

Advanced Liquid Crystal Materials for Fast Switching Times

Min-Ok Jin, Dong-Kyu Yoon, Eun-Young Kim, Seung-Eun Lee
LC Technical Centre, Merck Advanced Technologies Ltd.,
1173-2 Wonjong-Ri, Poseung-Myon, Pyongtaek-shi, Gyonggi-Do, Korea
Phone : +82-31-680-7300, FAX: +82-31-680-7397, E-mail : mo.jin@merck.co.kr

M. Heckmeier, M. Klasen-Memmer, G L? sem, K. Tarumi
Liquid Crystals Division, Liquid Crystal Research, Merck KGaA
D-64271 Darmstadt, Germany

Abstract

For LCD-TVs with full capability to show moving pictures and LCD monitors for multi media use, it is necessary that the switching times of Liquid Crystal (LC) mixtures are within one frame (16.7ms). In order to achieve faster switching times, new LC materials have been identified, mainly focusing on the further reduction of the rotational viscosity (γ_1).

1. Introduction

The past years have seen a remarkable achievement in the field of Liquid Crystal Display (LCD) technologies. Worldwide demand for LCDs is constantly increasing from small sized displays to high definition ones. Further expansion of the LCD market can be assured by a higher penetration rate of LCD TV into the CRT dominated TV market.

Advanced TFT LCD modes such as Twisted Nematic (TN) with compensation films, In Plane Switching (IPS) [1] and Vertically Aligned (VA) [2, 3] have opened the possibility to fulfill the required performance levels of modern desktop and TV monitors. In contrast to CRTs, LCDs exhibit what is described as 'holding picture problem' which can cause blurring of images [4]. To overcome this problem, new techniques in driving method [5, 6] and backlight system [7] have already been introduced by LCD makers. Additionally, it is strongly required that the switching times of LC mixtures are reduced to one frame (16.7ms).

The switching time of LCDs is a relatively complicated function of driving voltage, optical anisotropy, elastic constant, dielectric anisotropy and rotational viscosity etc. However, unlike other parameters, the rotational viscosity (γ_1) of liquid crystals is directly proportional to the switching time

in the TFT panel. Therefore, demonstration of newly developed liquid crystal materials with improved viscosity properties forms the core of this presentation. Two new novel classes of LC materials were identified. The first class are highly polar CF_2O -linked materials, possessing a good combination of dielectric anisotropy ($\Delta\epsilon$) and γ_1 . The second class are diluters, which are dielectrically neutral and have very low viscosity. Apart from reduction of γ_1 , other important reliability parameters such as voltage holding ratio (VHR) and nematic phase stability at low temperature are discussed.

2. Experimental

The dielectric anisotropy ($\Delta\epsilon$) is determined by the capacitive method at a frequency of 1 kHz (ϵ_{\parallel} with a homeotropically, and ϵ_{\perp} with a planar oriented sample). The optical birefringence Δn of the homeotropically aligned sample is measured by the use of the Abbe refractometer ($\lambda = 589 \text{ nm}$). Rotational viscosity (γ_1) is obtained from the torque of the sample in a rotating magnetic field [8]. All measurements are carried out at $T = 20^\circ\text{C}$. The clearing point T_{NI} , Δn and γ_1 of the LC materials are extrapolated from 10% solutions in the host mixture, ZLI-4792. The liquid crystalline phases are characterised using a hot stage under a polarizing microscope. The phase transition temperatures are determined by differential scanning calorimetry. UV irradiation cell (Mercury-Xenon lamp (i-line), 1000mW, 3000-5000mJ) was exposed to the LC mixtures in the test cells. The electrical parameters applied to the voltage holding ratio (VHR) are 1.0 V data voltage and 60 Hz frame frequency measured at 20°C and 100°C .

3. Results and Discussions

A new generation of nematic LC materials was targeted at having a large $\Delta\epsilon$ at the same time as maintaining or lowering γ_1 as much as possible. In Figure 1, γ_1 is plotted against TNI for the reference materials and newly developed highly polar LC materials (A) in the high Δn range of 0.14-0.22. These new polar materials (A) consist of a CF_2O -group between two fluorinated phenyl rings. When $\Delta\epsilon$ is increased, Δn also tends to increase owing to the behaviour of the electronic polarizabilities in the molecule. In addition, an increase of polarity is needed to reduce operating voltage but in turn, will increase rotational viscosity. The new materials (A) overcome this drawback and significantly decrease the values of rotational viscosity at the extreme high $\Delta\epsilon$ values around 25.

