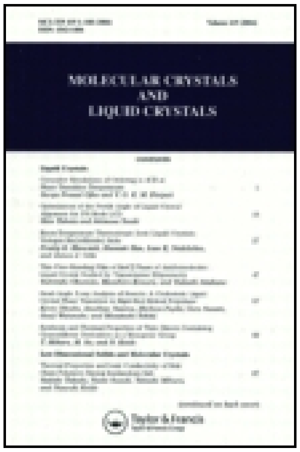

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Effects and Structural Model of Surfactants on the Hysteresis Behavior of Polymer Dispersed Liquid Crystals

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EFFECTS AND STRUCTURAL MODEL OF SURFACTANTS ON THE HYSTERESIS BEHAVIOR OF POLYMER DISPERSED LIQUID CRYSTALS

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Abstract There are numerous reports in the literature dealing with the electro-optical properties of PDLC with experiments designed to reduce the material's hysteresis. Most suggest strong interaction relationship between the liquid crystals and the polymeric materials. We present the approach of correlating the hysteresis behavior of the PDLC films with the interaction of surfactants at the material interface. Experimental results and structural model will be described.

INTRODUCTION

The application of polymer dispersed liquid crystal material (PDLC) has gained increasing interest particularly among display manufacturers and research scientists. The advantage in the application of these materials to projection devices has been well recognized [1] because they use no polarizer and possess inherent high brightness. They are simpler to make, with better performance, and lower cost. There are certain electro-optical requirements associated with the PDLC material in the video application. To realize correct gray scales while properly displaying video rate images, the hysteresis of electro-optical response should be close to zero.

Reviewing the topic of hysteresis in PDLC, we find various approaches in the subject matter. It has been related to the liquid crystal droplet size, droplet shape, density and size distribution [1-5]. The rubbing of the substrates, the application of an applied field during polymerization[6], the addition of chrome complex[7], fluorinated

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acrylate monomer[8] and other new monomer[9] in the material system, the choice of liquid crystal materials and process conditions [3,10-13], the distribution of the pole's direction of the droplets[1], and the chemical nature of the polymer and the polymer surface[14], are reported as capable of modifying the PDLC hysteresis. In summary, hysteresis is an attribute influenced by material properties, physical condition, chemical nature and material selection of the material matrix. Zero hysteresis is not inherent in the structure of PDLC. To find a general approach of control, we are reporting the hysteresis of the PDLC material being reduced by the addition of a surfactant to the material matrix. A structural model will be briefly described.

EXPERIMENTAL RESULTS AND DISCUSSION

There are many useful surfactant candidates for the purpose of this work. They could be broadly described as anionic, cationic and charge neutral entities. The in-depth studies of surfactants are readily available in many physical chemistry texts and literature[15]. When they are added to the premixture of polymer and liquid crystal material, they progressively reduce the hysteresis of the material upon curing, irrespective of the materials used. They modify the surface and interface of the materials so as to induce more favorable electro-optic response when under the applied switching voltage.

As an example of our work, typical material systems are off the shelf items such as PN393 from EM Industries or other proprietary polymer modifications and TL202 and other liquid crystal materials from EM Industries. The ratio of mixing for polymer and liquid crystals varies around 75:25. For surfactants, we use materials of commercial sources, typically with high molecular weight organic derivatives. The amount of surfactant added is a percentage of the polymer matrix by weight. As shown in figures 1, 2, and 3 in our data, the decrease in hysteresis is commensurate to the amount of surfactants used as shown. The optimum concentration of surfactant depends on the polymer matrix and the surfactant used. The highest concentrations of surfactant in our work are less than 25%, so as to preserve the integrity of the material system.

We measure the transmittance of the cells at various applied voltages with the following relationship:

$$T_{50} = [T_{100} - T_0] / 2$$

where

T_{100} = transmittance at saturation voltage

T_0 = transmittance at zero voltage

The voltage at T_{50} while ramping voltage upward is defined as V_{50}(Inc), and the voltage at T_{50} while ramping voltage downward is defined as V_{50}(dec). Hysteresis is defined as:

$$\Delta V_{50} = V_{50}(\mathrm{Inc}) - V_{50}(\mathrm{dec})$$

When V_{50}(Inc) and V_{50}(dec) are identical, hysteresis is zero. A large value of ΔV_{50} represents the seriousness of the hysteresis problem. Figure 1 shows the transmittance curve of material with no surfactant. The hysteresis, ΔV_{50} , value in this case is approximate 1.0V. Figure 2 shows the same material system with hysteresis reduced by the addition of about 15% of surfactant. ΔV_{50} values lower than 0.01V have been achieved by this method from initially unacceptable intrinsic values. A typical diagram displaying the decrease of hysteresis with the addition of different surfactant concentration is shown in Figure 3.

