Molecular Crystals and Liquid Crystals

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

Fast switching polymer stabilized splay cell (PSSC)

V. Sergan [a b], X. Wang [a], P. J. Bos [a] & G. D. Sharp [c]

[a] Liquid Crystal Institute and Chemical Physics Interdisciplinary program, Kent State University, Kent, OH

[b] Department of Physics & Astronomy, California State University, Sacramento, CA

[c] ColorLink Inc., Bolder, CO

Version of record first published: 18 Oct 2010

To cite this article: V. Sergan, X. Wang, P. J. Bos & G. D. Sharp (2004): Fast switching polymer stabilized splay cell (PSSC), Molecular Crystals and Liquid Crystals, 410:1, 487-493

To link to this article: http://dx.doi.org/10.1080/15421400490433550

Mol. Cryst. Liq. Cryst., Vol. 410, pp. 487/[1015]–493/[1021], 2004

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400490433550

FAST SWITCHING POLYMER STABILIZED SPLAY CELL (PSSC)

V. Sergan
Liquid Crystal Institute and Chemical Physics Interdisciplinary program, Kent State University, Kent, OH, and Department of Physics & Astronomy, California State University, Sacramento 6000 J Street, Sacramento, CA 95819-6041

*X. Wang and P. J. Bos**
Liquid Crystal Institute and Chemical Physics Interdisciplinary program, Kent State University, Kent, OH

G. D. Sharp
ColorLink Inc., Bolder, CO

The polymer stabilization method was used to stabilize a splayed configuration in a nematic liquid crystal cell. A study of the electrooptical properties of such a cell was performed. The optimized configuration features an off-time of less than 0.5 ms for a 3.5 μm cell and is an excellent candidate for field-sequential color display applications.

INTRODUCTION

For many applications, for example, field-sequential color displays and color management systems the most important parameter of a Liquid Crystal (LC) light valve is a short relaxation time [1]. Among the fastest LC device modes, π-cells are frequently considered [2]. However, one of the main disadvantages of the π-cell is the non-stable bend director configuration at the low levels of applied voltage. Below the critical voltage V_c, a splay configuration has a lower free energy than bend configuration. Because of that the domains with splay director configuration nucleate at lower voltages. This transition puts the limitations on the voltage controllable retardation of pi-cell. Calculations of the elastic energy for two

*Correspondence author. Tel.: (330)672-2511, E-mail: pbos@kent.edu

possible director configurations at voltages higher than V_c have made it clear that the splay configuration has the higher free energy in comparison to the bend configuration [3], and so it should provide the faster relaxation because of its higher elastic restoring force.

However to realize splay configuration at voltages higher than Vc, a method must be devised to stabilize it and to prevent the spontaneous conversion of this director configuration to the bend configuration. In order to stabilize the splay configuration, we have used the technique of creating a polymer network inside the cell [4]. We call our new device a polymer stabilized splay cell, and in this paper we report on our initial investigation of it.

MODELING

We modeled the device performance using Twist Cell Optics software. For the modeling we considered a splay cell filled with MLC-6080 that has the following parameters: $\Delta n = 0.2024$; $\Delta\varepsilon = 7.2$; $\gamma_1 = 0.133$ Pa·s.; thickness = 5 microns; pretilt = 2 degrees.

We calculated the director configurations for the splay mode by setting appropriate boundary conditions and voltages. Figure 1(a) shows the director distribution in the splay cell when no voltage is applied. Figure 1(b) shows a possible symmetric splay configuration when 20 V is applied (we fixed the director in the center of the cell to obtain this configuration).