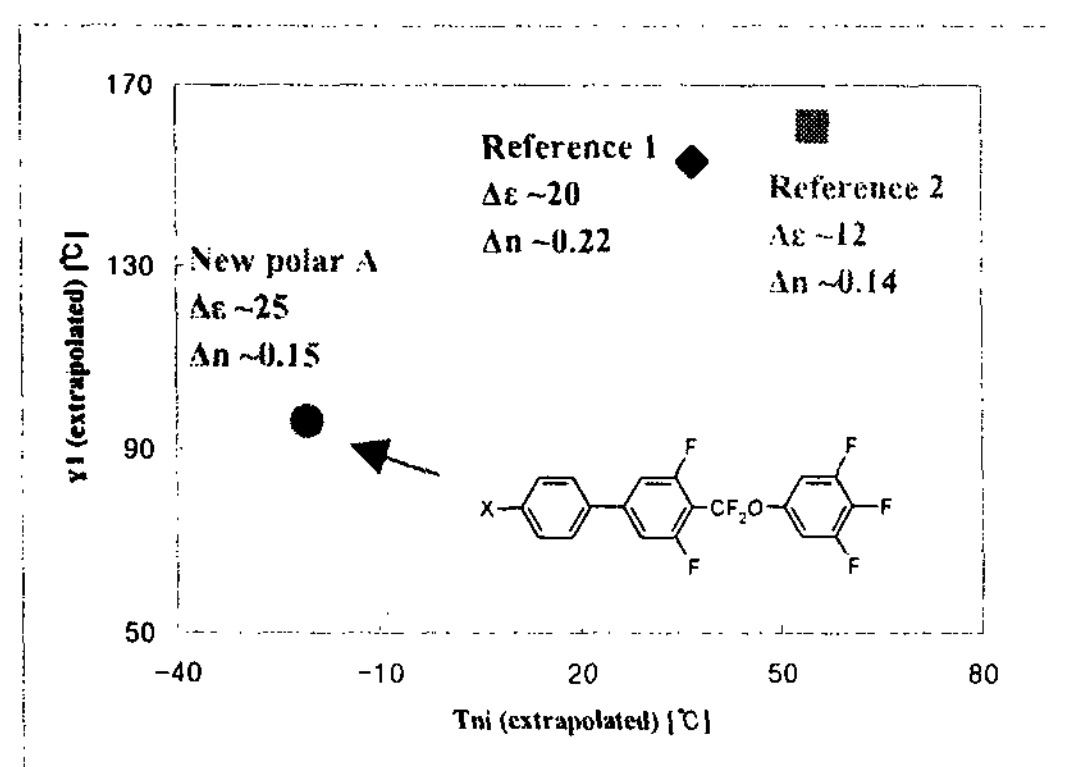


Figure 1 New polar A material structures and their properties compared to the Reference Materials

Another new polar LC material class (B) was identified for the very low Δn value of around 0.067. These new materials (B) possess a CF_2O linking bridge between bicyclohexyl and phenyl ring core structure. As shown in Figure 2, in comparisons to two reference materials, the new polar materials (B) combine a reasonable clearing point with a reduced rotational viscosity.

The phase sequences for the new polar material (B) and reference 3 are illustrated in Table 1. By inserting CF_2O linkage, the melting point is lowered and transition temperature from nematic to isotropic is increased, providing a broad range of nematic phase. The broadened nematic phase of CF_2O linked material can strengthen the low temperature stability (LTS) of the LC mixtures.

