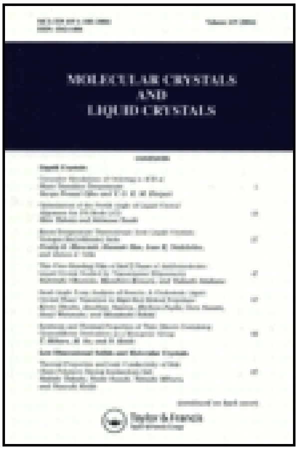

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

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

Surface Trapping of Ions and Symmetric Addressing Scheme for FLCDs

Hua Zhang [a] & Koen D'havé [a]

[a] Department of Electronics and Information Systems, University of Gent Sint-Pietersnieuwstraat, 41, B-9000, Gent, Belgium

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 351, pp. 27-34
Reprints available directly from the publisher
Photocopying permitted by license only

Surface Trapping of Ions and Symmetric Addressing Scheme for FLCDs

HUA ZHANG and KOEN D'HAVÉ

Department of Electronics and Information Systems, University of Gent Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium

It has been considered that applying symmetric addressing schemes can avoid the ionic effect in FLCDs. In this paper, image sticking measurements have been performed to investigate the ion transport process on applying symmetric addressing signals and hence its influence. It has been found that by reversing the polarity of the addressing voltage each frame, image sticking effect has been prominently reduced, nevertheless not completely to zero. Further study has revealed the fact that although accumulation of ions is avoided to a large extent, a number of ions are still trapped at the interface of alignment layer and the liquid crystal layer. These trapped ions cannot be easily released by simply reversing the polarity of the addressing signal and thus influence the electric field distribution in FLC. The number of trapped ions depends on the property of the interface.

Keywords: symmetric addressing; ion transport; trapping; release constant; image sticking

INTRODUCTION

Surface stabilized ferroelectric liquid crystal displays have been a popular research topic for several years. Their bistability, relatively fast switching and wide viewing angles are potential advantages in comparison with the commonly used nematic materials. There are however also a number of problems and one of them is to achieve controlled grey levels. In practice, hysteresis effect and image sticking are usually observed [1] and are main obstacles in obtaining good display performance. These effects can usually be explained by ion transport process[2]. When the FLC device is in one of the switched state, ions drift in the field of the spontaneous polarization. This has a significant effect on subsequent switching and the result is the memory effect which leads to image sticking in display applications.

It has been proposed that this problem could be overcome by addressing the FLC device in the similar way as AFLC, i.e. symmetrically, by reversing the polarity of the addressing waveform every frame [3, 4]. In this way, the FLC is alternatively switched between opposite states, so that there is no net polarization across the device and therefore no ionic accumulation. But of course in case of FLC, a reversed polarity corresponds to an optically inverted picture. Consequently every second frame must be suppressed optically, by stroboscope illumination.

IMAGE STICKING EXPERIMENTS [1]

We have prepared some sample cells of 2.1μm thick, filled with ZLI4655-000 and ZLI4655-100, respectively. The measurement setup is shown in figure 1. The sample is put between crossed polarisers. The function generator outputs the addressing waveform which is then applied to the test cell. The transmitted light is detected by the photo diode and converted to voltage signals. The results can be seen on the oscilloscope and stored in the computer. The whole measurement is controlled by a LabVIEW program automatically. The addressing waveform applied is the same as in [1] and the frame period is chosen to be 40ms. In the image sticking measurement, we have applied the standard slow on-off cycle (81 times on state — 81 times off state) [1]. The optical transmission is integrated over the entire frame and then normalized. The measurement results are summarized in table 1.

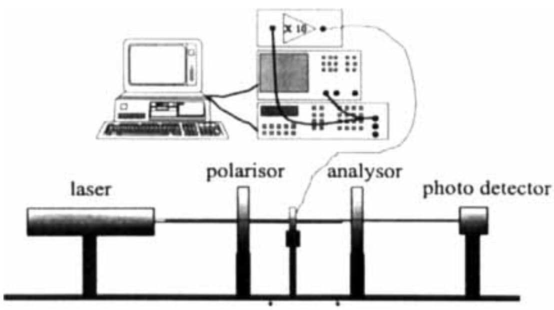

FIGURE 1. Image sticking measurement setup.

	image sticking[1] (non-symmetric addressing)	image sticking[1] (symmetric addressing)	improvement percentage
ZLI-4655-000	0.146	0.079	45.9%
ZLI-4655-100	0.210	0.182	13.3%

TABLE 1. Comparison of Image sticking results of two kinds of FLC material.

