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Physical Properties of Liquid Crystal Single Compounds with 1,3,2–Dioxaborinane Group for LCD Applications

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Liquid crystal(LC) materials with 1,3,2-dioxaborinane group have been synthesized and their physical properties have been investigated to get new LC mixtures. The test LC samples were made up of a base LC material doped with 5, 10, 15, 20, and 25 % of each compound in weight. We have measured optical and dielectric anisotropy, nematic-isotropic phase transition temperature, and threshold voltages as a function of doping concentration. From our measurements, it is found that each compound has different properties compared with other ones. So, these results would contribute to development of new LC mixtures for LCD applications.

Keywords: 1,3,2-dioxaborinane group; optical anisotropy; dielectric anisotropy; phase transition temperature; threshold voltage

INTRODUCTION

The application range of supertwisted nematic(STN) liquid crystal displays (LCDs) span from low information content displays such as mobile telephone

and pagers to high resolution display such as PDA's, notebook PC's and monitors. In order to achieve better applications, it is essential to synthesize new LC single compounds with suitable properties. During the past 20 years, attempts to optimize the physical properties of polar nematogens for LCDs[1] have been concerned themselves with varying the rings in the core[2], the terminal substituents[3] and the central linkages[4].

For good quality of LCD applications, high contrast ratio, wide temperature range of nematic phase, low driving voltage, and high duty ratio, etc. are required. These characteristics are strongly related to the basic physical properties of each LC single compound. The basic physical properties are Δn, $\Delta\varepsilon$, and T_{NI} etc. Furthermore, it is essential to characterize the properties of newly developed LC materials before applying to the LCDs.

In this study, the properties of newly synthesized LC single compounds were investigated by measuring several physical quantities. And for these materials, some suggestions were made, in the area of blending new LC mixtures, for high quality LCD applications.

EXPERIMENTAL

The LC single materials with 1,3,2-dioxaborinane group (boroxane compounds) used in this study are listed in Table 1. From this table, we know that Bx1 and Bx2 (or Bx3 and Bx4) have same structures but different terminal functional groups(-CN or -F), but Bx1 and Bx3 (or Bx2 and Bx4) have different central linkage groups.

In order to investigate the physical properties of these materials, the changes of optical anisotropy (Δnd), dielectric anisotropy ($\Delta\varepsilon$), nematic-isotropic phase transition temperature (T_{NI}), threshold voltage (V_{th}) and duty ratio ($N_{10\text{-}90}$) were measured as a function of doping ratio(5, 10, 5, 20, and 25 % in weight) in base material, which is blended with three single LC compounds as shown in Table 2. Since these three single compounds have very low optical and dielectric anisotropy(see Table 3), the measured properties of LC materials with boroxane compounds are not influenced by base material. All

measurements were carried out at room temperature except for measuring the T_{NI}. The properties of these LC materials are shown in following section.

Table 1. LC single materials with 1,3,2-dioxaborinane group

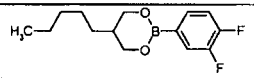
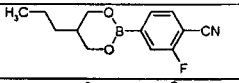
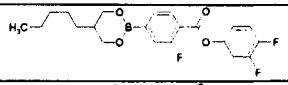
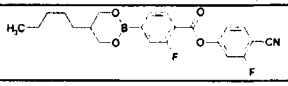
Name	Structure
Bx1	
Bx2	
Bx3	
Bx4	

Table 2. Base material is made up of following LC single compounds.

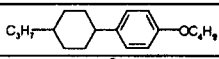
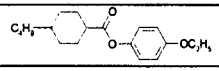
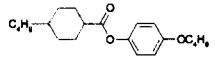
Structure	Mixing ratio
	20%
	40%
	40%

Table 3. Physical properties of base material.

n_e	n_o	Δn	$\varepsilon_{\parallel}$	$\varepsilon_{\perp}$	$\Delta\varepsilon$	T_{NI}(℃)
1.5590	1.4786	0.0804	4.19	3.94	0.25	59

RESULTS AND DISCUSSION

Optical anisotropy(Δn)

For twisted nematic(TN) or supertwisted nematic(STN) LCD, irregularity of

background color mainly due to Δnd. In order to get proper Δnd for each device, we can control the cell gap of LCD panel and/or the Δn of LC mixtures.

