Recent Progress in Advanced LC Mixture Development for TFT LCD

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Abstract

We reviewed our recent advances in LC mixture development identifying the new classes of materials to yield LC mixtures with faster switching times and better reliability

1. Introduction

Liquid Crystal Displays (LCDs) have been well accepted and played a dominant role in flat panel displays. Technology has been significantly improved through higher resolution, wider viewing angle, faster switching time, higher brightness and larger panel size etc. A rapid and substantial growth of the LCD market is expected to continue in future years. However, the LCD market is getting more competitive and demands for high quality products will be extremely strong in order to meet the high standards required by the market. Advanced TFT LCD modes such as TN with compensation films, In Plane Switching (IPS) and Vertically Aligned (VA) have been designed to fulfill the performance levels of modern desktop and TV applications.

Recently LCD technology is about to penetrate into TV applications where the CRT still holds the majority share in the market. In order to open the LCD TV era, LCD technology should offer, not only the perfect high-definition picture quality without distorting the video signals but also the long-term display stability to guarantee end-users longevity of use. In this paper, our recent progress in advanced LC mixture development will be reviewed identifying new materials to yield LC mixtures with improved switching times and better reliability [1,2].

2. Results

For monitor and TV applications, the switching time represents one of the key requirements. To improve the switching time of modern LCDs, a very fast response time of the LC itself is necessary. As already reported [3,4], the best strategy for a fast response time is the development of advanced LC mixtures exhibiting a very low rotational viscosity $\gamma1$. To achieve this, the identification of new molecular structures as well as new LC mixture concepts is needed. A second approach for the improvement of switching time is the reduction of the cell gap of the display itself.

From both strategies, namely the reduction of $\gamma1$ as well as the lowering of the cell gap of the display, required are the development of novel materials to be used for modern concept of the LC mixtures. The Figure 1 gives an overview on the former development of the main important IPS and TN material classes. The evolution of IPS and TN substances enabled the replacement of former ester or dioxane substances.

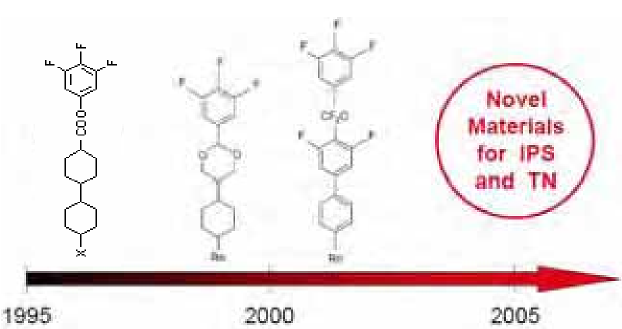

Figure 1. Representative materials for IPS and TN-mode

Some years ago, the third substance was introduced which comprised a CF_2O linkage, having a strong impact on the LC technology. Today, we disclose a new kind of material class (new high polar material C). This molecular structure can be used not only for IPS, but also for TN-mode.

The properties of the new material C in comparison to former materials is summerised in the Figure 2. As depicted, the developments in previous years resulted in the clear enhancement of polarity with respect to the former reference materials. By the introduction of the CF_2O-materials, a new efficient source of polarity was found.

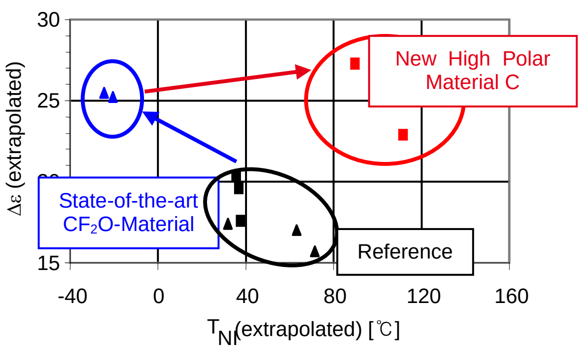

Figure 2. Dielectric anisotropy and Tni of new high polar material C

A new class of high polar materials C is shown in on the right side of Figure 2. These new materials possess the high polarity but much higher clearing point than the previous CF_2O-materials. In summary, a new high polar material class C with very high clearing point is now available which can strongly improve TN and IPS mixtures.

In the Figure 3, the impact of the new high polar material C on LC mixtures for usage in TN and IPS technology is shown. For the range of threshold voltage parameter shown, the new materials show an clear improvement in the switching time parameter $\gamma 1/\Delta n^2$.

While the new high polar material C already improves LC mixtures by itself, it also allows a more efficient usage of the new dielectrically neutral material, so-called “diluters” B, which has very low $\gamma 1$ value. This diluter is of advantage commonly for TN and IPS technology.