From the measurement results, it is clear that the image sticking decreases when the FLC is driven symmetrically but it has not been removed completely. The percentage of improvement depends on the FLC material used. Since the frame period (in this case 40ms) is much shorter than the transit time of ions under the depolaization field [2] (around 1s), the separation of ions should be avoided to a large extent. But the fact that the image sticking does not decrease to zero indicates that some other effects, besides the accumulation of ions, are responsible for the image sticking.

LEAKAGE CURRENT MEASUREMENT AND TRAPPING PHENOMENON

Figure 2 shows the steady state leakage current measured on applying a square wave of $\pm$10V, 10Hz. We can notice that there is a big difference in the current profile. A big bump appears in the current of ZLI4655-100. While in the case of ZLI-4655-000, the bump is quite small. From our previous experience, this bump can be explained by the trapping of ions at the alignment layer[5]. A large current bump in case of ZLI4655-100 may indicate that there are a large number of ions trapped at the alignment layers at the end of each pulse, while in case of ZLI4655-000 the number of trapped ions is relatively small. We know that it is the ionic field that influences the optical transmission. And this ionic field has two contributions, one is from the free ions, the other is from the trapped ions, i.e. $E_{ion}=E_{free}+E_{trapped}$. By applying the symmetric addressing scheme, the influence from the free ions can be almost avoided, as expected. So the term of E_{free} becomes almost zero. But some of the ions get trapped when they reach the alignment layer, and consequently the term of $E_{trapped}$ remains.

In our trapping model [5], we use two parameters to describe the trapping phenomenon, k_{trap} and τ, where τ represents the life time of the interface charges and k_{trap} stands for the trapping speed. We do not consider the interaction between the positive and negative ions that are trapped in the surface states. Using this trapping model, combined with the transport equations of ions [5], we are able to simulate quite accurately the measured leakage current. Figure 3 gives an example of the comparison between the simulation and measurement.

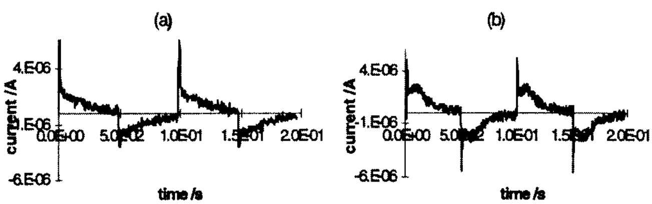

FIGURE 2. Steady state leakage current for (a) ZLI-4655-000 and (b) ZLI-4655-100, respectively.

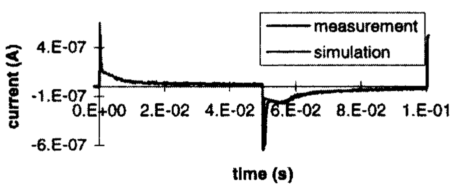

FIGURE 3. Simulation and measurement of the leakage current.

We have measured the ion content in the two FLC mixtures and then evaluated the two trapping parameters k_{trap} and τ. In both mixtures, we have detected two ion species. The results are given in table 2 and 3.

	ion species1		ion species 2	
	mobility ($V.m/s^2$)	concentration ($\#/m^3$)	mobility ($V.m/s^2$)	concentration ($\#/m^3$)
ZLI4655-000	1.05e-10	2.99e19	5.8e-11	3.21e19
ZLI4655-100	2.81e-12	2.72e21	9.33e-13	1.53e21

TABLE 2. Measured ion content in two FLC mixtures.

	ion species 1		ion species 2	
	k_{trap} (m/s)	τ (s)	k_{trap} (m/s)	τ (s)
ZLI4655-000	6e-6	9.92e-4	5e-6	1.86e-3
ZLI4655-100	9.3e-7	2.56e-3	1.45e-7	8.1e-2

TABLE 3. Trapping parameters evaluated from the measurement and simulations.