It is well known that the successes of all LCDs are closely related to interfacial interactions of the liquid crystal materials with the surface of the substrates and/or the coating on them; such as the artificial alignment process which gives a state of reference for the twist to start in the Twist Nematic devices. Therefore, the control of the interfacial interactions will render the device as useful or otherwise. When looking at PDLC materials in the same perspective, the control of the interfacial interactions

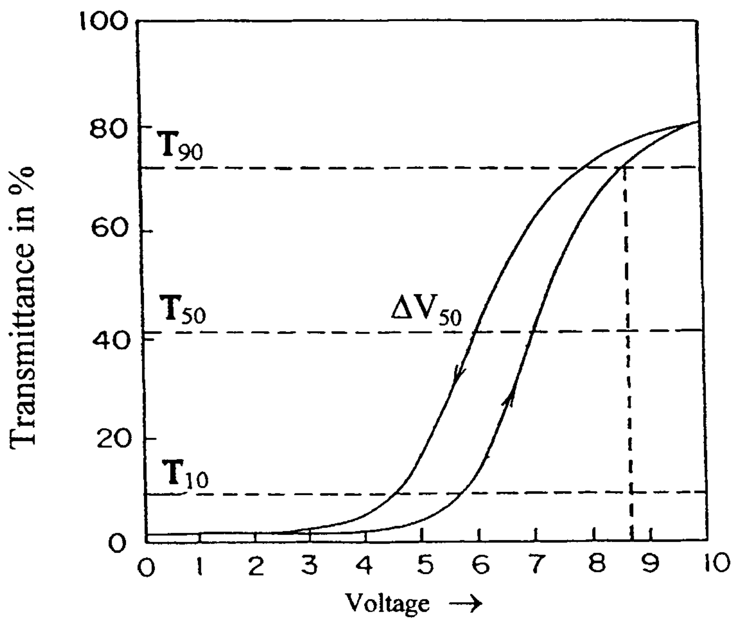

FIGURE 1

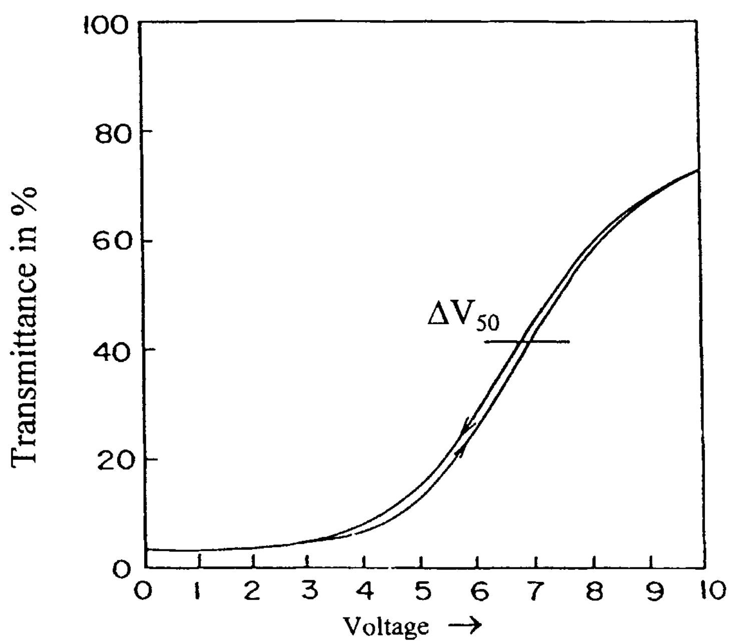

FIGURE 2

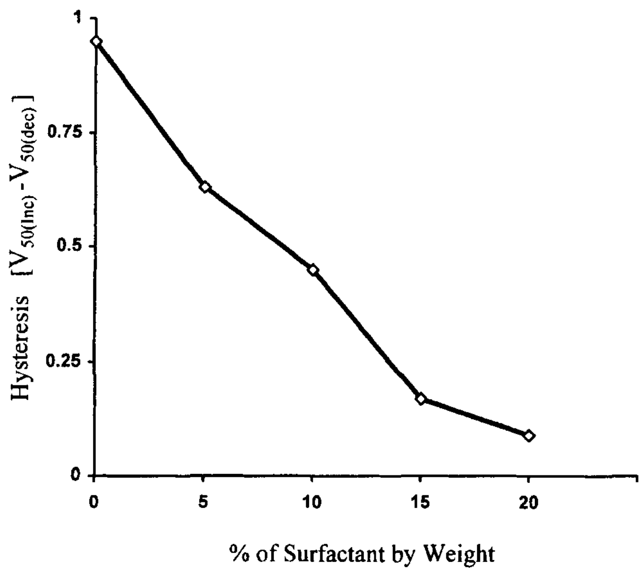

FIGURE 3

between the liquid crystal materials and the dispersed polymer materials, now in 3D, will inevitably decide the usefulness of the devices.

As a conceptual model, we present the following schematics to represent the modes of interaction in bulk between the materials. In Figure 4A, the surfactant molecules behave as single molecules in "handshaking" with the liquid crystal material for the polymer. This would modify the original anchoring of the liquid crystal molecules to the surface of the polymer. On the other hand, Figure 4B shows that the surfactant molecules "encrusting" over the polymer with their own chemistry so as to modify the surface morphology and most likely the electron density localization, thus modifying the anchoring formation and orientation direction of the liquid crystal material with respect to the polymeric surface. These modifications present a less rigid interface and thus provide to lessen the occurrence of hysteresis. Other possible modes of interaction will emerge as more detailed studies are done in the future.