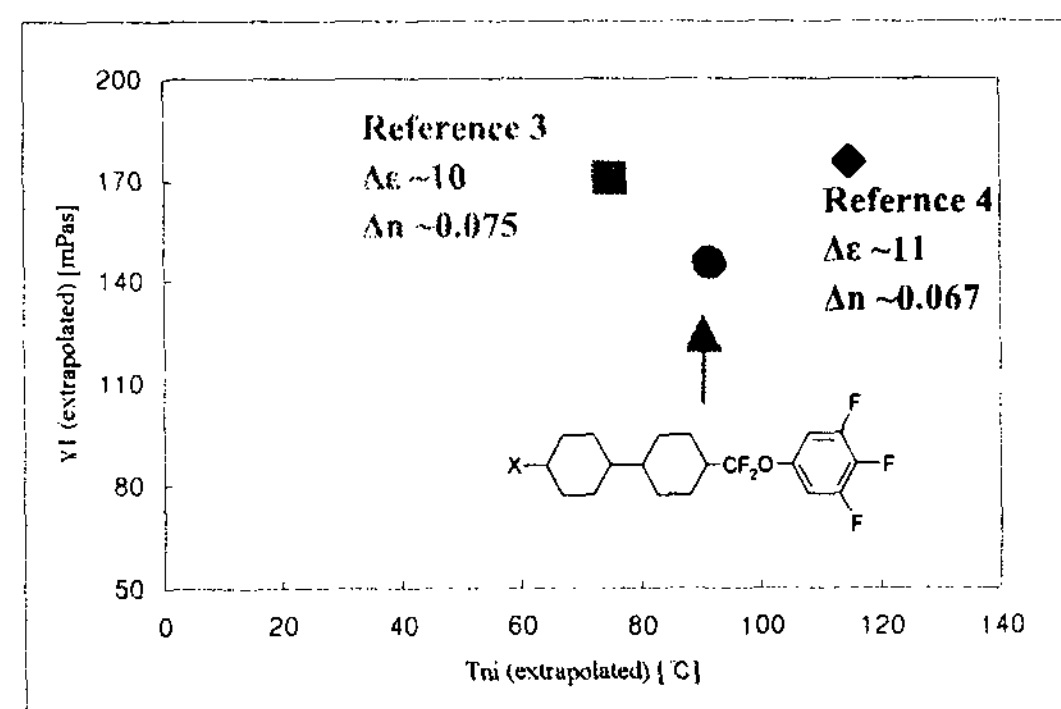


Figure 2 New polar B material structures and their properties compared to the Reference Materials

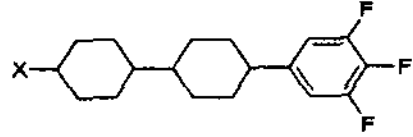
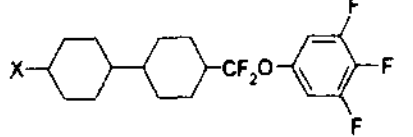
LC	Phase Transition
 Reference 3 (X=C ₃ H ₇)	K 66 N 94.1 I
 New Polar B (X=C ₃ H ₇)	K 44 N 105.3 I

Table 1 Phase transition of Reference 3 and New Polar B material

It is a general rule that the voltage holding ratio (VHR) decreases as the polarity of material increases. The voltage retention capability of the pixel determines the electro-optical properties, i.e. contrast and flicker of the display and indicates a high level of reliability of the display. Therefore, it is important to keep a high voltage holding ratio for satisfactory device performance. In Figure 3, VHR values after UV stress were measured at 100°C for the new polar material (B) and reference 4 which contains an ester linking group. Ester groups are commonly used in conventional LC materials in order to achieve high polarity. The results clearly show that the new polar material (B) maintained a higher VHR value compared to the ester linked reference 4 even though both materials have a comparable polarity. This leads us to achieve the new mixture concept without any

ester compounds and with higher VHR at the same time.

Besides these two polar materials (A and B), a dielectrically neutral compound, a so called 'diluter' with very low rotational viscosity was identified. As shown in Figure 4, we were successful in finding a new diluter having a substantial advantage in γ_1 to all other reference single materials that were available so far.

