UBplus/UB-FFS – Premium Performance for Liquid-Crystal TV and IT Displays

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Abstract

Premium displays that offer outstanding characteristics are becoming more important in LCD market. Globally, researchers are looking for ways to improve contrast, transmittance, viewing angle dependency, resolution and switching speed while keep the high reliability level of liquid crystal devices. UB (Ultra Bright)-technology (UBplus and UB-FFS) can increase panel transmittance by using negative dielectric anisotropy LC mixtures compared with traditional FFS Mode, supporting higher resolution devices. In this paper we demonstrate the advantage of UB-LC technology for TV as well as IT applications.

1.Introduction

Displays are important human–machine interfaces. Conventional liquid crystal displays (LCD) have a dominating position in this market mainly because they are a mature technology with a long lifetime and have reasonable cost. With the development of the display industry, picture quality becomes more and more important. High frequency driving and high resolution will be used widely in the future. These are also strong driving force for the development of the liquid crystal materials. One solution to increase transmittance in FFS/IPS liquid crystal displays was to use positive dielectric anistropy (+Δε) liquid crystal mixtures with a higher ε⊥, achieved by adding negative dielectric anisotropy (-Δε) LC singles. This technology is called HB (High Brightness)-FFS. The ultimate solution for the highest transmittance is offered by liquid crystal mixtures with a negative dielectric anistropy, which are called UB (Ultra Brightness)-FFS for smaller devices and UBplus for large screen displays. As UBplus mixtures are designed for large screen displays the general requirements are different from UB-FFS. The idea of using a mixture with a negative dielectric anistropy was previously presented as early as 1998 and 1999 at the SID Display Week [1], [2], [3], [4], [5] but just recently it became of interest for large size devices due to the market trend of higher resolution. In the past, liquid crystal mixtures with a negative dielectric anistropy faced some challenges such as higher rotational viscosity (g_1) and worse reliability compared with FFS mixtures. This created limitations to the development of premium displays. By continuous development of new liquid crystal materials with negative dielectric anisotropy, the drawbacks were significant reduced [6]. In this paper, we will demonstrate the latest achievements in liquid crystal material development to overcome the challenges and offer Premium performance for UBplus and UB-FFS liquid crystal displays.

2.Optical Performance of UBplus/UB-FFS

To evaluate LCD quality, optical performance is one important parameter which includes high contrast ratio and fast response time. Nowadays, to call a display Premium it should not only offer excellent optical performance but also a high level of reliability. Besides these parameters, the overall power consumption must be considered to create a more sustainable future.

Contrast is defined as the ratio between the bright and the dark state of the display. UBplus as well as UB-FFS offer a higher brightness compared to conventional FFS or HB-FFS technologies. On top of this improvement, the dark state is also positively influenced. Therefore, it intrinsically offers higher contrast.

The scattering parameter, which impacts the dark state, can be influenced by the birefringence (Dn), cell gap and the elastic constants (K_{ii}). The reason for the higher transmittance of UBplus and UB-FFS is the more efficient director profile, which also enables the usage of LC mixtures with a lower birefringence (lower optimum d·Δn). This lower birefringence additionally improves the scattering parameter and the contrast compared to conventional FFS and HB-FFS LC mixtures. Comparable LC mixture examples can be found in table 1 (Mixture A vs. Mixture B, C and D) where in addition the most important physical properties are listed.

Table 1. Physical properties of LC mixtures for TV applications, contrast performance

Application	**HB-FFS**	**UBplus**	**UBplus**	**UBplus**
Mixture	**A**	**B**	**C**	**D**
Clp. / ºC	80.0	99.0	98.0	95.5
Dn (@589 nm)	0.100	0.093	0.091	0.087
De (@1 kHz)	2.7	-3.9	-4.0	-4.0
g_1 / mPas	65	134	147	149
K_{11} / pN	13.1	18.5	20.8	20.3
K_{33} /pN	14.9	19.3	20.4	20.9
$K_{Avg.}$ / pN	11.5	15.7	17.2	17.1
g_1/K_{11} / mPas/pN	5.0	7.2	7.1	7.3

Additionally, the contrast of a display can be improved by reducing the scattering parameter further by using liquid crystal mixtures with higher elastic constants ($K_{Avg.}$).