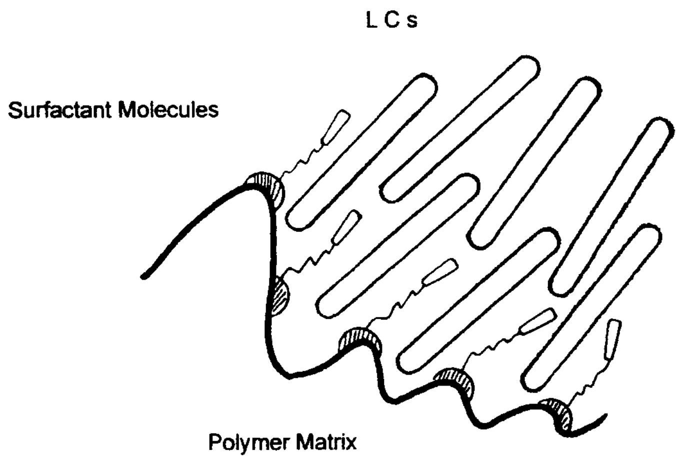

FIGURE 4A

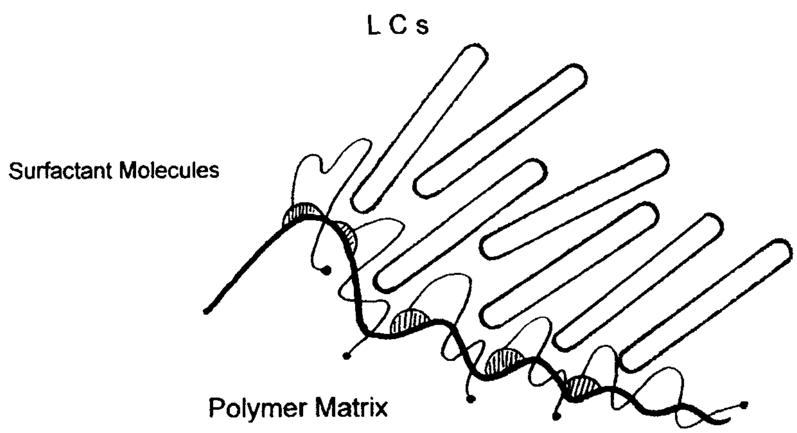

FIGURE 4B

CONCLUSIONS

Surfactants can be used to lower the hysteresis problems in PDLC materials. We have proposed a physical model for such behaviors through empirical studies of the action of the surfactant on the polymeric matrix. Further work promises to be exciting because of the implication on material control for specific device applications.

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REFERENCES

1. S. Niiyama, Y. Hirai, Y. Ooi, M. Kunigita, H. Kuma, T. Wakabayashi, S. Iida, T. Gunjima, SID Digest '93, 869 (1993) and references therein.
2. Y. Hirai, S. Niiyama, Y. Ooi, M. Kunigita, H. Kumai, M. Yuki and T. Gumjima, SID Digest '91, 594 (1991).
3. S. Niiyama, Y. Hirai, H. Kumai, T. Wakabayashi, and T. Gumjima, SID Digest '92, 575 (1992).
4. B. G. Wu, J. H. Erdman and J. W. Doane, Liquid Crystals, 5 (5), 1453 (1989).
5. P. S. Drzaic and A. Muller, Liquid Crystals, 5 (5), 1467 (1989).
6. E. Shimada and T. Uchida, Japan Display 1992, 699 (1992).
7. H. Hirai, Y. Kinosita,K. Syohara, A. Murayama and H. Hatoh, Proc. of 17th Liquid Crystal Symposium, Sapporo, Japan, 4F115 (1991)
8. N. Yamada, T. Hirai, N. Ohnishi, S. Kouzaki, F. Funada, K. Awane, Japan Display 1992, 695 (1992).
9. J. De Baets, J. Capon, A. M. De Cubber, H. De Smet, A. Van Calster, J. Vanfleteren, T. Fujisawa, H. Ogawa, M. Aizawa, H. Takatsu, Europe Display 1993, 117 (1993).
10. A. Tomita, P. Jones, Proc. SPIE, 1665, 274 (1992).
11. N. Yamada, T. Hirai, N. Ohnishi, S. Kouzaki, F. Funada, K. Awane, Japan Display 1992, 695 (1992).
12. E. Shimada and T. Uchida, Japan Display 1992, 699 (1992)
13. D. Coates, S. Greenfield, M. Goulding, E. Brown, P. Nolan, Proc. SPIE, 1911, 2, (1993)
14. L. Bouteiller, P. Lebarn, F. Massie & P. Robin, Europe Display 1993, 325 (1993)
15. See for example: D. Myers, Surfactant Science and Technology, (VCH Publishers Inc., New York, 1988).