Figure 1. Δn variations of LC mixtures with boroxane compounds.

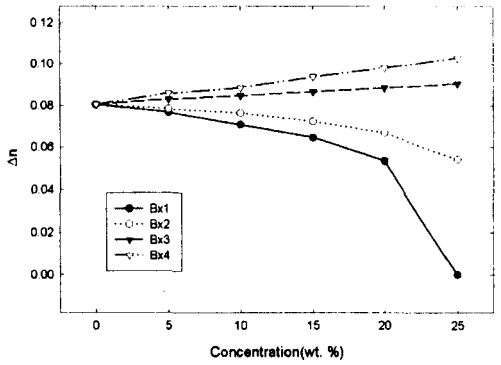


Figure 1 shows Δn variations of LC mixtures as a function of doping ratio of boroxane compounds. From this figure, LC mixtures doped with Bx1 or Bx2 decrease Δn, but doped with Bx3 or Bx4 increase Δn. This means that the central linkage group is the main factor of increasing Δn. And Δn is 0 at the point of 25 wt. % doping with Bx1. In this point LC phase does not exist. From Figure 1, we can calculate the Δn of each boroxane compound and these values are shown in Table 4.

Table 4. Δn of each boroxane compounds.

Name	Bx1	Bx2	Bx3	Bx4
Δn	0	0.0183	0.1237	0.1713

Dielectric anisotropy(Δε)

The Δε of LC mixtures affect the threshold voltage(V_{th}) of LCD. Therefore LC mixtures with low Δε are necessary to reduce the V_{th}. But decreasing Δε has a

bad influence on other properties of LC mixtures. So it is essential to optimize these values. The changes of Δε according to concentration of each boroxane compound are shown in Figure 2. The tendency of Δε variations is similar to that of Δn. In this case, we can also calculate the Δε of each boroxane compound and Table 5 shows them.

Figure 2. Δε variations of LC mixtures with boroxane compounds

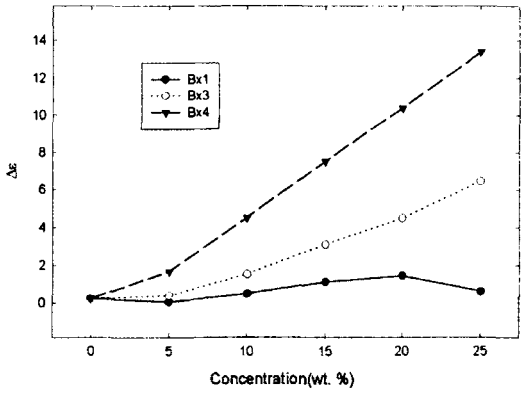


Table 5. Δε of each boroxane compounds.

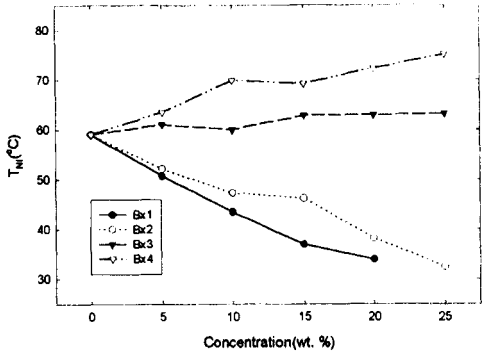
Name	Bx1	Bx3	Bx4
Δε	0	16.14	44.66

Phase transition temperature(T_{NI})

To make regular use of new blended LC mixtures, it is very important for these LC mixtures to take wide driving temperature range. So we check that each boroxane compound has an influence on the T_{NI} of LC mixtures. These results are shown in Figure 3. It is known from this figure that T_{NI} is decreased by Bx1 or Bx2, and that Bx4 increase T_{NI}. But in the case of Bx3, T_{NI} is

independent of this compound.

