material with negative dielectric anisotropy. The pixel capacitance change between the ON and OFF states of the pure discotic nematic material is known to be small even from our earlier studies [1]. To check if these features are true in the mixtures also, we carried out dielectric measurements on one of the mixtures. The plot of the variation of the dielectric constant as a function of temperature for the 4.9% mixture is shown in Figure 5. The difference in the dielectric constant between the OFF and ON states (thus along and perpendicular to the director) is ~ 0.25, which is quite small and as mentioned above is an attractive feature to reduce the cross talk problem.

The electro-optic response and the switching characteristics were studied for both the mixtures. The results obtained for 10% mixture are plotted in Figure 6. The response times (both switch ON and switch OFF) show a significant reduction for this mixture compared to that of pure RTDNM. Figure 7 shows the plot of response times obtained at a constant temperature of 27°C as a function of the octadecane concentration in RTDNM. As the concentration of octadecane increases, both the switch ON

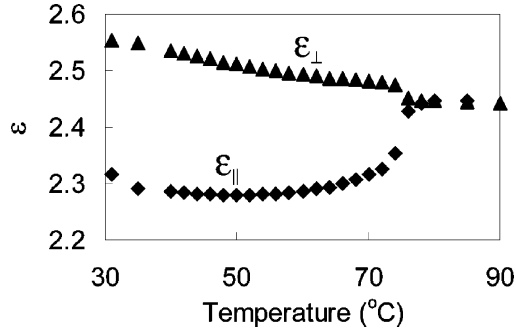

FIGURE 5 Dielectric permittivity as a function of temperature for the mixture 4.9 wt% of octadecane in RTDNM along ($\varepsilon_{||}$) and perpendicular ($\varepsilon_{\perp}$) to the director. The maximum value of the dielectric anisotropy $\Delta\varepsilon$ ($=\varepsilon_{||}-\varepsilon_{\perp}$) is -0.25.

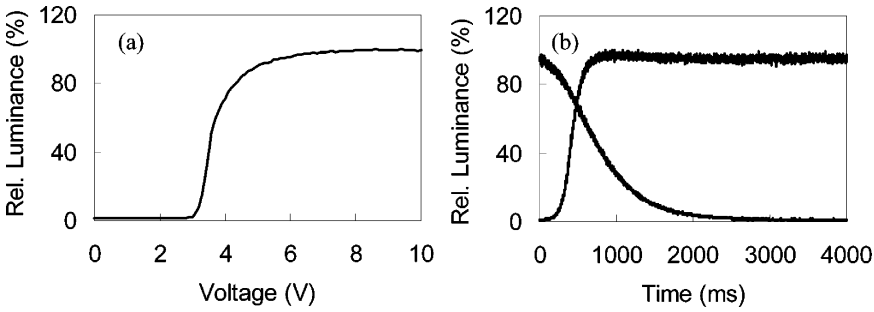

FIGURE 6 a) Light transmission as a function of applied electric field of the device employing the mixture 10 wt% of octadecane in RTDNM. (b) Electro-optic response of the device when an electric field of 10 V, 1 kHz sine wave was applied.

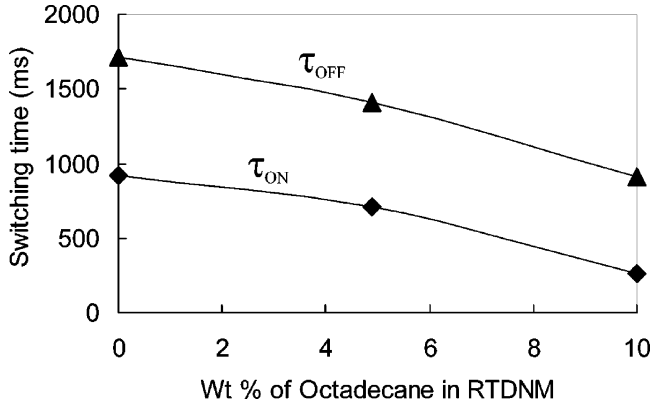

FIGURE 7 Plot of switch OFF and ON times as a function of the concentration of octadecane in RTDNM.

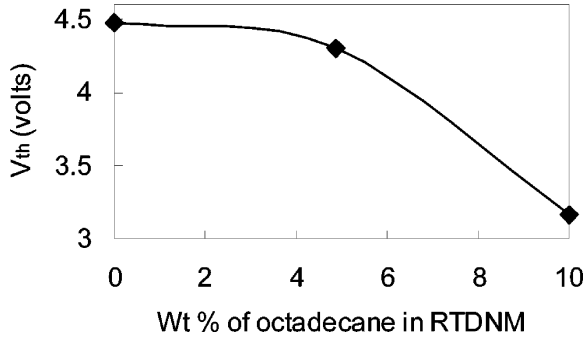

FIGURE 8 Plot of threshold voltage vs the concentration of octadecane in RTDNM.

