Flicker Minimization in Power-Saving Displays using Positive Dielectric Anisotropy Liquid Crystals by Optimization of Flexoelectric Coefficients

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ABSTRACT

We present a method to enhance the image quality in low-power LCD using positive dielectric anisotropy LCs (pLCs). The proposed method to measure the flexoelectric coefficient difference (es – eb) enables precise material screening and optimized mixtures. The resulting pLC mixture shows minimized flexoelectric coefficient difference, brightness fluctuation under low-frequency driving.

1 Introduction

Reducing liquid crystal display (LCD) power consumption is crucial for energy efficiency [1]. Driving fringe-field switching (FFS) [2,3] LCDs at low refresh rates (e.g., 1 Hz) is promising but inevitably causes flicker, image degradation due to the flexoelectric effect—transmittance differences between odd and even frames in AC voltage. To optimize or minimize the transmittance difference, flexoelectric effect must be controlled, and measurement of flexoelectric coefficients are crucial for designing LC mixtures with verification of the mechanism. This study presents simplified but yet practical measurement method of flexoelectric coefficient difference (e_s – e_b) using vertically aligned FFS cells for pLCs. By minimizing (e_s – e_b) in pLCs, we were able to suppress flicker and optimized LC mixtures accordingly. Our findings, validated through simulation and experiments, demonstrate a practical pathway toward ultralow-power, flicker-free LCDs [4-8] using pLCs as a sustainable alternative to traditional negative dielectric anisotropy LCs.

2 Experiment

Materials: We confirmed the flexoelectric effect using pLC0 and tested three optimized LC mixtures (pLC1–3). Single molecules with different polarities were combined to adjust dielectric and elastic properties. (see Table 1).

Cell Preparation: Planarly (vertically) aligned FFS cells were fabricated based on substrates with ITO and photoalignment layers (SiN_x) coated on it. LC mixtures were filled by capillary action. Vertically aligned cells were used to evaluate flexoelectric coefficients as described in Fig. 1.

LC mixture	K_{33}/K_{11} vi)	$C1$ vii) / [%]	$C2$ viii) / [%]	$C3$ ix) / [%]	$e_s - e_b$ x) [pC/m]
pLC0	$1.3k_{31}$	-	-	-	-
pLC1	k_{31} xi)	c_1 xi)	c_2 xi)	c_3 xi)	2.5
pLC2	$1.0k_{31}$	$1.2c_1$	-	$1.0c_3$	2.0
pLC3	$1.0k_{31}$	$0.5c_1$	$1.9c_2$	$1.2c_3$	0.5

Table 1. Relative values of physical properties of liquid crystal (LC) mixtures.

Electro-Optic Measurement: Transmittance curves were recorded using a He-Ne laser and a photodiode under applied voltages. Driving frequencies of 1 kHz and 1 Hz were used for normal and flexoelectric modes.

FEM Simulation: We simulated electric potential and transmittance using a commercialized simulator (TechWiz LCD, Sanayi System) based on the extended Jones matrix and free energy density including Leslie-Erickson models. Laplace’s equation was solved based on elastic, dielectric, and flexoelectric parameters.

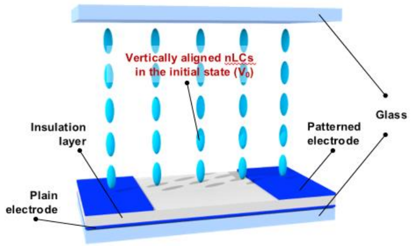

Fig 1. A vertically aligned LC director in an FFS cell.

3 Results and discussion

We investigated the spatial transmittance profiles of various LC conditions using vertically aligned FFS cells, which are primarily influenced by splay and bend deformations—key contributors to the flexoelectric effect.

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The results in Fig. 2 show the spatial transmittance profiles of pLCs obtained through FEM simulation, confirming that each LC exhibits distinct transmittance differences between alternating frames. These variations in spatial transmittance trends across different LCs suggest a significant impact on flicker in actual display.