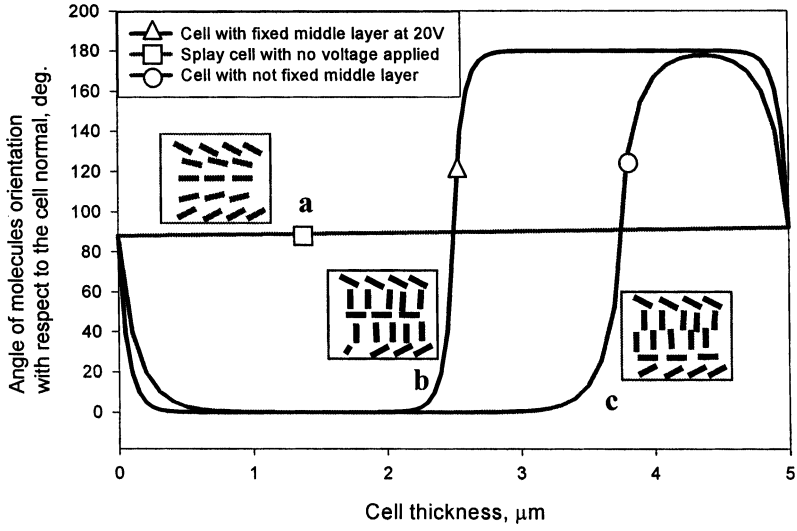

FIGURE 1 Director configurations in polymer stabilized splay cell.

Figure 1(c) shows the calculated director distribution when 20 V is applied to the cell (with no constraints on the director field). We include here the calculation with the constrained director field because in our experiments to be considered below, we used a polymer additive that was cured at zero volts in order to stabilize splay configuration. Thus, it was considered possible that the polymer could act to stabilize the symmetric configuration. We then modeled the relaxation times after 20 volts was removed from the cells from different splay (Fig. 2(a)–(b)) and pi-cell configurations (Fig. 2(c)). We also modeled the relaxation of a cell with more common homogeneous alignment for comparison (Fig. 2(d)). The calculation for the retardation of the pi-cell ends at about 2 milliseconds because at this point the director configuration begins to twist. The modeling was performed using parameters of MLC-6080 for light source with $\lambda = 633$ nm. nm. The results of this modeling show that the cell with a asymmetric director configuration (Fig. 1(c)) has the fastest relaxation as shown by curve (a) in Figure 2.

EXPERIMENT AND DISCUSSION

In order to confirm the result of modeling we build the cells with a polymer network to stabilize the splay configuration. 5 μm cells with parallel rubbed PI surfaces were filled with 2.5% (by weight) solution of RM-82 in

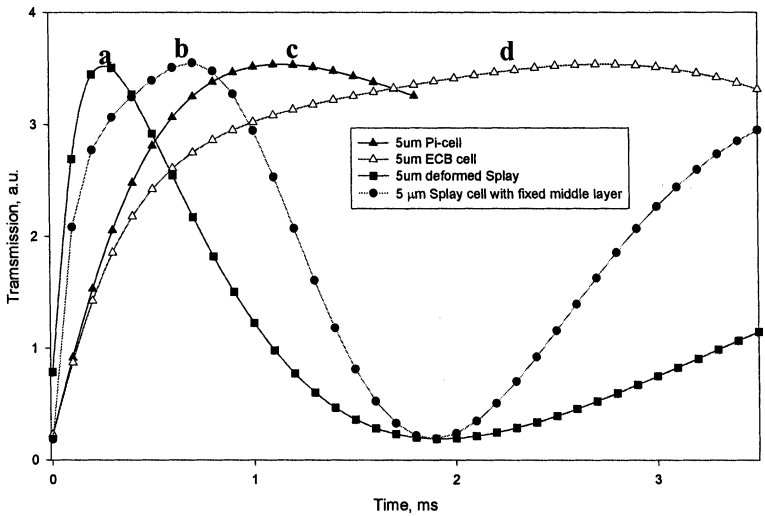

FIGURE 2 Calculated relaxation curves for different electrically controlled birefringence LC modes.

MLC-6080. Sealed cells where exposed to an UV source ($I = 0.1\,mW/cm^2$, $t = 30\,min$) for curing the monomer and form the polymer network with no voltage applied. After preparation the texture and its changes under electric field was studied by the polarizing microscope. We have considered the splay configuration stabilized if application of AC electric field at 30 Vrms during 1 minute did not lead to formation of bend configuration in the cell.