For this purpose, Merck is developing new Liquid Crystals which enable UBplus and UB-FFS LC mixtures with significant higher elastic constants to achieve the highest possible contrast without sacrificing other properties. The latest development (Mixture C) which contains the latest liquid crystal material (LC-21-1) shows a clear increase in elastic constants compared to the state of the art (Mixture B) while all other parameters are kept similar.

To give even more freedom to the display manufacturer in terms of contrast, it is also possible to design LC mixtures with this new liquid crystal single which has the same response time but an even lower scattering parameter due to lower birefringence (Mixture D). Nevertheless, for such a solution a good balance between color, transmittance and contrast needs to be achieved.

Compared to the large size display specification, required for UBplus, specifications for IT applications can be quite diverse as this market is more segmented. For certain IT applications a high contrast may be even more important than for TV applications.

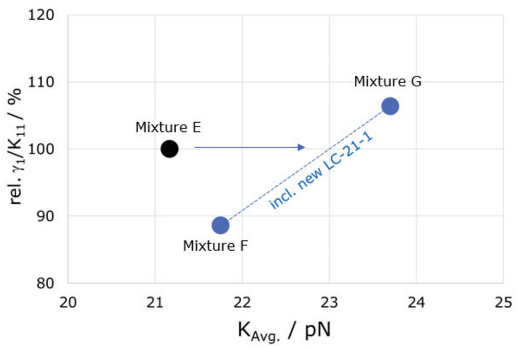

Figure 1. Response time vs contrast of latest UB-FFS LC mixtures

As shown in figure 1, it is possible to improve UB-FFS LC mixtures towards even higher contrast (higher elastic constants) or offer a faster switching (lower g_1) of mixtures which offer already a high contrast because of high elastic constants by using the latest developed liquid crystal (LC-21-1).

Below in table 2, is a comprehensive summary of the physical properties of the latest UB-FFS LC mixtures which are also shown in figure 1.

Table 2. Physical properties of LC mixtures for IT applications

Application	UB-FFS	UB-FFS	UB-FFS
Mixture	**E**	**F**	**G**
Clp. / ºC	122.0	118.0	118.0
Dn (@589 nm)	0.103	0.101	0.103
De (@1 kHz)	-3.8	-3.7	-4.1
g_1 / mPas	197	177	224
K_{11} / pN	26.7	27.2	28.7
K_{33} /pN	23.2	24.5	28.1
$K_{Avg.}$ / pN	21.1	21.8	23.7
g_1/K_{11} / mPas/pN	7.4	6.5	7.8

Merck pushed the limits in terms of achievable physical properties of LC mixtures with our latest materials and is continuously working on further material development to improve the display quality together with our customers. You can already be excited about our future development and experience how far we can push the boarder in the future.

Another development trend for LCD TV and IT products is to create a segment designed for Gaming. To fulfill the requirement for gaming products, fast response time is the most important factor, and it can be realized by a high driving frequency, a lower cell gap and a lower rotational viscosity of the liquid crystal material. As highlighted in the previous description, UBplus and UB-FFS mixtures both show higher transmittance and contrast compared with FFS or HB-FFS mixtures under the same condition. Unfortunately, LC mixtures with a negative dielectric anisotropy, designed for UBplus and UB-FFS, still have some disadvantages compared to LC mixtures having a positive dielectric anisotropy when it comes to the lowest rotational viscosity and therefore fastest response time.

The fast response time requirement for $-\Delta\varepsilon$ mixtures was started intensively already in 1999 (targeted initially at the MVA technology for TV products) [7], [8]. In the in-plane switching mode, the rotational viscosity and twist elastic constant (K_{22}) are the two key factors to judge liquid crystal response time performance. No matter $+\Delta\varepsilon$ mixtures or $-\Delta\varepsilon$ mixtures, the response time of a liquid crystal in IPS/FFS mode is proportional to γ_1/K_{22}. It was found that there is a close relationship between the twist elastic constant (K_{22}) and the splay elastic constant (K_{11}), allowing K_{22} to be approximated by $K_{22}/2$ [6]. To easily compare response time in different LC mixtures, γ_1/K_{11} can be used to express response time in IPS/FFS mode, where a smaller number means a faster response time.

