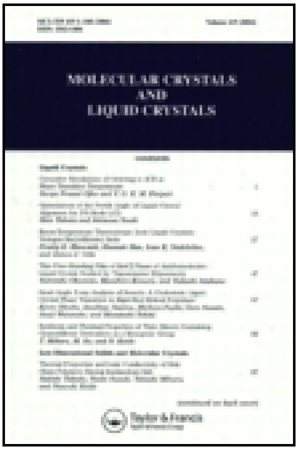

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Physical Property of New Liquid Crystal Materials and Mixture Design for Active Matrix LCD

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Physical Property of New Liquid Crystal Materials and Mixture Design for Active Matrix LCD

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We studied the physical properties of three series of new fluorinated liquid crystal components and prepared some mixtures by using these components. Decahydronaphthalenes have low Δn with relatively high T_{NI}. Naphthalenes and Tetrahydronaphthalenes have large $\Delta\varepsilon$ and variety range of Δn (0.08–0.21). Moreover, we have revealed that the fluoro- substituent at C-1 position for the naphthalene and the tetrahydronaphthalene ring has effects to increase T_{NI} and to reduce γ_1 with good solubility. Then, we have designed some LC mixtures for AM-LCD having good performance with 4V-driving, quick response, high birefringence, low birefringence, wide temperature range and low driving voltage.

Keywords: Fused Ring; Decahydronaphthalenes; Tetrahydronaphthalenes; Naphthalenes; AM-LCD

INTRODUCTION

Recently, active matrix liquid crystal display (AM-LCD) demands high characteristics such as quick response, low viscosity, a variety of birefringence and low driving voltage.

We are interested in the liquid crystals of fused ring systems[1,2,3] with some positions which can be substituted by the fluoro groups. In this paper, we have developed some series of LC components such as Decahydronaphthalenes, Naphthalenes, and Tetrahydronaphthalenes of fused ring systems which are quite new especially as LC components for AM-LCD. The physical and electro-optical properties of these components were evaluated. The LC components with tetrahydronaphthalene and naphthalene rings have the interesting properties for the design of LC mixtures with high quality for AM-LCD.

EXPERIMENTAL

We prepared the LC mixtures including 20 wt% of each single component in host LC. We carried out the following measurements by using these LC mixtures;

The nematic-isotropic phase transition temperature T_{NI}, the crystal-, grassy- or smectic-nematic phase transition temperature $T_{\cdot>n}$, the birefringence Δn and the dielectric anisotropy $\Delta\varepsilon$ were measured. The measurements of Δn and $\Delta\varepsilon$ were carried out at 25 °C. The value of Δn and $\Delta\varepsilon$ were obtained by extrapolation.

The γ_1 / k_{11}, which are related to the response time, were determined from the decay response time τ_d using the following equation [4];

$$\tau_d = \left(\frac{d}{\pi}\right)^2 \frac{\gamma_1}{k_{11}}$$

where d, γ_1 and k_{11} show the cell thickness, the rotational viscosity and the elastic constant of splay, respectively. The measurements were also carried out at 25 °C.

Rectangular waves of 1 kHz were applied to a twisted nematic cell, and then transmitted light was detected by a photo diode in normally white mode. The threshold voltage V_{th} was measured at the 90 % of transmittance in 6 μm of cell thickness. Response time $\tau_r = \tau_d$, was measured at the voltage where the rise and the decay response time indicate a same value. These measurements were also carried out at 25 °C.

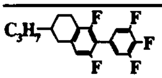
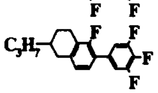
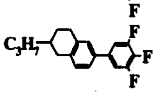
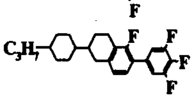
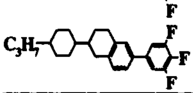
RESULTS AND DISCUSSION

The synthetic methods and the physical properties of Decahydronaphthalenes and Naphthalenes were reported in previous papers [5, 6].

Tetrahydronaphthalenes

Tetrahydronaphthalene ring has many substitution positions which can be substituted by fluoro groups. The π conjugation length of tetrahydronaphthalene-phenyl system is nearly same as that of biphenyl ring. Table 1 shows physical properties of Tetrahydronaphthalenes. Tetrahydronaphthalenes have large $\Delta\varepsilon$ and moderate Δn and reduce the driving voltage.