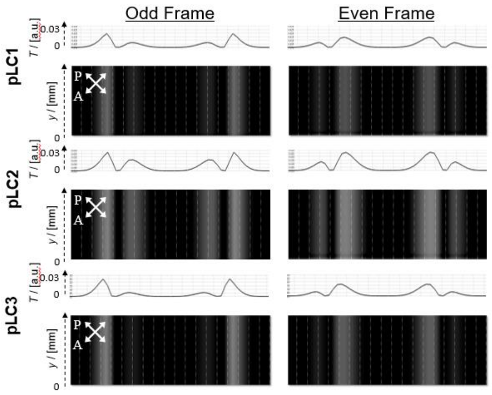

Fig 2. The spatial transmittance profiles (1st row), POM-like images of pLC1, pLC2, pLC3 .

To understand the cause of spatial transmittance differences based on electrode position, we analyzed the flexoelectric effect in pLCs through constructive and destructive coupling between the electric field and the LC director, as illustrated in Fig. 3. For more detail, Fig. 3 separately shows the contributions of splay and bend flexoelectric polarizations to these couplings. In the odd frame, assuming splay deformation, a constructive configuration is observed above the electrode, while a destructive one appears at the electrode edge. In contrast, in the even frame, the vertical component of the electric field is inverted, so the constructive configuration shifts to the electrode edge, and a destructive one appears above the electrode.

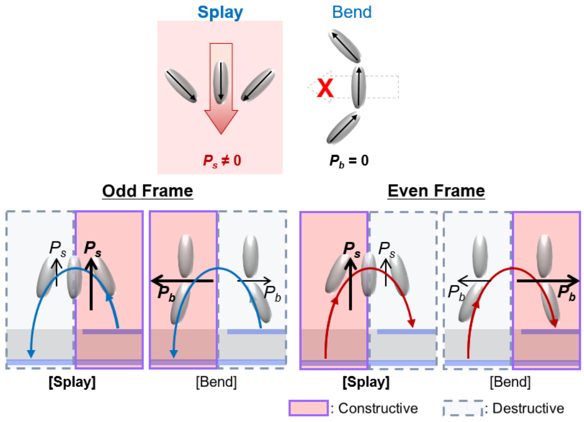

Fig 3. Splay and bend flexoelectric polarizations to both constructive and destructive couplings in pLC.

Here, a “constructive configuration” refers to the case where the electric field direction aligns with the flexoelectric polarization direction, resulting in stronger energy in that region, leading to lower transmittance in those regions.

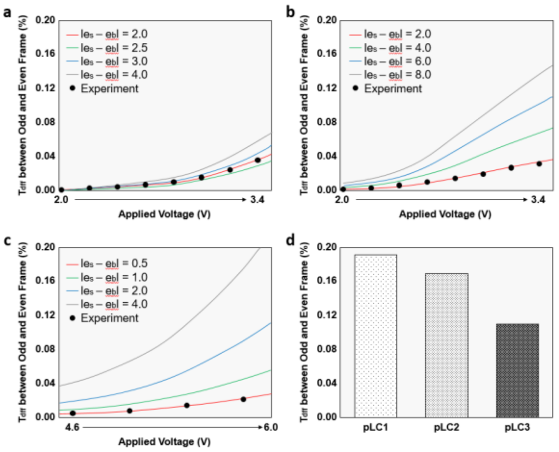

Fig 4. The contributions of splay and bend flexoelectric polarizations to both constructive and destructive couplings in pLC.

To confirm that pLC3 has the smallest flexoelectric effect, we measured $(e_s – e_b)$ for pLC1–3 and compared T_{diff} with FEM simulations (Fig. 4a–c). Results showed strong alignment: 2.5 (pLC1), 2.0 (pLC2), and 0.5 (pLC3). T_{diff} at 1 Hz in real FFS cells (Fig. 4d) matched simulation trends, confirming $(e_s – e_b)$ as a key factor in flicker. Minimizing this difference is essential for low-flicker, low-power LCD design.

4 Conclusion

pLCs have been overlooked for low-frequency driving due to flicker from splay deformation. However, pLCs offer lower driving voltage and greater formulation flexibility than nLCs. We propose a novel method to predict and measure the flexoelectric coefficient difference $(e_s – e_b)$, a key factor in flicker, using FEM simulations and vertically aligned FFS cells. This simplified, accurate approach enables the development of low-power, high-performance displays using pLCs, offering cost and performance advantages over nLC-based solutions.

5 Reference

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