(a)

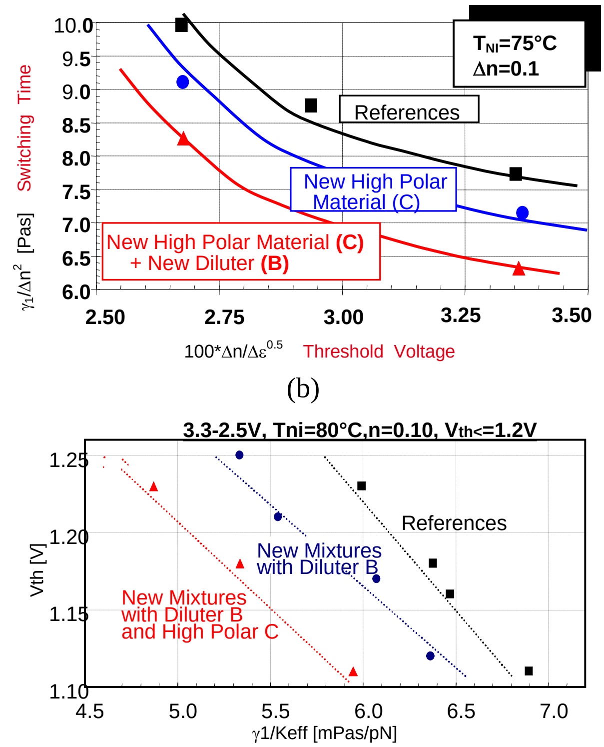

Figure 3. Properties of mixtures with new high polar material C. (a) mixtures for IPS (b) mixtures for TN

As shown in Figure 3, the combination of the new high polars C and the new diluter B results in an even more pronounced improvement in the switching time parameter. This high performance level can only be reached by sophisticated LC mixture concepts based on the unique combination of both new material classes.

In summary, for higher voltages, the diluter results in a clear improvement of the Switching Time. For the case of lower voltages, only the combination of the new diluter with the new high polar material is the most efficient strategy.

LC mixtures for mobile application are differentiated from the standard transmissive type in terms of Vth and Δn. This required parameter region couldn’t be covered by standard material, because a high dielectric anisotropy is needed in combination with a low birefringence and good phase properties.

In Figure 4, the extrapolated dielectric anisotropy Δε is plotted against the extrapolated optical birefringence Δn for the new single material D

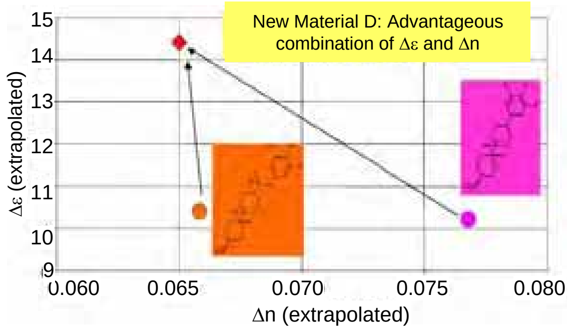

Figure 4. Single properties of new polar low Δn material D

and reference materials. One of the most striking points in properties of the new material is its large increase of Δε combined with a decrease of Δn compared to state of the art CF_2O material. As a reference, the material with same core structure but having no CF_2O linkage was used as denoted in purple circle in Figure 4.

As can be concluded from this diagram, the new material combines a large dielectric anisotropy Δε and low optical birefringence Δn and is therefore ideal to be used in reflective and transflective applications.

Figure 5 shows the advantage of using the new material D in typical mobile application targets having a clearing point Tni of around 80 °C, optical birefringence Δn between 0.065 and 0.080, high dielectric anisotropy Δε and low temperature stability (LTS) of around –30° C in bulk. In the diagram Δn vs Δε of mixtures with new material D compared to reference mixture in the optical birefringence regime Δn = 0.065 and Δn = 0.08

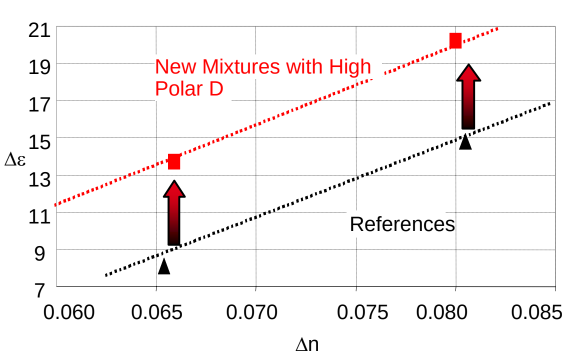

Figure 5. Performance benefit of LC mixtures with new polar material D

is shown. An increase of around 5 units in Δε could be achieved by using the new material. So, it's suitable for mobile application, which needs low power consumption.

Figure 6 shows a correlation of threshold voltage Vth with the optical birefringence Δn. Especially in the regime of low Δn (0.065), the use of the new material results in mixtures exhibiting a significant decrease of the threshold voltage compared to the reference mixture. But also in the regime of higher Δn (0.080), a decrease of Vth is achieved with mixtures using the new material compared to the reference mixture.

Due to the excellent properties of the new material D, not only the threshold voltage Vth, but also the rotational viscosity γ1 can be reduced. Rotational viscosity gamma1 (γ1) vs. threshold voltage Vth is shown for both reference targets (Δn =0.065 and Δn =0.08) in Figure 6. A reduction of around 50 units was achieved in mixtures using the new material D compared to the references for both targets.