TABLE 1 Properties of Tetrahydronaphthalenes

	Phase	T_{NI}* [°C]	T_{-n}* [°C]	$\Delta\varepsilon$**	Δn**	γ_1/k_{11}* [m^{-2} s]
	Cr 46.3 I	75.7	14	22.8	0.082	7.5×10^9
	Cr 35 I	81.2	14	17.2	0.101	6.7×10^9
	Cr 31.5 I	80.9	13	12.1	0.100	10.4×10^9
	Cr 75.8 N 135.8 I	118.7	-3	17.9	0.140	7.5×10^9
	Cr 73.5 N 126.5 I	118.1	-3	11.3	0.140	13.9×10^9
Host	-	116.7	11	4.8	0.090	4.9×10^9

* 20 % of addtion in host LC ** Extrapolated

Relationship between $\Delta\varepsilon$ and Δn of Fused Ring Components

Figure 1 shows the relationship between $\Delta\varepsilon$ and Δn of fused ring components and low viscosity components. In general, Decahydronaphthalenes have small $\Delta\varepsilon$ and low Δn. Naphthalenes have large $\Delta\varepsilon$ and high Δn. Some of Tetrahydronaphthalenes indicate large $\Delta\varepsilon$ with comparatively low Δn. We have already developed the tolan derivatives and the low viscosity components having high Δn with small $\Delta\varepsilon$ and low Δn with very small $\Delta\varepsilon$, respectively. Consequently, the LC mixtures including these four series of LC systems can cover very wide range of $\Delta\varepsilon$ and Δn.

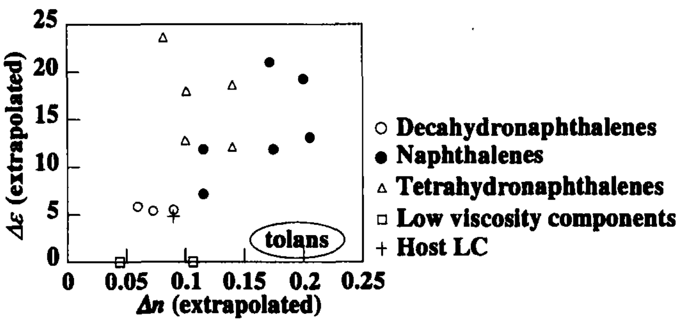


FIGURE 1 Relationship between $\Delta\varepsilon$ and Δn

<u>Effects of Fluoro-substituents for Naphthalenes and Tetrahydronaphthalenes</u>

Figure 3 shows the relationship between γ_1 / k_{11} and $\Delta\varepsilon$ of Naphthalenes. While, the fluoro-substituents of the practical fluorinated LC components reduce the T_{NI} and increase γ_1 / k_{11}. Each fluorinated naphthalene derivative at C-1 position shows rather lower γ_1 / k_{11} than unsubstituted derivatives. There is small difference of T_{NI} between the substituted and the unsubstituted derivatives. Tetrahydronaphthalenes indicate a similar behavior. Figure 4 shows the relationship between γ_1 / k_{11} and $\Delta\varepsilon$ of Tetrahydronaphthalenes. In the case of Tetrahydronaphthalenes, the effect of the fluoro-substituents to reduce γ_1 / k_{11} is extremely large. Therefore, the fluoro-substituents of Naphthalenes and Tetrahydronaphthalenes improved the response time with reducing the driving voltage.

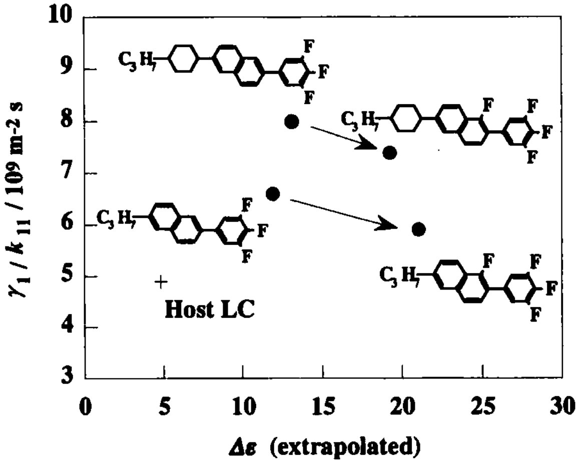


FIGURE 2 Effect of fluoro-substituent for Naphthalenes

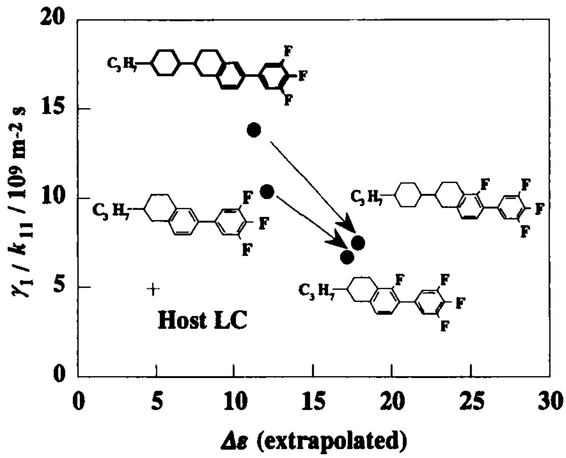
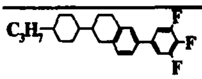
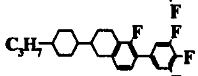
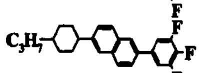
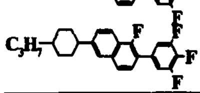