Table 3. Physical properties of LC mixtures for fast response time

Application	**HB-FFS**	**UBplus**	**UBplus**
Mixture	**H**	**I**	**J**
Clp. / ºC	80	99	84
Dn (@589 nm)	0.100	0.093	0.093
De (@1 kHz)	2.7	-3.9	-3.1
g_1 / mPas	65	134	81
K_{11} / pN	13.1	18.5	15.8
K_{33} /pN	14.9	19.3	16.4
g_1/K_{11} / mPas/pN	5.0	7.2	5.1

The mixtures shown in table 3, HB-FFS mixture H and the UBplus mixtures I and J were developed for TV application. Mixture I was developed in 2019 and γ_1/K_{11} is higher than mixture H which means 44% slower response time than mixture H. Even mixture I shows better contrast due to lower birefringence (Dn) and higher elastic constants, but response time (γ_1/K_{11}) still needed to be further improved. Therefore, Mixture J was developed for fast response time in 2020, and not only keeps a high transmittance and contrast but also shows comparable response time with HB-FFS mixture H. Therefore, the latest UBplus mixture has proven that it can reach similar response times compared with HB-FFS mixtures which is essential for the Gaming TV segment.

3.Reliability Improvement of UBplus

TV applications require a high standard of reliability due to the lifetime specification of commercial products. One important reliability parameter of liquid crystal mixtures is called voltage holding ratio (VHR) [9]. In the in-plane switching mode, negative dielectric anisotropy ($-\Delta\varepsilon$) mixtures show lower VHR than positive dielectric anisotropy ($+\Delta\varepsilon$) mixtures on rubbed planar alignment layers. One of the challenges to improve long term reliability is related to ion impurity generation during light and thermal stress, which may result in the image sticking phenomena. Merck KGaA, Darmstadt, Germany developed various materials to improve long term reliability of LC mixtures which we applied to UBplus LC mixtures to overcome this low VHR issue.

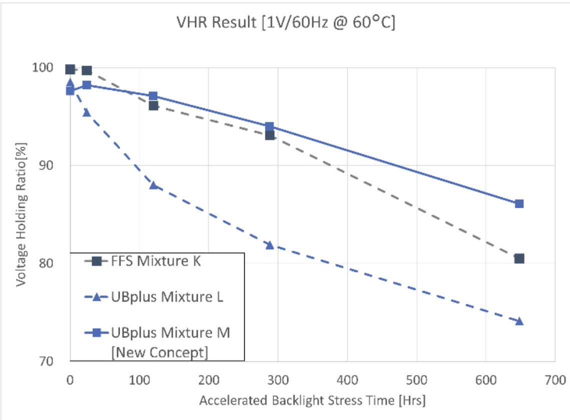

Figure 2. VHR result for TV application

As shown in figure 2, after accelerated backlight stress, the conventional FFS mixture K shows better VHR performance compared to UBplus mixture L. The latest reliability improved concept (UBplus mixture M) shows comparable VHR performance like mixture K. This significant improvement shows UBplus mixtures can overcome the previously considered inferior reliability behavior to compete with conventional FFS mixtures.

4.Conclusion

UBplus and UB-FFS offer a unique solution to improve the optical performance of in-plane switching mode displays. High transmission of UB-technologies contributes to higher contrast ratio which is important for the picture quality of LCDs. Besides transmission and contrast ratio, fast response time is one of the key factors to realize the next generation performance LCDs. Fast response time can be supported by higher driving frequency which is also required for high end LCDs. The latest development of new liquid crystals enables an improved response time like HB-FFS mixtures. We expect UB applications will reach FFS response time levels due to our continuous development of new LC materials.

To further realize mass production of UBplus in commercial LCD products, we do not only consider optical performance but also reliability. We have been developing various materials to improve long term reliability of LC mixtures and applied it to the latest UBplus/UB-FFS mixtures which can be used on planar rubbed polyimide (PI). Here, we achieved better reliability compared with traditional FFS mixtures. UBplus/UB-FFS technology is a premium performance solution for LCD products, and we expect even further performance improvement with new LC materials for this technology in near future.

5.References

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