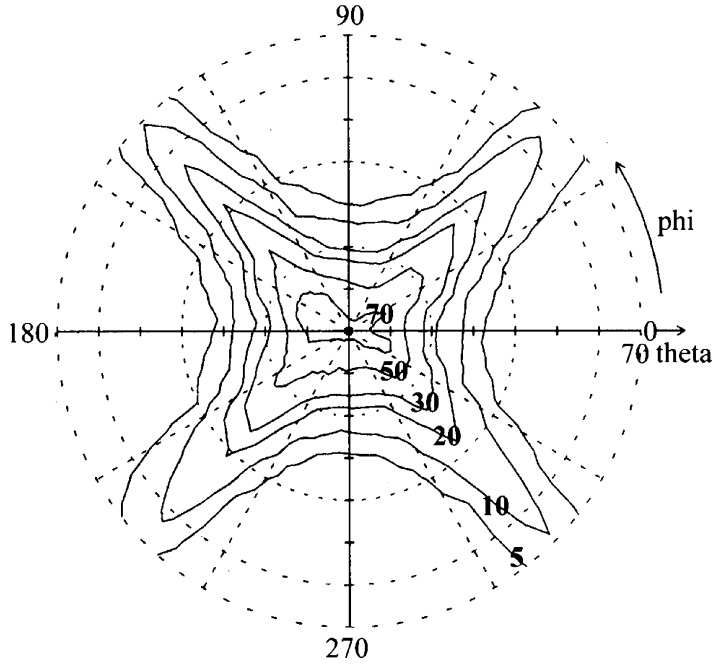

FIGURE 9 Iso-contrast plot of the device incorporating 10 wt% mixture of octadecane in RTDNM. The plot shows symmetric and wide viewing angle profile. (The numbers on the contour lines indicate the contrast ratios.)

and OFF processes become faster. The Freedericksz thresold V_{th} also shows a significant reduction when the concentration of octadecane increases in the mixture (See Fig. 8).

It was also important to find out if the device fabricated with the mixtures also exhibited wide and symmetric viewing angle characteristics just as pure discotic nematic material does [1]. The viewing angle measurements carried out on test cells filled with the mixtures showed that this is indeed the case. Figure 9 shows the iso-contrast plot obtained for the 10% mixture at $\sim 27^{\circ}$C. The applied a.c. voltage was 10 V, 1 kHz (sine wave). As can be seen from the plot, the viewing angle characteristics remain wide and symmetric or in other words unaltered by the presence of octadecane.

To summarize, we have attempted to improve the dynamic characteristics of a display device incorporating a discotic nematic material. The material was doped with a long chain alkane in small concentrations and this helped in making the device switch faster to both ON and OFF states. The excellent viewing angle characteristics of the device fabricated with the pure RTDNM were retained even after adding the long chain alkane up to a concentration of 10 wt%. Similarly the difference in the pixel capacitance between the ON and OFF states remains small for the mixtures a feature useful for reducing the cross talk between the neighbouring pixels in a multiplexed device. Further work is underway to synthesize discotic nematic materials, having a faster electro-optic response.

REFERENCES

[1] Chandrasekhar, S., Prasad, S. K., Nair, G. G., Rao, D. S. S., Kumar, S., & Manickam, M., paper presented at the Eurodisplay Conference held in Berlin, 6–9 September 1999, p. 9–11 (1999), published in the proceedings of the conference.

[2] Schadt, M., Schmitt, K., Kozinkov, V., & Chigrinov, V. (1992). *Jpn. J. Appl. Phys.*, *31*, 2155.

[3] Yang, K. H. (1992). *Jpn. J. Appl. Phys.*, *31*, L 1603.

[4] Chen, J., Bos, P. J., Bryant, D. R., Johnson, D. L., Jamal, S. H., & Kelly, J. R. (1995). SID 95 Digest, 865.

[5] Sugiyama, T., Hashimoto, T., Katoh, K., Iimura, Y., & Kobayashi, S. (1995). *Jpn. J. Appl. Phys.*, *34*, 2396.

[6] Mori, H. (1997) *Jpn. J. Appl. Phys.*, *36*, 1068–1072.

[7] Mori, H., Itoh, Y., Nishiura, Y., Nakamura, T., & Shinagawa, Y. (1997). *Jpn. J. Appl. Phys.*, *36*, 143.

[8] Ong, H. L. (1998). *Mol. Cryst. Liq. Cryst.*, *320*, 59.

[9] Baur, G., Kiefer, R., Klausmann, H., & Windscheid, F. (1995). *Liquid Crystals Today*, *5*, 13.

[10] Oh-e, M., Yoneya, M., & Kondo, K. (1997). *J. Appl. Phys.*, *82*, 528.

[11] Lee, S. H., Kim, H. Y., Park, I. C., Rho, B. G., Park, J. S., Park, H. S., & Lee, C. H. (1997). *Appl. Phys. Lett.*, *71*, 2851.

[12] Toko, Y., Sugiyama, T., Katoh, K., Iimura, Y., & Kobayashi, S. (1993). SID 93 Digest, 622.

[13] Toko, Y., Sugiyama, T., Katoh, K., Iimura, Y., & Kobayashi, S. (1993). *J. Appl. Phys.*, *74*, 2071.

[14] Kumar, S. & Varshney, S. K. (2000). *Angew. Chemie*, *39*, 3140.