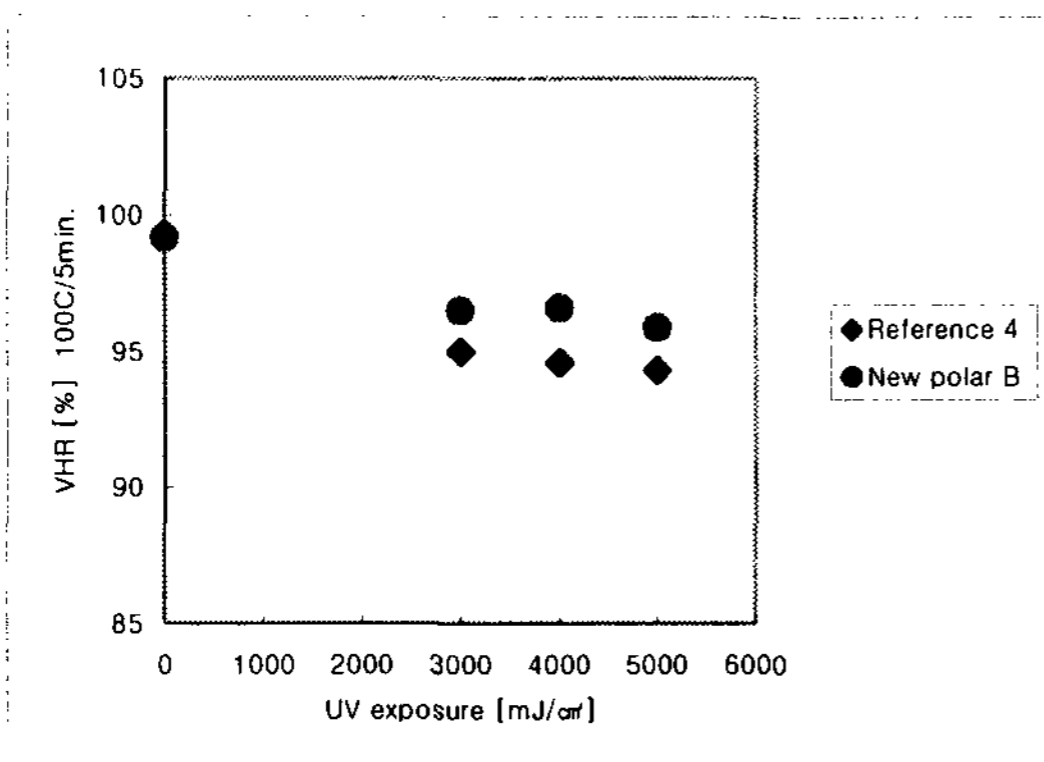


Figure 3 VHR of Ester single (Reference 4) and New polar B material in Heat + UV Load (10% in a Host)