To understand the structure of polymer stabilized splay cell and its changes in electric field we measured and modeled angular dependence of cell luminance at zero field state and with a voltage applied to the cell. The idea behind this measurement is rather simple, a symmetrical director configuration should yield a symmetrical angular dependence of luminance. Figure 3 shows the measured luminance for the polymer stabilized cell with 0 V. The cell was placed between crossed polarizers with the rubbing directions at 45 deg to the transmission axes of polarizers. The curves symmetry indicates the symmetric director configuration shown in Figure 1(a). Figure 4 shows the luminance curves for the device when 2.35 V is applied. In order figure out what director configuration is realized in this case, we modeled the luminance curves for the cells with the possible splay configurations that are shown in Figure 1(b–c). The results of modeling (Fig. 5) show that the configuration presented in Figure 1(c) is realized in practice.

In order to investigate the effect of the polymer network on the relaxation time of a splay cell we prepared and measured 3.5 μm cells with

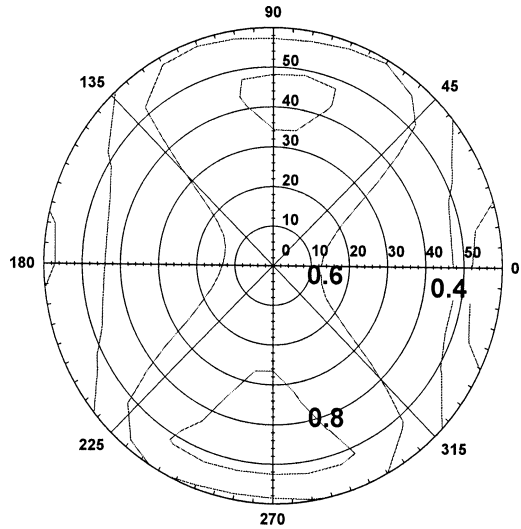

FIGURE 3 Isoluminance curves for polymer stabilized splay cell at 0 V.

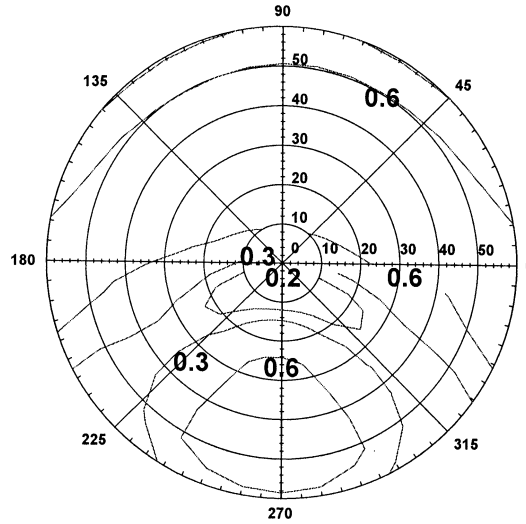

FIGURE 4 Isoluminance curves for polymer stabilized splay cell at 2.35 V (measured).

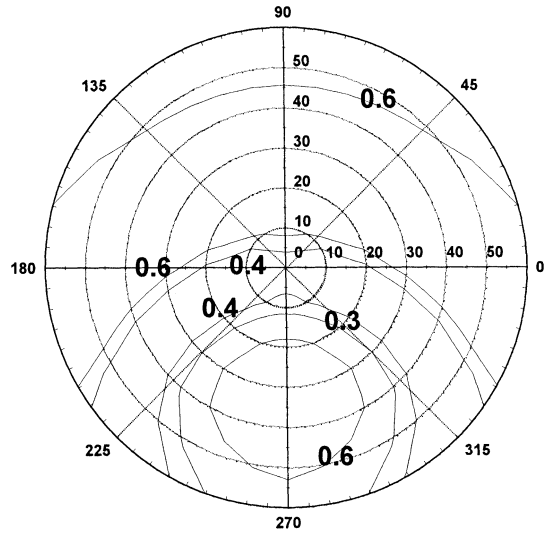

FIGURE 5 Isoluminance curves for splay cell as in figure 1(c) at 2.35 V (calculated). Luminance is normalized.