FIGURE 3 Effect of fluoro-substituent for Tetrahydronaphthalenes

Table 2 shows k_{11}, γ_1 and γ_1 / k_{11} of Naphthalenes and Tetrahydronaphthalenes. The value of k_{11} was evaluated by Freedericksz transition method. The value of γ_1 was obtained from values of k_{11} and γ_1 / k_{11}. There is small difference on k_{11} between the fluorinated fused ring and the unfluorinated fused ring. Therefore, the variation of γ_1 reduces the response time. The reason why the fluoro-substituents at C-1 position for fused ring make γ_1 reduce is not clear.

TABLE 2 Effect of fluoro-substituent of C-1 position on k_{11}, γ_1 and γ_1 / k_{11} for naphthalene ring and tetrahydronaphthalene ring

	k_{11} / pN	γ_1 / mPa s	γ_1 / k_{11} / 10^9 m^{-2} s
	10.0	138	13.9
	9.9	74	7.5
	9.4	76	8.0
	8.2	61	7.4

Mixtures for AM-LCD

Table 3 shows the LC mixtures including fused ring components.

LC mixtures S1, S2 and S3 can be applied to the LCD for 4V-driving monitors.

Mixtures Q1, Q2 and Q3 show quick response and are applicable for the LCD-TV. Mixtures Q2 and Q3 have 16 ms of $\tau_r = \tau_d$ at $\Delta nd = 0.45$.

Mixtures H1, H2 and H3 have high birefringence. When a cell thickness is fixed to 3 μm at the first-minimum condition of Δnd=0.45 for LC mixture H3, the response time is about 16 ms. Therefore, mixture H3 with quick response is suitable for the LCD-TV.

In general, it is difficult to obtain low Δn LC mixtures less than 0.08 by using LC components currently used. Mixtures L1, L2 and L3 have low birefringence below 0.08. These mixtures are suitable for reflective LCDs.

TABLE 3 Properties of LC mixtures including fused ring components.

	T_{NI} [°C]	$T_{\to n}$ [°C]	Δn	$\Delta\varepsilon$	γ_1/k_{11} [$m^{-2}s$]	V_{th}^* [V_{rms}]	$\tau_r=\tau_d^*$ [ms]
S1	95.2	-31	0.076	4.8	5.4	1.83	42
S2	86.4	-51	0.084	5.6	6.8	1.63	47
S3	88.9	-27	0.088	5.7	5.4	1.74	38
Q1	86.1	-50	0.088	3.3	3.8	2.22	26
Q2	72.5	-24	0.096	4.6	3.2	1.92	20
Q3	88.7	-34	0.123	7.3	4.8	1.88	24
H1	91.5	-39	0.120	10.1	9.1	1.59	41
H2	100.1	-40	0.120	11.0	11.0	1.61	51
H3	87.7	-45	0.147	9.5	8.1	1.68	34
L1	96.7	-28	0.065	3.3	5.0	2.22	38
L2	84.1	-35	0.070	4.9	5.4	1.66	44
L3	72.8	-47	0.073	7.2	7.6	1.36	61
W1	112.2	-44	0.084	3.5	5.3	2.28	39
W2	108.5	-32	0.090	7.1	8.4	1.61	47
W3	105.1	-48	0.128	10.0	9.6	1.73	43
V1	77.7	-41	0.105	10.8	13.3	1.30	66
V2	88.0	-43	0.107	9.8	11.6	1.46	49
V3	87.7	-38	0.113	9.8	10.3	1.49	51
V4	70.4	-39	0.132	15.4	14.7	1.20	62

* $d = 6\ \mu m$

Mixtures W1, W2 and W3 have high T_{NI}. Mixture W2 has wide temperature range of nematic phase and can be driven by 4V. The birefringences of LC mixtures can be adjusted to meet the requirement by using Naphthalenes and Decahydronaphthalenes.

Mixtures V1, V2, V3 and V4 have less than 3.3 V of low driving voltages. Mixture V4 can be driven by less than 2.5 V of ultra low driving voltage. These mixtures are suitable for mobile PC monitors and cellular phones, which require low consumption of electricity.

SUMMARY

We found that the fluoro-substituents at C-1 position for tetrahydronaphthalene and naphthalene rings have the effect to reduce γ_1 of LC components. We obtained the LC mixtures which are suitable for AM-LCD highly diversified for LCD-TV, PC monitors, note PCs, reflective PDA, car navigators and so on.

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