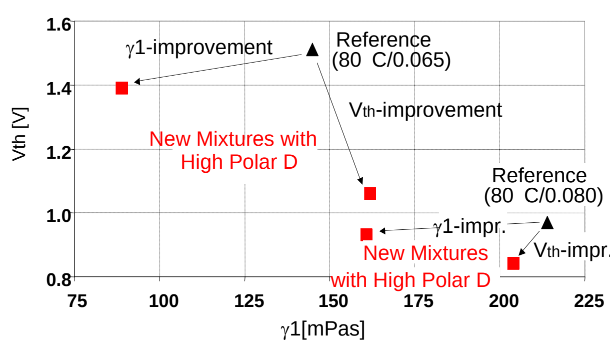

Figure 6. Improvement of Vth and γ1 using the new polar material D

Due to introduction of these new polar single C and D, mixture performance has been enhanced, furthermore the excellent reliability regarding voltage-holding ratio (VHR) also could be obtained when utilizing these new materials.

At first, we evaluated the voltage holding ratio of bulk mixtures with these new singles before and after UV-exposure. Total UV dosage was 3000mJ and VHR was measured at an elevated temperature of 100°C. For the long-term reliability, we checked the change of VHR value weekly under loading on the backlight unit with

electric filed applied circuit. This VHR measurement was carried out at 60 °C.
In Figure 7, Mixture I & II indicate w/ and w/o a new single C respectively, having similar dielectric anisotropy.
VHR drop of Mixture I with new single C was smaller than Mixture II w/o new single after UV-stress. Figure 8 also indicates better stability on the backlight & field load test over the long-term period.

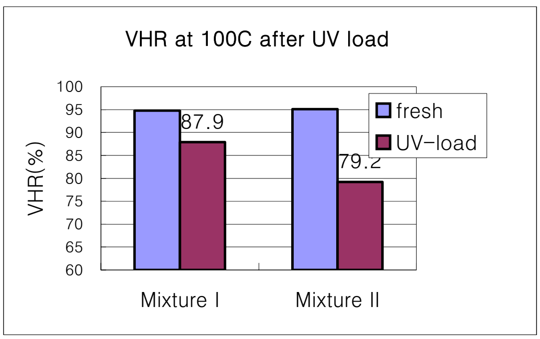

Figure 7. VHR drop of fresh mixture after UV-stress

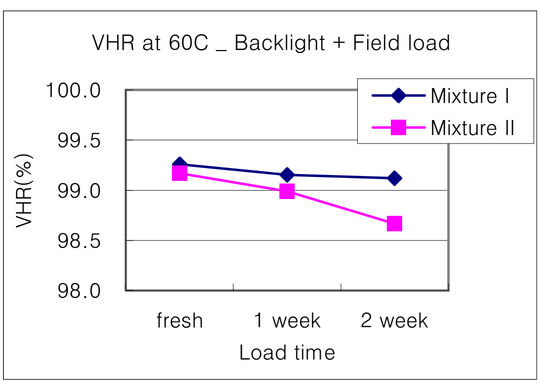

Figure 8. Backlight and electric filed load test

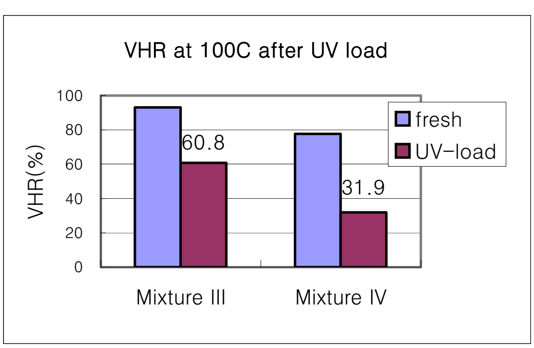

Figure 9. VHR drop of fresh mixture after UV-stress

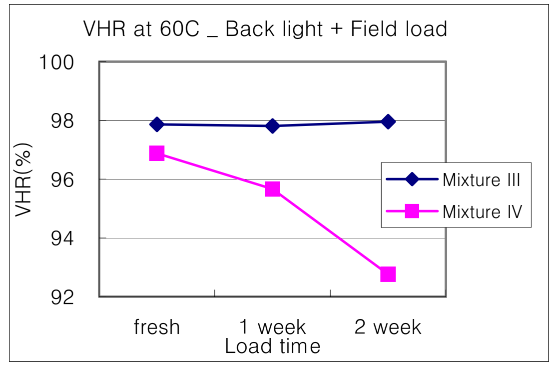

Figure 10. Backlight and electric filed load test

In Figure 9, Mixture III and IV mean w/ and w/o new single D respectively. Mixture IV shows bigger drop in VHR value than Mixture III. It means that the introduction of new polar single D makes the mixture more stable against UV stress. In the backlight and electric field load test, we observed that VHR of Mixture III was constant but VHR of Mixture IV dramatically dropped (in Figure 10) indicating contribution of new single D on the long-term reliability.

3. Conclusion

We identified the improvement of response time by introducing the combination of diluter B and new high polar material C, D for the TV, Monitor, and Mobile applications. By applying these mixture concepts, high reliable performance that is requested in resent display market was also achieved.

Acknowledgements

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5. References

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