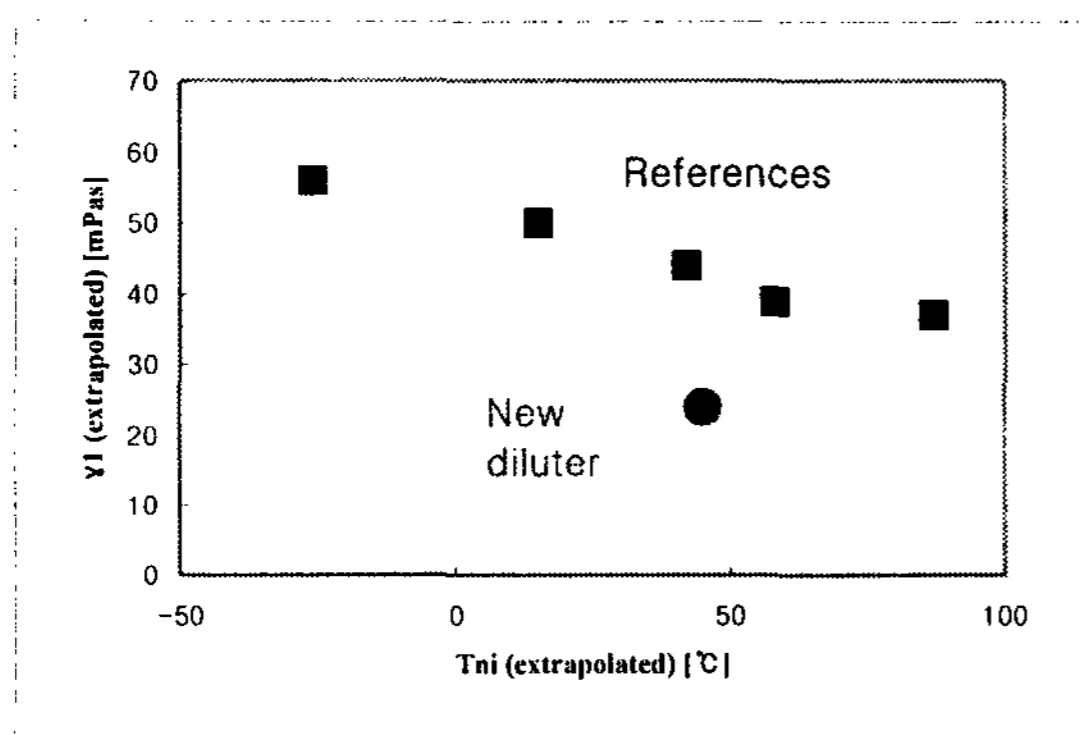


Figure 4 New diluter compared to the reference materials ($\Delta \epsilon \sim 0$)

The combination of the newly identified materials has made it possible to develop new LC mixture concepts with reduced rotational viscosities. Figure 5 demonstrates one of our new mixture developments where both the new polar and diluter materials were utilized. In this latest mixture concept, the γ_1 values of

the mixtures are at the level below 75mPas which can achieve a 16ms of the switching times in LCDs.

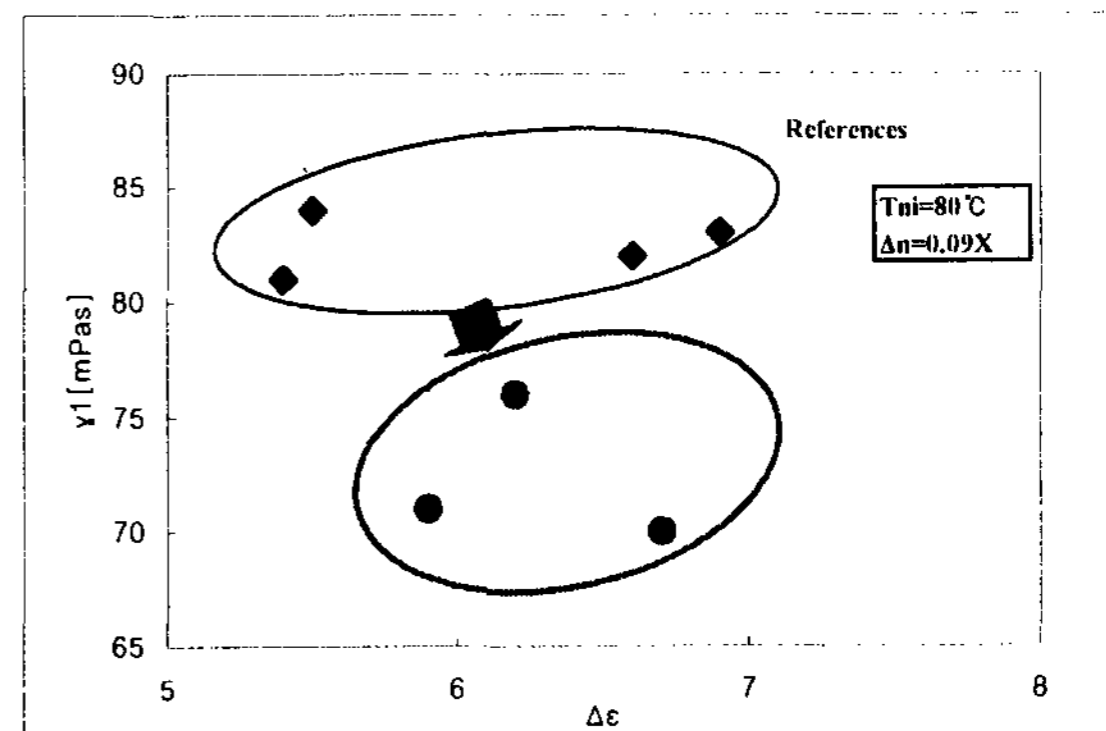


Figure 5 Rotational viscosity versus dielectric anisotropy $\Delta \epsilon$ for the LC mixtures with newly identified materials and reference mixtures.

4. Conclusion

The combination of newly identified single substances leads to advanced LC mixtures fulfilling the highly demanding requirements of fast switching times together with good reliability which is essential for TV and multi-media monitor applications.

5. Acknowledgements

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6. References

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