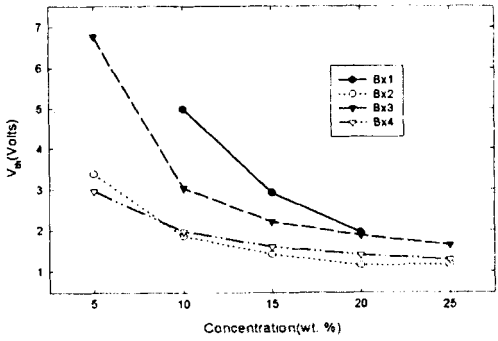
Figure 3. Boroxane compounds affect the T_{NI} of LC mixture.



Threshold voltage(V_{th})

The V_{th} is closely related to the $\Delta\varepsilon$. As already shown from Figure 2, $\Delta\varepsilon$'s of

Figure 4. V_{th} dependence on boroxane compounds.

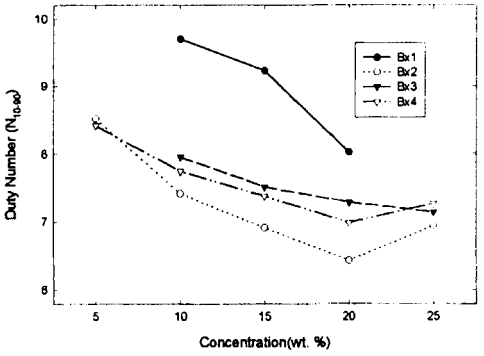


new blended LC mixtures increased monotonously. Since the reverse relation exists between V_{th} and $\Delta\varepsilon$, it is guessed that V_{th} of LC mixtures with boroxane compounds decreases monotonously. These results are shown in Figure 4.

Duty number($N_{10\text{-}90}$)

Duty number is very important factor for LCD devices. Large duty number means high resolution of LCD. In general, this value is about 10 ~ 30 for TN LCD, and is about several hundreds for STN LCD. In our case, all measurements are carried out in 90° TN test cells. Figure 5 shows the change of duty number and these values decrease monotonously until 20 wt.%.

Figure 5. The changes of duty number as a function of concentration.



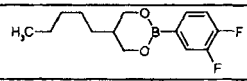
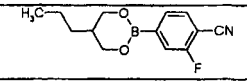
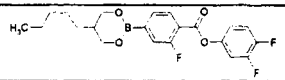
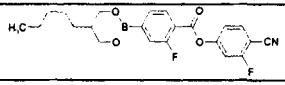
CONCLUSION

We have studied the physical properties of boroxane compounds and Table 6 shows the role of each compound in blending with base material. In Table 6, "Dec" and "Inc" mean that the variation of each property is decrease and increase, respectively when each boroxane compound is mixed with base

material.

From the results in Table 6, we suggest the following method for blending good LC mixtures in order to get more higher quality LCD devices. (a) To decrease the Δn and the T_{NI}, but to maintain the Δε of LC mixture ⇒ use Bx1 and Bx2, (b) To increase the Δε, Δn, and T_{NI} of LC mixture ⇒ use Bx4, (c) To increase the Δε but to maintain Δn and T_{NI} ⇒ use Bx3. But the mutual tradeoff relations in LC properties are first considered in blending new LC mixtures.

Table 6. The characteristics of boroxane compounds for applying LC mixtures.

Name	Structure	Δn	Δε	T_{NI}(℃)
Bx1		Dec	-	Dec
Bx2		Dec	×	Dec
Bx3		-	Inc	-
Bx4		Inc	Inc	Inc

Acknowledgements

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