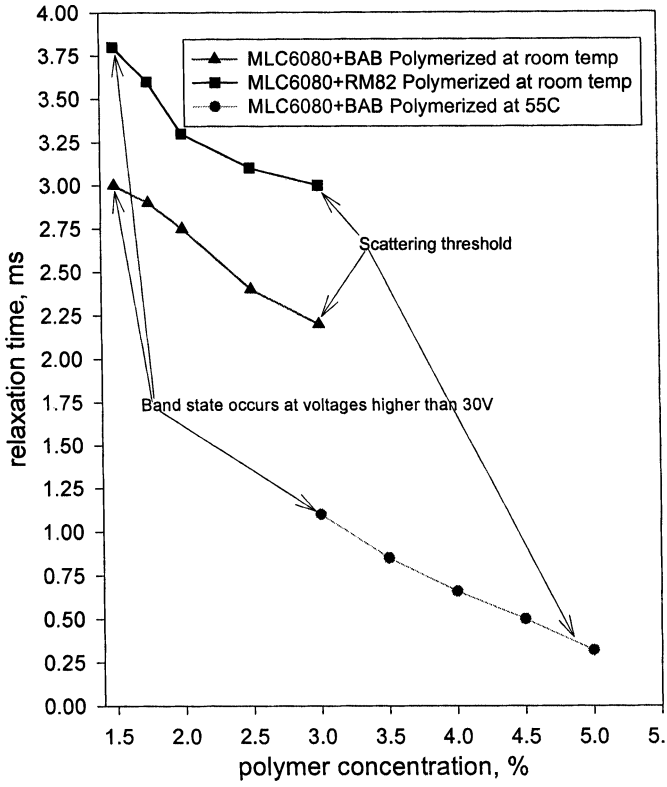

FIGURE 6 Relaxation time (20-0V, $\lambda = 633\,\text{nm}$) of polymer stabilized splay cell as a function of the polymer concentration, type of polymer and temperature of polymerization.

different polymer concentrations. Two reactive monomers where used: RM-82 (from Merck) and BAB (synthesized at LCI, known also as RM-84). RM-82 has additional side chains (spacers) and forms (presumably) a more flexible polymer network. The Figure 6 summarizes the experiment. As can be seen from Figure 6, the relaxation time is shorter in the case of the rigid polymer network formed by BAB. At room temperature, the maximum concentration of the BAB was limited to less than 3%, however if the curing temperature was increased to 55 degrees C, the concentration of polymer in the cell can be increased up to 5% (the maximum concentration was determined as a concentration at which noticeable scattering in the cell occurred after polymerization was completed). In the case of the 5% polymer concentration, the relaxation time is very close to that predicted by modeling.

CONCLUSIONS

We have created and investigated electrooptical properties of a new type of nematic LC device–a polymer stabilized splay cell. We have shown that the introduction of polymer network in the nematic cell with parallel rubbing can prevent the structure from transforming to the bend state at voltages well above V_c and at monomer concentrations as low as 1.5%. We have achieved relaxation time of less than 0.5 ms for the cells with polymer concentration greater than 4%.

REFERENCES

[1] Sharp, G. D., Birge, J. R., Chen, J., & Robinson, M. G. (2000). High throuphput color switch for sequential color projection. *SID'00 Digest*, 96.
[2] Bos, P. J. & Koehler/Beran(R), K. R. (1984). The π-cell, a fast liquid-crystal optical switching device. *Mol. Cryst. Liq. Cryst.*, *113*, 329.
[3] Watson, P., Bos, P. J., Gandhi J., Ji, Y., & Stefanov, M. (1999). Optimization of bend cells for field-sequencial-color microdisplay applications. *SID Digest XXX*, 994.
[4] Yang, D.-K., Chien, L.-C., & Doane, J. W. (1992). Cholesteric liquid crystal/polymer dispersion for haze-free light shutters. *Appl. Phys. Lett.*, *60*, No. 25, 22.