Contribution of LC material and PI trapping effect to ionic contamination in STN-LCD cells

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Abstract

The transient current of STN-LCD cells was measured and simulated to characterize ionic behavior in LCD cells. An experiment was performed to investigate the contribution of LC material and PI trapping effect to mobile ions in the LC layer. We observed that most of ions are trapped on the PI surface rather than stay in the LC layer in case of normal STN-LCD, and PI surface favors larger ions in general. A linear correlation of ion density and V_{50} shift of the Transmission-Voltage (TV) curve between 30Hz and 1kHz at typical ion mobility was found.

1. Introduction

The ionic impurities inside LCD cells have significant influence on the other electro-optical performance. Many studies have been performed to investigate the behavior of free ions in LC layers and the interaction between LC and alignment layers. [1-4] In case of STN-LCD, the mobile ions in the LC layer play a major role in the electrical properties of LC cells because the driving signal doesn't contain a systematic DC component. We measured the transient current of cells to detect the contribution of mobile ions and the ion trapping effect on the Polyimide (PI) layer to the electro-optical properties of LC cells.

2. Experiment

Four types of test cells with different cell gaps and PI coatings were randomized and filled by two types of LC in one filling cycle. The batch-making and semi-finishing process followed typical STN settings. The transmission-voltage curves of cells were measured by a DMS LCD characterization system; and the transient current of cells was measured by TOYO Model 6254 Multi-Channel Liquid Crystal Evaluation System. A full factorial experiment on 3 selected factors was performed. The experiment setup is tabulated below:

Factors	-	+
PI	Typical STN-LCD	No
Cell gap (μm)	6.5	9.5
LC	A	B

3. Result

We followed the method reported by Colpaert et al. [1-2] to estimate the ion density and mobility of samples. Fig.1 shows a typical transient current curve and respective simulation result. The simulation result was fitting to measurement result very well.

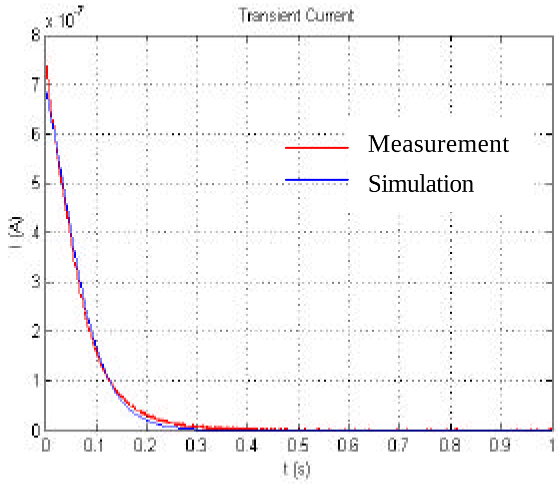


Fig. 1 A typical model fitting to the measurement result of the transient current

According to previous studies [5], the V_{50} (the voltage of relative 50% transmission) shift of transmission-voltage curves between 30Hz and 1kHz is a key parameter to characterize the frequency dependency of LC cells. We measured the V_{50} shift between 30Hz to 1kHz on randomly selected samples, and then correlated with the measurement result of the ion density. In the typical range of the ion mobility of the samples measured, the ion density shows a good linear correlation with V_{50} shift of TV curves as shown Fig.2. It suggests that the average ion density of mobile ions in the LC layer were related to electro-optical properties of LC cells directly.

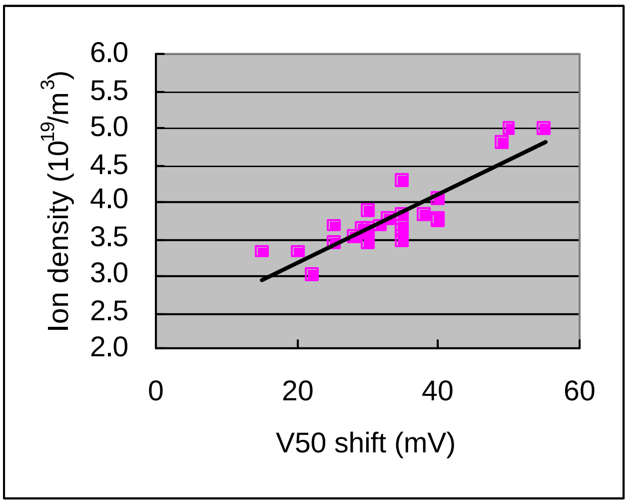
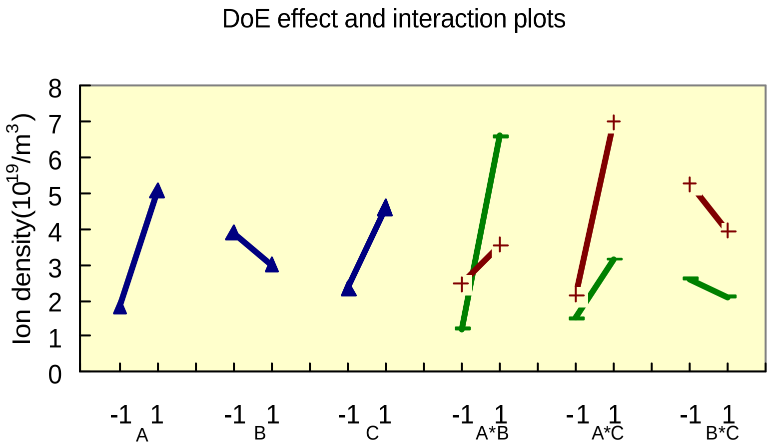