From table 3, we see that in the case of ZLI4655-100, the release constant τ is about 2.5ms for ion1 and 81ms for ion2. In comparison with the frame period, normally ranging from 10 to 50ms, the release constant of ion1 is much smaller, so most of these ions will get free during the second frame when the voltage is reversed. For ion2, the release constant is much larger than the frame period, which means once trapped these ions can hardly get free even the polarity of the addressing voltage is reversed in the next frame and therefore remain trapped. While in the case of ZLI4655-000, the release constant for both ion species is smaller than the frame period and consequently the trapping effect is much less pronounced than that in ZLI4655-100 as shown in figure 2.

We define $\Delta\sigma$ as the difference of surface charge density between the two side of the cell. Figure 4 shows the simulation result of $\Delta\sigma$ for ZLI4655-100, In the simulation, we start from the state where no ions are trapped, i.e. $\sigma_{bottom} = \sigma_{top} = 0$. On applying the symmetric addressing signal, after one frame, $\Delta\sigma$ becomes negative, indicating that some ions get trapped. Since in the next frame the polarity of the voltage is reversed, some trapped ions become free and $\Delta\sigma$ becomes less negative, but it does not become zero, which means that not all the trapped ions are released. In the following frames, $\Delta\sigma$ becomes more and more negative and eventually get almost saturated. When we try to switch the FLC to the other state, more and more ions get trapped on the other side of the cell, therefore $\Delta\sigma$ increases gradually, and eventually becomes positive. Since there are a different number of ions trapped at the bottom and top interfaces, there exists an electric field, which influences the applied field, hence the optical transmission.

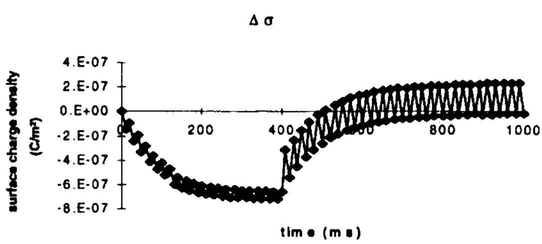

FIGURE 4. Time evolution of surface charge density difference between the top and bottom interface with the alignment layers.

CONCLUSION

By doing image sticking measurement, we have observed that the symmetric addressing scheme can decrease the memory effect in FLC to a certain degree but not completely. Simulation and measurement results show that by applying the symmetric addressing schemes, accumulation of free ions at alignment layer can be avoided to a large extent, however, the trapping effect still remains, especially for slow ions. Since the release time of the trapped slow ions is much longer than the frame time, these trapped ions can hardly get free by reversing the polarity of the voltage in the next frame. Consequently these trapped ions influence the electric field distribution in FLC and hence the optical transmission. In conclusion we have found that surface trapping of ions is an important factor which is responsible for the image sticking under the symmetric addressing condition and we have succeeded in simulating this phenomenon. Further investigation will be done to gain more insight of the trapping effect.

References

[1] P. Maltese, R. Beccherelli, F. Bernardini, M. Wnek, F. Zuliani, Ferroelectrics, "Measurements of image sticking and hysteresis in SSFLC cells", *Ferroelectrics*, vol.**178**, pp.27–39, (1996).

[2] H. Zhang, K. D'havé, B. Verweire, H. Pauwels, V. Ferrara, P. Maltese, F. Compoli, "Influence of ion transport in SSFLC addressing and image sticking", Proceeding of Asia Display98, pp. 241–244, 1998.

[3] S. T. Lagerwall, *Liquid Crystals Today*, vol. **6**, 2, (1996).

[4] S. J. Elston, *Displays*, **16**, 141, (1995).

[5] B. Maximus, D. De Ley, A. De Meyere, H. Pauwels, "Ion transport in SSFLCD's", *Ferroelectrics*, vol. **121**, pp. 103–112, 1991.