Fig. 2 Correlation of ion density and V_{50} shift of TV curves between 30 and 1kHz

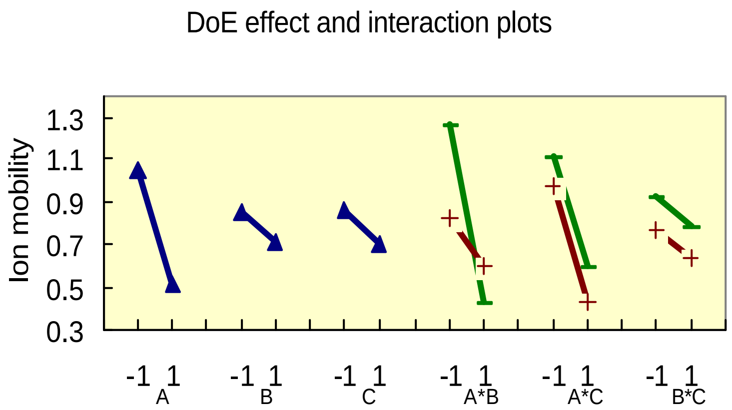
The effect-plot of the ion density of the experiment is shown in Fig.3. PI layer and LC materials had the largest contribution to the ion density, i.e. 40% and 19%. Samples without PI layer had much higher ion density than those with PI layer, i.e. $5.1\times10^{19}/m^3$ vs. $1.6\times10^{19}/m^3$. It implies that most of ions were absorbed on the PI surface rather than moving in LC layer in case of typical STN-LCD. Type-B LC led to higher ion density than type-A because of its higher dielectric constant.

For the ion mobility, the PI layer has a dominating contribution as shown in Fig. 4. The ion mobility of samples with PI layer was around twice of those without PI layer. It can be interpreted that PI surface much more favors ions with larger radius that are moving slowly in LC layer; while most of slow ions are absorbed on the PI surface, there are mainly fast ions moving in the LC layer and consequently higher ion mobility is detected.



Factor	Name	Low level	High Level	Significance
A	PI	PI	without PI	41%
B	Cell gap	6.5	9.5	3%
C	LC	A	B	19%
A*B	PI*Cell gap			17%
A*C	PI*LC			10%
Model fit	82%			

Fig. 3 The effect-plot of the ion density of the experiment



Factor	Name	Low level	High Level	Significance
A	PI	PI	no PI	60%
B	Cell gap	6.5	9.5	4%
C	LC	C1	Y4+	5%
A*B	PI*Cell gap			20%
Model fit		90%		

Fig. 4 The effect-plot of the ion mobility of the experiment

We can see that both ion density and mobility are relatively independent on cell gap; which supports the correction of the used model of Colpaert. The dominating impact of PI layer suggests that the ions after normal process mainly come from the dissociation of impurities and LC itself instead of from the PI material; and most of ions are absorbed on the PI surface.

We also measured the ion density and mobility before and after a high temperature curing process. On the average, the ion density increased 219% and the ion mobility decreased 30% after the curing. It implies that many slow ions were released from the PI surface during the high temperature curing. And we observed the de-trapping of ions from the PI surface would induce the increase of V_{50} shift of TV curves. This is in accordance with the experimental result.

4 Impact

LC material itself is the dominant factor to the mobile ion behavior in an STN-LCD, because the ions originate from the dissociation of impurities or from the LC; and the ion dissociation process is strongly influenced by the LC properties. Additionally the PI layer also plays an important role on the ionic behavior in a LCD; most of ions are trapped on the PI surface rather than moving in LC layer for normal STN-LCD; and the PI surface in general favors larger ions. A high temperature curing process will free slow ions from the PI surface, which leads to higher ion density and lower ion mobility.

5. Acknowledgements

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6. References

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